Biomechanical Evaluation of Caregiver Safety During Assisted Transfers Pre and Post Education

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Introduction

Background

•Many individuals with disabilities rely on **informal caregivers** for support with **Activities of Daily Living (ADLs)**.

•**94%** of informal caregivers assisting adults with chronic physical disabilities report **musculoskeletal discomfort** linked to caregiving [1].

•**41%** of informal caregivers regularly perform **manual transfers** (wheelchair ↔ chair/bed) [2].

•The **manual lifting technique** is the most used method—fast and convenient but places **high loads on the back and upper extremities**, increasing risk of injury.

Biomechanical Risk

•**Sustained trunk flexion** between **20–60°** is associated with a higher risk of **low back discomfort** [3, 4].

•This posture is classified as **"potentially dangerous."**

•The **squat technique** is recommended to reduce trunk flexion [5].

•However, many informal caregivers lack training on **safe lifting postures** and techniques [6].

•Even with proper technique, **transfer tasks remain high-risk**, contributing to both **physical and mental health decline** [7].

Aim:

•Quantify **biomechanical impact** of professional **intervention and education** on manual lifting technique in informal caregivers as it relates to lower extremity joint kinematics

Variable	Pre-Education (Expected)	Post-Education (Expected)
Trunk Flexion Angle	High	Lower
Knee Flexion Angle	Low	Higher
Time in Non-neutral Posture	High	Lower

Table 1. Hypotheses of measured variables pre and post education

Data Analysis

•Only manual transfer trials included in analysis

•IMU raw data post-processed in Noraxon MR 4.0.14

•Trunk and knee joint angles further analyzed in MATLAB

Lifting Phase Definition

•Start: Physical contact between caregiver and care recipient

•End: Caregiver releases recipient

Biomechanical Metrics Computed

•Time spent in lifting phase (s), Time in non-neutral posture (trunk flexion >20°) [3, 4], Average and maximum trunk flexion (°), Maximum knee flexion (°) (Right/left max values averaged)

•All metrics averaged pre- and post-intervention across both directions

Notes on Data Presentation

•Due to variability in interventions, results are presented on a case-by-case basis

•All joint angles are defined from vertical (0° = standing posture)

Results

	Dyad 1		Dyad 2		Dyad 3		Dyad 4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Time for Transfer (s)	14.0 (1.3)	21.2 (4.8)	9.1 (0.5)	8.1 (2.6)	7.4 (1.7)	4.3 (1.2)	15.8 (11.5)	7.0 (0.6)
Time spent in non-neutral posture (% of total transfer time) (s)	13.9 (99.4%)	9.7 (45.5%)	5.6 (61.6%)	6.9 (85.7%)	1.8 (23.4%)	4.3 (100%)	15.1 (94.9%)	6.7 (94.6%)
Average Trunk Flexion (degrees)	32.3 (3)	20.9 (0.2)	24.1(1.2)	27.9 (4.7)	15.8 (1.7)	26.7 (0.3)	41 (0.2)	33.7 (1.4)
Max Trunk Flexion (degrees)	40.3 (2.3)	32.6 (1.1)	51.6 (3.4)	37.1 (4.1)	24.1 (2)	33.1 (1.6)	52.2 (2.9)	40.7 (3.0)
Max Knee Flexion (degrees)	36.3 (2.8)	58.8 (2.8)	86 (6.9)	39 (13.4)	49.5 (5.1)	46.7 (6.9)	62.4 (8.9)	79.2 (1.7)

Table 2. Mean (Standard Deviation) of transfer technique variables pre- and post- education

Methods

Study Approval & Participants

•Approved by the VA Pittsburgh Healthcare Human Subjects Subcommittee

Inclusion Criteria:

•Caregiver with no formal training

•Caregiver providing care ≥3 months

•Caregiver has no current musculoskeletal injuries

•Care recipient is a U.S. Veteran with a disability

•Care recipient requires assistance with transfers

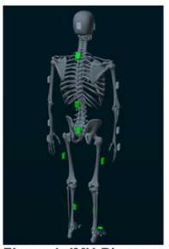


Figure 1. IMU Placement

Data Collection Setup

•Caregiver was fitted with 9 inertial measurement units (IMUs) (Noraxon USA, Scottsdale, AZ) on the lower limbs and trunk (Figure 1)

•Calibration performed using Noraxon MyoResearch (MR) 4.0.14 with "Full leg, Spine" configuration and walking calibration

•Video recordings were collected using HD Pro Webcam C920, synchronized with IMU data

Transfer Trials

•Participants performed two transfers: Wheelchair → Armchair, Armchair → Wheelchair

•IMU data collected at 200 Hz during each transfer

Intervention Protocol

•Videos reviewed by a physical therapist and rehabilitation professional

•Feedback was provided after ≥24 hours, including personalized suggestions for improved technique, educational videos, and live demonstrations

