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

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INTRODUCTION

Many individuals with disabilities rely on informal caregivers to provide support and perform activities of daily living (ADL). However, of the informal caregivers who aid adults with chronic physical disabilities, 94% reported musculoskeletal discomfort exacerbated by their caregiving activities [1]. The most common caregiving activities include assisted transfers, with approximately 41% of informal caregivers routinely performing transfers between wheelchairs, chairs, and beds [2]. The most prevalent method of transfer is the manual lifting technique, which is fast and convenient; however, this method also poses significant risk of injury to the caregiver as it places high loads on the back and upper extremities during both lifting and repositioning.

Previous studies have also shown that maintaining 20 to 60 degrees of trunk flexion for an extended period increases the risk of lower back discomfort, causing this posture to be classified as "potentially dangerous" [3, 4]. As a result, the most frequently recommended lifting method is the squat technique [5], which aims to minimize the trunk flexion angle throughout the entire lift. However, because informal caregivers often receive little to no training regarding safe lifting posture, they can be unaware of proper practices regarding assisted transfers and other assisted ADLs [6]. Further, because transfer tasks place high loads on the back and upper extremities of caregivers, they are considered high risk even when using proper lifting techniques. With the routine performance of these tasks, these caregivers will likely experience a decline in both physical and mental health [7].

This study aims to quantify the biomechanical impact of professional intervention and education of informal caregivers on standard manual lifting techniques. An additional aim is the assessment of time spent by caregivers in non-neutral posture, or any posture involving a trunk flexion angle of 20 degrees or more. It is hypothesized that after intervention, trunk flexion angles will decrease, knee flexion angles will increase, and time spent in non-neutral posture will decrease.

METHODS

This study was approved by the VA Pittsburgh Healthcare Human Subjects Subcommittee. Inclusion criteria included: caregiver has received no formal training, caregiver has been providing support to the care recipient for at least three months, caregiver has no current musculoskeletal disorders/injuries that would impact their ability to conduct transfers in this study, care recipient is a U.S. military Veteran with a disability, and care recipient requires assistance with transfers.

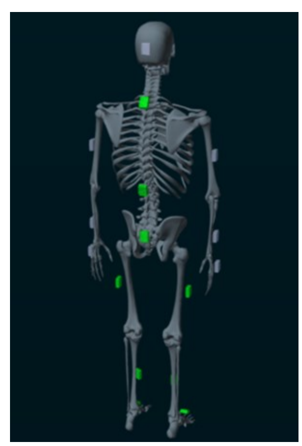

Figure 1. IMU Placement

After informed consent, the caregiver was outfitted with nine inertial measurement units (IMUs) (Noraxon USA, Scottsdale, AZ, USA) on the lower extremities and trunk following the manufacturer's instructions for sensor placement. Within the Noraxon MyoResearch (MR) 4.0.14 software, the "Full leg, Spine" course stabilization was applied and the participant was asked to perform a walking calibration. Caregivers were asked to transfer their care recipient from their wheelchair to an armchair using their preferred transfer technique (manual, Hoyer lift, gait belt, transfer board). Another trial was collected with the caregiver transferring the care recipient back to their wheelchair. IMU data was collected at 200 Hz for the duration of the transfer. Videos were also recorded during transfers using a video camera connected to the Noraxon MR 4.0.14 software (HD Pro Webcam C920). After collecting these trials, a physical therapist and a rehabilitation professional reviewed the videos and noted suggestions for improved transfer technique. After at least 24 hours, the caregiver and care recipient returned and were given education regarding proper transfer techniques and personalized suggestions for improvement based on their first visit. Education materials included instructional videos and demonstrations from the physical therapist. After education, the caregiver was outfitted with IMUs and asked to repeat the same wheelchair to surface transfers from the previous visit.

Only transfers that used a manual transfer technique were included in the analysis. The Noraxon IMU raw data was post-processed to obtain joint angles using the company's proprietary MR 4.0.14 software. Trunk and knee flexion joint angle data were further analyzed using MATLAB. The lifting phase of each transfer was determined using time stamps from the video recordings. The start of the lifting phase was defined as the moment of physical contact between the caregiver and care recipient. The end of the lifting phase was defined as the moment when the caregiver released the care recipient. The following metrics were computed for the lifting phase of each of the two transfers (wheelchair to armchair and armchair to wheelchair) and averaged pre and post intervention: time spent performing the lifting phase of the transfer, time spent in non-neutral posture (trunk flexion greater than 20 degrees), average and maximum trunk flexion, and maximum knee flexion. The maximum right and left knee flexion angles were combined to yield an average value for knee flexion. The results are presented on a case-by-case basis due to the high level of variability in the interventions that were provided. Positive trunk and knee flexion angles are defined from the vertical axis. Both metrics define the standing calibration pose as zero degrees.

RESULTS

Four dyads were included in this analysis. Caregivers were Caucasian females (n=4), and most care recipients were Caucasian males (n=3).

Table 1. Mean (Standard Deviation) of transfer technique variables pre- and post- Intervention

	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)

Dyad 1 had a female caregiver (68 years old, 148 lbs), and a male care recipient (76 years old, 190 lbs, spinal cord injury (SCI) at L1). Prior to the intervention, the caregiver transferred the recipient from behind their wheelchair using both hands around the recipient's waist. The caregiver was told to remain behind the wheelchair but improve posture while performing the transfer (decrease trunk flexion, increase knee flexion) and shown a video on manual transfer technique. After the intervention, the average and maximum trunk flexion and time spent in non-neutral positions decreased although the overall time to transfer increased. Furthermore, maximum knee flexion values increased.

