Effect of Virtual Reality Environment Training on Functional Mobility in Persons with Transtibial and Transfemoral Amputation

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Clinical Question: In persons with transtibial and transfemoral amputation, does virtual-reality environment training improve gait kinematics and balance?

Background: Each year in the United States, more than 75,000 lower-limb amputations are performed.[2,5] Even following a full rehabilitation program, many lower-limb amputees continue to walk with deficits in their gait. Returning to independent community ambulation presents a challenge for individuals with lower-limb amputations, as the community environment requires navigating diverse terrains, including varied surface angles.[6] Forty-nine percent of amputees report a fear of falling, and 52 percent report at least one fall per year.[6]

The use of virtual reality for rehabilitation has increased as clinicians and researchers attempt to find new, innovative methods to augment clinical care and optimize the physical abilities of their patients.[3] Virtual environments have been shown to be effective rehabilitation tools that offer extensive control, repeatability, and adaptability.[1] The purpose of this CAT is to evaluate the effectiveness of virtual reality environments as a rehabilitation method to improve the functional mobility of patients with lower-limb amputations.

Search Strategy:

Databases Searched: PubMed, Google Scholar, www.oandp.org

Search Terms: (“virtual reality” OR “virtual environment”) AND training AND amputation

Inclusion/Exclusion Criteria: English, published after 2010

Synthesis of Results: Four studies[1,3,4,6] assessed the effect of virtual-environment rehabilitation training on mobility factors in a total of 19 adults with lower-limb amputations (sample sizes ranged from 1[1,6] to 11[4]). The studies included one interrupted time series trial,[1] two before-and-after trials,[3,4] and one case study with a before-and-after design.[6] The ability to draw clinical conclusions was limited by the small sample sizes,[1,6] the lack of variability in patient presentation concerning activity levels, and inadequate[1,6] or no follow up.[3,4] Three studies used the Computer Assisted Rehabilitation Environment (CAREN) as the training intervention, two focused on training people with transfemoral amputation[1,6] and one focused on training people with transtibial amputation.[4] All three studies reported improvement in gait outcomes, such as self-selected walking speed,[6] step width[1,6] and length,[1] and frontal plane motion.[1,4] Further, the two studies[3,4] that assessed transtibial subjects, the results showed improvements with the Wii Fit system[3] and the CAREN system[4] on the balance confidence, measured with the Activities-Specific Balance Confidence (ABC) Scale. Three[1,3,6] of the four articles are highly applicable to the clinical question; however, they involved a small number of subjects with very similar presentations, which limits generalizability of results to the overall amputee population. The other article[4] focused on only one outcome, making it difficult to support a claim of increased mobility overall.

Clinical Message: The results indicate that the use of a virtual-reality environment is effective as a rehabilitation intervention for improving aspects of mobility (e.g., step length, step width, walking speed, walking capacity, and balance confidence). Future research should utilize a larger sample size and a broader spectrum of subjects, such as elderly individuals, individuals with greater mobility limitations (e.g., K2 Medicare classification level), and individuals with different mechanisms of injury.

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Evidence Table

	[Darter, 2011][1]	[Imam, 2013][3]	[Kaufman, 2014][4]	[Sheehan, 2016][6]
Purpose	Describes the use of virtual-reality-based gait training program to provide real-time feedback to improve biomechanical and physiological performance in a person with a transfemoral amputation.	To evaluate the feasibility of the Nintendo Wii Fit as an adjunct to usual therapy in individuals with a lower-limb amputation.	Assess the effectiveness of a fall-prevention training program by quantifying improvements in trunk control, measuring responses to a standardized perturbation and demonstrating retention at three and six months after training.	Describes the walking function and mediolateral stability outcomes of an individual with a unilateral transfemoral amputation following a novel perturbation-based gait training intervention in a virtual environment.
Population of Interest	1 24-year-old man transfemoral amputation from a traumatic blast Height=174 cm, weight= 86.8kg	6 Median age 48.5 ranging from 45–59 years, 5/1 M/F 4 transtibial and 2 transfemoral	11 (14*) male military servicemembers (26±3 years) unilateral transtibial amputations *Three subjects did not finish (one needed revision of residual limb, one had mental health issues, and one moved from the area)	1 43-year-old male right transfemoral amputation from traumatic blast injury Height=183cm, weight=106.6kg
Recruitment Source	Center for the Intrepid rehabilitation patient	Convenience sample of rehabilitation center	Comprehensive Combat and Complex Casualty Care program at the Naval Medical Center San Diego	Center for the Intrepid rehabilitation patient
Inclusion/Exclusion Criteria	18 to 45 years of age Independent ambulation without assistive device for a minimum of three months Ambulate continuously for minimum of 15 minutes	19 years of age or older First amputation < 12 months ago No wounds on residual limb preventing wear of prosthesis No complex medical problems	Traumatic transtibial amputation Between ages 18 and 40 who ambulated without assistive device Medically cleared for high-level functional activities	Participated in intensive PT, OT, and recreational therapy following injury; expected to have reached his rehabilitation plateau History of falls and stumbles

