PROMOTION OF PHYSICAL ACTIVITY IN ADULTS WITH VISUAL IMPAIRMENT

by

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PROMOTION OF PHYSICAL ACTIVITY IN ADULTS WITH VISUAL IMPAIRMENT

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DEDICATION

"The only thing worse than being blind is having sight but no vision"

~ Helen Keller

To my loving family:

Thank you for your unwavering support as I continue to pursue my vision of promoting lifetime wellness for all.

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It is with immeasurable gratitude toward the visionaries of accessible wellness that I have been able to complete this project. Dr. Morgan, thank you for encouraging me to pursue this massive undertaking. I have appreciated your mentorship and will forever be indebted to you for the experiences you have provided me. Most of all, thank you for believing in me and for allowing me to play a role in the genesis of the *Center for Physical Activity and Health in Youth.* I have enjoyed watching your life's ambitions unfold before my eyes. Dr. Rimmer, you are the king of inclusive physical activity, and your collaboration on this project has been nothing short of a dream come true. Thank you for your brilliant research and your tireless advocacy for persons with disabilities.

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ABSTRACT

Visual impairment is currently the fourth-most prevalent class of disability in the United States. Despite a higher incidence of comorbidity and obesity among persons with vision loss, public health efforts aimed at promoting physical activity and health in persons with visual impairment do not currently exist. The grand objective of this dissertation was to lay the groundwork for conducting the first-known community-based walking intervention (*"Walk for Health"*) designed specifically for adults with blindness. In studies 1 and 2, measurement issues related to accurately and reliably quantifying physical activity in persons with visual impairment are addressed. In Study 3, the impact of the *Walk for Health* program on the daily step activity and health status of adults with varying levels of vision loss is documented. As a result of this collection of studies, recommendations are offered to guide future research efforts aimed at promoting physical activity, fitness, and health among persons with visual impairment.

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CHAPTER I

Introduction

Despite a higher incidence of functional limitations (West et al., 2002), comorbid conditions (Crews, & Campbell, 2001; Crews, Jones, & Kim, 2006), obesity (Holbrook, Caputo, Perry, Fuller, & Morgan, 2009; Ray, Horvat, Williams, & Blasch, 2007; Weil et al., 2002), depression (Margolis et al., 2002), and mortality (Christ, Lee, Lam, Zheng, & Arheart, 2008), public health efforts aimed at promoting the health status of persons with visual impairment have been virtually non-existent. Given the relatively low prevalence of this condition and the disconnect between public health and vision-related rehabilitation sectors (DiStefano, Huebner, Garber, & Smith, 2006), programs and policies for persons with visual impairment have focused primarily on mobility services and vocational preparation (Kirchner, 2006), with little regard to the prevention of comorbidity.

It is expected that as the proportion of the population experiencing vision loss rises in parallel with increases in the aging population (Friedman, Congdon, Kempen, Tielsch, & O'Colmain, 2002), a concomitant increase in secondary conditions will follow. In anticipation of this development, changes in health policy and practice for persons with visual impairment are inevitable (Mulhorn, 2004). With the publication of the *Healthy People 2010* (*HP2010*) report, which includes two chapters pertaining to the health-related needs associated with disability and vision loss, advocates of the blindness community have finally secured a position on the nation's public health agenda. In fact, the vision-related *HP2010* objectives may have been instrumental in raising awareness toward the health-related needs of persons with visual impairment, insofar as an entire supplement of the *Journal of Visual Impairment and Blindness* was recently devoted to this cause (2006) and a complementary program, Healthy Vision 2010, was developed to espouse these objectives. As a result of developments which ensued following the publication of *HP2010*, researchers, clinicians, and practitioners have been provided with a blueprint to guide future attempts to secure funding and public support for health promotion efforts within the community of persons with vision loss. The next plausible step, which has been echoed by researchers in the fields of visual impairment and public health, is to conduct health-related interventions which specifically target the needs of persons with visual impairment and the *HP2010* objectives (Capella-McDonnal, 2007; Crews et al., 2006).

From a general health perspective, perhaps the most pressing need of the visually impaired community is the prevention and treatment of debilitating secondary conditions. Crews and Campbell (2000) recently quantified the percentage of older adults with and without visual impairment experiencing comorbid conditions and found that adults with visual disabilities were more likely to report the presence of diabetes, stroke, heart disease, and hypertension than were their peers without vision loss. The incidence of functional limitations also tracks with comorbidity in this group, as older adults with visual disability were more than twice as likely to indicate difficulty with walking or standing from a seated or supine position. Specifically, 28% of elderly persons with visual impairment reported their overall health status as poor, compared to only 6% of persons without vision loss (Crews & Campbell, 2000).

Although the generalizability of the findings reported by Crews and Campbell is limited to older adults (70 to 74 years) with low vision, a gradual decline in health across the lifespan of persons with visual impairment has been noted in the recent literature (2000). Beginning in youth, children with vision loss display lower levels of cardiorespiratory function (Hopkins, Gaeta, Thomas, & Hill, 1987; Jankowski & Evans, 1981), poor body composition profiles (Hopkins et al., 1987; Jankowski & Evans, 1981; Shindo, Kumagai, & Tanaka, 1987; Suzuki et al., 1991), and diminished levels of physical fitness (Lieberman, Byrne, Mattrn, Watt, & Fernandez-Vivo, 2010; Seelye, 1983; Shindo et al.,1987). This trend continues throughout adolescence and young adulthood and is manifested by an enduring decline in physical activity and physical fitness (Bunc, Segetova, & Safarikova, 2000; Singh & Singh, 1993). By middle age, persons with visual impairment are 1.5 times more likely to be obese than the general population, displaying higher rates of excess weight and extreme obesity (Holbrook et al., 2009; Ray et al., 2007). Moreover, engagement in physical activity among adults with visual impairment remains below recommended levels for producing health benefits (Holbrook et al., 2009). When extrapolated across the lifespan, the collective effect of low activity levels, poor physical fitness, and overweight status is a panorama of comorbidity, comprised of functional limitations, depression, and cardiovascular disorders.

Call to Action

Given the pervasive nature of suboptimal health in the population of persons with visual impairment, health-promoting interventions designed specifically for persons with vision loss have been recommended (Capella-McDonnall, 2007). Moreover, advocates of the blind community have been encouraged to develop innovative solutions to mitigate the emotional, environmental, and physical barriers experienced by persons with visual impairment so as to lessen the impact of these factors on the health status of this population (Capella-McDonnall, 2007). In response to these recommendations, the series of papers contained within this dissertation lay the groundwork for implementing the first-known pedometer-based walking program designed specifically to increase the health status and physical activity levels of persons with vision-related disability.

Purpose Statement

The primary purpose of this series of investigations was to provide an outlet through which adults with visual impairment could become self-promoters of health and well-being by leading a more physically active lifestyle. It was hypothesized that the implementation of a self-directed, pedometer-based physical activity program could result in improvements in various health indicators, while enabling adults with visual impairment to overcome specific social, environmental, and emotional barriers which have been shown to impede physical activity participation across the lifespan.

The three investigations contained within this dissertation were intended to address current limitations within the research literature concerning persons with visual impairment, culminating with the first-known walking program aimed at improving the health status of visually impaired adults. **The purpose of the first study** was to establish validity evidence for a pedometer featuring the adaptive technologies necessary to make a pedometer-based physical activity intervention possible for persons with visual impairment. This project, which documented the influence of environmental familiarity, walking speed, and mobility aid use on the accuracy of a talking pedometer, included a host of factors not previously examined in persons with visual impairment. The establishment of validity evidence for this adaptive activity monitor provided the impetus for developing the first physical activity intervention for adults with visual impairment.

The purpose of the second study was to determine the minimum number of days of pedometer monitoring needed to reliably estimate physical activity in adults with visual impairment. Generalizability theory was used to identify the proportion of variance in weekly physical activity attributable to individual participants and days of monitoring. Information gleaned from this investigation was subsequently applied within the context of the final study to ensure that reliable estimates of baseline and post-intervention physical activity could be obtained in physical activity programs featuring persons with visual impairment.

The purpose of the third study was to implement a goal-based physical activity intervention for adults with visual impairment using the previously validated adaptive pedometer. A secondary aim was to quantify the effects of increased physical activity on specific health indices in our sample of adults with visual impairment.

Significance

The recent publication of *Healthy People 2010* changed the public perspective towards health-related needs of individuals with visual disability. Given the widespread impact of comorbidity in adults with visual impairment, public health officials have cited the need for research-based interventions aimed at eliminating health disparities between persons with and without vision loss. The three investigations contained within this dissertation provide the basis for conducting the first-known, evidence-based walking intervention for visually impaired adults. By incorporating a voice-announcement pedometer and an individually-tailored walking goal, this community walking program enabled persons with visual impairment to become "self promoters" of physical activity and health.

CHAPTER II

Effects of Mobility Aid Use and Environmental Influences on the Accuracy of a Talking Pedometer in Adults with Visual Impairment

Introduction

Despite a higher incidence of functional limitations (West et al., 2002), comorbid conditions (Crews & Campbell, 2001; Crews, Jones, & Kim, 2006), obesity (Holbrook, Caputo, Perry, Fuller & Morgan, 2009; Ray, Horvat, Williams, & Blasch, 2007; Weil et al., 2002), depression (Margolis et al., 2002), and mortality (Christ, Lee, Lam, Zheng, & Arheart, 2008), public health efforts aimed at promoting the health status of persons with visual impairment are generally nonexistent. Given the efficacy of pedometer-based walking interventions in promoting physical activity and improving health among large groups of clinical sub-populations (Araiza, Hewes, Gashetewa, Vella, & Burge, 2006; Chan, Ryan, & Tudor-Locke, 2004; Gray et al., 2008; Swartz et al., 2003; Talbot, Gaines, Huynh, & Metter, 2003; Tudor-Locke et al., 2004), previous investigators have considered establishing validity evidence for talking pedometers as a preliminary step towards promoting ambulatory activity in persons with vision loss (Beets, Foley, Tindall, & Lieberman, 2007; Lieberman, Stuart, Hand, & Robinson, 2006). Before physical activity interventions can be conducted, however, certain characteristics which are inherent to the population of persons with visual impairment and have been overlooked in previous validation studies should be addressed.

A number of factors have been identified in the measurement literature as having the potential to affect pedometer accuracy, including walking speed (Bassett, Ainsworth, Leggett, 1996; Holbrook, Barreira, & Kang, 2009; LeMasurier & Tudor-Locke, 2003), mounting position (Bassett et al., 1996; Holbrook, Barreira, & Kang, 2009), and the morphological and ambulatory characteristics of the individual wearing the pedometer (Crouter, Schneider, & Bassett, 2005; Holbrook, Barreira, & Kang, 2009; Melanson et al., 2004). The validity of a pedometer can also be influenced by the internal counting mechanism within the device. Piezoelectric pedometers, for instance, tend to be more accurate than spring-levered models at slow walking speeds (Bassett et al., 1996; LeMasurier & Tudor-Locke, 2003; Melanson et al., 2004) and when worn by overweight individuals (Crouter, Schneider, & Bassett, 2005; Melanson et al., 2004). It is possible, though, that in addition to the factors which are known to influence pedometer accuracy in the general population, other characteristics may need to be considered when validating a pedometer for use in special populations.

The locomotor patterns of individuals with visual impairment have previously been described as being mechanically inefficient (Chen, Wang, & Mok, 2009; Huang, Huang, Tsai, & Liu, 2004; Jankowski & Evans, 1981). Even among blind athletes, Ferro and colleagues (2002) observed higher stride rates, shorter stride lengths, and longer contact times (e.g., shorter flight phases) when compared to individuals without vision loss. Moreover, alterations in gait and long-cane mechanics have been observed in persons with visual impairment in response to changes in the environment, leading to a decrease in hip flexion velocity and stride length (Ramsey, Blasch, Kita, & Johnson, 1999). Consequently, for a pedometer to provide valid activity-related feedback to an individual with vision loss, it must be adaptive in nature (e.g., feature "voice announcement" technology) and sensitive enough to function in response to unique kinematic changes. Because commercially-available pedometers with adaptive features incorporate a spring-levered internal counting mechanism, kinematic alterations produced in response to environmental changes may affect the accuracy of these pedometers. With respect to this point, Beets and colleagues recently examined validity evidence for three models of adaptive pedometers (2007). During validation trials, youth with visual impairment were led by a sighted guide through a series of 100-meter walking trials. Potential kinematic alterations were not taken into account relative to (a) walking with a sighted guide in lieu of a mobility aid, (b) challenges associated with the built environment, or (c) course familiarity. Reflecting these limitations, an unexplainable systematic error (over- or under-estimation, depending on the model of pedometer) was observed in pedometers mounted on the left side of the body (Beets et al., 2007).

In an attempt to identify the source of the systematic error observed by Beets and colleagues (2007) and to provide an acceptable level of external validity evidence for adaptive pedometers, it would seem appropriate to incorporate different environmental settings within the context of validation trials when the pedometer is intended for use by persons with vision loss. Moreover, mobility aid use should be encouraged during validation studies so that potential interactions between pedometer mounting position and the type of mobility aid used can be discerned. The inclusion of specific environmental and mobility aid factors in walking validation trials of persons with vision loss would also help ensure that a more generalizable account of validity evidence is obtained. Against this backdrop, the purpose of the current study was to document the accuracy of a talking pedometer relative to mounting position and environmental familiarity in adults with visual impairment.

Methods

Participants. Upon receiving approval from the Institutional Review Board at a university in the southeastern United States, volunteers were solicited for participation using snowball sampling. Initial solicitations were made through presentations at various advocacy organizations for persons with visual impairment across a large metropolitan area and secondary solicitations occurred within the community of persons with vision loss via personal conversations. Inclusion in this study was limited to ambulatory adults (aged 18 years or older) with a visual acuity of 20/200 or less (e.g., legal blindness). Of the 61 individuals who were contacted, 14 adults (10 females, 4 males) consented to participate. In general, participants were overweight (body mass index = 26.5 ± 4.2 kg/m^2) and were self-reported "skilled travelers" (M = 4.14, SD =.93) as rated on a 5-point Likert scale evaluating proficiency with orientation and mobility. The severity of visual impairment among participants, which was classified using the International Statistical Classification of Diseases (ICD) schematic (World Health Organization, 2007), ranged from peripheral or travel vision (n = 8; ICD classification 1-3), to light perception (n = 3; ICD classification 4), and no light perception (n = 3; ICD classification 5). Two participants did not use a mobility aid, four participants used a dog guide, and eight participants used a long cane. Eight participants also reported having a congenital visual impairment.

Instrumentation. The Centrios talking pedometer (Orbyx Electronics, Model 6310620, Concord, Canada) features a spring-levered counting mechanism and provides estimates of the number of steps taken, total active time, distance walked, and caloric expenditure. This pedometer also features a personal alarm which can be activated by releasing an external pulley. The Centrios pedometer is commercially available through wholesale retailers of adaptive technology and ranges in price from $20 to $40. While the voice-announcement technology contained within the device makes the Centrios pedometer larger than typical spring-levered monitors, automated feedback can be announced periodically at the touch of a button or throughout the day (e.g., after every 1,000 steps or 10 minutes of accumulated activity time). The Centrios pedometer is reportedly accurate during locomotor activity when mounted vertically toward the mid-line of the waistband at the right or left hip (Orbyx Electronics, 2003).

Validation trials. Prior to conducting pedometer validation trials, a closed-course walking route was established. The route was a quarter-mile in length and consisted of a flat, meandering sidewalk on a college campus with a single street crossing and three bisecting sidewalks with curb cuts. To verify that the chosen route was safe and reflective of an environment typical of everyday living, a state-certified Orientation and Mobility Specialist assisted the primary investigator in developing the walking course.

Validation trials were conducted in a single session, during which participants completed multiple walking trials while wearing two Centrios talking pedometers positioned at the right and left hip along the waistband and in line with the knee. Prior to each trial, pedometers were randomly selected from a pool of eight devices. The first walking trial was used to simulate walking in an unfamiliar environment, as the established walking route was novel for all participants. During this trial, participants were instructed to walk at a self-selected pace and to use their mobility aid as they normally would in an unfamiliar environment. An investigator walking behind each participant tallied actual step counts using a hand counter. Pedometer-determined steps were recorded relative to mounting position at the right hip (RH) or left hip (LH) and as a function of the user's mobility aid (e.g., mobility aid side = MA; non-mobility aid side = NMA). The actual number of steps taken and the time to complete the quarter-mile course were also recorded. From measures of walking distance and time, walking speed was calculated.

After completing the first walking trial, participants were escorted by the primary investigator through a series of additional walks (over the same overground course) until a sense of familiarity with the course was established. During these exploratory walks, measures of actual- and pedometer-determined step counts and walking speed were not recorded. The number of additional walks needed to establish course familiarity varied among participants, reflecting an array of mobility skills and visual capabilities. Once participants were comfortable with the route, a final validation trial was conducted, reflecting walking in a "familiar environment." After completing this final walking trial, measurements of pedometer-determined step counts (across RH, LH, MA, and NMA mounting positions), actual step counts, and the time required to traverse the course were recorded and walking speed was calculated from distance and time values.

Data Analysis. Data screening and analyses were performed using SPSS (version 17.0) and Microsoft Excel for Windows. Due to a pedometer malfunction during a validation trial involving a dog guide user, data from 13 participants were included in the final analysis. Absolute percent error (APE) scores were calculated between actual steps and pedometer-determined steps (APE = [(pedometer steps - actual steps) / actual steps] x 100) across mounting positions and environmental conditions and used as an accuracy index, wherein a smaller APE represented better accuracy. Previous investigators have regarded an APE of less than 3% as an acceptable level of variance (Crouter, Schneider, Karabulut, & Bassett, 2003; Hatano, 1997; Holbrook, Barreira, & Kang, 2009). Paired *t*-tests were used to assess differences in APE relative to mounting position (RH vs. LH; MA vs. NMA) and environmental condition (unfamiliar and familiar walking trials). Cohen's *d* effect sizes were also calculated to evaluate the magnitude of the effect of mounting position and environmental familiarity on pedometer accuracy. Statistical significance was established *a priori* at $p < .05$.

