

Comparison of functional benefits of self-management training for amputees under virtual world and e-learning conditions

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ABSTRACT

Amputation is a life-long condition. Throughout their lifespan, amputees will need health, wellness and prosthetic-related information. This project used a randomized design to compare two methods of disseminating an evidence-based self-management intervention: avatar-based virtual world and e-learning environments. Of the 57 subjects randomized, 37 (65%) completed the study. The virtual world group had a significantly higher drop-out rate than the e-learning group. Both groups marginally improved on self-efficacy, perceived social support, pain interference, and functional status outcomes with no significant results found between the groups.

1. INTRODUCTION

Nearly 2 million people live with limb loss in the United States of America (ACA, 2012; K. Ziegler-Graham, E. J. MacKenzie, P. L. Ephraim, T. G. Trivison, & R. Brookmeyer, 2008), with projections to reach 3.6 million persons by 2050 (K. Ziegler-Graham, E.J. Mackenzie, P.L. Ephraim, T.G. Trivison, & R. Brookmeyer, 2008). Approximately 185,000 amputations occur in the U.S. each year (ACA, 2012; CDC, 1998). However, amputation is not only a U.S. issue, but a global one. For example, in countries such as Angola and Cambodia where land mines are the cause of most traumatic amputations, there are more than 50 amputees per 20,000 people ("Landmines: the facts," 1997). While global amputee prevalence rates are not available, the World Health Organization estimates that more than 30 million people in Africa, Asia, and Latin America combined are in need of prosthetic and other assistive devices (WHO, 2004).

Since amputation is a life-long condition, it is important for those with limb loss to be educated consumers of information about current and evolving medical procedures, prosthetic technologies, rehabilitative interventions, and health and wellness. Prosthetic devices must be provided throughout the lifespan of individuals with amputation. For example, prosthetic devices provided in the US by the Department of Defense or the Department of Veterans Affairs are typically replaced in less than two years (McFarland et al., 2009). Selecting appropriate prosthetic components can be overwhelming because of emerging technology. In fact, amputees have reported a lack of available information on new prosthetic devices (Berke et al., 2010). Prevention and treatment of secondary health conditions associated with amputation and prosthetic device use are also needed throughout the lifespan of individuals with amputation, for conditions such as pain (Ehde et al., 2000), skin

problems (Bui, Raugi, Nguyen, & Reiber, 2009; Meulenbelt, Geertzen, Dijkstra, & Jonkman, 2007; Reiber et al., 2010), heterotopic ossification (Berke et al., 2010), arthritis (Norvell et al., 2005; Reiber et al., 2010), cumulative trauma disorders and overuse injuries of the non-involved limb (McFarland et al., 2009), and psychological/mental health issues (Horgan & MacLachlan, 2004; Ostlie, Magnus, Skjeldal, Garfelt, & Tambs, 2011). Individuals with limb loss who feel they are well educated about their amputation care are more likely to adhere to treatment recommendations and have improved health outcomes (Berke et al., 2010).

Self-management interjects active participation into treatment (Creer, Renne, & Christian, 1976). The effectiveness of self-management programs is attributed not to changes in behaviour, but rather to enhanced self-efficacy or a feeling of control over the illness/disability (Bandura, 1977a; Lorig & Holman, 2003). Programs that teach self-efficacy are more effective in improving clinical outcomes than traditional patient education (Bodenheimer, Lorig, Holman, & Grumbach, 2002).

The problem that this research addresses is providing access to this self-management education, especially for amputees with mobility and/or geographic barriers. This training was initially designed to assist with community integration for service members with combat-related amputations who had been discharged from specialized rehabilitation and were returning home. The training was extended to non-service member amputees. Guided by Bandura's theoretical model, this project created a virtual world environment in Second Life® (SL; www.secondlife.com), thus expanding interactive dissemination of health and prosthetic-related evidence-based information from face-to-face (clinician to patient) to the Internet (virtual world). A virtual world environment removes travel and accessibility barriers that are particularly challenging for individuals in rural areas and individuals with disabilities (Chan, Hart, & Goodman, 2006; Guagliardo, 2004) and hosts a global audience. The research question asked if being able to observe yourself immersed, as an avatar, in performing balance and conditioning exercises, for example, added value to the training compared to watching video of peers performing the tasks.

