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Original Research Article

FEEDBACK TRAINING IMPROVES ACCURACY OF ESTIMATING UPPER EXTREMITY WEIGHT BEARING DURING FUNCTIONAL TASKS: IMPLICATIONS AFTER OPEN HEART SURGERY

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ABSTRACT

Background: Patients often need to use their arms to assist with functional activities, but after open heart surgery pushing with the arms is limited to minimize force across the healing sternum.

Objectives: The main purposes of this study were to determine: 1) how accurately patients can estimate arm weight bearing with 10 lb or less of force and 2) if feedback training is effective for improving ability to estimate arm force and reduce pectoralis major muscle contraction during functional activities.

Materials and Methods: An instrumented walker was used to measure arm force during functional mobility tasks including walker ambulation and sit-stand transfers. Pectoralis major muscle electromyography (EMG) activity was measured simultaneously in study participants (n = 21). After baseline testing, study participants underwent a brief session of visual and auditory concurrent feedback training. Data analyses included t-tests, ANOVA, and Pearson correlations (P<0.05).

Results: Results showed that self-selected arm force was greater than 10 lb for all tasks (11.7-19.0 lb) but after feedback training, it was significantly lower (8.3-9.8 lb). During most trials (67%), study participants used more than 12 lb of arm force. Pectoralis major muscle EMG values were less than 10% of maximal voluntary contractions and were reduced (2.7-3.3%) after feedback training.

Conclusions: Results indicate that patients may not be able to accurately estimate upper extremity force used during weight bearing activities, and that visual and auditory feedback improves accuracy. Activation of the pectoralis major muscle during arm weight bearing is minimal, suggesting minor force occurs across the sternum. An instrumented walker and feedback training appear to be very clinically useful for patients recovering from open heart surgery.

KEY WORDS: Sternal precautions, median sternotomy, feedback training, functional mobility, walker ambulation, open heart surgery.

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INTRODUCTION

Median sternotomy is performed on over 400,000 patients during cardiac surgery in the United States alone each year [1]. A variety of different surgeries, such as coronary artery bypass, heart valve replacement, heart transplantation, and thoracic trauma repairs require median sternotomy to access the heart.

The procedure entails making a midline skin incision from the sternal notch to the xiphoid process, dividing the subcutaneous tissue and fascia, and separating the sternum with retractors. Finally, wires are used to reunite the sternal halves after surgery completion [2]. Median sternotomy is frequently used during cardiac surgery since it allows for optimal visualization and access to the heart and mediastinum [3,4].

Median sternotomy is associated with a variety of complications including superficial wound infections, bony nonunion / sternal instability, sternal dehiscence, and mediastinitis [5-8]. Several factors like obesity, diabetes, smoking, and gender increase the risk of these complications [6]. In order to avoid many of the complications associated with median sternotomy, stringent precautions are prescribed to minimize post-surgical stress across the healing sternal halves [8-10].

One of the most common sternal precautions is the significant restriction of weighted upper extremity (UE) movements to 10 lb (4.5 kg) or less. This strict parameter directly limits UE use in many daily tasks such as lifting groceries, 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 and motion between the sternal edges [7,9,10]. As one might expect, it is difficult to function independently with such severe limitations in place for daily tasks, especially for older adults who make up the majority of patients who have cardiac surgery [11,12]. Restricting UE use is particularly problematic for patients who need assistance sitting down / standing up from a chair and/or need to use a walker for ambulation. This loss of functional independence can contribute to increased time in the hospital after surgery and a greater need for assistance and rehabilitation after hospitalization [12-14]. These limitations on UE use impair patient function during mobility tasks (i.e. walking, sit-stand transfers) and activities of daily living (i.e. bathing, shopping) immediately after leaving the hospital and sometimes remain even 6-12 months after surgery [12,15,16]. Therefore, teaching patients appropriate arm use is important for optimal recovery and functional independence.

