THE EFFECT OF GRABRAIL POSITION ON PEAK LOWER BODY NETT JOINT FORCES DURING ASSISTED SIT-TO-STAND TRANSFERS

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INTRODUCTION

The sit-to-stand transfer is an essential activity of daily living that enables frail older aged adults to remain independent in the community. The ability to perform this action is critical to maintain quality of life for this population. Assistive devices such as grabrails can enable frail individuals to maintain independence while experiencing aged related changes and associated degeneration due to inactivity.

It is difficult to find empirical biomechanical data to explain how grabrails facilitate the sit-to-stand transfer. Literature has described the sit-to-stand transfer with consideration of many performance aspects including armrest assistance (Finlay et al. 1983; Burdett et al. 1985; Wheeler et al.; Alexander et al. 1991; Arborelius et al. 1992; Schultz et al. 1992; Bahrami et al., 2000), seat height (Burdett et al. 1985; Fleckenstein et al. 1988; Rodosky et al. 1989; Schenkman 1991; Hughes et al. 1994), rising speed (Pai et al. 1994; Hesse et al. 1996; Gross et al. 1998; Papa and Cappozzo 1999) and age (Kerr et al. 1997; Bohannon 1998; Gross et al. 1998; Kaya et al. 1998; Cahill et al. 1999; Lundin et al. 1999; Anglin and Wyss 2000). However, very few studies specifically focus on assistive devices such as grabrails (O’Meara 2002). This issue has been addressed in this study by determining the impact of grabrail position on lower body peak nett joint forces during grabrail assisted sit-to-stand transfers.

METHODS

Subjects
Twelve adults, 5 males and 7 females, aged between 69 and 88 years, with an average of 78 years (SD = 9.5 years), participated in this study.

Equipment
The three-dimensional motion of 10 mm retro-reflective spherical markers, which identified body segments and anatomical joint centres, was determined with 9 cameras (Falcon 8 mm, Motion Analysis Corp., Santa Rosa, CA) recording at 60 Hz and a motion analysis system (EVaRT3.0, MAC), as shown in Figure 1. Force platforms (Kistler 9287BA, Winterthur, Switzerland) were positioned under each foot allowing the bilateral measurement of ground reaction forces. Bilateral three-dimensional peak nett joint forces for the ankle, knee and hip joints were determined with computer software (KinTrak 6.2, MAC). A backless and armless seat 0.47 m high was constructed with four triaxial force transducers (Kistler, 9251A) fixed into the base of each leg to indicate seat unloading and loading. The height of the seat was consistent with the recommended height of a toilet seat from the Australian standard AS1428.1 (Standards Australia 1998).

A grabrail of 0.03 m diameter was attached to a wooden stand that was fixed to large horizontal wooden panels that increased the mass and base of support of the structure. The force data was collected at a rate of 200 Hz.

Figure 1: An able-body older aged adult performing the sit-to-stand with assistance from a vertical laterally placed grabrail (VG). Force sensors were fixed into the bottom of each leg of the seat, one force plate beneath each foot and nine cameras positioned around the subject.

Procedure
After the subject provided informed consent, retro-reflective spherical markers were placed on prominent anatomical landmarks to indicate fifteen body segments and six lower body joint centres. Three markers were positioned on each segment for three-dimensional kinematic analysis. A neutral trial was collected while the subject stood in the anatomical position to compare with the sit-to-stand data to determine anatomical joint angle references. The medial femoral condyle markers were removed after the neutral trial to avoid interference during sit-stand-sit cycle trials. The knee joint centre was determined using markers positioned on the anterior superior iliac spine and greater trochanter (Bell et al. 1990). The subject was dressed in minimal tight fitting clothing to avoid interruption to the positioning and viewing of the markers.

A neutral trial was collected while the subject stood in the anatomical position to compare with the sit-to-stand data to determine anatomical joint angle references. The medial femoral condyle markers were removed after the neutral trial to avoid interference during sit-stand-sit cycle trials. A coordinate system was embedded into each segment with the origin located at the proximal end of the segment and the long axis passing through the distal segment end. After a verbal explanation of the procedures the subject performed a number of test trials to familiarise themselves...
with the protocol. The subject was instructed to begin and end each trial in a seated position with their arms resting by their sides and wait for verbal instructions to initiate the sit-stand and stand-to-sit transfers. The words "stand up" were used to instruct the subject to initiate the sit-to-stand transfer, which they performed at their own pace. The subject then stood for three seconds before the command "sit down" was given to instruct the initiation of the stand-to-sit transfer. If the trial involved grabrail assistance the subject released the grabrail once a comfortable standing or seated position was achieved. The three seconds of standing between transfers was maintained without balance assistance. The arms were not restricted during each stage of the sit-stand-sit cycle, however the subjects were instructed not to use their arms to "push off" from the seat or thighs at the initiation of the sit-to-stand or to "feel their way" down to seat contact when completing the stand-to-sit.