2. METHODS

Institutional Review Board (IRB) approval was received from Nova Southeastern University and the Miami Veterans Affairs Healthcare System IRB and Research and Development Committee.

2.1 Design

This study had a development and an experimental phase. During the development phase, subject experts created the content of the self-management training based on Alberto Esquenazi's Stages of Rehabilitation for Amputees (Esquenazi, 2004). Using Microsoft PowerPoint as the authoring tool, a visual presentation with accompanying video and still graphics was created and then used by the virtual world and e-learning developers to build the experimental and control conditions, respectively. Content was beta-tested; results have been reported previously (Winkler et al., 2016). The two research environments—virtual world (VW) using SL and e-learning (EL) using Articulate® software (www.articulate.com) - were created based on identical PowerPoint content (see Figure 1).



Figure 1. A side-stepping balance exercise in the virtual world condition (left) and the e-learning condition (right).

2.2 *Subjects and Recruitment*

The experimental phase used a randomized, pre- and post-design to compare the effectiveness of the intervention under two conditions: virtual world and e-learning. The results of the experimental phase are reported in this paper.

Amputee subjects were recruited to participate via IRB-approved flyers with a targeted enrolment of 92. The majority of subjects were recruited from advertisement of the study on the Amputee Coalition website. Inclusion criteria included: major amputation; access to a computer; functional use of computer (mouse, voice activation software); English-speaking. The only exclusion criterion was finger or toe amputation(s) only. Subjects did not need to be using prostheses to be included in the study. See **Table 1** for a comparison of subjects randomized to the experimental and control groups as well as a comparison of those completing the study.

2.3 *Theoretical Approach*

This project was guided by Bandura's self-efficacy theory (Bandura, 1977b), addressing each of the four sources of self-efficacy: (1) Performance accomplishment/mastery, (2) Modeling/vicarious experience, (3) Verbal persuasion/Interpretation of symptoms, and (4) Social persuasion (Bandura, 1977a; Lorig & Holman, 2003). The project was also guided by Kraiger's theory of training evaluation (Kraiger, Ford, & Salas, 1993) that expands learning outcomes to include cognitive (knowledge, metacognition), skill-based (skill development, ability to apply learned behaviours to new task settings), and affective (self-efficacy) outcomes, all of which are represented in the self-management intervention.

2.4 *Procedure*

After signing the informed consent document, subjects provided baseline demographic information, including protected health information, over the phone. Baseline outcomes data were completed electronically using REDCap, an electronic data capture system (Harris, 2009) hosted at Nova Southeastern University; thus, the investigators were blinded to outcomes data collection. Subjects were then randomized and oriented to either the VW or EL trainings.

Subjects randomized to the EL group received an email with the link to the Articulate® software training. The e-learning presentation content (text and videos) was identical to the virtual world content. The difference was the modality of content delivery. For the EL training, amputees worked alone on their own computer, navigating through the content by menu selections. Only two subjects randomized to the EL training needed assistance, which consisted of instruction to click on the arrow icon to advance the slides.

Subjects randomized to the VW group were oriented by providing them with a manual (by research staff approved by the IRB to have subject contact) that explained how to get a free SL account and avatar, how to log into SL, and the SL location where they would meet a buddy who would train them in SL and how to operate their avatar. Once the subject had an avatar, a the same research staff member met them in SL and introduced them to their "buddy" who provided further training in basic avatar navigation and communication, the subjects were granted access to the research island. This hand off from research staff to "buddy" was important because only the research staff knew the subjects real identity. Once the subject had an avatar, they could be anonymous, as the "buddy" was not authorized by the IRB to have access to protected health information.

The research island had 17 stations with content including the history of prosthetics, the epidemiology of amputation, building prosthetic devices, conditioning and balance exercises, activities of daily living tasks, social emotional adjustment, and community reintegration. The experimental group walked their avatar through the 17 stations, with opportunities to wear virtual prosthetics and participate in virtual simulations, e.g., watching their avatar walk up and down stairs as a bilateral lower limb amputee, and to move through the stations with other amputees (avatars).

