Feedback Training Improves Accuracy of Estimating Upper Extremity Weight Bearing During Functional Tasks – Implications After Open Heart Surgery ✦ *by Ansel LaPier*

Median sternotomy is performed during cardiac surgery on over 400,000 patients in the US alone each year. Median sternotomy is associated with a variety of complications including infection, bony nonunion/ instability, and dehiscence.[1] To avoid many of the complications associated with median sternotomy, stringent sternal precautions are put in place to minimize post-surgical stress across the sternal halves.[2] One such precaution is the strict restriction of weighted **upper extremity (UE)** movements to 10 lb (4.5 kg) or less. This restriction directly limits UE use in many daily tasks, such as washing laundry or even just getting out of bed. The rationale for these restrictions is to promote sternal bone healing by minimizing sheer and distractive forces across the sternum as well as motion between the sternal edges.[2] It is difficult to function independently with limited UE use, especially for older adults who make up the majority of patients having open heart surgery. Restricting UE use is particularly problematic for patients that need assistance sitting down / standing up from a chair and or need to use a walker for ambulation. This can contribute to longer hospital stays after surgery and a greater need for assistance and rehabilitation after hospitalization.[3] Therefore optimal recovery requires appropriate UE use.

The purposes of this study were to determine: 1) if patients can accurately estimate using ≤ 10 lb of force 2) if a brief intervention using **feedback (FB)** training can improve patients' ability to estimate using ≤ 10 lb of force, and 3) if patients' age influences ability to estimate ≤ 10 lb of force through their UE during functional mobility tasks.

METHODS

This study was approved by the University's Institutional Review Board. Subjects (n=32) were sorted into a young (18-40 years) or old (60-85 years) cohort.

Force through the UE was measured using an instrumented walker I designed that had dynamometers mounted horizontally to grip holds of a **standard (Std)** walker frame (see Figure 1). The dynamometers were wirelessly connected to tablets and interfaced with an application that allowed continuous force data collection for up to 30 seconds. The front legs of the walker were replaced with wheeled legs for the **front wheeled (FW)** walker trials.

Figure 1. Instrumented walker.

Surface **electromyography (EMG)** was used to measure activity of the **pectoralis major (PM)** muscles. Electrodes were placed were placed 3.5 cm lateral to the anterior axillary line.[4] The electrodes had dual 1x10 mm, bipolar, silver-silver chloride surfaces, an interelectrode distance of 10 mm, and on-site preamplification with a gain of 1000. They were attached to an EMG data logger that employed a sampling frequency of 1000 Hz and a bandwidth of 20 to 450 Hz. Surface EMG data obtained were processed and normalized. Raw EMG signals were analyzed and expressed as root-mean-square amplitude which is the square root of the average power of an EMG signal for a given period of time. Muscle EMG activity was normalized by expressing data relative to a PM muscle **maximal voluntary isometric contraction (MVIC)**.[4]

Before and after FB training, data collection took place during 4 functional mobility tasks: 1) ambulation using a Std walker, 2) ambulation using a FW walker, 3) standing up from a chair, and 4) sitting down in a chair. Order of data collection was randomized. All trials of ambulating with a walker included a minimum of 5 steps and all trials of transferring from a chair included 3 repetitions. During both walker ambulation and sit-stand trials, subjects were instructed to "put 5-

Table 1. Force Mean (±SD) and Range for Young vs Old Subjects.

	Young Subjects (n=21)		Old Subjects (n=11)	
	Pre-FB	Post-FB	Pre-FB	Post-FB
Std Walker	18.5 ± 10.0 *(6.0 – 39.7)*	9.8 ± 3.0# *(5.3 – 17.6)*	24.2 ± 15.2 *(6.7 – 49.9)*	10.6 ± 2.8# *(6.4 – 16.2)*
FW Walker	11.7 ± 5.6 *(6.0 + 37.6)*	8.3 ± 2.4# *(4.4-14.0)*	14.6 ± 6.1%* *(4.9 – 23.9)*	9.8 ± 2.5# *4.9 – 14.5)*
Sit to Stand	17.7 ± 7.1 *(6.0 – 37.6)*	9.3 ± 3.5# *(5.7 + 22.4)*	28.3 ± 7.7* *(12.4 – 39.1)*	12.5 ± 6.0%# *(2.4 – 25.3)*
Stand to Sit	19.0 ± 7.6 *(6.9 – 38.8)*	9.6 ± 2.8# *(4.1 – 15.0)*	24.8 ± 7.8 *(10.1 – 39.4)*	13.4 ± 5.1# *(5.2 – 22.6)*