Dyad 2 had a female caregiver (67 years old, 185 lbs) and a female care recipient (64 years old, 110 lbs, SCI at T7). The caregiver initially transferred the recipient from in front of the wheelchair with squat lifting technique. However, the care recipient was able to contribute more independent movement to the transfer, and the caregiver was asked to perform the transfer from behind the wheelchair instead, providing less support. This allowed the care recipient to use her arms and head-hips relation to reduce caregiver burden.. There was a decrease in knee flexion, maximum trunk flexion , and time spent on the transfer after the intervention. Average trunk flexion values remained similar before and after intervention. For this caregiver, transferring behind the wheelchair resulted in more time spent in non-neutral posture, but aimed to reduce the load on the lower back.

Dyad 3 had a female caregiver (47 years old, 136 lbs) and a male care recipient (62 years old, 176 lbs, SCI at T12). This care recipient's wheelchair lacked brakes, causing rough landings during transfers. The caregiver initially used both arms around the care recipient's hips behind the wheelchair. During the intervention, the caregiver was taught to transfer with one arm on the care recipient's belt while stabilizing the wheelchair with the other arm to compensate for the lack of brakes. The caregiver transferred the care recipient from behind the wheelchair both before and after the intervention. Post intervention data showed an increase in trunk flexion and time spent in non-neutral posture for the caregiver but allowed for safer transfer of the care recipient.

Dyad 4 had a female caregiver (47 years old, 174 lbs) and a male care recipient (55 years old, 240 lbs, SCI at T6). The caregiver was using appropriate transfer techniques but was asked to improve posture (decrease trunk flexion, increase knee flexion). Although most of the transfer was still in non-neutral posture, the intervention allowed for less total time spent in non-neutral posture by decreasing the time for transfer. Additionally, average and maximum trunk flexion decreased as well. Average knee flexion angles also increased post intervention.

DISCUSSION

Optimizing assisted transfer techniques are dependent on many factors, including how much caregiver assistance is required, how much the care recipient can assist, presence or absence of wheelchair features (e.g. brakes), and efficiency of movement. Therefore, transfers are highly personalized to the dyad performing them.

In dyad 4, the care recipient required major assistance from their caregiver during transfers. The caregiver used appropriate squat and pivot technique prior to the intervention and only required minor modifications. In this case, the education provided decreased time spent in non-neutral posture, decreased trunk flexion, and increased knee flexion to provide a transfer closer to resembling proper squat lifting technique. The average time to transfer decreasing post intervention may indicate that improved technique allowed for a faster transfer. The relationship between transfer time and optimization of transfer technique warrants further research.

For dyad 1, the care recipient required minimal assistance from their caregiver during transfers. The caregiver already transferred from behind the recipient's wheelchair, so minor modifications during the intervention aimed to improve caregiver posture. After intervention, the results followed the hypothesis that trunk flexion angles and time spent in non-neutral posture would decrease, and knee flexion angles would increase despite this assisted transfer not being a traditional squat and pivot.

This was not the case for the other two dyads that assisted the transfer from behind their care recipient's wheelchair. For dyads 2 and 3, major modifications were made to the caregiver's transfer technique during the intervention. For dyads 1, 2, and 3, the care recipient had enough upper extremity and trunk function to do a sit-pivot transfer and required minimal assistance from the caregiver. For dyad 2, the intervention aimed to reduce caregiver burden by reducing the level of assistance the caregiver was providing. For dyad 3, the intervention aimed to increase stability for the care recipient. Post intervention, both caregivers in dyads 2 and 3 saw an increase in trunk flexion and an increase in time spent in non-neutral posture after assisting from behind the care recipient's wheelchair. Although there are postural risks for discomfort, these interventions increased stability for dyad 3 and reduced caregiver effort for dyad 2. The effect of level of assistance required by the caregiver and their location relative to the wheelchair and care recipient (e.g. assisting from the front or behind) on joint angles and loading warrants further research.

Limitations

The sample size is too low to generalize results of this study to all dyads who perform manual transfer techniques. A larger sample size will consequently lead to a greater understanding of the effects of a transfer technique intervention and allow for relating demographics, pain and other factors to the biomechanics outcomes. Forces pre- and post-intervention could also be beneficial to collect and analyze along with inverse dynamic calculations of loading on the lower back to allow for a more comprehensive biomechanical analysis of the intervention effects. Noraxon IMUs rely on local coordinate systems obtained from a walking calibration to assign a reference pose as an arbitrary zero. Thus, if a caregiver's standing neutral posture is different than that of the reference pose it can cause angles that are not physiologically accurate (such as knee hyperextension). Furthermore, caregivers were all Caucasian females, limiting the current analysis by race and sex.

IMPLICATIONS

Teaching the gold standard squat technique as an intervention did result in a decrease in trunk flexion, decrease in time spent in non-neutral posture, and an increase in knee flexion. However, while squat technique is the most universally accepted manual transfer technique, it may not be the best option for all dyads. It is important to suggest transfer techniques that are personalized and optimal for each dyad that will not put the caregiver nor the care recipient at increased risk. Preliminary results urge further investigation into minimal assist transfers performed behind the wheelchair, with some results indicating these transfers may put the caregiver at a higher risk for discomfort in terms of joint angles despite potentially reducing overall forces on the caregiver. Further testing is needed to determine what factors are the most important when deciding what transfer technique is optimal in terms of biomechanics and various demographic factors.

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