Subjects completed the trainings at their own pace. When finished, subjects completed the electronic outcomes assessment, using REDCap, for a second time.

2.5 *Outcomes*

The outcomes were self-efficacy, perceived social support, pain interference, and upper level and lower level limb function.

2.5.1 *Self-efficacy* was measured using two scales: the General Self-Efficacy Scale (GSE) and the Stanford University School of Medicine Patient Education Chronic Disease Self-Efficacy Scale (Lorig, Stewart, & Ritter, 1996) . The 10-item GSE scale assesses a general sense of perceived self-efficacy to predict coping with daily hassles as well as adaptation after experiencing all kinds of stressful life events. The GSE has 10 items with a

scale of 1 to 4 each and a possible total mean range from 1-4, with a higher score indicating greater self-efficacy. Six of the 10 Stanford scale items were used. The items each have a scale of 0 to 10 for a possible total mean range from 0-10, with a higher score indicating greater self-efficacy.

2.5.2 *Perceived social support* was measured using the Multidimensional Scale of Perceived Social Support (MSPSS) (Zimet, Powell, Farley, Werkman, & Berkoff, 1990). The MSPSS measures the perceived availability of support. The MSPSS has 12 items each with a Likert-type scale of 1 to 7 for a possible total mean range from 1-7; a higher score indicates greater perceived social support.

2.5.3 *Pain Interference* was measured using the “Pain Interference” component of the West Haven-Yale Multidimensional Pain Inventory (WHYMPI) (Kerns, Turk, & Rudy, 1985). The WHYMPI is a 52-item, 12-scale inventory that is divided into three parts. Part I includes five scales designed to measure important dimensions of the chronic pain experience including: 1) perceived interference of pain in vocational, social/recreational, and family/marital functioning; 2) support or concern from spouse or significant other; 3) pain severity; 4) perceived life control; and 5) affective distress. Part II assesses patients’ perceptions of the degree to which spouses or significant others display Solicitous, Distracting or Negative responses to their pain behaviours and complaints. Part III assesses patients’ report of the frequency with which they engage in four categories of common everyday activities; Household Chores, Outdoor Work, Activities Away from Home, and Social Activities. Only the nine items assessing the interference pain has on subjects’ lives and their levels of affective distress were used in this study. The nine WHYMPI items each have a Likert-type scale of 0 to 6 for a possible total mean range from 0-6; a higher score indicates greater pain interference.

2.5.4 *Functional Status* was measured using the Orthotics Prosthetics User’s Survey (OPUS) (Burger, Franchignoni, Heinemann, Kotnik, & Giordano, 2008; Heinemann, Bode, & O’Reilly, 2003; Jarl, Heinemann, & Norling Hermansson, 2012). The Orthotics and Prosthetics Users’ Survey (OPUS) is a patient-reported outcome measure consisting of five modules assessing Lower Extremity Functional Status (LEFS), Upper Extremity Functional Status (UEFS), Client Satisfaction with Device, Client Satisfaction with Services, and, Health-Related Quality of Life. Only the LEFS and/or UEFS modules (whichever were appropriate for the subject) were used in this study. The LEFS has 20 items each with a Likert-type scale of 1 to 5 for a possible mean range from 1-5; a higher score indicates better function. The UEFS has 28 items each with a Likert-type scale of 1 to 5 for a possible mean range from 1-5; a higher score indicates better function.

2.6 *Statistical Methods*

Descriptive statistics of the sample for both randomized subjects and study completers by group include race, gender, amputation type, time since amputation, etiology, prosthetic use frequency, and computer usage. Frequencies for categorical variables and means (standard deviation) for continuous variables are presented. For outcome measures, baseline outcomes were subtracted from post-treatment scores in order to create change scores. Change scores for the two groups were tested using two-sided Wilcoxon rank sum tests. A significance level of 0.05 was used for all tests.

3. RESULTS

Of the 59 subjects enrolled, 57 were randomized: 28 to the VW experimental group and 29 to the EL control group. Of the 57 subjects randomized, 37 (65%) completed the study. The VW group had a significantly higher drop-out rate; 14/28 (50%) of the VW group dropped out while 6/29 (21%) of the EL group dropped out ($p=0.02$).