Results

The influence of mounting position and environmental familiarity on the accuracy of the Centrios talking pedometer is shown in Table 1. During unfamiliar walking trials, walking speed and APE scores ranged from 0.74 m/sec to 2.22 m/sec ($M = 1.43$ m/sec) and 0.00% to 26.05%, respectively. Within this condition, the least amount of mean error was observed among pedometers mounted at the NMA position ($M = 2.14\%$,

Table 1

Absolute Percent Error of the Centrios Pedometer: Influence of Mounting Position and Environmental Familiarity

Condition	Position			
	RH (n = 13)	LH (n = 13)	MA (n = 11)	NMA (n = 11)
Unfamiliar	8.63 ± 11.39	3.35 ± 2.74	11.12 ± 11.29*	2.14 ± 1.98$^{\dagger *}$
Familiar	5.18 ± 5.18	2.14 ± 3.32†	5.29 ± 4.98	2.68 ± 4.52†

Note. Values expressed as percentages and $M \pm SD$; RH = right hip, LH = left hip, MA = mobility aid side, NMA = non-mobility aid side.
†denotes conditions which meet or exceed the accepted threshold for validity (APE < 3%).
$^{*}p < .05$.

SD = 1.98%) and the largest mean APE was found in the MA position (*M* = 11.12%, *SD* =11.29%). The accuracy of the Centrios pedometer during unfamiliar walking trials did not differ between the LH (*M* = 3.35%, *SD* = 2.74%) and RH mounting positions (*M* = 8.63%, *SD* = 11.39%, *t*(12) = 1.66, *p* = .123, *d* = .64). However, the pedometer was significantly more accurate when mounted at the NMA position (*M* = 2.14%, *SD* = 1.98%) compared to the MA position (*M* = 11.12%, *SD* = 11.29%, *t*(10) = 2.89, *p* = .016, *d* = 1.11).

Reflecting the heterogeneity of vision loss experienced by participants, the number of trials required to establish a sense of familiarity with the walking course varied from zero to three. Under familiar walking conditions, walking speed ranged from 0.84 m/sec to 2.23 m/sec (*M* = 1.59 m/sec) and APE ranged from 0.00% to 25.63%. Unlike the unfamiliar walking trials, the smallest mean APE score in the familiar setting occurred when pedometers were mounted at the LH position (*M* = 2.14%, *SD* = 3.32%), while the largest mean APE score was observed in RH-mounted pedometers (*M* = 5.18%, *SD* = 5.18%). During familiar walking trials, pedometer accuracy was similar between the RH (*M* = 5.18%, *SD* = 5.18%) and LH positions (*M* = 2.14%, *SD* = 3.32%, *t*(12) = 1.64, *p* = .127, *d* = 0.70), and between the MA (*M* = 5.29%, *SD* = 4.98%) and NMA positions (*M* = 2.68%, *SD* = 4.52%, *t*(10) = 1.13, *p* = .284, *d* = 0.55).

When comparing unfamiliar and familiar environmental conditions as a function of pedometer mounting position, no significant differences in APE were observed among pedometers mounted at the RH, *t*(12) = 1.04, *p* = .321, *d* = 0.39, LH, *t*(12) = 1.23, *p* =

.244, $d = 0.40$, MA, $t(10) = 1.65$, $p = .129$, $d = 0.67$, and NMA positions, $t(10) = -0.32$, $p = .755$, $d = -0.16$.

Discussion

It is well documented that pedometer-based walking interventions are an effective means of improving physical activity participation and health status in many clinical sub-populations (Araiza et al., 2006; Chan et al., 2004; Gray et al., 2008; Swartz et al., 2003; Talbot et al., 2003; Tudor-Locke et al., 2004). Based on these data, it is reasonable to infer that comparable health benefits could be gained by persons with visual impairment participating in similar walking programs if adaptive pedometers with voice announcement technology were employed. Previous investigations documenting the accuracy of talking pedometers in youth with visual impairment have featured highly-controlled walking trials and reported unexplainable systematic errors (Beets et al., 2007). Acknowledgement of the context-specific nature of validity evidence has led to the suggestion that investigators should actively seek to simulate "real-life" experiences during validation trials to generate validity evidence that is more ecologically appropriate (Kang, Holbrook, & Barreira, 2009; Rowe & Mahar, 2006; Shepard, 1993). By documenting the effects of mobility aid use and environmental familiarity on the validity of the Centrios pedometer, results from the current study collectively illustrate that this device can serve as an accurate means of monitoring physical activity among adults with vision loss in both unfamiliar and familiar settings.

Validity Evidence. Based on the recommended threshold for pedometer validity (an APE of 3% or less; Crouter et al., 2003; Hatano, 1997), validity evidence was established for the Centrios pedometer across a range of walking speeds and environmental conditions. In the unfamiliar setting, validity evidence was obtained when the pedometer was mounted in the NMA mounting position. Similarly, in the familiar environmental setting, validity evidence for the Centrios pedometer was established at the NMA- and LH-mounted positions. Within the context of both environmental conditions, APE was consistently higher in pedometers worn at the RH compared to the LH and when mounted on the MA side compared to the NMA side. Interestingly, these findings contradict the observations of Beets et al. (2007), who reported a systematic error among LH-mounted pedometers. In the current study, allowing participants to use their mobility aid during validation trials enabled the source of the systematic error observed among pedometers mounted at the RH to be linked to the use of the mobility aid. Specifically, the majority of participants in the current study were long cane users (n = 8) displaying a large degree of movement in the right arm while walking, which allowed environmental feedback to be gained from the long cane. Although speculative, the movement of the right arm across the body in long cane users may have interfered with the spring-levered counting mechanism of the pedometer, resulting in a consistent overestimation of steps in the RH- and MA-mounted pedometers. It would also be expected that this level of interference would be greater when walking in an unfamiliar versus familiar environment due to a need to increase the range of motion of the long cane (and thus, the right arm) to obtain a greater amount of feedback from the environment. Our data support this notion, as pedometer error was highest in the RH and MA positions when participants walked in an unfamiliar setting.

Influence of Environmental Familiarity. It is well documented that a generally linear relationship exists between walking speed and pedometer accuracy (Bassett et al., 1996; Crouter et al., 2005; Couter, Schneider, Karabulut, & Bassett, 2003; Karabulut & Crouter, 2005). In particular, the dynamic gait pattern associated with moderate-to-brisk walking speeds, while eliciting a heightened degree of accuracy in many pedometers, is particularly detrimental to the accuracy of spring-levered pedometers (Melanson et al., 2004). In the current investigation, slower walking speeds, a more "shuffling" gait pattern, and a greater reliance on mobility aid use were noted during unfamiliar walking trials compared to walking in a familiar setting. This triad of responses was anticipated, as previous investigators have documented similar findings in adults with visual impairment during attention-demanding tasks (Ramsey et al., 1999).

Despite observable kinematic differences between unfamiliar and familiar environments, no statistically significant differences in APE were apparent between mounting positions across walking conditions. A large effect for environmental familiarity was detected for MA-mounted devices, however, insofar as MA pedometers were more accurate during familiar compared to unfamiliar trials. In addition, the Centrios pedometer met the criterion for acceptable accuracy (< 3% APE) when it was worn in the NMA position during walking trials in the unfamiliar setting and in the LH and NMA positions while walking in the familiar setting. It is possible that the level of orientation and mobility skill of the participants may partially explain these findings. As self-reported "skilled travelers", only five of our participants exhibited non-congenital vision loss, while the remaining participants reported a congenital visual condition. It has been documented that persons with congenital blindness display more developed compensatory strategies when performing novel tasks (Monegato, Cattaneo, Pece, & Vecchi, 2007). Hence, given the brisk walking speeds recorded during both unfamiliar and familiar walking conditions (1.43 m/sec and 1.59 m/sec, respectively), the Centrios pedometer may have yielded less accurate step count readings had persons with inferior mobility skill been tested. Consequently, the findings of this investigation are probably most applicable to visually impaired individuals with a modest-to-high degree of travel skill.

Influence of Mobility Aid Use. The heightened reliance on mobility aid use while orienting in an unfamiliar environment and the consistent use of mobility aids when walking in a familiar setting may have contributed to the more favorable degree of accuracy displayed by NMA-mounted pedometers (APE < 2.70%) in both walking environments. One possibility is that an increased range of motion among long cane users and a more pronounced level of arm rigidity among dog guide users may have caused interference with the pedometer mounted in the MA position. When locating a sidewalk, for instance, long cane users typically employ a sweeping motion of the cane from side-to-side to explore the surrounding area. Although beneficial, this motion may result in over- or under-estimations of step activity in spring-levered pedometers, as the increased range of motion of the arm across the body may impede or increase pedometer oscillations (e.g., in the current study, an overestimation of steps was observed).

Because a long cane is typically held in the right hand and a dog guide is usually held in the left hand, we thought that additional trends might be detected by evaluating our findings in relation to the use of specific types of mobility aids. Therefore, an exploratory *post hoc* analysis was conducted to compare the influence of long cane use versus dog guide use on pedometer accuracy. Results of this secondary analysis, presented in Table 2, demonstrated that in the unfamiliar setting, the impact of mobility aid use was particularly noticeable, as a higher degree of pedometer accuracy was registered among dog guide users (APE < 2%) at the RH/NMA position and among long cane users (APE < 2.8%) at the LH/NMA position. In addition, among participants who did not use a mobility aid, an acceptable level of accuracy was achieved when the pedometer was mounted at both the RH and LH positions. Because the dog guide and long cane are held in opposite hands, these trends were anticipated. Moreover, the observation that non-mobility aid users experienced similar APE scores at both RH and LH positions further supports the notion of mobility aid interference on pedometer accuracy.

In the current study, mean APE scores among long cane users and non-mobility aid users improved across pedometer mounting positions in the familiar setting. This was not a particularly surprising result, as it can be hypothesized that greater familiarity with one's walking surroundings would result in a faster walking speed and a more normalized gait pattern. While the influence of mobility aid use on pedometer accuracy remained consistent among long cane users in the familiar setting (such that higher levels of accuracy were recorded in the LH/NMA position versus the RH/MA position), this trend was not observed among dog guide users. Whereas pedometers mounted at the RH/NMA position met the criteria for acceptable accuracy in the unfamiliar setting (< 3% APE), the

Table 2

Absolute Percent Error of the Centrios Pedometer: Influence of Mounting Position and Environmental Familiarity as a Function of Mobility Aid Type

	Position			
Condition	RH	LH	MA	NMA
Unfamiliar environment				
Dog guide ($n = 3$)	1.53 ± 2.04†	5.57 ± 3.56	5.57 ± 3.56	1.53 ± 2.04†
Long cane ($n = 8$)	12.82 ± 12.98	2.76 ± 2.29†	13.21 ± 12.66	2.37 ± 2.05†
None ($n = 2$)	2.56 ± 2.11†	2.39 ± 2.88†		
Familiar environment				
Dog guide ($n = 3$)	7.34 ± 7.35	1.42 ± 0.91†	1.42 ± 0.91†	7.34 ± 7.35
Long cane ($n = 8$)	5.15 ± 5.00	2.53 ± 4.22†	6.74 ± 5.14	0.94 ± 1.01†
None ($n = 2$)	2.04 ± 2.36†	1.65 ± 1.81†		

Note. Values expressed as percentages and $M \pm SD$; RH = right hip, LH = left hip, MA = mobility aid side, NMA = non-mobility aid side.
†denotes conditions which meet or exceed accepted threshold for validity (APE < 3%).

opposite was observed in the familiar setting, as LH/MA mounted pedometers were tied to lower APE values. With only three dog guide users, it is difficult to explain why this may have occurred. However, two dog guide users continued to exhibit lower APE scores at the RH/NMA position in the familiar setting, while one experienced an overestimation of 15% in RH/NMA mounted pedometers. Given these findings, continued efforts to distinguish the influence of specific types of mobility aids on pedometer accuracy are needed.

Conclusions and Suggestions for Future Research

In view of the known limitations of spring-levered pedometers and the large degree of variability present in the gait patterns of persons with vision loss, advocates of inclusive fitness equipment should encourage makers of piezoelectric pedometers to offer adaptive models for persons with visual impairment. Until adaptive piezoelectric pedometers become available, however, the spring-levered Centrios talking pedometer can serve as an acceptably valid means for monitoring physical activity in persons with visual impairment. Because our sample size was relatively small, the influence of specific types of mobility aids on pedometer accuracy deserves further study. Specifically, while distinct trends were noted among long cane users (indicating a mobility aid-induced overestimation of steps), the impact of mobility aid interference among dog guide users was less clear and should be examined more fully. In addition, a mere 22% of solicited study-eligible individuals chose to participate in this investigation. Given the difficulty associated with locating, recruiting, and providing transportation for a large number of individuals with visual impairment, future investigations of persons with vision loss should be collaborative in nature, featuring multi-site efforts in a number of metropolitan areas.

In summary, the objective of this study was to establish generalizable validity evidence for the Centrios talking pedometer by documenting the influences of environmental familiarity and mobility aid use on the accuracy of the device. Findings from this investigation revealed that familiarity with the environment, pedometer mounting position, and the type of mobility aid used by participants influenced pedometer accuracy. Similar to previous studies involving persons with normal visual function, the environmental impact on pedometer accuracy was determined to be a function of participant walking speed. Specifically, as participants became familiar with their surroundings, walking speed and pedometer accuracy improved concomitantly. However, the need to alter the mounting position of the pedometer appears to be a consideration that is unique to the population of persons with vision loss. The impact of mounting position as a means to improve pedometer accuracy was recently examined among overweight adults without visual impairment (Holbrook et al., 2009a) and no difference in step-based physical activity was observed relative to right-hip and left-hip mounted pedometers. In contrast, results from the current study indicated that the Centrios talking pedometer provided an accurate account of step-based activity in persons with visual impairment when mounted at the hip opposite the user's mobility aid. This finding highlights the importance of altering data collection strategies when working with special populations to ensure that valid assessments of physical activity can be obtained. From a health-related standpoint, the Centrios pedometer may be an appropriate tool for future interventions aimed at promoting physical activity participation in the visually impaired community. Given the dual challenges of recruiting large samples of persons with vision loss and further documenting the influence of specific types of mobility aids on the accuracy of voice-announcement pedometers, collaborative multi-site investigations should be conducted.

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CHAPTER III

Reliable Estimation of Physical Activity in Adults with Visual Impairment

Introduction

As a result of minimal engagement in physical activity (Holbrook, Caputo, Perry, Fuller, & Morgan, 2009), persons with low vision display a greater prevalence of hypokinetic conditions, such as obesity, co-morbidity, and limitations in performing activities of daily living, compared to the general population (Crews & Campbell, 2001; Holbrook et al., 2009; Ray, Horvat, Williams, & Blasch, 2007; Weil et al., 2002). Due to the capacity of pedometer-based walking interventions to improve health outcomes and enhance the physical activity levels of various clinical sub-populations (Araiza, Hewes, Gashetewa, Vella & Burge, 2006; de Blok et al., 2005; Moreau et al., 2001; Talbot, Gaines, Huynh, & Metter, 2003; Tudor-Locke et al., 2004), persons with visual impairment may experience comparable benefits from participating in similar physical activity programs.

As pedometers with adaptive technologies (e.g., "talking pedometers") become commercially available and are validated (Beets, Foley, Tindall, & Lieberman, 2007; Holbrook, 2010a), the potential to conduct walking programs aimed at improving the health status of persons with visual impairment becomes more plausible. However, before implementing goal-based walking programs that rely on pedometers to measure changes in activity patterns, stable estimates of baseline physical activity must be obtained. While the time frame needed to capture a reliable estimate of physical activity has been established for youth (Kim & Yun, 2009; Trost, Pate, Freedson, Sallis, & Taylor, 2000; Vincent & Pangrazi, 2002) and adults (Kang et al., 2009; Temple, & Stanish, 2009; Tudor-Locke et al., 2005) without vision loss, physical activity patterns may differ in persons with visual impairment. Specifically, a number of factors unique to the population of persons with visual impairment may influence daily patterns of physical activity, such as the progression and magnitude of visual impairment or level of orientation and mobility skill. Previous authors have also reported a high prevalence of social isolation and low rates of participation in leisure, outdoor, and social activities among persons with vision loss (Haymes, Johnston, & Heyes, 2002; Lamoureux, Hassell, & Keeffe, 2004; Verstraten, Brinkmann, Stevens, & Schouten, 2005). As a result, it is possible that persons with severe visual disability experience a more homogenous pattern of physical activity (i.e. less within-subject variability) compared to the general population. If this hypothesis is true, fewer days of objective monitoring may be required to capture a stable estimate of physical activity in persons with visual impairment.

In considering the monitoring time frame necessary to establish reliable estimates of physical activity, researchers have primarily employed models of classical test theory, such as interclass models, to estimate weekly physical activity (Temple & Stanish, 2009; Trost et al., 2000; Tudor-Locke et al., 2005). While interclass models allow for an infinite number of scores to be analyzed *en route* to determining the reliability of a measurement procedure (Morrow, 1989), they do not identify potential sources of variance for a given estimate. To address this issue, it has been suggested that Generalizability theory may provide a more complete assessment of the stability of behavioral patterns because it quantifies error sources which may limit the external validity of behaviors such as physical activity (Baranowski, Masse, Ragan, & Welk, 2008; Ragan & Kang, 2005). Specifically, Generalizability theory consists of generalizability study (G study) and decision study (D study) analyses. These analyses enable the magnitude of variance associated with specific sources of error to be discerned (G study), and for reliable measurement procedures to be established (D study) relative to a behavior of interest (Baranowski et al., 2008; Morrow, 1989; Webb & Shavelson, 2005). Key statistics derived from Generalizability theory include a G-coefficient, which is highly comparable to a standard reliability coefficient, and the proportion of variance within the estimate that is associated with various error sources (Morrow, 1989).