*$P < 0.05$ *Significant difference young vs old subjects*
#Significant difference pre- vs post-feedback training

10 lb of pressure through each arm." After completing all 4 functional tasks using self-selected movement strategies (pre-training), I used a brief FB training intervention with the subjects. The FB protocol included 30 sec training sessions as follows:

- Visual FB in standing while placing ~ 10 lb of force.
- Auditory FB (buzzer when force > 10 lb) while ambulating with the Std and FW walker.
- Visual FB in sitting while placing ~ 10 lb of force.
- Auditory FB (buzzer when force > 10 lb) during sit-stand transfers.

Subjects did sustained **weight bearing (WB)** through the instrumented walker. Using continuous visual FB, they used constant pressure of 5 lb, 10 lb, 20 lb, and 30 lb for 15 sec. Both peak and average force were recorded simultaneously with PM muscle EMG.

Mean EMG (of 3 trials) and peak force (over 3 trials) data were used in statistical testing. Paired *t*-tests were used to determined differences between variables before and after FB training. To determine differences among variable for the 4 tasks, ANOVA and Tukey's HSD post hoc test were used. Pearson correlations between EMG and force were calculated. Statistical analyses were performed using Excel ToolPak.

RESULTS

Mean force during each functional mobility task before and after FB training for both age cohorts is shown in Table 1 and Figure 1. Peak force after FB training was significantly lower than prior to training for all functional tasks. At baseline peak force during FW walker ambulation and sit to stand for the old subjects was higher than for the young subjects but not after FB training. Arm force during ambulation with a FW walker was significantly less than during ambulation with a Std walker and stand-to-sit. Mean

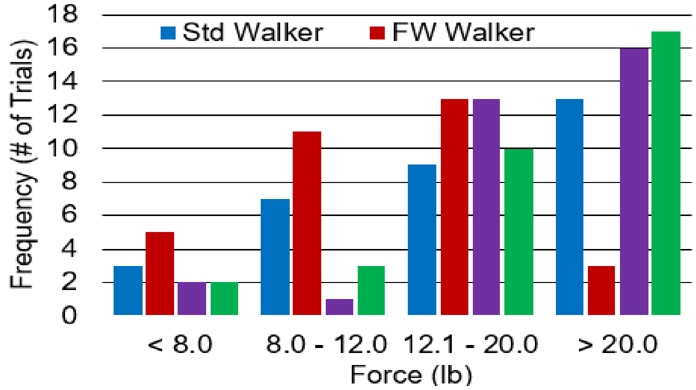

Figure 3. Frequency of force for all functional task trials.

values during all tasks were >10 lb, the limit commonly prescribed with sternal precautions. During most of the trials (67%), subjects over-estimated UE force as shown in Figure 3.

Mean PM muscle EMG data during each functional mobility task before and after FB training were less than 10% of MVIC as shown in Figure 4. I found that PM muscle EMG activity during FW walker use was significantly less than during stand-to-sit transfers. Also, PM muscle EMG values after FB training were significantly lower than prior to training for all functional tasks except FW walker use.

Inter-subject correlations between PM muscle EMG and UE average and peak force were low ($r < 0.17$). Intra-subject correlations between PM muscle EMG values and UE average and peak force ranged from 0.69 to 0.98 and 0.65 to 0.98, respectively.

DISCUSSION

This study found that during all of the functional tasks performed before FB training, on average the force put through the upper extremities by the subjects exceeded that generally recommended with sternal precaution ($\leq$ 10 lb).[2] With only verbal instructions regarding UE WB patients, especially older one, may

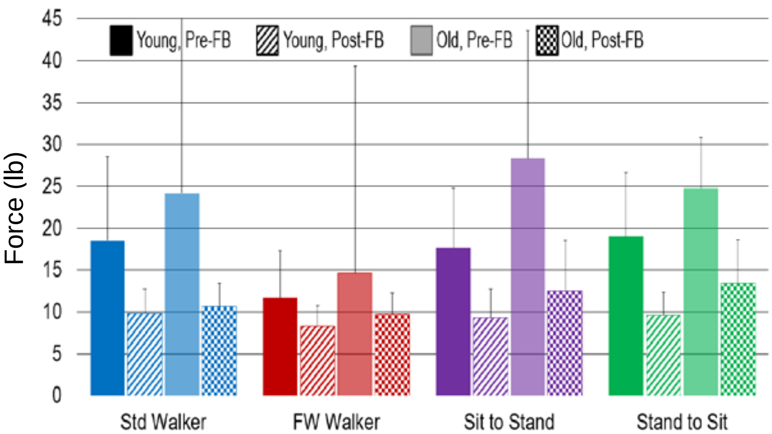

Figure 2. Force (mean $\pm$ SD) during all trials for young vs old subjects.