Table 1 compares characteristics of the VW (experimental) and EL (control) groups. While the dropout rate was high for the study (35% overall), measurable demographic differences were not found between study completers and dropouts, with only a trend towards newer amputees being more likely to complete the study. Randomization groups were comparable both overall and when comparing only completers.

Table 2 displays the change in self-efficacy, perceived social support, pain interference, and upper and lower limb functioning for the control and experimental groups. Both groups descriptively benefited from the self-management training, with small increases observed in self-efficacy, increases in social support, decreases in pain interference, and increases in lower limb function. While the VW group showed slightly better improvements, when using two-sided Wilcoxon rank sum tests to compare the groups on change scores, no statistically significant differences were observed.

Table 1. Description of sample.

		Total Randomized (n=57)		Study Completers (n=37)	
		VW	EL	VW	EL
		n=28	n=29	n=14	n=23
Age: mean (sd)		48.7 (14.4)	51.8 (14.9)	50.6 (12.4)	48.4 (13.9)
Race/ethnicity	White	22 (79)	25 (86)	13 (93)	20 (87)
n (%)	Black	4 (14)	1 (3)	1 (7)	1 (4)
	Other	2 (7)	3 (10)	0 (0)	2 (9)
Gender	Male	18 (64)	18 (62)	11 (79)	15 (65)
n (%)	Female	10 (36)	11 (38)	3 (21)	8 (35)
Amputation	Unilateral UL	2(7)	1 (3)	1 (7)	1 (4)
n (%)	Unilateral LL	22 (79)	21(72)	11 (79)	17 (74)
	Bilateral LL	1(4)	5 (17)	1 (7)	3 (13)
	Unilateral UL & Bilateral LL	1(4)	0(0)	1(7)	0(0)
	Unilateral UL & Bilateral LL	0 (0)	1 (3)	0 (0)	1 (4)
	Quad	2 (7)	1 (3)	0 (0)	1 (4)
Years since 1 st amputation	0-5	21 (75)	16 (55)	11 (79)	14 (61)
n (%)	6-10	2 (7)	7 (24)	1 (7)	3 (13)
	11-15	1 (4)	4 (14)	1 (7)	4 (17)
	>15	4 (14)	2 (7)	1 (7)	2 (9)
Etiology	Trauma	9 (32)	12 (41)	5 (36)	11 (48)
n (%)	Dysvascular Disease	8 (29)	7 (24)	4 (29)	10 (43)
	Other Medical	11 (39)	10 (34)	5 (36)	2 (9)
Prosthetic use	Daily	23 (82)	25(86)	10 (71)	19 (83)
n (%)	Weekly	0 (0)	2 (7)	0 (0)	2 (9)
	Monthly or less	0 (0)	1 (3)	0 (0)	1 (4)
	Did not use prosthesis	5(18)	1 (3)	4 (29)	1 (4)
On computer	Hours per week	29.6 (15.1)	31.2 (20.2)	28.9 (12.0)	31.8 (20.6)
Mean (sd)					

Table 2. Comparison of pre and post change in outcomes scores for the virtual world (VW) and e-learning (EL) groups.

Outcomes	VW (n=14)					EL (n=23)					P value
	n	Pre	Post	Change	ES ⁺	n	Pre	Post	Change	ES	
Self-efficacy (GSE)	14	3.54	3.56	0.03	0.11	23	3.48	3.49	0.01	0.05	0.97
Self-efficacy (SSE)	14	8.68	8.85	0.17	0.15	23	8.04	7.97	-0.07	-0.06	0.80
Social support	14	5.38	5.62	0.24	0.30	23	5.91	6.00	0.09	0.11	0.56
Pain interference [#]	9	2.05	1.85	-0.20	-0.21	19	3.28	3.10	-0.17	-0.18	0.75
Lower limb function [^]	11	3.34	3.44	0.10	0.37	20	3.23	3.33	0.10	0.37	0.87
Upper limb function [*]	2	3.13	3.00	-0.13	-0.37	3	2.75	2.86	0.11	0.31	---

