Virtual Reality For Gait And Balance In Adults With Unilateral Amputation: A Systematic Review

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Objectives

1. By the end of this presentation, the audience will be able to identify the benefits of virtual reality to improve gait and balance in adults with unilateral amputations.

2. By the end of this presentation, the audience will be able to name at least 3 outcome measures that were used to determine the gait and balance improvements in the adults with unilateral amputations.

Introduction

- More than 75,000 lower limb amputations are performed in the United States each year.[1]
- The gait and balance deficiencies in this population present a challenge to return to functioning independently in the community.[1]
- Virtual Reality is a new way to improve efficiency in balance and gait interventions that is currently being studied.[2]

Introduction

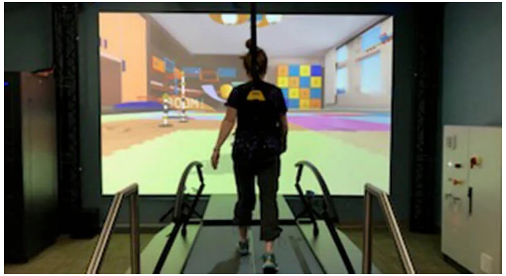
- Virtual Reality has gained popularity in PT treatments over the past 20 years due to its **reduced cost and increased availability**.[3]
- D'Angelo et al. conducted a systematic review in 2010 which analyzed the application of VR to aid amputee rehabilitation.[2]
  - A perturbation-based gait training program in challenging stimulated environments shows promise for improving walking stability and may be beneficial when integrated into a rehabilitation program.[2]

Introduction

- Since 2010, more research has been published on the efficacy of VR for adults with unilateral amputations.
- This research further investigates the effectiveness of VR on balance and mobility in adults with unilateral amputations to update the 2010 systematic review.

Clinical Examples of VR

https://i0.wp.com/www.vrfitnessinsider.com/wp-content/uploads/2019/08/neurorehab.jpg?fit=3648%2C2432&ssl=1



https://nortonhealthcareprovider.com/wp-content/uploads/gait-lab-2.jpg

https://i2.wp.com/www.vrfitnessinsider.com/wp-content/uploads/2017/05/vr-physio.jpg?fit=1000%2C667&ssl=1&resize=1280%2C720

Purpose

The purpose of this systematic review was to investigate the clinical applications of Virtual Reality (VR) for balance and gait in adults with unilateral lower extremity (LE) amputations.

Methods

Search Engines:

- CINAHL
- ProQuest
- PubMed
- Springer Link

Limits:

- English
- Peer-reviewed
- Human subjects
- 2011-2022

Methods

Search Terms:

("virtual reality" OR VR) AND (amputation OR amputee OR amputees OR "limb loss") AND (gait OR walking OR ambulation OR mobility OR balance)

Methods

Selection Criteria:

Sample Population

- Adults (≥18 years old)
- Unilateral LE amputation (Both transtibial and transfemoral)
- Men and women
- Traumatic or non-traumatic amputation

Interventions & Comparators

- Virtual Reality (Immersive or Non-Immersive)
- With or without other interventions
- Any setting

Methods

Definitions:

- **<u>Virtual Reality</u>**: Simulation of a real-world environment that is generated through computer software and is experienced by the user through a human-machine interface.[1]

Immersive VR

https://www.mwuclinics.com/arizona/services/therapy/caren-computer-assisted-rehabilitation-environment

Non-immersive VR

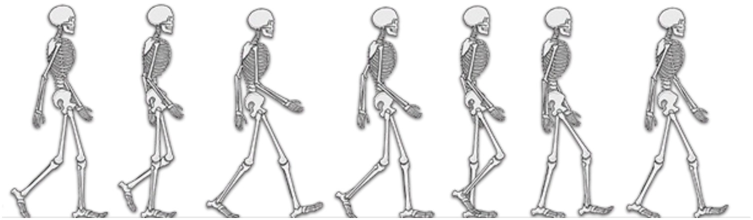
https://www.researchgate.net/publication/319165089_Fall-Prone_Older_People%27s_Attitudes_towards_the_Use_of_Virtual_Reality_Technology_for_Fall_Prevention/figures?lo=1

Methods

Definitions:

- **<u>Gait</u>**: The ability to ambulate with or without manual assistance and assistive devices safely.
- **<u>Balance</u>**: The ability to maintain upright posture within a base of support in a dynamic or steady state position with or without manual assistance and assistive devices.