In an effort to determine the monitoring time frame needed to obtain a stable estimate of physical activity in persons with visual impairment, the purpose of this study was to apply Generalizability theory to quantify variability in physical activity attributable to differences among participants, inconsistencies across days, and the participant-by-day interaction. As a by-product of this analysis, the minimum number of days of physical activity monitoring required to yield a reliable estimate of weekly physical activity in visually impaired adults was also determined. From a practical viewpoint, knowledge regarding the minimum time frame needed to establish baseline measures of physical activity would be useful in mitigating the burden of data collection experienced by both participants and practitioners. This latter point is an especially important one to consider when investigating health-related behaviors in special populations, which often feature low rates of volunteerism (Chen, Wang, & Mok, 2009;

Ferro, Graupera, & Vera, 2002; Green & Miyahara, 2008; Holbrook et al., 2009; Holbrook, 2010a; Jankowski & Evans, 1981; Oh, Ozturk, & Kuzub, 2004; Sherrill, Rainbolt, & Ervin, 1984; Singh & Singh, 1993; Williams, Armstrong, Eves, & Faulkner, 1996), and high rates of attrition (Holbrook, 2010b).

Method

Participants. Volunteer participants were solicited from regional chapters of the American Council of the Blind and the National Federation of the Blind in Tennessee. Solicitation progressed using snowball sampling, as recruitment efforts continued through the community of persons with visual impairment via email listservs and word-of-mouth. A total of 33 adults with visual impairment consented to participate and sufficient data were collected on 31 participants (19 female, 12 male). In general, participants were obese (body mass index = 30.8 ± 6.9 kg/m^2), middle-aged (age = 45.9 ± 11.2 years) adults with varying degrees of vision loss. According to the International Statistical Classification for Disease schematic (ICD; World Health Organization, 2007), 3 participants displayed mild vision loss (ICD Levels 1-3; travel vision), 13 displayed moderate visual impairment (ICD Level 4; light perception), and 15 reported a severe visual impairment (ICD Level 5; no light perception). Three participants did not use a mobility aid, six participants used a dog guide, and twenty-two participants used a long cane.

Participants completed a 7-day physical activity assessment during the months of March and September using the Centrios talking pedometer (Orbyx Electronics, Model

6310620, Concord, Canada). The Centrios pedometer is a spring-levered device that provides audible feedback to the wearer relative to step activity, total active time, distance walked, and calories expended. While the voice-announcement technology contained within the device makes the Centrios pedometer larger than typical spring-levered monitors, automated feedback can be announced periodically at the touch of a button or throughout the day (e.g., after every 1,000 steps or 10 minutes of accumulated activity time). When worn by adults with visual impairment, the Centrios pedometer provides estimates of step-based physical activity with an acceptable degree of accuracy (< 2.7% of actual steps) when mounted at the hip opposite the user's mobility aid (Holbrook, 2010a).

During the 7-day monitoring period, participants were instructed to maintain a normal level of physical activity. Participants wore the pedometer along the waistband at the hip opposite their mobility aid (e.g., long cane or dog guide) during all waking hours and were told to remove the monitor only during swimming activities or while bathing. Based on visual status and access to adaptive computer software, participants reported their daily step counts either by e-mail or telephone answering machine. To eliminate the potential for subject reactivity, investigators did not communicate with participants during the monitoring period.

Data analyses. For the 31 adults who completed five or more days of physical activity monitoring, data from missing days were replaced using an individual-information centered approach incorporating the average of the remaining step activity values for the participant (Kang, Rowe, Barreira, Robinson, & Mahar, 2009). One-way analysis of variance (ANOVA) was used to determine if pedometer reactivity was present during the 7-day monitoring period and whether mean differences existed in daily step activity relative to the day of the week. To quantify the amount of variance in daily step counts associated with the participants, inconsistencies across days, and the participant-by-day interaction (G-study), *participant* (P) and *day* (D) were considered random facets in a fully-crossed design (*P* x *D*). A follow-up D-study was conducted to determine the minimum number of days of data collection needed to achieve a desirable reliability coefficient ($G \geq .80$) for step count measurement. Generalizability theory calculations were performed using GENOVA software (Brennan, 2001).

Results

Across the 7-day physical activity monitoring period, participants accumulated an average of 5,456 ± 3,836 steps per day, ranging from a low of 712 steps to a high of 25,750 steps. Pedometer reactivity was not present, $F(6, 210) = .90$, $p = .498$, and no differences in daily step activity were observed across days of the week, $F(6, 210) = .73$, $p = .628$. Variance component estimates and their relative magnitude for weekly physical activity levels are displayed in Table 3. The G-study illustrated that participants (*P*) and days (*D*) accounted for 43.6% and 0.37% of the total variance in weekly physical activity, respectively. The interaction between *P* x *D* and unidentified error accounted for the largest percentage of variance (56.0%) in weekly physical activity. The D-study revealed that a minimum of six days are required to achieve a G- coefficient $\geq .80$.

Table 3

Daily Step Activity in Persons with Visual Impairment: Variance Components and Relative Magnitude of Error

Variation	Variance Component Estimates	Relative Magnitude
P	5984089	43.61%
D	49650	.37%
P x D	7686863	56.02%
Total	13720602	100%

Note. Relative magnitude of variance components was calculated using variance estimates divided by the total variance.

Reliability coefficients for different monitoring time frames are illustrated in Figure 1 and daily step counts are reported in Table 4.

Discussion

Before launching research- or community-based interventions aimed at increasing step activity levels, it is necessary to obtain a reliable estimate of physical activity for the population of interest. Using advanced statistical methods, the primary aim of this study was to quantify the minimum number of days required to establish a stable estimate of weekly physical activity in adults with visual impairment, and to identify existing sources of variance in the physical activity patterns of these individuals. Through the application of Generalizability theory, it was determined that a minimum of six days of pedometer monitoring are necessary to obtain an acceptably reliable estimate of physical activity in visually impaired adults. Because physical activity levels did not vary across days of the week, and because reactivity did not occur, any combination of six days appears to be sufficient to acquire a stable estimate of weekly step activity in adults with vision loss.

In previous work, models of classical test theory have been applied to establish the appropriate monitoring time frame for predicting weekly physical activity in youth and adults without disabilities. Among young children, four to five days of pedometer monitoring are recommended (Trost et al., 2000), whereas three to four days of step activity monitoring is appropriate for adults (Togo et al., 2008; Tudor-Locke et al., 2005). Similarly, among adults with intellectual disabilities and youth with developmental disabilities, three and four days of activity profiling are recommended, respectively (Kim

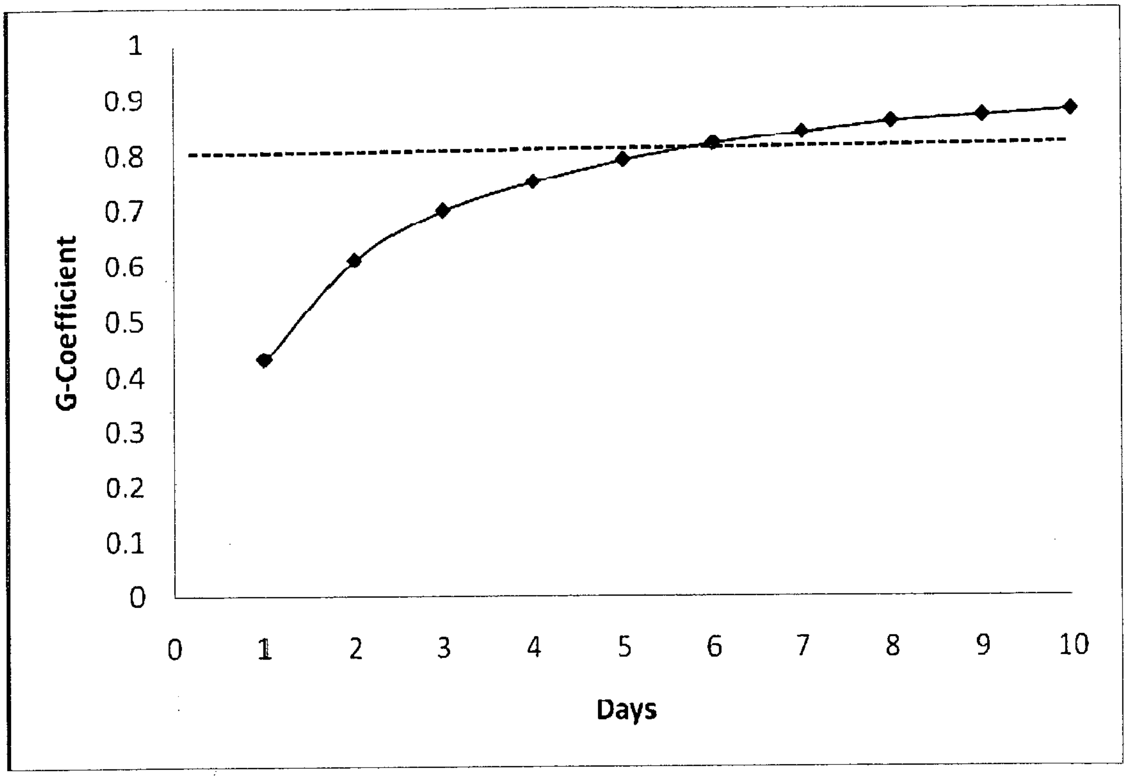

Figure 1. Reliability coefficients associated with the number of days of step activity monitoring needed to predict weekly physical activity in adults with visual impairment.

Table 4

Step-Based Physical Activity by Day of the Week

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Daily steps	5354	5499	5896	6443	4829	5432	4740
	(3510)	(3177)	(3841)	(4126)	(2872)	(4425)	(4665)

Note. Step counts are displayed as mean (standard deviation).

& Yun, 2009; Temple & Stanish, 2009). In the current study, the contribution of intra-individual variability was large in comparison to inter-individual variability, thus necessitating more days of pedometer monitoring to ensure that a reliable estimate of weekly activity was obtained (Tudor-Locke et al., 2005). Although speculative, it is possible that the heterogeneity of ocular disease manifestation, the elapsed time since the onset of visual impairment, and issues related to orientation and mobility may contribute to the need for more days of activity monitoring in persons with vision loss, as these factors are known to influence participation in activities of daily living in this population (Kraushar, De Santis, Kutsch, Kraushar, & Ruffalo, 2010; Lamoureux, Hassell, & Keeffe, 2004).

In the current study, the participant-by-day interaction term (*P* x *D*), also known as unidentified error, was associated with the largest proportion of variance in the weekly physical activity patterns of our sample of adults with blindness. Unfortunately, these sources of unidentified error could not be extracted from the interaction term. It seems reasonable to suggest that factors pertaining to visual classification (or acuity level), mobility aid type, or the presence of comorbidity, may have contributed to the magnitude of this component of error. However, a more complex examination of this question awaits collaborative multi-site efforts featuring a larger sample of persons with vision loss.

To the authors' knowledge, this is the first study to use Generalizability theory to document the reliability of physical activity behaviors in a population of persons with visual disabilities. As the prevalence of morbidity continues to proliferate in all populations, establishing time frame recommendations and variance estimates pertaining to physical activity assessment seems a necessary and useful step in developing health-related interventions. Among persons with visual impairment in particular, the availability of adaptive pedometers (Holbrook, 2010a) and knowledge of the appropriate physical activity monitoring time frame makes the effective delivery of a population-specific health intervention more feasible.

In summary, it is well documented that physical activity levels differ between persons with and without disabilities (Rimmer, Riley, Wang, Rauworth, & Jurkowski, 2004). As such, data collection strategies should be tailored to better suit the inherent characteristics of the population of interest. Collectively, the present investigation is the first-known attempt to document the reliability of physical activity patterns in persons with visual disabilities. Results from the current study demonstrate that six days of objective monitoring are needed to establish a reliable estimate of physical activity in adults with visual impairment. Although the relatively small participant sample was an inherent limitation in this project, the application of Generalizability theory allowed for variance sources affecting the stability of physical activity estimates in adults with vision loss to be identified. Because a large proportion of the variance in step activity patterns of persons with vision loss remains unexplained, further research is needed to ascertain additional sources of error. Specifically, factors such as visual acuity, orientation and mobility skill, and comorbidity should be considered. In addition, monitoring physical activity levels for extended time periods in persons with vision loss would allow for the consideration of issues related to the validity of long-term physical activity estimates and the time frame required to estimate monthly, yearly, or seasonal patterns of physical activity.

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CHAPTER IV

Development and Implementation of *Walk for Health:* A Pedometer-Based Walking Intervention for Adults with Visual Impairment

Introduction

As an accompaniment to recent initiatives to include persons with disabilities in matters of public health policy, the *Healthy People 2010* report called for a reduction in the health disparity between persons with and without disabilities (United States Department of Health and Human Services [USDHSS], 2001). Although vision-related disability ranks as the fourth-leading class of disability in the United States (USDHHS, 2008), the relatively low prevalence of severe visual impairment (e.g., low vision and blindness) belies the significant health-related needs of persons with vision loss. Compared to adults without visual disability, the incidence of overweight, obesity, and morbid obesity is nearly twice as high among persons with visual impairment (Holbrook, Caputo, Perry, Fuller, & Morgan, 2009a; Weil et al., 2002), leading to a heightened risk for developing comorbid conditions and functional limitations (Crews & Campbell, 2001).

Previous investigators have reported that physically-active individuals with visual disabilities are able to maintain levels of physical fitness and mobility status similar to those found among age-matched individuals without vision loss (Blessing, McCrimmon, Stovall, & Williford, 1993; Bunc, Segetova, & Safarikova, 2000; Colak, Bamac, Aydin, Meric, & Ozbek, 2004; Jankowski & Evans, 1981; Lieberman & McHugh, 2001; Shindo, Kumagai, & Tanaka, 1987; Singh & Singh, 1993). This observation has led to speculation that the pervasiveness of comorbidity recently documented in persons with visual impairment is largely attributable to inadequate levels of physical activity. It has also been suggested that physical inactivity in persons with vision loss begins in childhood as the result of poor motor skill development and leads to a higher energy cost of movement in adulthood (Bunc et al., 2000; Lieberman et al., 2006; Lieberman & McHugh, 2001; Colak et al., 2004). As a result of these factors and other unique barriers to physical activity participation (Lee, Zhu, Holbrook, Brower, & McMurray, *in review*), persons with vision impairment are more likely to experience severe functional limitations, debilitating falls, and hypokinetic conditions compared to the general population (Cacchione, 2010; Crews & Campbell, 2000; Holbrook et al., 2009a; Legood, Scuffham, & Cryer, 2002). Based on the association between low levels of physical activity and negative health outcomes among persons with blindness, increased levels of habitual physical activity participation may improve health status and reduce comorbidity in adults with visual impairment.

Regarded as the most basic form of all physical activities, walking has been described as the "perfect exercise" (Morris & Hardman, 1997). An enjoyable and repeatable activity, walking is capable of producing significant health benefits, even when performed at modest intensities (USDHHS, 2008a). Consequently, walking programs featuring step-based activity recommendations and pedometer monitoring are gaining in popularity worldwide. In 2007, Bravata and colleagues reviewed 26 studies demonstrating the effectiveness of pedometer-based physical activity programs in sedentary and obese persons and individuals with diabetes and functional limitations. Although the dose-response relationship between step-based physical activity and specific health outcomes is unclear, walking programs incorporating formal activity goals (such as accumulating 10,000 steps per day or making gradual increases in step activity over time) have been associated with improvements in cardiovascular, metabolic, musculoskeletal, and mental health (Bravata et al., 2007; Kang, Marshall, Barreira, & Lee, 2009; Murphy, Nevill, Murtagh, & Holder, 2007; Ogilvie et al., 2007). In view of these findings, it seems reasonable to suggest that adults with visual impairment may experience comparable increases in health status by engaging in similar types of walking programs. Surprisingly, a community-based walking initiative targeting adults with blindness has yet to be conducted. Because the two leading barriers to physical activity reported among persons with vision loss include transportation challenges and a lack of access to adaptive facilities (Rimmer, 2005; Lee et al., *in review*), home-based walking programs may prove to be an attractive and practical approach to encourage persons with visual impairment to engage in regular physical activity.

The purpose of this study was to develop and implement an adaptive, short-term physical activity intervention for visually impaired adults and to document the impact of this program (dubbed "*Walk for Health*") on the walking behaviors and health outcomes of persons with vision loss. Specifically, the goal of this project was to determine if personalized walking goals implemented over a 2-month period would lead to higher physical activity levels and improvements in selected indices of cardiovascular health, anthropometric status, and lipid function.

Methods

Participant recruitment. Recruitment of participants occurred within a 5-county region of middle Tennessee (including Rutherford, Davidson, Wilson, Williamson, and Hamilton counties) and preceded using snowball sampling. Primary solicitation efforts occurred through various advocacy organizations for persons with visual impairment (including the Nashville, Stones River, and Lookout Mountain chapters of the National Federation of the Blind, the Nashville chapter of the American Council of the Blind, the Tennessee School for the Blind, and the Tennessee state chapters of the Association for Blind Athletes and the Foundation Fighting Blindness), as well as through contacts at three universities in the middle Tennessee region. Recruitment efforts continued throughout the community of persons with visual impairment via word-of-mouth, listserv e-mailings, and flier postings at a number of adaptive resource centers in middle Tennessee. As a result of these efforts, approximately 320 eligible individuals were invited to participate in the *Walk for Health* program and a total of 33 ambulatory adult volunteers (age range = 24 to 67 years) with a best-corrected visual acuity of 20/200 or less (e.g., legal blindness) were recruited as study participants. Approval for this study was granted by the Institutional Review Board at a university located in the southeastern United States.

Study design. A quasi-experimental research design was employed to assess the efficacy of the *Walk for Health* program. Specifically, assignment to the control or experimental groups was not randomized, but rather, was based on the proximity of participants' domiciles to the university testing facility. While acknowledging the limitations associated with conducting a non-randomized trial, this approach was necessary to overcome the challenge of providing transportation for all participants, who were recruited within a 2-hour radius of the university testing site. Based on this criterion, 12 participants (8 females and 4 males) were assigned to the control group and 21 participants (12 females and 9 males) were assigned to the intervention group.