To date, few studies have examined force through the UE or pectoralis major (PM) muscle electromyography (EMG) activity during functional mobility tasks. Previous studies have found that force through the UE while using a single arm to assist with standing up from a bench was 27.5 lb, and while moving from side lying to sitting in a bed was 22.2 lb [17,18]. No data are available on UE force during ambulation with a walker in patients attempting to limit weight bearing to 10 lb or less. In addition, PM muscle activity could provide a good estimation of force across the sternum since is it the primary muscle attached to this bone. Further, the PM muscle has a lateral direction of pull across the sternum, which may be perceived as having the potential to separate the post-operatively rejoined sternal halves. Pectoralis major muscle EMG activity has not previously been measured while using a walker or during sit-stand transfers.

Therefore, the primary purposes of this study were to determine: 1) if patients can accurately estimate using 10 lb or less of force through their UE when performing functional mobility tasks and 2) if a brief intervention using feedback training can improve patients' ability to estimate using 10 lb or less of force through their UE during functional mobility tasks. Secondary purposes of this study were to determine: 1) if force through the UE is symmetrical during bilateral weight bearing and 2) if PM muscle activation is directly related to UE weight bearing force.

METHODOLOGY

Study Participants: This study used a within-subjects design with repeated measures. Participants (n=21) were a convenience sample recruited from a university community via flyers posted around campus and sent electronically (email and text messages). Inclusion criteria were: 1) age 18-40 years, 2) able to walk without an assistive device, 3) normal balance, 4) no pain with UE activity, and 5) able to provide informed consent. Exclusion criteria were: 1) diagnosis of stroke, myocardial infarction, or coronary revascularization (interventional catheterization or bypass surgery), 2) impaired active range of motion, sensation, or strength in the UE, 3) any contraindication for exercise participation as outlined by the American College of Sports Medicine Guidelines for Exercise Testing [19], and 4) previous surgery or chronic pathology involving the UE or chest wall muscles attached to the humerus or scapula. This research project was reviewed and approved by the University's Institutional Review Board.

Force Measurement: Force through the UE was measured using handgrip dynamometers mounted to the horizontal grip holds of a walker frame. The dynamometers (Jamar Smart, Performance Health, Chicago, IL) were wirelessly connected to tablets (Fire HD 10 Tablet, 1080p Full HD, Amazon, Seattle, WA) and interfaced with an application (Jamar Smart, Performance Health, Chicago, IL) that allowed continuous force data collection for up to 30 seconds. The dynamometers were attached to a standard walker frame (Deluxe Two Button Folding Walker Drive, No. 10200-1, Drive Medical, Port Washington, NY) using platform attachments (Platform Walker/Crutch Attachment No. 10105-1, Drive Medical, Port Washington, NY) and 2.5 cm U-bolts. The front legs of the walker were replaced with wheeled legs (Universal 5" Walker Wheels, Drive Medical, Port Washington, NY) for the front wheeled walker trials. The front legs of the walker could also be replaced with extension legs (Tall Extension Legs, Drive Medical, Port Washington, NY) to accommodate study participants up to 200 cm tall.

During sitting and standing trials, the instrumented walker was turned backward and placed behind a stool to simulate a chair with armrests. This configuration created a seat height of 46 cm and armrest height of 60 cm which is similar to standard chairs.

Electromyography: Surface EMG was used to measure bilateral activity of the PM muscles. Electrodes were placed 3.5 cm lateral to the anterior axillary line [20]. An additional ground electrode was secured to the study participant's left wrist. 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 (DataLOG Multisensor System MWX8, Biometrics Ltd, Newport, UK) that employed a sampling frequency of 1000 Hz and a bandwidth of 20 to 450 Hz. The unit was held close to the study participant to ensure that movement was not impeded and electrode leads did not become detached during data collection.

Surface EMG data obtained were processed and normalized. Raw EMG signals were analyzed (DataLOG Software, version 8.51, Biometrics Ltd, Newport, UK) 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. A data capture window was set for each task between event markers placed during data collection. Normalization of the muscle EMG activity was done by expressing data relative to maximal voluntary isometric contraction (MVIC) of the PM muscle [20-22]. A palm press was performed with "shoulders flexed 90 degrees bilaterally with the heel of the hands together and elbows flexed 20 degrees as arms were horizontally adducted" [20]. Study participants held the reference MVIC for 5 seconds, and the middle 3 seconds were used for analysis. The mean of 3 normalization contractions was used for calculating percent MVIC. Study participants rested for 90 seconds between MVIC trials.