+Effect Size, mean change divided by the pooled standard deviation of change scores

#Pain Interference: Lower scores indicate less interference

[^]Lower Limb Function: 4 subjects excluded due to data entry errors

*Upper Limb function was not tested due to small sample size (n=5)

4. DISCUSSION

This project compared the dissemination of a self-management training for amputees under two conditions: virtual world and e-learning. The difference between the two conditions was that the subjects in the avatar-based VW group were immersed in the training, engaging in simulations of desired health activities, e.g., performing activities of daily living transfers, conditioning and balance exercises, going up and down stairs, etc. Small benefits from the self-management training were observed for both groups across the outcomes considered. However, no statistically significant differences were observed between the groups.

The original study plan called for a total enrolment of n=100 in order to achieve 92 evaluable subjects, and was powered to detect moderate effect sizes of 0.6. Unfortunately, the enrolment rate was less than expected and dropout rates were higher than expected. Additionally, the dropout rate for the VW group was significantly larger than for the EL group. Because of the lower than expected enrolment and high dropout rate (50% in the VW group and 21% in the EL group), the study was underpowered to detect a significant difference unless large effect sizes were observed. The reasons for subjects dropping out of the SL group varied. One subject believed that the SL software was a virus and took his computer to a repair shop to have it removed. Two to three two subjects (out of the 57 randomized) did not have an adequate graphic card to run SL. A couple of older subjects (aged over 80) were frustrated with the technology. Two of the three amputees with loss of all four limbs had difficulty with navigation; the third completed the study using voice recognition software. Several amputees were just too busy to complete 17 stations: these amputees were working, raising children, engaged in sports, etc. In reflection, the training was comprehensive but probably too long. Most drops outs went into the virtual world once or twice, but not the multiple times needed to complete the study. That being said, one or two subjects completed the 17 virtual world stations in one or two sessions. Only one amputee reported not feeling safe in a virtual world. Recruitment was also affected by the nature of the intervention; many amputees who inquired about the study did not enrol. Subjects reported wanting to participate in studies if it helped other amputees, but were perhaps negatively influenced about having to participate in the study as an avatar. Younger subjects who were familiar with avatars seemed to complete the intervention more easily and quickly.

There were limitations with the way that two of the outcomes measures, pain interference and function, were used in this study. Pain interference data was excluded for nine subjects because seven subjects put not applicable for all items pre/post, one put not applicable for all items post, and one had pre, but rated seven out of nine items not applicable on the post test. Future studies will include a clarifying item: I have pain, yes or no, and then ask subjects who have pain to complete the pain interference questions.

Additionally, there was confusion for the upper and lower limb functioning questionnaire that led to further data loss. Each participant has access to complete both measures, regardless of amputation type. While not applicable was a choice that many correctly used, others inadvertently filled out incorrect portions. Specifically, two participants did not complete the pre-test, one did not complete the post-test, and two other completed the pre-test for upper limb function, but not for lower limb function. Contributing to this confusion was the investigators' use of electronic data collection for the first time. Although the electronic forms were piloted before use, future studies will include more extensive pilot testing prior to implementation.

In general, the amputees most likely to complete the virtual world training were new amputees; in fact, several subjects' avatars were wearing virtual prostheses before they received their real life or non-virtual prostheses. Notably, dropouts had lower baseline pain interference (less pain interference) on average than completers (Wilcoxon two-sided $p=0.024$), suggesting that dropout could be related to less need for therapy. The study results suggest that the virtual world training may be most appropriate for amputees who are receiving inpatient and outpatient rehabilitation, do not have access to rehabilitation, want to connect with other amputees, and want to experience activities that they can no longer do post-amputation. In a current project, this research team is adding a self-management training for diabetics at risk for foot ulcers; participants will have an opportunity to interact with amputees who have experienced diabetes-related amputations.

5. CONCLUSIONS

Amputees in the e-learning and virtual world groups benefited somewhat from the self-management training. The results suggest that the virtual world training may be most appropriate for amputees who do not have access to rehabilitation and as an adjunct to inpatient and outpatient rehabilitation, especially for amputees who want to connect with other amputees or experience activities that they can no longer do post-amputation(s).

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