https://www.medbridgeeducation.com/h/limb-loss-resources/



https://www.gcmas.org

Methods

Selection Criteria:

Outcomes

At least one outcome measure of Gait and/or Balance

- Any valid and reliable outcome measure of gait
- Any valid and reliable outcome measurement of balance

Study Design

- Accept all primary research designs

Results

Identification

Records identified from:
- Databases (n= 466)
    - CINHAL (n=12)
    - Pro-Quest (n= 63)
    - PubMed (n= 24)
    - Springer Link (n = 367)
- Registers (n = 25)
- Citation Searching (n= 1)

Records removed before screening:
- Duplicated records (n = 57)
- Records marked as ineligible by automatic tools (n = 2)

Screening

Records screened (n = 433)

Records excluded based on title or abstract (n=390)

Reports sought for retrieval (n=43)

Records not able to be retrieved (n=4)

Records assessed for eligibility (n = 74)

Records excluded:
- Did not include 1 outcome measure of gait and/or balance (n=6)
- Did not include virtual reality (n=7)
- Did not include subjects with LE amputations (n=8)
- Not a form of primary research (n=5)

Included

Records included (n = 15)

Results

Data Analysis:

- Sample sizes ranged from 1-34 (N=271).
- Nine distinct samples sizes were identified.
  - Multiple articles repeated use of the same sample with different outcome measures.
- Three virtual reality systems were used.
- Examiners were not blinded to outcomes.

Results

Samples Characteristics:

- All studies included individuals with chronic (> 6 mo.) unilateral transtibial amputations (TTA, n=122) or transfemoral amputations (TFA, n=18).
    - TTA and TFA age ranged from 21-63 years.
- Healthy controls (HC) (n=136) were utilized within 11 of the studies.
    - HC age ranged from 19-63 years.

Kinapsys ™

https://www.fitness-gaming.com/news/health-and-rehab/kinapsys-offers-comprehensive-range-of-options-for-functional-rehabilitation.html

https://www.fitness-gaming.com/news/health-and-rehab/kinapsys-offers-comprehensive-range-of-options-for-functional-rehabilitation.html

VR systems included Kinapsys ™(1)

CAREN High End

https://hospitalnews.com/computer-assisted-rehabilitation-environment/

CAREN Extended

https://www.medicalexpo.com/prod/motek-medical/product-99119-639642.html

VR systems included CAREN (High-End=7; Extended=5)

Results

Exam Studies – Outcome Measures

<u>Gait Measures</u>

- Temporal Spatial
  - Ex.) Step Width, Step Length, Step Time, etc.
- Kinematic
  - Ex.) Medial-Lateral Margins of Stability, Frontal/Sagittal Plane Angular Momentum

<u>Balance Measures</u>

- Stability
  - Ex.) Margins of Stability, Trunk Stability

Results

Intervention Studies – Outcome Measures

Gait Measures

- 6-Minute Walk Test (6MWT)
- Dynamic Gait Index (DGI)
- Functional Stepping Test Time
- Self-Selected Walking Speed
- Step Width

Balance Measures

- Berg Balance Scale
- Timed Up and Go (TUG)

Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence Scores

Authors	Year	Research Focus	Study Design	Level of Evidence
Abbas et al. [4]	2021	Intervention	Randomized Control Trial	2
Beltran et al.[5]	2014	Exam	Cross-Sectional, No-Blinding	3
Beurskens et al. [6]	2014	Exam	Cross-Sectional, No-Blinding	3
Beurskens et al. [7]	2014	Exam	Cross-Sectional, No-Blinding	3
Darter et al. [3]	2011	Intervention	Case Study	4
Gates et al. [8]	2012	Exam	Cross-Sectional, No-Blinding	3
Hak et al. [9]	2013	Exam	Cross-Sectional, No-Blinding	3

Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence Scores

Authors	**Year**	**Research Focus**	**Study Design**	**Level of Evidence**
Sinitski et al. [10]	2022	Exam	Cross-Sectional, No-Blinding	3
Sinitski et al. [11]	2015	Exam	Cross-Sectional, No-Blinding	3
Sinitski et al. [12]	2021	Exam	Cross-Sectional, No-Blinding	3
Sheehan et al. [13]	2015	Exam	Cross-Sectional, No-Blinding	3
Sheehan et al. [1]	2016	Intervention	Case Study	4
Sturk et al. [14]	2019	Exam	Cross-Sectional, No-Blinding	3

Results

Exam Studies - Perturbations

- Four exam studies (LoE 3) using the CAREN found *significant* impairment of TTA vs. HC for **stability during ML platform perturbations** (n=3), **temporal-distance parameters** (n=2) and **gait kinematics** (n=1).[5-7, 9]
- There were no between group differences noted with the visual perturbation conditions.