Data Collection: After obtaining informed consent, study participants underwent a basic health history and physical examination to obtain baseline physiological data and health information. First, study participants completed an intake questionnaire to ensure they met study criteria and to provide demographic data. Next, a screening examination was completed which including resting vital signs, Body Mass Index, UE range of motion, strength, sensation, and grip strength, and coordination, gait, and balance. Baseline handgrip strength was measured with a digital dynamometer (GripTrack Commander; JTECH Medical, Salt Lake City, UT). For all study participants, the handle of the dynamometer was set at the middle position. Participant stood with their arm at their side (shoulder in neutral, elbow in extension, wrist in neutral) and 3 trials were recorded. The Timed Up and Go Test was used to assess balance and ambulation. Study participants were instructed to stand up from a chair, walk to and around a cone 3 meters away, and return to sitting in the chair. A time of greater than 14 seconds indicates increased risk of falling and was used as an exclusion criterion [23,24].

Next, the testing procedures were explained to the study participant and 2 electrodes were placed on the participant's upper chest (as described previously) to monitor PM muscle EMG activity. Study participants performed the 3 MVIC that were averaged and used for data normalization. Both before and after feedback training, data collection took place during 4 functional mobility tasks which included: 1) ambulation using a standard walker, 2) ambulation using a front wheeled walker, 3) standing up from a chair, and 4) sitting down in a chair. Order of data collection was randomized. All trials of walking with an assistive device included a minimum of 5 steps and all trials of transferring from a chair included 3 repetitions of the movement. Testing was stopped if a study participant experienced any pain or was unable to perform the task safely (i.e. with proper form, without loss of balance).

During both walker ambulation trials, study participants were instructed to "put 5-10 pounds of pressure through each arm" and to walk until instructed to stop. Study participants were allowed to determine which foot they initiated stepping with, and a marker was placed at each heel contact of that foot. The 2nd through 4th gait cycles were used for data analysis. For EMG data analysis, the time capture window was set from the beginning of a heel strike to the beginning of the next heel strike.

During both of the transfer trials, study participants were instructed to "put 5-10 pounds of pressure through each arm while standing up and sitting down." In sitting, study participants began with hands on the dynamometers. During all trials, markers were placed at the initiation and completion of the movement. For EMG data analysis, the time capture window was set from the beginning of the first marker to the end of the second marker.

After completing all 4 functional tasks using self-selected movement strategies, study participants were given an intervention using feedback training. The feedback protocol included 30 second training sessions repeated once after a brief rest period as follows:

· Practice with visual feedback standing in place putting approximately 10 lb of force through the instrumented walker.

· Practice with auditory feedback (buzzer when force exceeded 10 lb) while ambulating with the standard and the front wheeled walker.

· Practice with visual feedback sitting in place putting approximately 10 lb of force through the instrumented "chair" handles.

· Practice with auditory feedback (buzzer when force exceeding 10 lb) during sit to stand transfers.

Feedback training took place in the same randomized order as data collection.

After the post-feedback training measurements were taken, study participants completed 4 trials of sustained weight bearing through the instrumented walker. Using continuous visual feedback, they placed constant pressure of 5, 10, 20, and 30 lb for 15 seconds each. Both peak and average force were recorded simultaneously with PM muscle EMG data.

Statistical Analyses: Mean EMG (of 3 trials) and peak force (over 3 trials) data were used in statistical testing. All EMG data were normalized and expressed as a percent of MVIC. Descriptive statistics for force and EMG activity measurements were calculated. Paired *t*-tests were used to determine differences between variables before and after feedback training. To determine differences in measurements among the 4 tasks, ANOVA and Tukey's Honest Significant Difference post hoc test were used. The alpha level was set at < 0.05. Pearson Product Moment Correlations were used to examine the relationship between PM muscle EMG activity and UE force. Statistical analyses were performed using Excel ToolPak (Microsoft Corporation, Redmond, WA).