•Participants repeated the same transfers post-education, outfitted with IMUs

Discussion

Dyad 1: Improved Posture with Increased Transfer Time

Caregiver: Female, 68 y/o, 148 lbs
Care Recipient: Male, 76 y/o, 190 lbs, SCI at L1
Pre-Intervention:
• Transfer from **behind wheelchair**
• Used both arms around waist
Intervention:
• Maintain transfer from behind
• Improve posture (↓ trunk flexion, ↑ knee flexion)
• Watched training video on manual transfers
Post-Intervention Outcomes:
↓ **Average/maximum trunk flexion**
↓ **Time in non-neutral posture**
↑ **Maximum knee flexion**
↑ **Transfer duration**
Interpretation: Improved posture came at the cost of increased transfer time

Dyad 2: Reduced Caregiver Load Through Recipient Engagement

Caregiver: Female, 67 y/o, 185 lbs
Care Recipient: Female, 64 y/o, 110 lbs, SCI at T7
Pre-Intervention:
• Transfer from **front of wheelchair** using squat technique
Intervention:
• Changed caregiver position to **behind wheelchair**
• Encouraged **care recipient to assist** more using upper extremities
Post-Intervention Outcomes:
↓ **Maximum trunk flexion**
↓ **Knee flexion**
↓ **Transfer duration**
↑ **Time in non-neutral posture** (due to shift in caregiver role)
Interpretation: Allowed greater independence for care recipient, reducing caregiver load but with more time in non-neutral posture

Dyad 3: Prioritizing Safety in Low-Stability Environment

Caregiver: Female, 47 y/o, 136 lbs
Care Recipient: Male, 62 y/o, 176 lbs, SCI at T12
Pre-Intervention:
• Transferred from **behind wheelchair**
• Used both arms around hips
• Wheelchair lacked brakes
Intervention:
• One arm on belt, one stabilizing wheelchair
• Maintained rear approach
Post-Intervention Outcomes:
↑ **Trunk flexion**
↑ **Time in non-neutral posture**
Interpretation: Postural cost accepted to increase transfer safety in absence of equipment stability

Dyad 4: Efficient Technique with Minor Modifications

Caregiver:Female, 47 y/o, 174 lbs
Care Recipient: Male, 55 y/o, 240 lbs, SCI at T6
Pre-Intervention:
• Already used **squat and pivot** technique
Intervention:
• Minor posture improvements (↓ trunk flexion, ↑ knee flexion)
Post-Intervention Outcomes:
↓ **Trunk flexion (average & max)**
↑ **Knee flexion**
↓ **Transfer duration**
↓ **Time in non-neutral posture**
Interpretation: Reinforced good habits, improved posture and efficiency

Limitations

Small Sample Size

• Results cannot be generalized across all dyads

• Larger studies needed to explore links between demographics, pain, and biomechanics

Lack of Force and Loading Data

• Future studies should include loading on the lower back for a more complete biomechanical picture

Lack of Demographic Diversity

Key Takeaways

Squat Transfers Show Promising Trends

↓ Trunk flexion

↓ Time in non-neutral posture

↑ Knee flexion

→ Align with gold standard technique

One Size Does *Not* Fit All

• Squat-and-pivot may not suit every dyad

• Interventions were personalized to dyad safety and maximizing care recipient's ability to assist when possible

Behind-the-Wheelchair Transfers Require More Study

• May reduce overall force but increase postural risk

• Especially relevant in minimal assist transfers

Future Research Directions

• Define what makes a transfer *biomechanically optimal*

• Include joint loading, caregiver burden, pain, and demographic variability

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References

[1] Darragh, A.R., C.M. Sommerich, S.A. Lavender, K.J. Tanner, K. Vogel, and M. Campo, Musculoskeletal discomfort, physical demand, and caregiving activities in informal caregivers. Journal of Applied Gerontology, 2015. 34(6): p. 734-760.
[2] Caregiving in the U.S. 2020, National Alliance for Caregiving and the AARP Public Policy Institute
[3] E. Valero, A. Sivanathan, F. Bosché, and M. Abdel-Wahab, "Analysis of construction trade worker body motions using a wearable and wireless motion sensor network," Autom. Constr., vol. 83, no. July, pp. 48–55, 2017.
[4] H. Yan, X., Li, H., Li, A. R., & Zhang, "Wearable IMU-based real-time motion warning system for construction workers' musculoskeletal disorders prevention," J. Res. Med. Sci., vol. 19, no. 2, pp. 87–89, 2017.
[5] Garg et al. 1992
[6] Fredericks, D., Mitigating burden associated with informal caregiving. Journal of Patient Experience, 2018. 5(1): p. 50-55.
[7] McCann, J.J., L.E. Hebert, J.L. Bienias, M.C. Morris, and D.A. Evans, Predictors of beginning and ending caregiving during a 3-year period in a biracial community population of older adults. American journal of public health, 2004. 94(10): p. 1800-1806.