	Year	LoE-Design	Participants	Methods	Outcomes	Significant Findings
Beltran et al.	2014	3 – CSS	<u>SAMPLE A</u> N = 21 TTA = 9 HC = 13	**CAREN High-End** -NOP -PLAT -VIS	**Stability** -MOS	- TTA had greater mean MOS than HC during PLAT. ($p<0.05$)
Beurskens et al.	2014	3 – CSS	<u>SAMPLE A</u> N = 21 TTA = 9 HC = 13	**CAREN High-End** -NOP -PLAT -VIS	**Temporal Spatial** -SW -SL **Stability** -Trunk Stability	- TTA had greater step width variability compared to HC during PLAT. ($p=0.01$) - TTA had greater trunk movement variability compared to HC during PLAT. ($p=0.04$)
Beurskens et al.	2014	3 – CSS	<u>SAMPLE A</u> N = 21 TTA = 9 HC = 13	**CAREN High-End** -NOP -PLAT -VIS	**Stability** -Local Instability -Orbital Instability	- TTA had greater local instability of the shank segment compared to HC during PLAT and VIS. ($p<0.05$) - TTA had less orbital instability of the ML foot movements compared to HC during PLAT. ($p=0.05$)
Hak et al.	2013	3 – CSS	<u>SAMPLE B</u> N = 19 TTA = 10 HC = 9	**CAREN High-End** -NOP -PLAT -Gait adaptability task to hit targets	**Temporal Spatial** -Gait Speed -Step Frequency -SW -SL	- TTA had slower gait speed compared to HC for NOP. ($p=0.015$) - TTA had lower step frequency compared to HC for NOP. ($p<0.01$) - TTA had larger SW compared to HC for all conditions. ($p=0.015$)

Results

Exam Studies– Overground Walking

- Six exam studies (LoE 3) using CAREN found that using a park like scene resulted in significant differences.[1,8,10-12,14]
  - TTA groups had significantly decreased gait speed and step time vs. HC for level, ML translation, rolling hills, and cross-slopes.
  - TFA groups had significantly increased step width and decreased gait speed vs. HC for downhill, uphill and cross slope terrains.

	Year	LoE-Design	Participants	Methods	Outcomes	Significant Findings
Gates et al.	2012	3 – CSS	SAMPLE C N = 34 TTA = 7 HC = 27	**CAREN High-End** -20 strides on forest-like path	**Temporal Spatial** -ST -SL -SW	- TTA took longer steps on their intact limb when walking on the treadmill than walking over- ground (p = 0.016). - Both TTA (p = 0.029) and HC (p = 0.004) exhibited increased step width variability on the treadmill compared to overground.
Sheehan et al.	2015	3 – CSS	SAMPLE D N = 22 TTA = 9 HC = 13	**CAREN-Extended** Park-Like Scene with 20 meters of each: -Level -Cross-Slope	**Temporal Spatial** -Speed -SL, SW -ST, DST **Kinematics** -Sagittal Plane -Frontal Plane	-TTA participants walked slower (P < 0.001) with longer ST (P < 0.013) and similar SL (P = 0.111), compared to HC participants. -When considering treadmill speed as a covariate, TTA SL was significantly different than HC (P < 0.012). -TTA participants had greater SL limb asymmetries on cross-slopes compared to HC participants (P <0.035).
Sturk et al.	2019	3 – CSS	SAMPLE E N = 20 TFA = 10 HC = 10	**CAREN-Extended** Park-Like Scene with 20 meters of each: -Level, DS, US, TCS, BCS, MLT, HL, RO	**Temporal Spatial** -Gait Speed -Step Length -Step Width -Step Time -DST **Kinematics** -ML MoS	-TFA had slower gait speed compared to HC for all conditions. (p=0.010) -TFA had greater step width for uphill, MLT, and RO conditions compared to level walking. (p<0.001) -TFA had lower double support time of prosthetic limb compared to intact limb for DS and US walking. (p<0.008) -TFA had higher ML MoS for the prosthetic limb compared to HC nondominant limb for DS, US, and BCS conditions. (p<0.04)