RESULTS

The participants (n = 21) in this study had a mean ($\pm$SD) age of 24.7 ($\pm$1.3) years and 33% were men. Their mean height, weight, and Body Mass Index were 171.7 ($\pm$10.4) cm, 73.5 ($\pm$12.8) kg, and 24.8 ($\pm$2.8) kg/m^2, respectively. Mean time to complete the Timed Up and Go was 5.5 ($\pm$0.9) seconds. Study participants' mean resting vital signs were: heart rate 70 ($\pm$7) bpm, systolic

Fig. 1: Upper extremity force (mean ± SD) during all functional task trials.
SW = standard walker; FWW = front wheeled walker

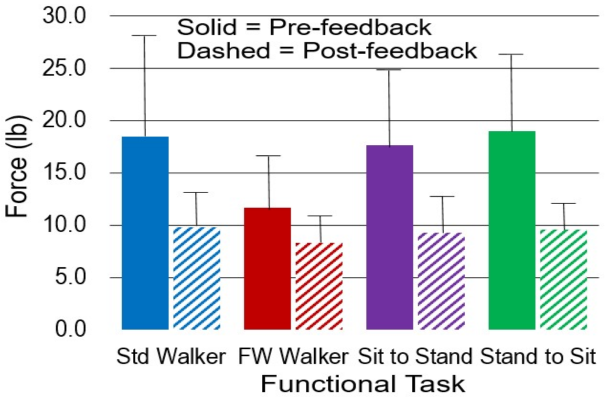

Fig. 2: Frequency of upper extremity force for all functional task trials.
SW = standard walker; FWW = front wheeled walker

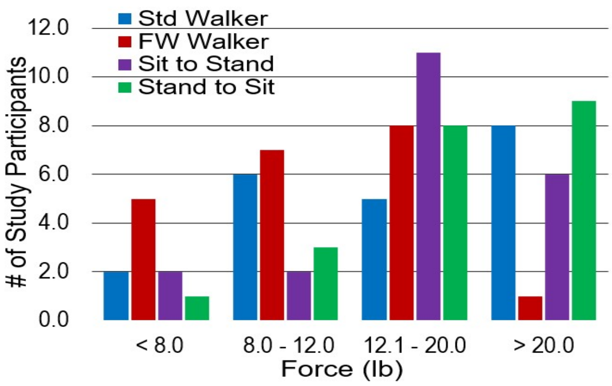

Fig. 3: Force (mean ± SD) through left and right arm during all functional task trials.

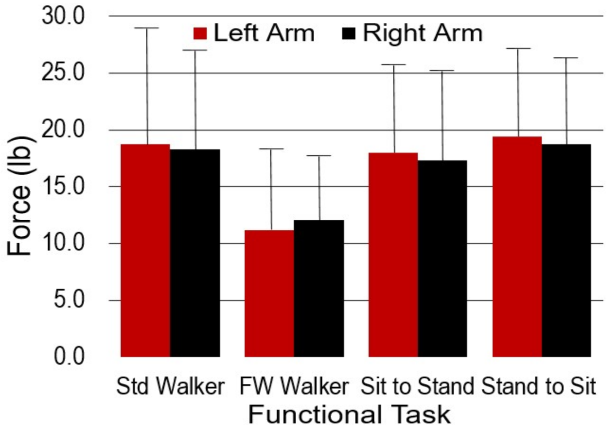

Fig. 4: Pectoralis major muscle electromyography (EMG) activity (mean ± SD) during all functional task trials.
MVIC = maximal voluntary isometric contraction.

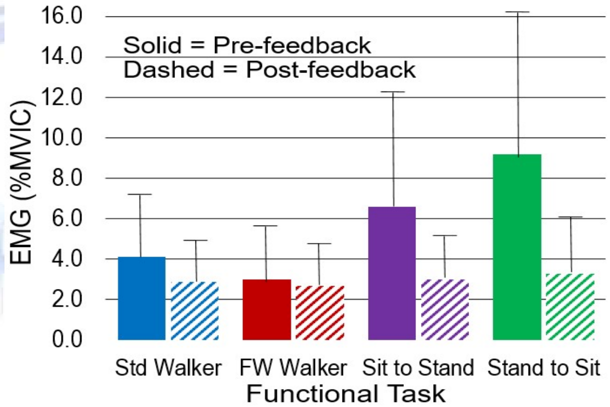

Table 1. Force and Electromyography (EMG) Data Mean (+SD) and Range for Functional Tasks Pre and Post Feedback Training. *MVIC = Maximal Voluntary Isometric Contraction*