Overview of the *Walk for Health* program. Developed as an 8-week community-based intervention to improve the health status of persons with visual impairment, the primary objective of the *Walk for Health* program was to promote a level of physical activity among participants that met or exceeded the *Physical Activity Guidelines for Americans* (USDHHS, 2008a). The development of the *Walk for Health* program was also spurred by the desire to overcome a number of challenges with particular relevance to the community of persons with vision loss. Specifically, in addition to barriers to physical activity participation that are generic to all individuals (e.g., not enough time, lack of motivation or self discipline), persons with visual impairment have identified "a lack of transportation to an exercise facility" as a primary extrinsic barrier to engaging in physical activity (Lee et al., *in review*). To lessen the impact of this extrinsic barrier, safe and accessible home-based walking routes were established for participants in the experimental group. To implement this program component, the primary investigator oriented participants to walking routes within their neighborhood, established walking routes to fitness facilities, and provided removable, tactile covers for treadmill operating panels. The creation of home-based walking routes and user-friendly instrument panels for treadmills assisted participants in the intervention in surmounting the daily challenge of relying on public transportation to travel to recreational and exercise facilities.

A second and equally challenging barrier to promoting physical activity participation among blind adults is the limited availability of adaptive fitness equipment. Because most fitness equipment (including step activity monitors) provides some level of visual feedback, it is often difficult for meaningful activity-related information to be assimilated by persons with vision loss. However, recent work conducted by the primary investigator (Holbrook, 2010a) has shown that the Centrios talking pedometer (Orbyx Electronics, Model 6310620, Concord, Canada) can accurately report step-based physical activity in adults with visual impairment when it is mounted at the hip opposite the user's mobility aid (Holbrook, 2010a). Hence, the Centrios pedometer was used to provide accessible feedback to participants regarding their ability to meet walking goals during the *Walk for Health* program.

Aside from the unique adaptive components of *Walk for Health*, key elements of this program were derived from the recommendations of previous investigators, including authors of three recent systematic reviews of pedometer-based walking interventions. In their papers, the authors recommended the use of progressive and individualized activity goals in walking programs (Kang, Rowe, Barriera, Robinson, & Mahar, 2009) and emphasized the need to incorporate activity logs as a means of instilling participant accountability (Bravata et al., 2007; Ogilvie et al., 2007). The 8-week duration of the program was selected based on the success of previous short-term walking interventions (Araiza et al., 2006; Clarke et al., 2007; Croteau, 2004; Sidman et al., 2004; Swartz et al.)

in improving metabolic, cardiovascular, musculoskeletal, and mental health in sedentary adults. The metabolic and cardiovascular markers assessed in this program were derived from the recommendations of previous meta-analyses of walking-based health interventions (Bravata et al., 2007; Ogilvie et al., 2007). Further support for implementing a relatively short-term walking program was provided by Kang et al. (2009), who noted that the magnitude of fitness improvements reported in longer-term interventions may not be substantial enough to outweigh the burdens associated with maintaining extended activity programs.

Pre-intervention testing procedures. An in-home meeting was conducted with each participant prior to the measurement of baseline physical activity level and health status, both of which occurred approximately one week before the start of the *Walk for Health* program. The purpose of the in-home meeting was to allow participants to receive hands-on instruction relative to the proper use of the pedometer and to arrange for transportation to the university clinic for a pre-intervention blood draw. The in-home meeting also enabled the primary investigator to survey the environment surrounding the homes of the experimental participants in order to map out safe and accessible walking routes in close proximity to each participant's home.

Assessment of baseline physical activity. Step count values were monitored over the course of a 6-day period based on data showing that six days of monitoring are necessary to establish a stable estimate of weekly physical activity in adults with visual disabilities (Holbrook, 2010c). Participants were asked to maintain a normal level of physical activity throughout the monitoring period and to wear the pedometer along their waistband at the hip opposite their mobility aid during all waking hours, except when bathing or swimming (Holbrook, 2010a). At the conclusion of the pre-intervention monitoring period, participants in the experimental group were instructed to wear their pedometer each day for the duration of the walking program, and pedometers were collected from control participants.

Assessment of health status. Participants living within a 1.5-hour radius of the university testing site were transported to campus in small groups to complete the entire battery of cardiovascular, anthropometric, and lipid testing in a single session. While in-home assessments of cardiovascular and anthropometric variables were provided for participants living more than 1.5-hours from campus, measurements were conducted by the same individual, using identical testing protocols and equipment on all study participants. With respect to testing for lipid variables, participants living more than 1.5 hours from the university were transported to a centralized location where blood samples were drawn by a phlebotomist and transported to the university for further processing and analysis. All participants were instructed to abstain from food or beverage intake for a minimum of eight hours preceding the blood draw.

Cardiovascular variables. Resting measures of heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were obtained according to established guidelines (American College of Sports Medicine, 2009; European Society of Hypertension, 2008) using a previously validated (Bruce, 2007) automated blood pressure cuff (Welch Allyn Spot Vital Signs, Beaverton, OR: Model 420). Prior to testing, each participant was seated and remained quiet for 15 minutes with their right arm elevated at heart level. Heart rate and blood pressure variables were assessed in duplicate with a 1-min rest period separating each measurement (American College of Sports Medicine, 2009; European Society of Hypertension, 2008).

Anthropometric variables. Body mass and height were determined while participants wore light clothing and stood barefoot. Body mass was measured to the nearest 0.1 kg using a digital scale (SECA Corporation, Model 770, Germany) and height was assessed to the nearest 0.1 cm using a stadiometer (SECA Corporation, Model 222, Germany). For descriptive purposes, body mass index (BMI) was calculated by dividing body mass (kg) by height squared (m^2). A Gulick measuring tape (Creative Health Products, Ann Arbor, MI) was used to measure waist circumference over light clothing (American College of Sports Medicine, 2009).

Based on standardized procedures (American College of Sports Medicine, 2009), skinfold thicknesses at three sites (males – chest, triceps, subscapular; females - triceps, suprailiac, and thigh) were quantified using a Harpendon skinfold caliper (Creative Health Products, Ann Arbor, MI). Two skinfold measures at each location were taken in sequential order on the right side of the body. A third measurement was obtained when duplicate skinfold thicknesses at a given site differed by more than 1 mm, and the average of the two closest values (within 1 mm) was used to represent the skinfold thickness at that site. Average measures for each of the three skinfold locations were added to derive an overall skinfold sum, and body density was calculated from this value using generalized prediction equations developed by Jackson and Pollock (1985). Body fat percentage was determined by substituting body density values into population-specific formulas (Nieman, 2007).

Lipid profile. A 10-ml fasted blood sample was drawn from the antecubital vein into a vacutainer. The vacutainers were centrifuged and the supernatant was removed prior to enzymatically analyzing the samples for triglycerides (Trig), total cholesterol (Tot-C), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotien cholesterol (LDL-C; Allain, Poon, Chan, Richmond, & Fu, 1974; Bucolo & Davis, 1973) using an autoanalyzer (Olympus AU640, County Clare, Ireland). These lipid markers were selected due to their identification as risk factors for cardiovascular disease and diabetes (Araiza et al., 2006; Hahn, Heath, & Chang, 1998).

Balance confidence and health history assessment. A balance confidence scale (the Activities-specific Balance Confidence [ABC] scale; Powell & Myers, 1995) and health history questionnaire were verbally administered to each participant (see Appendices 1 and 2, respectively). The ABC questionnaire was used to assess falls efficacy pertaining to a series of activities typical of everyday living, while the health history questionnaire prompted respondents to provide information relative to their visual, medical, and demographic backgrounds.

Implementation of the *Walk for Health* program. Following completion of the pre-intervention assessments, members of the experimental group began the *Walk for Health* program. As noted earlier, this program was designed as an 8-week, community-based walking intervention aimed at improving selected health indices through the application of personalized activity goals. To mitigate the confounding influence of nutrition on indices of lipid health, participants were asked to maintain their normal nutritional and medication intake for the duration of the program. By using a "talking pedometer", tracking daily step counts with a personal physical activity calendar, and creating accessible walking routes, it was hoped that the *Walk for Health* program would result in a level of physical activity among participants that met or exceeded activity goals outlined in the *Physical Activity Guidelines for Americans* (USDHHS, 2008a).

Relative to baseline step-count values established during the pre-intervention phase of the study, participants in the experimental group were asked to increase their daily step count by 1,000 steps (roughly equivalent to an additional 10 minutes of walking) every two weeks. To ensure that gradual and attainable goals were prescribed, the 1,000 steps per day (s/d) increase in walking activity was applied to the actual mean daily step count value calculated for the preceding two weeks. Therefore, if participants were unable to reach their personalized step goal for a particular 2-week period, the 1,000 s/d increase was applied to the actual mean daily step count value for that given bi-weekly time span. In total, three step goals were implemented at bi-weekly intervals (i.e., week 1, week 3, and week 5) to motivate participants to gradually increase their daily step activity by 3,000 s/d above baseline and thereby engage in 30 minutes of daily walking above baseline levels by the end of the sixth week of the program. Intervention participants were challenged to maintain their final step activity goal during the final two weeks of the *Walk for Health* program.

To assess participant compliance and provide individually-tailored motivation, step count data and daily comments regarding the program were logged onto personal activity calendars and submitted to the primary investigator on a weekly basis via email or by phone. Due to the heterogeneous visual status of participants in the intervention group, the format of the activity calendar varied from adaptive computer spreadsheets to voice-recorded logs to written accounts of daily activity. The personal activity calendars served as a tool to enable participants to track their daily step activity, while providing feedback about their experience in the program. Information contained in the activity calendars was scrutinized to adjust step goals for study participants and to supply personalized motivational feedback on a weekly basis.

To implement the motivational feedback component of the program, participants received a personally-tailored, weekly summary of their progress in the walking program that reflected the data and comments included in their personal activity calendar. Within the summary, participants were reminded of their previous week's walking goal and were provided with data indicating their average daily step activity from the previous week. During weeks 1, 3, and 5, participants were also provided with a new walking goal and, through individually-tailored comments, were encouraged to consistently attain the goal in the ensuring 2-week period. During weeks 2, 4, 6, 7, and 8, participants were asked to continue to work toward their previously prescribed walking goal, and individually-tailored motivational feedback was provided. Feedback provided to participants consisted of information supporting the benefits of leading a physically-active lifestyle, the role of short bouts of activity for inducing health benefits (e.g., 10 minutes or more), and a description of creative approaches (e.g., walking the stairs in their apartment complexes, creating short walking routes in safe areas within or around their homes) to overcome the challenges of maintaining a physically-active posed by their surroundings.

Post-intervention assessment procedures. Post-intervention measurements of cardiovascular, anthropometric, and lipid variables were obtained from control and experimental participants using testing procedures identical to those employed during the pre-intervention phase of the study. With regard to the assessment of post-intervention physical activity, experimental participants underwent six days of pedometer monitoring following the eighth week of the *Walk for Health* program. For control participants, pedometers were delivered to their homes and six days of pedometer-monitoring were completed eight weeks after the original assessment period. The ABC scale and health history questionnaire were also administered to evaluate changes in balance confidence and self-reported health status and to ensure consistency in medication use and nutritional intake throughout the program. To further document the effectiveness of the *Walk for Health* program, participants in the intervention group completed a second questionnaire addressing perceived changes in overall well-being and self-efficacy resulting from participation in the walking program. This secondary evaluation also included open-ended questions designed to identify strengths and limitations of the *Walk for Health* initiative (Appendix 3).

Statistical analysis. Data screening and analyses were performed using PASW (version 18.0) and Microsoft Excel for Windows. Descriptive characteristics for study participants were expressed as means ± standard deviations. Two *t*-tests for dependent samples were conducted to document changes in physical activity and balance confidence (ABC scale) across time. Three group by time multivariate mixed model (MMM) analyses were performed to compare pre- and post-intervention assessments of (1) cardiovascular (resting HR, SBP, DBP), (2) anthropometric (percent body fat, waist circumference, and body mass), and (3) lipid (Tot-C, HDL-C, LDL-C, and Trig) variable clusters. Because there were only two levels of the time within-subjects factor (e.g., pre- and post-intervention), the assumption of sphericity was met (Anshel & Kang, 2007). The MMM analyses allowed for comparisons of multiple groups of dependent variables with repeated measures on time to be conducted while controlling for Type I error (Anshel & Kang, 2007; Liu, 2002; Schutz & Gessaroli, 1989). Statistical significance for all tests was established *a priori* at $P < .05$.

Results

A total of 33 adults with legal blindness provided written informed consent and completed pre-intervention health assessments. Detailed characteristics of the total sample relative to vision and socio-demographic characteristics are included in Tables 5 and 6. After accounting for attrition ($n = 9$) and non-compliance with medications ($n = 2$), a summary of pre- and post-intervention indicators of physical activity and health status for the remaining 22 participants is provided in Table 7. Data analyses pertaining to physical activity, balance confidence, and non-physiological descriptive data were included for the two individuals who stopped taking prescription medications during the intervention.

Table 5

Descriptive Characteristics of Study Participants: Vision-Related Factors

	Control $n = 12$	Experimental $n = 21$	Total $N = 33$
VI onset			
Congenital	50	38	58
Non-congenital	50	62	42
VI severity			
Travel vision	8	14	12
Light perception	59	29	39
No light perception	33	57	49
Mobility Aid Type			
None	8	14	12
Long cane	67	67	67
Dog guide	25	19	21

Note. Values expressed as percentages; VI = visual impairment.

Table 6

Socio-Demographic Characteristics of Study Participants

	Control $n = 12$	Experimental $n = 21$	Total $N = 33$
Education level			
High school	33	19	24
College	50	62	58
Graduate school	17	19	18
Employment			
Employed	33	76	61
Unemployed	67	24	39
Marital status			
Single	17	24	21
Married	33	57	49
Divorced	50	19	30

Note. Values expressed as percentages.

Table 7

Physical Activity and Health Status of Walk for Health Participants

	Control (n = 7)		Experimental (n = 15)	
Index of Health	Pre-test	Post-test	Pre-test	Post-test
Physical Activity	7695 ± 3712†	7911 ± 4170$^{\Delta}$	4925 ± 2234†	8506 ± 3063$^{\Delta}$
Balance Confidence	82.6 ± 17.7	80.2 ± 21.2	77.4 ± 32.6	77.3 ± 32.3
Cardiovascular health				
Heart rate (beats/min)	71 ± 14	66 ± 5	69 ± 11	70 ± 11
SBP (mm Hg)	133 ± 13†	127 ± 12	108 ± 13†	110 ± 14
DBP (mm Hg)	81 ± 11†	80 ± 11	69 ± 9†	69 ± 10
Anthropometric health				
Body mass (kg)	77.6 ± 16.2	78.0 ± 16.3	85.0 ± 20.6	85.1 ± 20.3
Body fat (%)	32.5 ±13.4	33.2 ± 12.1	31.9 ± 8.3	30.1 ± 9.3
Waist (cm)	95.7 ± 11.5	94.6 ± 12.9	93.6 ± 18.1	93.5 ± 16.8
Metabolic health				
Total cholesterol	195.9 ± 43.5	193.7 ± 40.0	177.7 ± 24.3	177.7 ± 33.6

(continued)

Index of Health	Control (n = 7)		Experimental (n = 15)	
	Pre-test	Post-test	Pre-test	Post-test
HDL-cholesterol	55.9 ± 12.1	54.0 ± 14.8	51.9 ± 16.6	48.7 ± 16.8
LDL-cholesterol	112.6 ± 37.5	113.7 ± 36.9	99.3 ± 18.6	106.9 ± 23.7
Triglycerides	136.7 ± 52.6	130.7 ± 56.8	131.3 ± 96.5	110.7 ± 75.1

Note. Physical activity measures included information from 24 participants, including 2 who stopped taking prescription medications prior to the conclusion of *Walk for Health*; Physical activity is measured in steps per day; SBP = systolic blood pressure; DBP = diastolic blood pressure; waist = waist circumference; cholesterol and triglycerides are measured in mg/dL.

† Indicates significant between-group difference at pre-test.

* Indicates significant between-group difference at post-test.

Δ Indicates significant within-group difference from pre-test to post-test.

Overall, study participants were obese ($M = 30.1$, $SD = 6.6$ kg/m^2), middle-aged adults ($M = 46.7$, $SD = 11.9$ years) who reported a congenital visual disability (58% of total sample), had completed at least some college-level education (76%), and were employed on a full or part-time basis (61%). The severity of visual impairment experienced by participants, which was classified using the International Statistical Classification of Diseases (ICD) schematic (World Health Organization, 2007), varied from peripheral or travel vision ($n = 4$; ICD classification 1-3), to light perception ($n = 13$; ICD classification 4), and no light perception ($n = 16$; ICD classification 5). Four participants did not use a mobility aid, seven participants used a dog guide, and 22 participants used a long cane. During baseline assessments, the most commonly reported comorbid conditions included hypertension (36%), depression (36%), hypercholesterolemia (30%), diabetes (27%), and osteoporosis (15%). While nine participants reported irregular participation in leisure-time physical activity, only five participants were active (e.g., walking or lifting weights) on a regular basis. The primary barriers to physical activity identified by participants included "lack of sidewalks", "lack of social support", "lack of transportation", and "limitations due to vision".

Physical activity and balance confidence. At the beginning of the study, control participants were more physically active, $t(22) = 2.27$, $p = .033$, compared to participants in the experimental group. A significant increase, $t(16) = -4.79$, $p = .000$, in step-based physical activity was observed among participants in the experimental group from pre-test ($M = 4{,}925$, $SD = 2{,}234$ s/d) to post-test ($M = 8{,}506$, $SD = 3{,}063$ s/d). However, no significant difference in physical activity was noted among control participants, $t(6) =$

-.14, $p = .896$, from the pre-testing ($M = 7,695$, $SD = 3,712$ s/d), to the post-testing phase ($M = 7,911$, $SD = 4,107$ s/d). With respect to balance confidence, no significant changes were detected among experimental participants from pre-test ($M = 77.4$, $SD = 32.6$) to post-test ($M = 77.3$, $SD = 32.3$), $t(14) = .09$, $p = .928$, or among control participants from pre-test ($M = 82.6$, $SD = 17.8$) to post-test ($M = 80.2$, $SD = 21.2$), $t(6) = .65$, $p = .540$. As an aside, two experimental participants expressed opposition to the notion that a potential relationship might exist between balance confidence and vision loss and refused to complete the ABC scale.