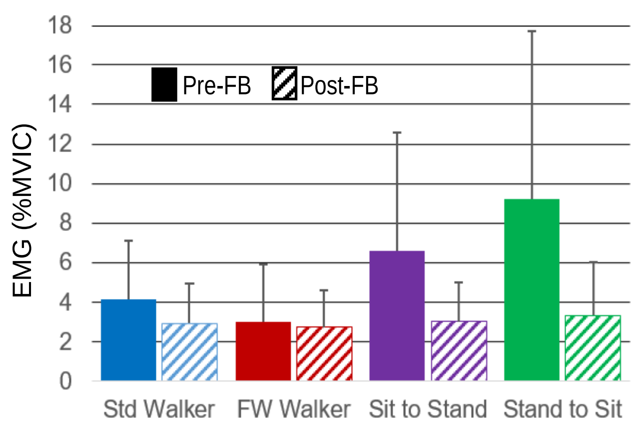

Figure 4. EMG activity (mean $\pm$ SD) during all trials.

not be able to accurately estimate force. Ishikura et al found when healthy subjects used a 4 wheeled walker that UE force varied from 13-40% of their body weight during a gait cycle.[5] This same trend has been observed in previous studies examining WB through the legs (and therefore inversely through a walker) during ambulation. Studies examining compliance with touch down WB (defined as <25 lb) in patients with leg trauma have found that overestimation of weight placed through the involved side is common.[6,7] Hustedt et al instructed subjects to use touch down WB with axillary crutches and found on average >60 lb was placed through the leg.[8,9]

Ambulation using a FW walker produced less UE force as compared to ambulation using a Std walker. This finding supports current sternal precautions and general clinical consensus that using a FW walker is the preferred assistive device for patients after median sternotomy.[2] Previous studies have found that leg WB varied throughout the gait cycle during ambulation with a 4 wheeled walker and Std walker.[5,10]

This study found that UE WB force during stand-to-sit transfers was significant. Little information is available on UE force during transfers. Similar to my study, Anglin et al reported higher maximal UE loads during stand-to-sit (179 N) than during sit-to-stand (154 N).[11] Schultz et al also reported force on chair armrests during sit-to-stand of approximately 150 N which occurred at the initiation of the movement.[12]

The results of this study demonstrate that a brief FB intervention can be effective at reducing UE force exerted during both ambulation with an assistive device and sit-to-stand transfers. Furthermore, study results suggest that older patients may benefit more from FB training because they use more force at baseline and improve to a greater degree than young patients. Both visual and auditory FB were utilized to provide subjects in this study information regarding force placed through their upper extremities. In this study, a combination of both auditory (buzzer) and visual (force output seen on a tablet screen) FB were given to subjects. This FB was provided concurrently (during practice of the skill) as opposed to terminally (after practice of the skill) because this is thought to best facilitate the acquisition of a novel skill. Subjects were first given prescriptive (information on exactly how much weight was being placed through the walker) visual FB while statically practicing UE WB in standing or sitting. Then they were given descriptive (buzzer was sounded if force >10 lb) auditory FB while practicing the whole task. This method also facilitated part-practice first followed by whole-practice. After FB training, UE force was reduced during all functional tasks (mean $\leq$10 lb). Studies have found that concurrent visual FB training is effective at reducing leg WB.[6,8,9]

Results of this study suggest that PM muscle activation is small during functional mobility and that FB training can further minimize it. During this study, PM muscle activity was measured, because it attaches to the lateral borders of the sternum, pulls horizontally from medial to lateral, and is the primary mover for shoulder horizontal adduction. No previous studies have examined PM muscle EMG activity during walker ambulation or sit-stand.

In conclusion, study results suggest that patients may not be not good at estimating UE force during WB activities. But, visual and auditory FB may be effective at reducing UE WB and PM muscle EMG activity.

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