	Year	LoE-Design	Participants	Methods	Outcomes	Significant Findings
Sinitski et al.	2022	3 – CSS	<u>SAMPLE F</u> N = 24 TTA = 12 HC = 12	**CAREN-Extended** Park-Like Scene with 20 meters each: -Level -Cross-Slopes	**Temporal Spatial** -Gait Speed -SL, SW -ST, DST **Kinematics** -Sagittal Plane -Frontal Plane	- TTA had slower gait speeds than HC for all conditions. ($p<0.001$) - TTA had longer SL than HC for all conditions when controlled for speed. ($p<0.012$) - TTA had greater SL compared to HC asymmetries for cross-slope walking. ($p<0.035$)
Sinitski et al.	2015	3 – CSS	<u>SAMPLE F</u> N = 24 TTA = 12 HC = 12	**CAREN-Extended** Park-Like Scene with 20 meters of each... -US/ DS ± Cross-Slope -MLT -RH -RO	**Temporal Spatial** -Gait Speed -Stride Length -Stride Time	- TTA had slower gait speed compared to HC for level and DS. ($p<0.03$), ($p<0.001$)
Sinitski et al.	2021	3 – CSS	<u>SAMPLE F</u> N = 24 TTA = 12 HC = 12	**CAREN-Extended** Park-Like Scene with 20 meters of each: -Level -MLT -RH -RO	**Temporal Spatial** -SW -SL -ST -DOS **Kinematics** -COM Position -ML MoS	-TTA had slower gait speeds compared to HC for all conditions expect rocky. ($p<0.03$) -TTA had greater DOS on the intact limb compared to HC for all conditions. ($p<0.005$)

Results

Intervention Studies:

- One intervention study (LoE 3) found *statistically significant* between group differences for VR group (KinapsysTM) compared to traditional rehab in balance (BBS, TUG) and complex gait (DGI) post 3x/wk for 6 wks.[3]
- Two case studies (LoE 4) using CAREN for real-time feedback (30 min, 4x/wk x 3 wks) or surface perturbations (2x/wk x 4 wks) reported improved gait kinematics (n=2) and gait speed (n=1).[4,13]

	Year	LoE-Design	Participants	Methods	Outcomes	Significant Findings
Abbas et al.	2021	2 - RCT	**N=32** Control Group= 16 VR Group=16	**Kinapsys^{TM}** -Built-in games designed to foster balance and gait	**Stability and Gait** BBS TUG DGI 6MWT	- VR demonstrated significant superior effects only on the balance markers, TUG test, DGI, and BBS ($P < 0.05$)
Darter et al.	2011	4 – Case Study	**N=1** TFA = 1	**CAREN High-End** -12 x30-minute sessions over 3 weeks	**Kinematics** -Frontal-plane trunk rotation -Foot position relative to mid-pelvis	- 12 sessions of VR-based gait training produced more normalized overground gait biomechanics. - Improvements in frontal-plane trunk, pelvis, and hip kinematics post-training compared to pre-training.
Sheehan et al.	2016	4 – Case Study	**N = 1** TFA = 1	**CAREN High-End** - 8 gait training sessions over increasingly difficult terrain	**Temporal Spatial** -Functional Stepping Test Time -Gait Speed - SW	- The patient decreased his functional stepping test time by 13% from the pretraining evaluation - Increased his self-selected walking speed by 0.09 m/s, from 1.21 m/s to 1.30 m/s, a change greater than the 0.05 m/s MDC - SW decreased by more than the condition-specific MDC for all conditions. - The patient's SW variability was reduced by more than the condition specific MDC

Conclusion

There is **low to moderate evidence** in support of using VR systems to examine/ identify impairments and provide interventions for balance and/or gait in adults with LE amputations.

Limitations

- The sample size was **small** and **heterogeneous.**
- Application of VR **varied** widely between studies.
- There is **limited** VR system availability within practice.

Future Research

- Future research should focus on evaluating the effects and clinical utility of VR for both **examination and intervention** in persons with LE amputation.

https://www.gre.ac.uk/articles/ils/research

Clinical Relevance

- Clinicians may consider application of exam evidence from complex VR systems to target key impairments following LE amputations such as **sensory organization** and **adaptability in destabilizing environments.**

Clinical Relevance

- VR training may improve **postural stability, gait kinematics, and complex gait** using real-time feedback, surface perturbations, and gaming scenarios.
- Future advances in VR may **reduce cost, increase accessibility, and enhance care** of adults with chronic unilateral LE amputations.

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- Physical Therapy Department at The University of Scranton
- Peers of DPT Class of 2023

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Questions?