Health Status. Independent samples *t*-test revealed that prior to the study, control participants displayed higher resting SBP, $t(20) = 4.29$, $p = .000$, and DBP, $t(20) = 2.90$, $p = .009$, values compared to participants in the experimental group. No significant multivariate group by time effects were observed for the cardiovascular markers, $F(3,18) = 2.74$, $p = .074$, $\eta^2 = .31$, body composition variables, $F(3,18) = 2.40$, $p = .102$, $\eta^2 = .29$, or blood lipid indices, $F(3,18) = .78$, $p = .556$, $\eta^2 = .16$.

Discussion

The primary objective of this study was to document the efficacy of a graduated, pedometer-based program to increase physical activity participation in adults with blindness. A secondary objective of this investigation was to evaluate the impact of this personalized walking program on various indicators of cardiovascular function, anthropometric status, and lipid health. As the first community-based health intervention developed specifically for adults with visual impairment, the *Walk for Health* program was successful in eliciting a significant increase in daily step activity. Despite this marked improvement in physical activity level, however, no change in the health status of our adult sample of visually impaired adults was noted.

Participant compliance and program attrition. Among the 22 participants who completed the *Walk for Health* intervention, compliance with the program was considerably higher (94%) than has been reported in previous walking interventions for persons with chronic health conditions (Tudor-Locke et al., 2004). This statistic reflects the participants' compliance with wearing the pedometer and recording daily steps within the physical activity calendar. From a qualitative viewpoint, this rate of adherence reflects a strong desire among participants to meet personalized walking goals (as determined by inspection of self-reported weekly activity calendars) and an openness to motivational strategies designed to encourage consistent daily step activity. However, the attrition rate associated with *Walk for Health* (27%) was also slightly higher than has been reported (20%) in previous walking programs (Bravata et al., 2007). Vision-related factors appear to explain this disparity in attrition, because in addition to typical losses to follow-up ($n = 3$), dropout among intervention participants resulted from extended hospital admissions for severe falls ($n = 2$) and depression ($n = 2$). Within the control group, attrition was related only to losses to follow-up ($n = 5$).

Changes in physical activity level. Although members of the control group did not display a significant change in daily step activity over time, they exhibited considerably higher baseline values of physical activity ($M = 7{,}695$ s/d) compared to the experimental group ($M = 4{,}925$ s/d). In an attempt to explain this finding, further scrutiny of the data revealed that each group contained two individuals who were employed as vending machine service providers. Not only is vending a common occupation among persons with visual impairment, but it often requires a great deal of walking. Since the control group contained fewer participants (*n* = 7) than the experimental group (*n* =15), it stands to reason that overall physical activity levels would be influenced to a greater relative extent from two fairly active control participants compared to two similarly-active participants in the intervention group.

The average daily step activity of intervention participants is shown in Figure 2. As was intended, the application of progressive walking goals resulted in a mean increase in daily step activity of 3,581 s/d over the course of the 8-week program, roughly equivalent to 35 minutes of additional daily walking activity. Previous investigators have reported similar increases in step activity (2,400 to 3,000 s/d) among sedentary adults (Baker et al., 2008; Bravata et al., 2007; Chan, Ryan, & Tudor-Locke, 2004; Gray et al., 2008; Moreau et al., 2001; Talbot, Gaines, Huynh, & Metter, 2003). However, based on the level of physical inactivity exhibited by participants in the intervention group at baseline, the increase in daily step activity among intervention participants represented a 73% increase in physical activity. In relative terms, this walking volume is nearly three times greater than the 26.9% improvement in baseline activity that has typically been observed following walking programs of various durations (Bravata et al., 2007).

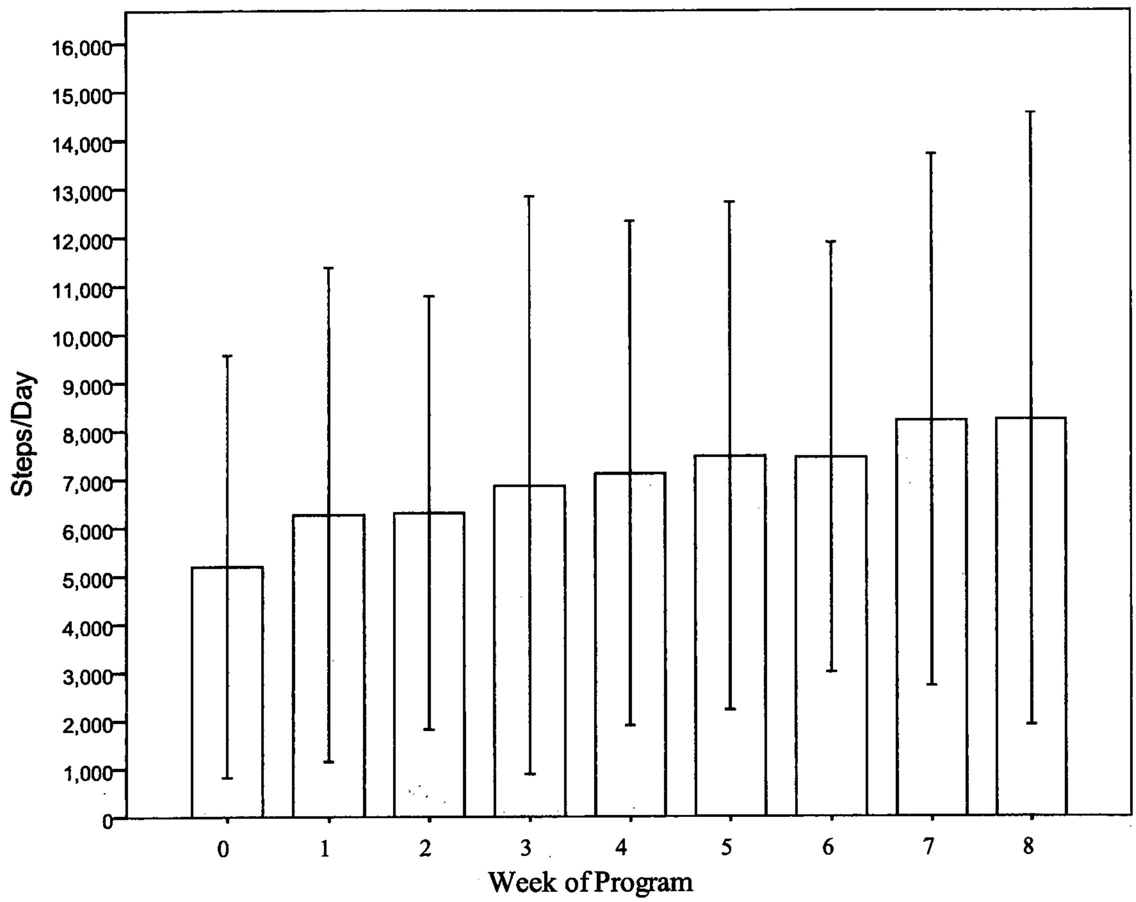

Figure 2

Changes in weekly step activity among participants in the Walk for Health program

According to step-based activity cutoff points for adults, participants in the current investigation progressed from a "sedentary" classification (< 5,000 s/d) at baseline to a classification of "somewhat active" (7,500 – 9,999 s/d) at the end of the *Walk for Health* program (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008).

The marked elevation in daily step activity displayed by the experimental group can be traced to a number of innovative components of the *Walk for Health* program. For example, the incorporation of adaptive technologies (e.g., a "talking" pedometer) allowed real-time step-activity feedback to be available to participants. The use of internet-based activity calendars, bi-weekly goal implementation strategies, and personalized feedback aimed at reducing barriers to physical activity also served as reinforcing strategies to motivate participants to become more physically active. Related to this point, a final 1,000 s/d increase in walking activity was imposed at the beginning of the fifth week of the program, and participants were asked to sustain that level of activity through the eighth week. As depicted in Figure 2, however, mean step count data revealed that participants actually elevated their daily step activity through the final week of the program.

Balance confidence. Despite marked increases in physical activity among intervention participants, balance confidence remained unchanged. It should be noted that a questionnaire-based assessment of balance confidence was used an alternative to conducting an in-home functional balance assessment. In interpreting the scores, participants in this investigation were considered to have a moderate to high level of physical functioning at both the pre- and post-test assessments (Myers, Fletcher, Myers,

& Sherk, 1998). However, based on participant feedback, it is possible that the activities described in the balance questionnaire did not identify or properly assess factors influencing balance confidence in persons with visual disabilities. As a result, the relatively high balance scores reported by participants may also reflect a ceiling effect related to the use of the balance questionnaire. Because a vision-related falls efficacy sub-scale does not currently exist, future investigators should consider applying measurement techniques to pre-existing balance questionnaires (such as Rasch model and item response theory) to develop a more population-appropriate subscale. The use of the Berg balance assessment, which is typically used with older adults exhibiting functional limitations, should also be evaluated as a potentially robust in-home assessment of functional balance in persons with vision loss. Given the high prevalence of falls reported among persons with visual impairment (Cacchione, 2010; Crews & Campbell, 2000; Legood, Scuffham, & Cryer, 2002), continued study of the relationship between improved physical activity and falls efficacy is needed.

Health indicators. In view of recommendations from the U.S. Surgeon General, which highlight walking-based physical activity as a means to prevent and treat comorbid health conditions, manage body weight, and improve cardiovascular, metabolic and musculoskeletal health (USDHHS, 2008), modest improvements were expected in selected health outcomes given the degree of physical inactivity measured among participants (mean = 4,925 s/d) at the start of the *Walk for Health* program. This expectation was based on the recommendations of Ogilvie et al., who reported in a recent meta-analysis that the participants who made the greatest improvements in health status following a walking intervention were those who were least healthy at the onset of the program (2009). In the current study, an average increase of 73% in daily step activity was documented for participants in the intervention group, who, as a group, were classified as sedentary at baseline (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). However, this substantial gain in step-based activity did not translate into significant improvements in various markers of resting cardiovascular function, anthropometric status, or lipid health. Although this finding was not anticipated, results from a recent meta-analysis (Barreira, 2010) suggest that the magnitude of the intervention effect observed in the current study is consistent with findings from previous randomized control studies relative to body composition (g = 0.19-0.27) and lipid status (g = 0.14-0.25). In retrospect, it is possible that a larger effect for cardiovascular function may have been detected if an exercise- or walking-related index of cardiac fitness had been studied. In support of this assertion, Barriera (2010) reported a very large effect (g = 0.95) for maximal aerobic power resulting from previous activity-based interventions. Because resting heart rate and blood pressure can be influenced by factors such as stress or anticipation, these indices may not have been ideal measures of cardiovascular fitness. However, because adults with visual impairment are prone to falls, display low levels of physical fitness, and typically live in low-income neighborhoods with limited accessibility to sidewalks, estimating maximal aerobic power during overground walking or treadmill testing could be problematic, or, in some cases, impractical.

The lack of change in health variables among members of the intervention group may be related to a number of factors. First, the cardiovascular and lipid indices were generally within acceptable ranges. Because exercise is more prophylactic in nature for individuals with existing risk factors, the absence of significant modification in cardiovascular and lipid function may have been related to the use of medications or to the presence of acceptable levels of cardiovascular health. Second, it is possible that the lack of change may be related to the graduated nature of goal implementation featured in the *Walk for Health* program. In the *Physical Activity Guidelines for Americans*, there is clear support for the role of 30 minutes of daily, moderate intensity physical activity in improving general health. However, because walking goals were applied in increments of 1,000 s/d (equivalent to about 10 minutes of walking), more than six weeks were required for participants to meet the recommended level of physical activity. Moreover, since intensity cannot be inferred from measures of pedometer-determined steps, the assumption that participants engaged in sufficiently moderate levels of physical activity cannot be confirmed.

A review of findings from community-based walking interventions demonstrates that a number of programs with similar goal setting strategies have been successful in improving body composition (Chan et al., 2004; Moreau et al., 2001; Murphy et al., 2007; Richardson et al., 2008) and cardiovascular health (Chan et al., 2004; Gray et al., 2008; Murphy, 2007; Swartz et al., 2003; Talbot, Gaines, Huynh, & Metter, 2003), while other studies have reported no changes in these variables (Araiza et al., 2006; Baker et al., 2008; Gray et al., 2008; Swartz et al., 2003; Tudor-Locke et al., 2004). While the length of the intervention may play a key role in producing positive health changes, a meta-analytic review addressing the effect of intervention length on health status has not been conducted. Examination of the literature indicates that few short-term interventions (8 to 10 weeks) are capable of producing significant reductions in body mass index (BMI) and body fatness (Clarke et al., 2007), whereas most programs of reduced length result in the maintenance of body fatness and metabolic indices (Croteau et al., 2004; de Bolk, 2005; Swartz et al., 2003). The impact of longer-term interventions (12 or more weeks) on health outcomes is even less clear, with changes occurring in body mass index (Chan et al., 2004; Haines et al., 2007; Jensen et al., 2004; Moreau et al., 2001) and metabolic variables (Jensen et al., 2004) in certain investigations, but not in others employing similar goal-setting strategies (Baker et al., 2008; Gray et al. 2008; Haines et al., 2007; Moreau et al., 2001; Schofield et al., 2005). Although speculative, reductions in adiposity may need to exceed a certain threshold before improvements in metabolic biomarkers can be detected. Based on the direct association between truncal fat mass and insulin sensitivity (Rosenfalck et al., 2002), for instance, it is reasonable to hypothesize that a walking program that is successful in causing changes in body mass or fat mass may be also be potent enough to elicit reductions in blood lipids or increase insulin sensitivity.

Participant evaluation of the *Walk for Health* program. Despite no measurable changes in the health indices of interest, 93% of intervention participants believed their physical health improved as a result of their involvement in the program (as indicated by responses on the post-intervention evaluation; see Appendix 3). Specifically, participants reported perceived improvements in cardiovascular endurance and productivity (93%), mood and mental health (73%), outlook on life, self confidence and functional mobility

(67%), and, to a lesser extent, travel confidence, sleep, and the ability to carry out activities of daily living (< 40%). All of the participants in the intervention group reported a high level of satisfaction with the program, identifying "access to a structured program" and "the challenge of achieving a goal" as the most enjoyable aspects of *Walk for Health*. The majority of participants also appreciated the feedback provided by the Centrios talking pedometer.

Strengths and limitations. While acknowledging the valuable contribution of the Centrios talking pedometer in monitoring the daily step activity of study participants, durability concerns became an issue as the investigation progressed. On average, each participant exchanged their pedometer batteries once and replaced their pedometer twice because of broken spring-levered counting mechanisms. Therefore, while only 15 participants completed the intervention, 52 pedometers and 84 replacement batteries were needed to complete this study. Hence, the seemingly constant need to travel to participants' homes to replace pedometers and batteries became a tremendous burden for the primary investigator and participants alike. Given this scenario, the development of an adaptive piezoelectric pedometer for persons with visual impairment should be explored.

The manner in which physical activity was tracked and activity goals were implemented served as an additional strength of this investigation. Because the majority of the walking program was delivered through email, tracking participants' progress was relatively simple. The individualized nature of *Walk for Health* was also a positive attribute of the intervention. However, the incorporation of personalized motivational feedback was somewhat challenging to implement, as this feedback was tailored to address the specific needs of each participant relative to his or her progress and perceived barriers to activity. With respect to creating walkable environments for intervention participants, only two individuals took advantage of the option to have accessible walking routes established, as the remaining 13 participants did not believe that the environment around their home or workplace was conducive to walking. Of the 15 participants that completed the intervention, 4 lived in close proximity to an area with sidewalks and 11 resided in areas unsafe for walking, as exemplified by a lack of sidewalks, the presence of fast-moving traffic, untethered dogs, or cars parked along the road. Consequently, the motivational feedback provided each week was used primarily to encourage the accumulation of physical activity, wherever possible, in multiple 10-minute bouts throughout the day. Participants responded to this challenge in a variety of creative and resourceful ways, garnering steps by marching up and down stairs in their apartment complexes, creating room-to-room routes within their homes, or paying colleagues to drive them to a fitness facility to walk on a treadmill fitted with a handmade tactile foam board.

In addition to providing a means of tracking participants' progress during the program, internet-based communication between participants and the primary investigator enabled program adherence to be evaluated on a regular basis. Although self-reported, the weekly receipt of step-count data from participants allowed walking goals to be monitored and adjusted in an individualized manner. Collecting activity data only once per week further minimized the burden associated with reporting step counts.

Participants responded favorably to this element of the program and looked forward to receiving personalized progress reports each week. However, because of the challenges experienced by participants relative to the built environment (e.g., lack of accessible walking routes outside of the home), a few participants expressed a sense of boredom associated with walking within the confines of their homes to attain their weekly activity goal. Consequently, participants with very limited accessibility to activity locales felt that the 8-week program was too long.

A noteworthy limitation of this investigation was the challenge of overcoming transportation barriers. In particular, assessments of cardiovascular function and body composition were chosen not only on the basis of previous research recommendations, but also because of the ease of measuring these variables in participants' homes. Perhaps the greatest limitation of this project, however, was the inability to recruit a subgroup of the visually impaired population exhibiting the greatest need for the *Walk for Health* program. Reports in the epidemiological literature indicated that persons who are unemployed, display poor health status, and have limited education are less likely to participate in population-based studies (Munoz et al., 1999). Therefore, recruitment strategies targeting visually impaired individuals with this specific health and socio-demographic profile are needed. However, the challenge involved in recruiting potential participants that fit this general description is magnified by difficulties associated with locating adults with sight impairments. Since approximately 77% of blind adults are unemployed (American Federation for the Blind, 2010), and because only a limited cross-section of the visually impaired population is affiliated with advocacy outlets, educational institutions or rehabilitation programs, recruitment efforts aimed at securing an adequately-sized, representative sample of individuals with vision loss can fall short. Put more simply, traditional approaches to recruiting adults with visual impairment are not sufficiently effective in reaching those who would benefit most from participation in health interventions. Consequently, the need for multi-site collaborations and new methods of recruiting participants in this line of research cannot be overstated.