The order of administration of the conditions was counterbalanced to reduce the possibility of carryover effects. The grabrail was positioned either forward or on the right side of the subject and oriented into horizontal, vertical and 45° inclined (right-side) positions. For the right-side conditions the grabrail location complied with the Australian standard AS1428.1 (Standards Australia 1998). Comparisons with the right-side and forward assisted conditions were made with the unassisted sit-stand-sit cycle producing nine conditions for analysis. For the right-side positions the grabrail assisted conditions included H150; horizontal grabrail held at 150mm, H400; horizontal held at 400mm, VG; vertical grabrail, and IG; 45° inclined grabrail. The position of the hand in the two horizontal conditions was measured from the front edge of the seat. The forward conditions included H1; horizontal one hand, H2; horizontal two hands, V1; vertical one hand, and V2; vertical two hands.

Five trials were performed for each condition. For each trial three-dimensional force data was collected from the transducers instrumented into the seat and from the force platforms beneath each foot.

Data Analysis
Post processing of three-dimensional marker position data involved tracking the marker position coordinates to ensure continuous data throughout the entire trial period. The three-dimensional marker position coordinates and force platform data were then imported into a software package (KinTrak 6.2, Motion Analysis Corp.) to perform inverse dynamics and kinematic calculations. Three-dimensional bilateral net joint forces are reported here.

All of the data were collated, time normalised, and discrete variables (maximum and minimum) were determined for statistical analysis. For the sit-to-stand the data was time normalised to the period between seat lift-off, the start of zero vertical seat force, and the start of the standing position, maximal vertical centre of mass (COM) position. For the stand-to-sit reverse events were selected; from the end of the maximal vertical COM position until seat touch-down. The discrete variables were calculated for a period of 300% of movement time. For the sit-to-stand this period was between -100% of movement, 100% before seat lift-off, until 200% of movement, 100% after the start of maximal vertical COM position. The same procedure was followed in reverse for the stand-to-sit; -100% of movement, 100% before the end of maximum COM position, until 200% of movement, 100% after seat touch-down.

The data was filtered with a 2nd order zero phase shift Butterworth low-pass digital filter. Separate cut-off frequencies were determined for the kinetic and kinematic data from a power spectrum analysis of the data. A cut-off frequency of 5 and 6 Hz for the kinetic and kinematic data respectively retained 99% of the raw data.

A statistical software package (SPSS for Windows, 10.0) was used to perform a repeated measures ANOVA on the data to test for significant within-subject differences among the five trials, the conditions; unassisted transfer (UT), the right-side assisted conditions (H150, H400, VG, IG) and the forward assisted conditions (H1, H2, V1, V2), and sit-to-stand and stand-to-sit transfer actions. A pair-wise comparison, which was adjusted for multiple comparisons (Bonferroni), was performed to identify the origin of significant within-subject differences.

RESULTS AND DISCUSSION

Assistance from right-side positioned grabrails significantly increased anterior shear joint force in the right ankle and right knee, as shown in Figure 2. The left knee experienced a reduction in anterior shear and lateral shear joint forces...
while the left hip also experienced a reduction in posterior shear joint force, however medial shear hip joint force increased. No significant changes to compressive joint force occurred from right-side assistance, as shown in Table 1.

Assistance from forward grabrails significantly increased anterior shear joint force in the left and right ankles and reduced posterior shear joint force in the right hip, as shown in Figure 3. The left knee experienced an increase in lateral shear joint force while the left and right hips saw a reduction in medial shear joint force. The right ankle and right knee had reductions in compressive joint forces, as shown in Table 1.

Figure 3: Bilateral net anterior-posterior shear joint forces during the sit-to-stand transfer when assisted by forward grabrails. Ensemble averages of 12 subjects and 5 trials for the four forward grabrail conditions shown by the grey lines and the unassisted condition shown by the black line.

Right-side assistance has reduced contra-lateral knee and hip joint forces, and increased ipsilateral ankle and knee joint forces due to dominant ipsilateral body mass distribution, as shown in Figure 2. Thus assistance from a grabrail positioned to the side may help reduce contralateral lower body joint stress. Forward assistance has increased anterior shear ankle joint forces while predominantly reducing right hip joint forces, as shown in Figure 3. Forward grabrails may serve to reduce stress on dominant limbs as its assistance promotes an even body weight distribution. However greater pivoting at the ankle, possibly due to upper body intervention, has somewhat compromised this position causing greater ankle joint stress.

SUMMARY

The use of a grabrail has produced asymmetrical changes to lower body kinetics during sit-to-stand performance. These results would go undetected if symmetry was assumed during grabrail assisted sit-to-stand motion. Grabrail positioning has been found to influence peak nett joint forces of the lower body during assisted sit-to-stand transfers. This study thus provides empirical data for determining appropriate grabrail placement.

REFERENCES

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