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	[Darter, 2011][1]	[Imam, 2013][3]	[Kaufman, 2014][4]	[Sheehan, 2016][6]
	Verbal pain rating of less than 4/10 on involved side Ankle, knee, and hip strength of 4 or greater on uninvolved side No other conditions affecting walking ability in patient's history. Not actively engaged in treadmill walking or other physical fitness program at time of study	No previous experience with Wii Fit or other VR games	Able to walk easily for more than 15 minutes. Exclusion criteria: traumatic brain injury, vestibular dysfunction, significant traumatic injury of contralateral limb, pain or neuromuscular problems	
Study Design	Interrupted time series trial	Non-concurrent, before-and-after trial	Prospective before and after	Case study with before-and-after trial
Intervention	Training in Computer Assisted Rehabilitation Environment (CAREN) 12 30-minute sessions walking on the treadmill in system over the span of 3 weeks	Training with Wii Fit system 30 minutes, 5 times a week for a minimum of 2 weeks (10 sessions) and a maximum of 6 weeks (30 sessions)	Training program with microprocessor-controlled treadmill and assessment of the training program using a Computer-Assisted Rehabilitation Environment (CAREN)	Training in Computer Assisted Rehabilitation Environment (CAREN) 2 training sessions/week for 4 weeks
Location	Brook Army Medical Center, Ft. Sam Houston, Texas, in a military performance gait lab CAREN system	Outpatient amputee rehabilitation program at GF Strong Rehabilitation Centre, Vancouver, British Columbia, Canada	Naval Medical Center San Diego, California	Center for the Intrepid, Brook Army Medical Center, Ft. Sam Houston, Texas, in a military performance gait lab CAREN system
Outcomes and Outcome Instruments	Full-Body gait kinematic and kinetic measurements frontal-plane motion of the hip, pelvis and trunk, mid-stance joint angles, temporal-spatial asymmetries in step length,	Walking capacity using 2 Minute Walk Test, Short Physical Performance Battery (SPPB) for standing balance, gait speed and lower-limb strength, L-Test for basic	Trunk flexion angle and velocity of both prosthetic and non-prosthetic side captured by 12-camera motion capture system Patient reported outcomes collected from Activities-	Self-selected walking speed and reduced functional stepping time, mean step width, and step width variability. They were compared to a baseline to

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	stance time, and step width, reciprocal transverse-plane motion between trunk and pelvis, and breath-by-breath oxygen consumption	functional mobility, Activities-Specific Balance Confidence (ABC) for perceived balance confidence Pain and fatigue levels on a scale of 0–10	Specific Balance Confidence Scale and Prosthesis Evaluation Questionnaire Addendum	indicate improvements in function and stability
Key Findings	Lateral trunk lean decreased by 4 degrees, total excursion by half (16.6 to 8.5 degrees) Hip abduction decreased by 4 degrees, and the position of the pelvis over the foot and peak hip torque improved The patient continued vaulting on the intact side at 26% through gait Overall oxygen consumption from pretraining to final session improved from 8% to 23% No improvements: temporal spatial parameters, reciprocal pelvis and trunk motion, and early heel rise	No adverse effects occurred because of the intervention (pain and fatigue remained low) There was an increase in walking distance for all but one subject following the onset of the intervention Four subjects showed statistical improvement in SPPB and three in the ABC	Prosthetic limb trunk flexion angle improved from 42 degrees to 31 degrees after training Trunk flexion velocity improved from pretraining 187 degrees/sec to after training 143 degrees/sec Significant side-to-side difference for peak trunk flexion angle ($p=0.01$) with perturbations of the prosthetic limb resulting in higher peak angles. There were no significant changes in the peak trunk flexion angle ($p=0.16$) or peak trunk flexion velocity ($p=0.35$) over time after the training ended. Perturbations of the prosthetic side resulted in larger trunk flexion and higher trunk flexion velocities Subjects prospectively reported decreased stumbles, semi-controlled falls, and uncontrolled falls	A decrease in functional stepping test time by 13% from pretraining evaluation Increase in self-selected walking speed by 0.09 m/s into normative ranges Postintervention step width values reduced to within normative ranges for the VIS and PLAT conditions Subject eliminated nearly all unstable steps during the VIS condition Improvements observed at the end of the training retained or further enhanced at the 5-week follow up The patient stated that following training walking felt easier and more “efficient”
Strengths and Limitations	Internal validity: Maturation effect as the patient got stronger, especially in the hip abductor as mentioned, testing as the patient	Interaction of treatment and selection, due to the young, small, and heterogeneous sample of subjects studied	Small number of variables that were tested in the investigation-operational definitions	Treatment and selection: following only one subject; a larger-scale study needs to be done to further support the

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	got used to reading the feedback and incorporating it into gait Construct validity: Length of follow up and experimental bias (Hawthorne effect) External validity: Treatment and selection, treatment and setting because of only one subject and him being a young, otherwise healthy individual	Learning/testing effect because of the repeated testing to control maturation and history Attrition with 2 subjects dropping out with residual limb; prosthetic issues may have been from participation in study Maturation causing bias when using the 2SD method in which the baseline data may show improvement because of natural recovery	young servicemembers with traumatic transtibial amputations, and subjects with comorbidities were excluded, interaction of treatment and setting/selection	claims of the perturbation-based gait training Length of follow up: no information about the effects of the intervention beyond the 5-week follow up, so it is difficult to say how long the benefits last if the patient does not continue to maintain activity levels History: no information on what the patient had done for rehabilitation immediately following amputation until the time of this study
Overall Confidence	High-Medium	Medium-Low	Medium-Low	High-Medium