Conclusion. In direct response to a recent call to action (Capella-McDonnall, 2007), the *Walk for Health* program has served as the first health promotion intervention for adults with visual impairment. Seeking to overcome a series of practical impediments, such as transportation issues and a lack of accessible equipment, the *Walk for Health* program was developed with individual considerations of disability status in mind (Capella-McDonnall, 2007; Rimmer, 2005). Program features were implemented to overcome specific obstacles related to the extent of the participants' vision loss, orientation and mobility skill, incidence of comorbidity or functional limitation, and real or perceived barriers to physical activity. As a result of these strategies, *Walk for Health* participants exhibited higher levels of program compliance and greater relative increases in step-based physical activity compared to previous walking interventions. However, measurable changes in cardiovascular function, body composition, and lipid profiles were not observed. Nonetheless, intervention participants reported perceived improvements across the domains of physical fitness, emotional well-being, and functional health.

Given the vast heterogeneity of vision impairment manifestation, interactions with comorbidity, and socioeconomic factors, continued didactic efforts are needed to deliver effective health programming to the community of adults with blindness. In this spirit, future research should focus on incorporating and expanding goal-setting strategies and adaptive technologies employed in the *Walk for Health* program within the context of longer-duration interventions. The development and testing of population-specific assessment protocols to evaluate health and fitness parameters should also be considered. Lastly, the dose-response relationship between step-based physical activity and various health outcomes deserves further attention.

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APPENDIX 1: **The Activities-specific Balance Confidence (ABC) Scale***

Instructions to Participants:
For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask the administrator.

The Activities-specific Balance Confidence (ABC) Scale*

For each of the following activities, please indicate your level of self confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%
no confidence completely confident

"How confident are you that you will not lose your balance or become unsteady when you…

1. Walk around the house? ____%
2. Walk up or down stairs? ____%
3. Bend over and pick up a slipper from the front of a closet floor __%
4. Reach for a small can off a shelf at eye level? ____%
5. Stand on your tiptoes and reach for something above your head __%
6. Stand on a chair and reach for something ____%
7. Sweep the floor ____%
8. Walk outside the house to a car parked in the driveway? ____%
9. Get into or out of a car? ____%
10. Walk across a parking lot to the mall? ____%
11. Walk up or down a ramp? ____%
12. Walk in a crowded mall where people rapidly walk past you? ___%
13. Are bumped into by people as you walk through the mall? ____%
14. Step onto/off an escalator while you are holding onto a railing __%
15. Step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
16. Walk outside on icy sidewalks? ____%

APPENDIX 2: **Pre-Intervention Health History Questionnaire**

SN: __ **Age:** _____ **Sex:** __ **Ethnicity:** ____

Visual Impairment: (circle all that apply)

Light perception / No light perception Congenital / Non-congenital

Central vision / Peripheral vision Hand movements / Contrast

Visual Acuity: _________ (if known) **Name of condition:** ___________(if known)

Mobility Aid *(circle predominant):* None / Lone cane / Dog guide / Sighted guide

Mode of Transportation *(circle most predominant):* Public transportation / Walking

Employment:________ **Education status:**________ **Marital Status:**__________

Healthy History:

Smoke: Y / N **Currently Exercising**: Y / N # Days/week: __________

Diagnosed conditions: ____

Current medication (including supplements): ______________________________

Family medical history: ____

Barriers to Physical Activity:

What are your perceived barriers to physical activity, if any? (fear of falling, hesitant to walk alone, etc?) ____

____

Will you incorporate social support during this program? **Yes / No**

If yes: Walking partner / weight goal with friend / Other:____________________

Body Image / Fitness:

How do you perceive your body image? ___________________________________

How do you perceive your level of fitness? ________________________________

APPENDIX 3: **Post-intervention evaluation**

SN: _____________ **Age:** _____ **Sex:** ______ **Ethnicity:** _______________

Due to factors unrelated to the program, has your health status changed in the past 8 weeks? Y / N

Specifically, have you experienced a fall or mobility limitation, changes in sleep patterns, or changes in medications? ____

Are you taking a new medications or supplements, or have you altered the dose of your medication in the past 8 weeks? ____

How do you perceive your body image? ______________________________________

How do you perceive your level of physical fitness? ___________________________

What are your perceived barriers to physical activity? _________________________

Did you enjoy participating in the Walk for Health program? Yes / No

Do you feel that your PA level improved as a result of the program? Yes / No

Do you feel your overall health has improved? Yes / No

(circle all that apply)

Physical health	Mental health	Sleep	Mobility status
Mood	Outlook on life	Falls efficacy	Productivity
Endurance	Ability to carry out ADL's		Self confidence
Travel confidence	Other: ____________________________________		

What was your favorite part of the program:___________________________________

____

What was your least favorite part? ____

____

Did you like the pedometer? Yes / No Did we have to replace it? Yes / No

How many times? _______

Did we have to change the batteries in the pedometer? Yes / No

How many times? _____

CHAPTER V

Overall Conclusion

Due in large part to the inclusive nature of the *Healthy People 2010* report and the subsequent publication of the *Physical Activity Guidelines for Americans,* the need to minimize health disparities between persons with and without disabilities has garnered renewed attention. There is a pressing need to address the pervasiveness of hypokinetic conditions. Specifically, as the prevalence of visual impairment continues to rise in direct proportion to the increase in aging and obese populations, a greater manifestation of vision-related mortality and morbidity is expected. In recognition of the national agenda to reduce health disparities and promote wellness, the overriding theme of this dissertation was the promotion of health-producing levels of physical activity in adults with vision loss.

Results from the first study, entitled "*Effects of Mobility Aid Use and Environmental Influences on the Accuracy of a Talking Pedometer in Adults with Visual Impairment*," demonstrated that persons with vision loss exhibit noticeable kinematic changes in response to their level of familiarity with the surrounding environment, and that these changes influence the ability of an adaptive pedometer to accurately monitor step-based physical activity. In particular, it was shown that when walking in an unfamiliar setting, adults with visual impairment display slower walking speeds and a heightened reliance on mobility aid use compared to walking in a familiar setting. Overall, findings from this investigation revealed that the adaptive Centrios talking pedometer can serve as a suitable option for accurately monitoring step-based physical activity when mounted at the hip opposite the user's mobility aid.

In the second study, entitled "*Reliable Estimation of Physical Activity in Adults with Visual Impairment*," it was determined that six days of pedometer monitoring are needed to establish a stable estimate of physical activity in adults with blindness. When coupled with results from the first study, these findings highlight the need for investigators to modify data collection strategies when working with special populations to ensure that valid and reliable measures of physical activity are obtained.

In the final study of the dissertation, entitled "*Development and Implementation of Walk for Health: A Pedometer-Based Walking Intervention for Adults with Visual Impairment*," the influence of an 8-week, graduated walking program on physical activity participation and various health indicators was documented. Baseline assessments of daily step activity and health status revealed a more urgent need for health-related intervention in persons with visual impairment than has been reported previously. As a result of completing the *Walk for Health* program, participants experienced a 73% increase in walking activity and transitioned from a "sedentary" classification to "somewhat active" at the end of the intervention (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). Despite this pronounced improvement in step-based physical activity however, no significant changes in resting cardiovascular function, body composition profile, or lipid health were observed. Nonetheless, nearly all participants in the *Walk for Health* program reported positive perceived changes in health status, including improvements in cardiovascular endurance, self efficacy, mood and mental health, functional mobility, and the ability to perform activities of daily life.

In summary, the collective findings of this series of investigations fill a substantial void within the research literature pertaining to physical-activity promotion and the health-related needs of persons with blindness. Recommendations for future studies include conducting multi-site, longer-duration walking interventions which feature physical activity and health assessments that are specific to the needs of individuals with visual impairment. Because in-patient care for the treatment of depression and falls-related injury accounted for the majority of losses to follow-up, inclusion of a depression inventory and functional balance assessment is also recommended. As well, given the pervasiveness of diabetes and cardiovascular conditions among participants with visual impairment, inclusion of more robust and sophisticated measures of health and fitness, such as exercise heart rate, walking energy use, central obesity, bone density, and insulin resistance, should be considered.

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APPENDIX I

Review of the Literature

Introduction

This review begins with a synopsis of the prevalence of visual impairment and the health-related challenges of persons with visual disabilities in the United States. The impact of the *Healthy People 2010* (HP2010) initiatives on the future health of this population is highlighted, along with the need for public health efforts designed specifically for persons with visual impairment. The review then transitions into a summary of the most basic form of health-related intervention within the general population - pedometer-based walking interventions. In this section, specific attention is devoted to the influence of intervention length and goal implementation on anthropometric and metabolic biomarkers. A discussion of topics related to physical activity measurement issues, environmental and social barriers, and practical adaptations required to implement a basic walking program for adults with visual impairment follows in the next part of the review. The literature review concludes with an overall summary which calls attention to the importance of conducting walking programs aimed at improving the health status of the community of persons with vision loss.

Prevalence of Visual Impairment in the United States

The juxtaposition of visual impairment is that it is "at once too common and too rare" (Kirchner, 2006, pp. 782). Although vision-related disability ranks as the 4th most prevalent division of disability in the United States (United States Department of Health and Human Services [USDHHS], 2008b), the low prevalence of severe visual disability among Americans (e.g., low vision and blindness) has contributed to an under-appreciation of the significant health-related needs of this population.

In a progress review of vision-related objectives for the *Healthy People 2010* report, the National Center for Health Statistics reported that approximately 21 million adults in the United States are visually impaired (USDHHS, 2008). Depending on the criteria used to define visual disabilities, others have projected the estimated prevalence of visual disability in the U.S. to be between 3.4 million and 16.5 million (Hendershot, Placek, & Goodman, 2006). The basis for the substantive difference in prevalence estimates of visual impairment owes to the manner in which visual impairment is defined, which can vary depending on the classification scales of different organizations, the use of best-corrected versus presenting visual acuity, and the relative importance of etiological visual impairment (acuity or field) versus functionally-based visual impairment (independence in activities of daily living; Hendershot et al., 2006).

Although various schemes exist for defining visual disability, the World Health Organization (WHO) system will be used to classify visual impairment within the context of this dissertation (see Table 8). The WHO scale is an internationally recognized classification system which employs both visual acuity and visual field to distinguish between levels of visual disability, while excluding uncorrected visual impairments (National Eye Institute, 2009). A primary benefit to the WHO classification scale is that the majority of global prevalence and population estimates of visual impairment are

Table 8

World Health Organization Schematic for Defining Visual Impairment

Category of Visual Impairment	Visual acuity with best possible correction: Maximum less than:	Visual acuity with best possible correction: Minimum equal to or better than:
1	6/18 3/10 (0,3) 20/70	6/60 1/10 (0,1) 20/200
2	6/60 1/10 (0,1) 20/200	3/60 1/20 (0,05) 20/400
3	3/60 1/20 (0,05) 20/400	1/60 (finger counting at 1 m) 1/50 (0,02) 5/300 (20/1200)
4	1/60 (finger counting at 1 m) 1/50 (0,02) 5/300 (20/1200)	Light perception
5	No light perception	

Note. Adapted from World Health Organization: International Statistical Classification of Diseases and Related Health Problems. 10th revision. Version for 2007. Chapter VII. H54. Blindness and low vision. Retrieved from http://www.who.int/classifications/icd/en/

based on this scheme. In addition, the WHO scale excludes correctable impairments, such refractive errors, which can be mitigated through the use of prescription lenses. Limitations to this definition do exist, however, since factors such as contrast sensitivity (which may provide additional insight into vision-related functional decline before acuity-based declines occur) are not considered (Rubin et al., 2001).

Despite a lack of clarity regarding the criteria for quantifying the magnitude of visual impairment in the U.S., the demographic of the American population that is most affected can be easily stratified. Low vision and blindness affect a portion of the population that is typically older (Di Stefano, Huebner, Garber, & Smith, 2006), more female, of lower socio-economic status (Vitale, Cotch, & Sperduto, 2006), and of Hispanic descent (Friedman, Congdon, Kempen, Tielsch & O'Colmain, 2002). Based on these characteristics, it is reasonable to suggest that the prevalence of visual disability will rise as the ethnic demographic in America continues to change. Moreover, with two-thirds of the population of persons with visual impairment over the age of 65 years (Di Stefano et al., 2006), the age-related incidence of visual impairment is expected to double over the course of the next 20 years (Friedman et al., 2002). As a consequence of the demographic profile of this population, concurrent increases in secondary health conditions associated with age, socioeconomic status, and lifestyle factors will likely become more prevalent.

Persistence of Morbidity and the Health Needs of Persons with Visual Impairment

Secondary conditions have a profound negative influence on one's ability to perform activities of daily living independently, leading to higher rates of mortality, depression, functional limitations, and a concurrent reduction in quality of life (Crews & Campbell, 2000; Crews, Valluru, & Campbell, 2005; Rimmer, 1999). Due to the association between visual impairment and age, visual disabilities are often accompanied by comorbid (or secondary) conditions such as arthritis, heart disease, diabetes, hearing loss, stroke, depression, and mobility limitations (Crews & Campbell, 2000; Crews et al., 2005; Rudberg et al., 1993). In particular, Crews and Campbell reported that individuals with visual impairment were four times more likely to describe their health as being poor compared to people without vision loss (2000), with the incidence of poor health among persons with visual impairment increasing directly with age (Crews & Campbell, 2001).

The relationship between visual disability and comorbidity is a strong one, as visual impairment has been identified as an independent risk factor for comorbid disability (Rudberg et al., 1993) and mortality (Wang, Mitchell, Simpson, Cumming, & Smith, 2001). Among the general population, health behaviors such as dietary intake and a relative lack of physical activity have also been shown to contribute to the development of chronic health conditions (Pi-Sunyer, 2002). Specifically, a direct causal relationship exists between overweight and/or obesity (defined as a BMI of 25 kg/m^2 or higher) and comorbidity (American College of Sports Medicine, 2009), such that persons who are overweight or obese are at an increased risk for developing a host of health conditions, including coronary artery disease, diabetes mellitus, various eye diseases, cardiovascular disease, dyslipidemia, hypertension, glucose intolerance, osteoporosis, and certain types of cancer (Flegal, 2005; Halbot-Wilner & Belkin, 2005; Heyward & Wagner, 2004; Moeini, Masoudpour, & Ghanbari, 2005; Pi-Sunyer, 2002; USDHHS, 2000). As a result of an imbalance between caloric intake and energy expenditure, the incidence of adult obesity has increased dramatically among all populations over the past two decades (Baskin, Ard, Franklin, & Allison, 2005; Flegal; Habot-Wilner & Belkin; Harrison, 2006; Pi-Sunyer, 2002; Tudor-Locke & Myers, 2001). Given the constellation of barriers which preclude engagement in physical activity (Rimmer, Riley, Wang, Rauworth, & Jurkowski, 2004), adults with vision loss also find themselves among those most likely to be overweight or obese (Nosek et al., 2008). Compared to adults without visual disability, the incidence of overweight, obesity, and morbid obesity is nearly twice as high among persons with vision loss (Holbrook, Caputo, Perry, Fuller, & Morgan, 2009; Weil et al., 2002), leading to a heightened risk for developing comorbid conditions due to unfavorable health behaviors such as physical inactivity and poor dietary habits. Unfortunately, because vision impairment has been identified as an independent risk factor for morbidity and mortality (Rudberg et al., 1993; Wang, Mitchell, Simpson, Cumming, Smith, 2001), it is difficult to determine whether the discrepancy in health status between individuals with and without vision loss is the result of sensory impairment or a consequence of leading a physically-inactive lifestyle. A closer look at physical activity patterns across the lifespan of persons with visual impairment underscores the potential role of physical inactivity in the development of comorbidity in adults with visual disabilities.

Contribution of Physical Inactivity to Morbidity in Adults with Visual Impairment

Previous authors have hypothesized that because of higher energy demands associated with locomotion, youth with visual impairment would typically avoid the physical activity necessary to improve health, mobility, and social integration (Bunc, Segetova, & Safarikova, 2000; Hopkins et al., 1987; Jankowski & Evans, 1981). The development of patterns of physical inactivity and poor mobility during childhood was believed to increase susceptibility for obesity, osteoporosis, diabetes mellitus, and a reduced life expectancy in adults with vision loss (Jankowski & Evans, 1981). Diminished health status reported among children and adolescents with visual impairment have included low levels of physical health across the five domains of fitness (Seelye, 1983; Shindo et al., 1987), which include cardiorespiratory fitness (Hopkins et al., 1987; Jankowski & Evans, 1981), muscular strength and endurance (Jankowski & Evans, 1981; Shindo et al., 1987), body composition (Hopkins et al., 1987; Jankowski & Evans, 1981; Shindo et al., 1987; Suzuki et al., 1991), and flexibility (Seelye, 1983). In addition, fitness level and mobility status appear to decrease in youth as the level of visual disability increases (Shindo et al., 1987). This trend disappears by adulthood, however, as adults display consistently low levels of physical activity, irrespective of vision loss (Holbrook et al., 2009a). Consequently, adults with vision loss are more likely to be overweight, obese, or morbidly obese compared to the general population (Capella-McDonnall, 2007; Holbrook et al., 2009a; Ray, Horvat, Williams & Blasch, 2007).

The lack of physical fitness in children and adolescents with visual impairment is manifested as an inability to efficiently perform fitness-related activities. When extrapolated from childhood to adulthood, the accumulated effect of a lifetime of physical inactivity, poor physical fitness, and overweight status in this population is exemplified by functional limitations, depression, and cardiovascular disorders (Crews & Campbell, 2000). Conversely, individuals with visual disabilities who remain active display levels of physical fitness and mobility status similar to those found among age-matched individuals without visual impairments (Blessing, McCrimmon, Stovall, & Williford, 1993; Bunc et al., 2000; Colak, Bamac, Aydin, Meric, & Ozbek, 2004; Jankowski & Evans, 1981; Lieberman & McHugh, 2001; Shindo et al., 1987; Singh & Singh, 1993). These findings suggest that the prevalence of poor fitness and comorbidity reported among persons with vision loss may be largely unrelated to sensory impairment and more attributable to inadequate levels of physical activity across the lifespan, a greater energy cost of movement associated with inadequate motor skill development during childhood (Bunc et al., 2000; Colak et al., 2004; Lieberman et al., 2006; Lieberman & McHugh, 2001), and the presence of specific barriers to physical activity (see Table 9; Lee et al., *in review*).

Visual Impairment and Public Health: Recognition through Healthy People 2010

For nearly three decades, the principal roadmap for guiding public health efforts in the United States has been the *Healthy People* report published by the U.S. Department of Health and Human Services. In early versions of this document, health objectives for persons with visual disabilities, as well as disabilities in general, were lacking due to the paucity of health-related information available. While the focus of past reports was on preventative strategies to reduce the occurrence of disease and disability in non-disabled individuals, persons with pre-existing disability were inadvertently ignored. As data related to comorbidity began to emerge for persons with disabilities, the public health perspective toward this group evolved as well. Within the context of the *HP2010* report, an expert panel from the U.S. Centers for Disease Control and Prevention and the

Table 9

Perceived Barriers to Physical Activity in Persons with Visual Impairment

Perceived barriers
1. Lack of self-discipline
2. Lack of transportation to get to an exercise facility
3. Lack of motivation
4. Not knowing how to use exercise equipment
5. Lack of time
6. Lack of exercise equipment
7. Poor accessibility to exercise facilities
8. Lack of trained staff for assistance
9. Lack of adapted exercise equipment
10. Lack of enjoyment during exercise or physical activity
11. Lack of company
12. Lack of skills
13. Lack of volunteers for assistance
14. Cost of exercising
15. People's misconception of my physical condition/ability

Note: Full list has been reduced to illustrate the 15 most influential barriers as perceived by persons with visual impairment. Adapted from Lee, M., Zhu, W., Holbrook, E. A., Brower, D., & McMurray, B. (*in review*). Measurement properties of the Physical activity Barriers Scale for persons who are blind or visually impaired. *Adapted Physical Activity Quarterly.*

National Institute on Disability and Rehabilitation Research harkened for a change in the approach to viewing the health of individuals with disabilities:

> Because disability status has been traditionally equated with health status, the health and well-being of people with disabilities has been addressed primarily in a medical care, rehabilitation, and long-term care financing context. Four main misconceptions emerge from this contextual approach: (1) all people with disabilities automatically have poor health, (2) public health should focus only on preventing disabling conditions, (3) a standard definition of "disability" or "people with disabilities" is not needed for public health purposes, and (4) the environment plays no role in the disabling process. These misconceptions have led to an under-emphasis of health promotion and disease prevention activities targeting people with disabilities and an increase in the occurrence of secondary conditions (medical, social, emotional, family, or community problems that a person with a primary disabling condition likely experiences). (p. 6-3)

For persons with disabilities, their advocates, and those involved in health policy reform, the significance of including a statement such as this within the context of America's "roadmap to health" was unprecedented.

The development of the inclusive *HP2010* objectives signified the first mainstream attempt to hoist disability onto the platform of the public health agenda. An outline of the *HP2010* objectives pertaining to persons with disabilities is included in Table 10. To summarize the primary foci of these objectives, particular attention is directed towards future efforts to (a) lower the incidence of depression in persons with

Table 10

Healthy People 2010: Health-related objectives for persons with disabilities

Number	Objective
5-2	Reduce the number of people with disabilities who are newly diagnosed with diabetes.
6-2	Reduce the proportion of youth with disabilities who are reportedly sad, unhappy, or depressed.
6-3	Reduce the proportion of adults with disabilities who report feelings, such as sadness, unhappiness, or depression that prevent them from being active.
6-4	Increase the proportion of adults with disabilities who participate in social activities.
6-5	Increase the proportion of adults with disabilities who report having sufficient emotional support.
6-6	Increase the proportion of adults with disabilities who report satisfaction with life.
6-10	Increase the proportion of people with disabilities who report having access to health, wellness, and treatment programs and facilities.
6-12	Reduce the proportion of people with disabilities who report encountering environmental barriers to participating in home, school, work, or community activities.
6-13	Increase the number of states and tribes that have public health surveillance and health promotion programs for people with disabilities and their caregivers.
7-6	Increase the number of people with disabilities who participate in employee-sponsored health promotion events.
7-12	Increase the number of people with disabilities who participated last year in one organized health activity.
12-8	Reduce the proportion of adults with disabilities who have hypertension.
12-13	Increase the number of adults with disabilities who have reduced mean total blood cholesterol.
12-14	Reduce the proportion of adults with disabilities who have high total blood cholesterol.

Number	Objective
19-1	Increase the number of adults with disabilities who are at a healthy body weight.
19-2	Reduce the proportion of adults with disabilities who are obese.
22-1	Reduce the number of adults with disabilities who engage in no leisure-time physical activity.
22-2a	Increase the number of adults with disabilities who are physically active for 30 minutes, five days/week.
22-2b	Increase the number of adults with disabilities who are physically active for 20 minutes, three days/week.
22-3	Increase the number of adults with disabilities who engage in vigorous activity 20+ minutes, three days/week.
22-4	Increase the number of adults with disabilities who engage in strengthening exercises.
22-5	Increase the number of adults with disabilities who are enhancing or maintaining their flexibility.

Note. Number = (chapter – objective); Adapted from U.S. Department of Health and Human Services (2004). *Healthy People with Disabilities in HP2010 Chapter 6: Fact Sheet*. Retrieved online August 10, 2009 from http://www.cdc.gov/ncbddd/factsheets/DH_hp2010.pdf disabilities and encourage participation in activities leading to improved quality of life, (b) increase the availability of adaptive wellness and rehabilitative facilities to promote engagement in physical activities, and (c) reduce health-related disparities between persons with and without disabilities.

While these objectives were not intended exclusively for persons with visual disabilities, another chapter in *HP2010* (Chapter 22: Vision and Hearing), provided more vision-specific objectives. Unfortunately, the perspective of this chapter circumvented the ideals of inclusive health promotion for persons already experiencing vision loss by taking a more preventative stance toward vision impairment. This trend has continued to exist throughout vision-related efforts in health policy such as the *Healthy Vision 2010* initiative. As Kirchner noted in her 2006 review, the health-related needs of persons with vision loss were not included in the *Healthy Vision 2010* initiative, illustrating a consistent disconnect among objectives outlined for persons with visual disabilities in the *Disabilities and Secondary Conditions* chapter of *HP2010*. Specifically, no reference to the broad health related needs of persons with visual impairment were discussed in the Healthy Vision 2010 initiative (Kirchner).

It is likely that the paucity of data available in vision-related research has contributed to the limited expansion of the inclusive perspective on health policy for persons with visual disabilities. However, as the incidence of visual impairment continues to rise, the elimination of health disparities between persons with and without vision loss deserves renewed attention. The development of the *2008 Physical Activity Guidelines for Americans* and the recent publication of the *National Physical Activity*

Plan provide additional examples of the national recognition of the health-related needs of persons with disabilities. As well, both reports highlight the potency of physical activity in preventing and treating chronic health conditions in persons with and without disabilities.

Using Physical Activity to Improve Health Status: Characteristics of Successful Interventions

Under the *2008 Physical Activity Guidelines for Americans,* specific recommendations are provided for persons with disabilities with regard to the frequency, intensity, duration, and types of physical activities known to yield health benefits (Table 11). Within the context of the *Guidelines* and elsewhere, walking was listed as the most frequently recommended mode of physical activity due to the associated health benefits and low risk of injury (Morris & Hardman, 1997; USDHHS, 2008a). Included in the beneficial returns of increasing walking-based physical activity are the treatment and prevention of comorbid health conditions, reduced risk for premature mortality, improved cardiovascular, metabolic and musculoskeletal health, weight management, and improved quality of life (USDHHS, 2008a). While the *Guidelines* are useful in outlining the specific frequency, intensity, and duration of physical activity associated with producing health benefits, it is often difficult for this information to be monitored. As an alternative to the duration- and intensity-based recommendations presented by the U.S. Department of Health and Human Services, pedometer-based recommendations featuring health-producing levels of steps per day are gaining popularity in the United States.

Table 11

Physical Activity Guidelines for Americans: Recommendations for Persons with Disabilities

Activity type	Recommendation
Aerobic	Adults with disabilities, who are able, should participate in at least 150 minutes of moderate-intensity activity, or 75 minutes of vigorous intensity activity each week. A combination of moderate- and vigorous-intensity activities can sufficiently meet these guidelines. Aerobic activity should be performed in bouts of at least 10 minutes, and activity should be spread throughout the week.
Muscle- / bone-strengthening	Muscle-strengthening activities of moderate- to-high intensity which incorporate all major muscle groups should be performed on two or more days per week.
Sedentary	Physical inactivity should be avoided.

Note. Adapted from U.S. Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* Washington, DC: U.S. Government Printing Office, October 2008.

Because pedometers can yield accurate and reliable accounts of locomotor activity (Crouter, Schneider, Karabulut, & Bassett, 2003; Holbrook, Barreira, & Kang, 2009b), the use of these body-worn devices in health-related interventions is growing. Pedometers enable real-time visual feedback to be provided to the wearer regarding the impact of behavioral choices on physical activity levels (Lubins, Morgan, & Tudor-Locke, 2009). This immediate feedback can act as a stimulus for health-related behavior change by serving as a motivational incentive and by providing a direct assessment of baseline stepping activity necessary for establishing appropriate activity goals. Step-based walking goals also eliminate participant confusion over intensity recall and may serve as an attractive alternative for individuals who perceive moderate-to-vigorous intensity activity as being very difficult to perform (Bassett & Strath, 2002).

While there are many advantages to using pedometers, limitations also exist. For example, non-ambulatory activities, such as swimming and cycling, cannot be captured with pedometry. Moreover, the lack of information regarding activity intensity and duration make it difficult to monitor participant compliance with the time-based physical activity recommendations endorsed by the U.S. Department of Health and Human Services (USDHHS, 2008a). The dose-response relationship between step-based activity recommendations and specific health outcomes also remains to be elucidated. Despite these limitations, pedometer-based walking interventions have been successful in improving the physical activity levels of sedentary adults.

Use of Stepping Goals and Pedometry to Improve Physical Activity and Health

In U.S. adults, the recommendation to achieve 10,000 steps per day has become a widely-accepted means of increasing physical activity in the general population and among persons representing a diverse range of clinical sub-populations. Associated with improvements across the dimensions of cardiovascular, metabolic, musculoskeletal, and mental health (Bravata et al., 2007; Kang, Marshall, Barreira, & Lee, 2009; Murphy, Nevill, Murtagh, & Holder, 2007; Ogilvie et al., 2007), this quantitative approach to physical activity promotion is considered to be an effective strategy for increasing pedometer-based physical activity in adults (Kang et al., 2009) and is congruent with current activity recommendations outlined in the *2008 Physical Activity Guidelines for Americans* (LeMasurier, Sidman, & Corbin, 2003; Welk, 2000). Due to the excessively low levels of physical activity (< 4,000 steps per day) recorded among the most sedentary portions of the U.S. population, however, the goal of achieving 10,000 steps per day may be unattainable for those most in need of raising their level of physical activity (Sidman, Corbin, & LeMasurier, 2004). Given the relative challenge associated with achieving the 10,000 steps per day recommendation, other step-based promotional strategies, such as increasing baseline physical activity on a percentage basis or setting individualized goals in concert with health professionals, may be more realistic approaches to motivate individuals to become more active. It has been reported that more personalized recommendations produce increases in physical activity which are of comparable magnitude to the 10,000 steps per day recommendation and thus are equally as effective (Chan, Ryan, & Tudor-Locke, 2004; Clarke et al., 2007; Gray et al., 2008; Haines et al., 2007; Kang et al., 2009; Moreau et al., 2001; Sidman et al., 2004; Tudor-Locke et al., 2004). Based on these reports, it appears that the key point in using pedometers to raise physical activity levels is to establish reasonable activity goals and to track progress toward those goals on an ongoing basis.

While it is accepted that habitual physical activity leads to improvements in health status, no clear relationship exists between physiological health indices and pedometer-based increases in physical activity relative to the type of goal being implemented (Kang et al., 2009; see Table 12). Whereas some interventions have been successful in improving body composition (Chan et al., 2004; Jensen et al., 2004; Moreau et al., 2001; Murphy et al., 2007; Richardson et al., 2008) and cardiovascular health (Chan et al., 2004; Gray et al., 2008; Murphy, 2007; Swartz et al., 2003; Talbot, Gaines, Huynh, & Metter, 2003), other studies employing similar goal setting strategies (Araiza et al., 2006; Baker et al., 2008; Gray et al., 2008; Swartz et al., 2003; Tudor-Locke et al., 2004) have reported no change in these indices. Metabolic biomarkers such as glycosylated hemoglobin A1c and glycemic indices also appear to remain stable across pedometer-based interventions, despite variations in the type of goal implemented (Araiza et al., 2006; Bravata et al., 2007; Gray et al., 2008; Jensen et al., 2004; Moreau et al., 2001; Swartz et al., 2003; Tudor-Locke et al., 2004).

Influence of Intervention Length on Physical Activity and Health

With regard to implementing goal strategies to augment physical activity, it appears the duration of an intervention is also not directly tied to the magnitude of change observed in physical activity and health outcomes. Specifically, increases in physical activity approximating 2,000 steps per day from baseline have been reported based on interventions lasting from 8 to 15 weeks (Kang et al., 2009). Although

Table 12

Efficacy of Pedometer-Based Interventions for Improving Health Outcomes

Source	Population	Duration	Goal	Physical activity	Health outcomes
Araiza et al. (2006)	Diabetic adults	6	10,000 s/d	+ 4,000	↑ HDL-C; no Δ BMI, %fat, WC, Tri, HbA_1c, LDL-C, glucose
Chan et al. (2004)	Sedentary adults	12	Personalized	+ 3,500	↓ BMI, body mass, WC, HR; no Δ BP
Clarke et al. (2007)	Sedentary mothers	8	45 min, 5 d/wk	+ 4,000	↓ body mass, %fat, WC; improved self-efficacy
Croteau (2004)	Adults	8	10,000 s/d	+ 2,000	No Δ BMI, % fat
de Blok et al. (2005)	Adults with COPD	9	Personalized	+ 1,700	No Δ BMI or functional assessments
Gray et al. (2008)	Sedentary adults	12	+ 3,000 from baseline	+ 3,000	No Δ BMI, %fat, WHR, BP, glycemic indices

(continued)

Source	Population	Duration	Goal	Physical activity	Health outcomes
Haines et al. (2007)	Adults	12	Increase to 10,000 s/d	+ 3,000	↓ BMI; No Δ blood glucose, Tot-C
Jensen et al. (2004)	Obese older women	12	Increase to 5,000 s/d	+ 1,800	↓BMI, body mass, WC, HC, fat mass, Tot-C, Tri, DBP; no Δ SBP, glucose, HbA_1c
Merom et al. (2007)	Sedentary adults	12	30 min, most days per week	+1,800	
Moreau et al. (2001)	Hypertensive, women	12 /24	+ 3km·day^{-1} from baseline	+ 4,000	↓ body mass, SBP and MAP; no Δ fasting glucose/insulin, DBP
Schofield et al. (2005)	Adolescent girls	12	Increase to 10,000 s/d	+ 1,000	No Δ BMI
Sherman et al. (2007)	Rural female adults	36	+ 2 miles/d	+ 2,500	

(continued)

Source	Population	Duration	Goal	Physical activity	Health outcomes
Sidman et al. (2004)	Sedentary women	3	10,000 s/d vs. personalized	+ 2,000	↑ PA, regardless of goal
Stovitz et al. (2005)	Sedentary patients	9	+ 10% per week	+2,100	
Swartz et al. (2003)	Overweight female adults	8	10,000 s/d	+ 4,000	↓ BP, post-load glucose; no Δ fasting glucose/insulin, %fat, WC, WHR, resting HR
Talbot et al. (2003)	Older adults with osteoarthritis	12	+ 30% from baseline	+1,000	No Δ PA; improved leg strength and walking efficiency
Tudor-Locke et al. (2004)	Diabetic adults	16	Personalized	+ 3,000	↓ WC, HC; no Δ BMI, Tri, HbA_1c, Tot-C, fasting glucose

Note. Physical activity is displayed as steps per day and has been rounded down to nearest hundred steps; HDL-C = high density lipoprotein cholesterol; BMI = body mass index; %fat = body fat percentage; WC = waist circumference; Tri = triglycerides; HbA_1c = glycoselated hemoglobin A_1c; LDL-C = low density lipoprotein cholesterol; HR = heart rate; BP = blood pressure; HC = hip circumference; Tot-C = total cholesterol; WHR = waist-to-hip ratio; SBP = systolic blood pressure; MAP = mean arterial pressure; DBP = diastolic blood pressure; PA = physical activity additional gains in physical activity have been noted in longer interventions, the magnitude of these changes may not be substantial enough to outweigh the burden associated with remaining committed to a longer program (Kang et al., 2009).

As shown in Table 12, the impact of pedometer-based walking interventions on body composition, cardiovascular fitness, and metabolic health is unclear, with no consistent benefits reported across programs of similar duration. For example, among relatively short-term interventions (8 to 10 weeks), Swartz et al. (2003), Croteau et al. (2004), and de Bolk (2005) reported mere maintenance of body fatness and metabolic indices, whereas Clarke et al. (2007) noted significant reductions in body mass index (BMI) and body fatness. The impact of longer-term interventions (12 weeks) on health outcomes is even less clear, with positive changes occurring in BMI (Chan et al., 2004; Haines et al., 2007; Jensen et al., 2004; Moreau et al., 2001) and metabolic indices (Jensen et al., 2004) in certain investigations, but not among others incorporating similar goal-setting strategies (Gray et al. 2008; Haines et al., 2007; Moreau et al., 2001; Schofield et al., 2005). Based on these equivocal findings, the potential impact of intervention length on specific health outcomes is an area worthy of further investigation.

In summary, the effects of intervention-related increases in physical activity and specific health variables remains unclear, as inconsistencies across health outcomes are present despite similarities or variations in program length, goal-setting strategies, and relative increases in post-intervention physical activity levels. With respect to metabolic factors, limited data tend to suggest that among physical activity interventions featuring low-to moderate intensity activities (such as walking) reductions in adiposity need to exceed a certain level before improvements can be observed. Based on the direct association between truncal fat mass and insulin sensitivity, for example (Rosenfalck et al., 2002), it is reasonable to hypothesize that an intervention successful in producing changes in body mass, BMI, or fat mass may be potent enough to elicit changes in glycemic indices (HbA_1c, fasting insulin and glucose), cholesterol, or triglycerides. However, until a meta-analysis is conducted which examines the influence of intervention duration and goal-setting strategies on specific health outcomes, the ability to accurately describe the dose-response relationship between step-based physical activity and selected health variables will continue to be limited.

Factors Involved in Developing an Adaptive Walking Intervention for Persons with Visual Impairment

Factors such as participant availability (especially among special populations), attrition, and effective implementation of behavior change strategies have been identified as key components influencing the effectiveness of pedometer-based walking interventions. A number of systematic reviews have identified other strategies associated with successful walking programs. Specifically, Kang et al. (2009) and Bravata and colleagues (2007) have reported that the most significant increases from baseline physical activity occurred in studies featuring a walking goal in concert with a step diary. Although both reviews concluded that the type of goal that was implemented was not a major factor, the concurrent use of a step diary has been supported in past studies (Sidman, Corbin, & LeMasurier, 2004; Speck & Looney, 2001). While the association between intervention length and other health outcomes was not examined, intervention length (short versus long) did not influence the magnitude of change in physical activity behavior, (Sidman et al., 2004; Speck & Looney, 2001). Lastly, although the effectiveness of personalized physical activity consultations has yet to be determined (Bravata et al., 2007), a review by Ogilvie and colleagues (2007) indicated that adherence to a walking program can be enhanced by tailoring specific components of walking interventions to suit the needs of individual participants.

Developing a Physical Activity Intervention for Persons with Visual Impairment

Due to the association between ambulatory physical activity and health, numerous walking-based physical activity programs have been implemented to improve the health status of the general population. In contrast, interventions and community-based programs designed to raise the health levels of persons with visual impairment have yet to be conducted (Capella-McDonnall, 2007). Considering the unique needs of the community of persons with vision loss, a personalized walking program would be advantageous for a number of reasons. Because leading barriers to physical activity among persons with vision loss include transportation issues, restricted access to exercise facilities, and a general lack of knowledge regarding how to use exercise equipment, a walking-based program would be feasible, especially if it was conducted out of the home. Moreover, one of the greatest assets of the community of persons with visual impairment is the deep sense of culture and vast connectedness it exudes. Through health-related education, physical activity and fitness counseling, and the development of personalized activity plans, individuals with visual disabilities could become self-promoters of physical activity and healthful living. If supported properly, this ideal could potentially circulate throughout the entire community of persons with vision loss in a given area, thus lessening much of the burden which would ordinarily be placed on vocational rehabilitation staff, mobility and orientation specialists, and healthcare professionals to deliver formal health interventions.

In developing physical activity interventions for persons with visual impairment, recommendations from previous studies should be considered, with particular attention paid to the unique needs of this population. A sound pedometer-based walking intervention should include the assessment of quantitative physiological and biochemical measures (Green & Miyahara, 2008; Ogilvie et al., 2007), incorporate a stringent research design (Green & Miyahara, 2008), and enable progression in physical activity level to be monitored throughout the duration of the intervention. To maximize increases in physical activity, the intervention should feature the use of a walking goal and a step diary (Bravata et al., 2007). Personalized physical activity consultations should be provided and researchers should be prepared to collaborate with orientation and mobility specialists to develop accessible walking routes as a means to alleviating barriers known to hinder physical activity among persons with vision loss. Finally, all intervention materials should be adaptive in nature, including the pedometer, step diary, and print materials supporting the walking goal.

Given the paucity of information currently available for persons with visual impairment, it would be beneficial to conduct a series of investigations prior to developing a walking intervention. Specifically, researchers need to determine if adaptive pedometers are available and accurate enough to support a pedometer-based intervention for persons with vision loss. During validation trials of adaptive pedometers, the influence of the built environment, the type of mobility aid used, and the unique gait characteristics of persons with visual impairment should be considered. Secondly, to capture reliable estimates of physical activity, a representative time frame for pedometer monitoring must be established. Finally, the duration of the intervention should take into account the minimum length of time necessary to produce health benefits, while weighing the low rates of volunteerism and high levels of attrition that are often typical of special populations. In the ensuing section, each of these factors will be addressed in detail as they relate to the development of a pedometer-based physical activity intervention for adults with visual disabilities.

Establishing Generalizable Validity Evidence for an Adaptive Pedometer

Although hundreds of models of pedometers are currently available to consumers, only a handful of pedometers have achieved the established level of validity evidence required to support their use in research or intervention settings (Bassett, Ainsworth, & Leggett, 1996; Crouter, Schneider, Karabulut, & Bassett, 2003; Holbrook, Barreira, & Kang, 2009b). While these pedometers typically feature a digital display to convey recorded steps taken, very few incorporate the adaptive capabilities necessary to transmit step-based information to a wearer who is visually impaired. Even though pedometers with voice-announcement capabilities are available, none have undergone the scrutiny required for use in research involving adults with vision loss.

Before a pedometer can be included in a research-based walking intervention intended for any population, investigators need to evaluate the validity of the device under a series of locomotor (and sometimes non-locomotor) conditions. To maximize internal and external validity, pedometer validation trials often feature a series of moderate-duration walks conducted over a range of speeds and environmental conditions (e.g., controlled treadmill trials, flat or graded walking, stairs), and include sensitivity trials to document the impact of non-locomotor behaviors (e.g. motor vehicle travel and heel tapping) on the accuracy of the device (Holbrook et al., 2009b). Prior to conducting a pedometer-based health intervention on a special population, additional factors which may influence the accuracy of step counting should be considered. For example, it is possible that persons with visual impairment exhibit kinematic characteristics that differ from the general population. Additionally, because the use of a mobility aid (such as a dog guide or long cane) can interfere with upper extremity patterns of movement in adults with visual impairment during locomotion, concomitant changes in the lower extremities may occur which influence the monitoring capabilities of the pedometer.

Previous investigations concerned with establishing validity evidence of voice-announcement pedometers have ignored the inherent characteristics of persons with visual impairment which make their gait patterns unique. In a recent study of youth with visual impairment, Beets and colleagues attempted to establish validity evidence for three models of voice-announcement pedometers (2007). During validation trials performed on a track, participants were not allowed to use their mobility aid, but could walk with a sighted guide if assistance was needed. Potential kinematic alterations were not taken into account relative to (a) walking with a sighted guide in lieu of a mobility aid, (b) challenges associated with the built environment, and (c) course familiarity. Data from Beets et al. revealed an unexplainable systematic over- or under-estimation among pedometers mounted on the left side of the body. These findings support the notion that unique gait patterns may exist in persons with visual impairment that may be affected by mobility aid use and changes in the environment.

A review of the literature indicates that the locomotor patterns of individuals with visual impairment have previously been described as mechanically inefficient (Buell, 1982; Chen, Wang, & Ching, 2009; Jankowski & Evans, 1981). Even among blind athletes, Ferro, Graupera, and Vera (2002) observed higher stride rates, shorter stride lengths, and longer contact times (e.g. shorter flight phases) when compared to sighted controls. Based on observations of young children with blindness (MacGowan, 1983), it was hypothesized that the alterations in gait characteristics may be associated with the age of disability onset or the severity of visual impairment. Along these lines, previous investigators have suggested that a higher degree of mechanical inefficiency persists among individuals with congenital versus adventitious blindness, primarily because persons with non-congenital blindness are able to derive benefits from visual feedback during early motor learning processes (Adelson & Fraiberg, 1974; Levtzion-Korach, Tennenbaum, Schnitzer, & Ornoy, 2000). Similarly, persons with more severe visual impairment are believed to exhibit reduced mechanical efficiency and tend to perform more poorly during locomotor activities compared to individuals with less severe visual disability (Makris, Yee, Langefeld, Chappell, & Slemenda, 1993). This concept provided the basis for establishing a three-tiered system for classifying blind athletes, which enables only those persons with similar degrees of visual loss to compete against each other (United States Association for Blind Athletes, 1982).

In view of the preceding discussion, evaluating the validity of an adaptive pedometer among participants displaying various levels of disability manifestation would seem to be a reasonable first step prior to its use in a health-related intervention for people with vision loss. In performing this task, the extent of monitoring error associated with the interaction between specific device limitations and an inefficient gait pattern can be quantified and assessed according to the accepted standard of less than 3% error (or fewer than 3 missed steps per 100 steps taken; Crouter, Schneider, Karabulut, & Bassett, 2003; Hatano, 1997; Holbrook et al., 2009b). Moreover, since the locomotor characteristics and patterns of mobility aid use in persons with visual impairment may vary in response to alterations in the built environment and an individual's familiarity with the environment, it may be necessary to simulate environmental changes to ensure that accurate and generalizable assessments of physical activity can be obtained.

Capturing a Reliable Estimate of Physical Activity in Persons with Vision Loss

When gathering information pertaining to an individual's physical activity level, it is important for researchers to collect data that are meaningful. Specifically, if a pedometer-based baseline physical activity assessment is conducted for a few days prior to the onset of a walking intervention, how can one be certain that this monitoring period is sufficient to represent an individual's typical level of physical activity? Previous studies addressing this question relative to the lay population have determined that four to seven days of pedometer monitoring are required to achieve a stable estimate of physical activity in youth (Trost, Pate, Freedson, Sallis, & Taylor, 2000; Vincent & Pangrazi, 2002). Among adolescents in particular, substantial differences in activity have been shown to occur from weekdays to weekend days, such that less activity is performed on weekend days (Trost et al., 2000). This finding implies that objective measures of both weekdays and weekend days should be included in assessments of adolescent physical activity. However in younger children, daily variability in physical activity is considerably less noticeable, such that reliable estimates of activity to be acquired in as few as two to three days (Trost et al., 2000). While the influence of weekend days (Sunday, in particular) significantly impacts physical activity assessment in adults, any combination of three days of monitoring can be used to achieve a reliable estimate of physical activity in adults (Tudor-Locke et al., 2005).

Because of differences in activity barriers experienced by persons with visual disabilities (Lee et al., *in review*), it could be reasonably hypothesized that persons with and without visual impairment exhibit vastly different patterns of physical activity compared to the general population. Similarly, it may not be unreasonable to expect that persons with severe visual impairment display more homogeneous patterns of physical activity (e.g., less day-to-day variation) compared to individuals with less severe vision loss or no visual disability. Although a previous investigation found that physical activity levels of adults with visual impairment were similar despite differences in disability manifestation (Holbrook et al., 2009a), the appropriate number of days needed to establish a stable estimate of physical activity in adults with vision loss has yet to be determined. Consequently, for meaningful comparisons of pre- and post-intervention levels of physical activity to be made, it is necessary to determine the number of days required to obtain reliable physical activity data. By quantifying the time period necessary to establish stable estimates of physical activity, researchers and clinicians will be able to better assess the effectiveness of walking interventions aimed at improving physical activity participation in persons with visual impairment.

Developing an Adaptive Pedometer-based Walking Intervention

Based on recommendations drawn from previous investigators, a series of components have been identified as key features of a successful walking intervention. Based on Bravata's systematic review (2007), a successful program should incorporate the use of a walking goal and a step diary. In the case of an adaptive intervention for persons with vision loss, the step diary must be accessible. To account for the specific barriers known to preclude engagement in physical activity among persons with visual impairment, personalized physical activity consultations should be provided (Baker et al., 2008; Ogilvie et al., 2007). The physical activity consultation should include the development of a walking plan that is tailored to participants' needs and address factors which increase motivation and lower personal barriers to behavior change. If possible, the consultation should also include the establishment of walking routes that are easily accessible and safe for each participant.

Identifying Appropriate Health Outcomes

The research literature indicates that the greatest improvements in cardiovascular and anthropometric indices resulting from physical activity programs are seen among persons with elevated health risk profiles, such as those with hypertension or obesity. Although data supporting the role of prescribed physical activity for improving health outcomes remains unclear, the association between truncal adiposity and metabolic biomarkers and the prevalence of obesity and comorbidity among persons with visual impairment warrants the assessment of specific health variables. At a minimum, baseline assessments of anthropometric and cardiovascular variables, as well as basic metabolic markers (such as those included in a lipid panel), would lead to a better understanding of the current health status of adults with visual impairment and provide insight regarding the impact of physical activity in reducing risk factors for comorbidity in this population.

Intervention Duration and Sample Recruitment

When weighing the feasibility of conducting a walking program which elicits meaningful improvements in health outcomes against the need to minimize participant burden, researchers and clinicians must consider issues such as participant availability, attrition, and program funding. Along these lines, Holbrook and colleagues (2009a; unpublished data) found volunteerism rates to be quite low among the visually impaired community in a large city (with only ~ 20% of eligible individuals consenting to participate). Others have reported similar difficulties, as sample sizes in physical activity-based research for persons with visual impairment are typically fewer than 20 participants (Chen et al., 2009; Ferro, Graupera, & Vera, 2002; Green & Miyahara, 2008; Jankowski

& Evans, 1981; Oh, Ozturk, & Kuzub, 2004; Sherrill, Rainbolt, & Ervin, 1984; Singh & Singh, 1993; Williams, Armstrong, Eves, & Faulkner, 1996). Considering that attrition rates for pedometer-based interventions in the lay population average around 16% (Engel & Lidner, 2006; Moreau et al., 2001; Swartz et al., 2003; Tudor-Locke et al., 2005), an intervention of relatively short duration may be necessary to achieve an acceptable level of participant adherence, while being of sufficient length to produce measurable health benefits. In view of previous data showing improvements in physical activity level (Araiza et al., 2006; Clarke et al., 2007; Croteau, 2004; Sidman et al., 2004; Swartz et al., 2003), body composition (Clarke et al., 2007), cholesterol (Araiza et al., 2006), and blood pressure (Swartz et al., 2003) in eight weeks or less among persons without vision loss, eight weeks seems an appropriate length for an initial investigation of the effects of a walking program on the health status of adults with visual impairment.

Due to inconsistencies in the manner in which visual impairment is defined in vision-related research, and given the role that classification of vision status can have on the selection of individuals eligible for participation in an intervention for persons with vision loss, the internationally-recognized WHO guidelines for defining visual impairment should be employed as a classification scale. During the recruitment process, program directors should be encouraged to become involved with advocacy organizations for persons with visual impairment, as this can be helpful in identifying potential participants. Finally, to determine an appropriate sample size for an initial intervention, the minimum number of individuals recruited to participate should reflect the magnitude of the effects of previous investigations that have been conducted in the lay population.

Specifically, *a priori* power analyses conducted can be helpful in determining the required sample sizes necessary to detect a significant improvement in various health outcomes and physical activity based on mean difference scores for those outcomes reported in previous studies.

Overall Summary

Despite a higher incidence of functional limitations (West et al., 2002), comorbid conditions (Crews, & Campbell, 2001; Crews et al., 2006), obesity (Holbrook et al., 2009a; Ray et al., 2007; Weil et al., 2002), depression (Margolis, Coyne, Kennedy-Martin, Baker, Schein, & Revicki, 2002), and mortality (Christ, Lee, Lam, Zheng, & Arheart, 2008), public health efforts aimed at promoting the health status of persons with visual impairment are virtually non-existent. Based on the success of pedometer-based walking interventions to increase physical activity levels and improve health outcomes in the lay population, designing and implementing an accessible walking-based intervention for persons with visual impairment seems an obvious first step in reducing comorbidity in this population. Before starting a physical activity intervention for adults with vision loss, however, it is important to demonstrate the efficacy of a talking pedometer in monitoring physical activity and to establish the minimum time frame necessary to capture a reliable estimate of physical activity in persons with vision loss. The series of investigations contained in this dissertation follow this approach and provide a basis for the first-known, evidence-based walking intervention for persons with visual impairment.

APPENDIX 2

IRB Approval Letter A

November 3, 2008

Elizabeth Ackley Holbrook, Dr. Minsoo Kang, Dr. Tara Perry & Dr. Don Morgan
Department of Health and Human Performance
eia2a@mtsu.edu, mkang@mtsu.edu, tperry@mtsu.edu, dmorgan@mtsu.edu

Re: Protocol Title: "Efficacy of Talking Pedometers in Adults With Visual Impairment"
Protocol Number: 09-099 **Expedited Research**

Dear Investigator(s):

I have reviewed the research proposal identified above and determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 Category 4. Approval is for one (1) year from the date of this letter for **30** participants.

According to MTSU Policy, **a researcher is defined as anyone who works with data or has contact with participants**. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance before they begin to work on the project. **Any changes to the protocol must be submitted to the IRB before implementing this change.**

Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 as soon as possible.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. **Your study expires November 3, 2009.**

Please note, all research materials must be retained by the PI or **faculty advisor (if the PI is a student)** for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Dr. William Leggett
Tara M. Prairie

APPENDIX 3

IRB Approval Letter B

May 12, 2009

Elizabeth A. Holbrook, Dr. Don Morgan, Dr. Tara Perry & Dr. Minsoo Kang
Department of Health and Human Performance
eia2a@mtsu.edu, dmorgan@mtsu.edu tperry@mtsu.edu, mkang@mtsu.edu

Protocol Title: Health Benefits of a Pedometer-Based Physical Activity Intervention for Adults with Visual Impairment
Protocol #: 09-281

Dear Investigators,

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 Categories 2 & 4.

Approval is granted for one (1) year from the date of this letter for **100** participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Tara Prairie, Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change. Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires **May 12, 2010**. Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Tara M. Prairie
Research Compliance Officer