	Force (lb)		EMG (%MVIC)	
	Self-Selected (Pre-training)	After Feedback (Post-training)	Self-Selected (Pre-training)	After Feedback (Post-training)
Standard Walker	18.5 ± 10.0* (6.0 – 39.7)	9.8 ± 3.0$^{\#}$ (5.3 – 17.6)	4.1 ± 3.0% (1.1 – 12.2%)	2.9 ± 2.0%$^{\#}$ (0.7 – 9.2%)
Front Wheeled Walker	11.7 ± 5.6 (6.0 + 37.6)	8.3 ± 2.4$^{\#}$ (4.4-14.0)	3.0 ± 2.9% (0.8 – 14.4%)	2.7 ± 1.9% (0.5 – 7.2%)
Sit to Stand	17.7 ± 7.1 (6.0 – 37.6)	9.3 ± 3.5$^{\#}$ (5.7 + 22.4)	6.6 ± 6.0% (0.5 – 27.7%)	3.0 ± 2.0%$^{\#}$ (0.6 – 9.1%)
Stand to Sit	19.0 ± 7.6* (6.9 – 38.8)	9.6 ± 2.8$^{\#}$ (4.1 – 15.0)	9.2 ± 8.5%* (0.8 – 35.0%)	3.3 ± 2.7%$^{\#}$ (0.5 – 10.8%)

Table 2: Intra-subject Correlations Between Average Force and Electromyography Data.

Subject #	r	Subject #	r	Subject #	r
1	0.98	8	0.96	15	0.92
2	0.69	9	0.78	16	0.87
3	0.83	10	0.76	17	0.9
4	0.91	11	0.96	18	0.94
5	0.95	12	0.92	19	0.93
6	0.84	13	0.96	20	0.93
7	0.97	14	0.86	21	0.82

Table 3: Intra-subject Correlations Between Peak Force and Electromyography Data.

Subject #	r	Subject #	r	Subject #	r
1	0.98	8	0.97	15	0.89
2	0.65	9	0.77	16	0.84
3	0.86	10	0.78	17	0.85
4	0.98	11	0.97	18	0.98
5	0.97	12	0.9	19	0.9
6	0.8	13	0.96	20	0.94
7	0.98	14	0.87	21	0.87

blood pressure 115 (±9) mm Hg, and diastolic blood pressure 73 (±6) mm Hg.

Force Data: Force data during each functional mobility task before and after feedback training are shown in Table 1 and Figure 1. Upper extremity force during ambulation with a front wheeled walker was significantly less than during ambulation with a standard walker and during stand-to-sit transfers. Mean values during all tasks were greater than 10 lb, the weight limit commonly prescribed with sternal precautions. During a majority of the trials (67%), study participants incorrectly estimated, using too much UE force, as shown in Figure 2. In addition, no significant differences in force were found between the left and right UE during bilateral weight bearing (Figure 3). Finally, peak force after feedback training was significantly lower than prior to training for all functional tasks.

EMG Data: Pectoralis major muscle EMG data during each functional mobility task before and after feedback training are shown in Table 1 and Figure 4. Mean PM muscle EMG values were less than 10% of MVIC. Pectoralis major muscle activity during front wheeled walker use was significantly less than during stand-to-sit transfers. Also, PM muscle EMG activity after feedback training was significantly lower than prior to training for all functional tasks except front wheeled walker use.

Correlational Data: Correlations between PM muscle EMG values and average UE force ranged from -0.17 to 0.08, and peak UE force ranged from -0.02 to 0.16 for all study participants. Intra-subject correlations between PM muscle EMG values and average UE force ranged from 0.69 to 0.98 as shown in Table 2. Intra-subject correlations between PM muscle EMG values and peak UE force ranged from 0.65 to 0.98 as shown in Table 3.

DISCUSSION

This study revealed that during all of the functional tasks performed before feedback training, on average the force put through the UE by the study participants exceeded that generally recommended with sternal precautions (10 lb or less) [8-10]. With only verbal instructions regarding UE weight bearing, patients may not be able to accurately estimate the amount of force through their UE. Po-Chan and Cheng-Ye found that healthy older adults on average put 22-28 lb of UE force through a standard walker when given no instructions to limit weight [25]. This is slightly greater than the mean value during ambulation with a standard walker in our study, but 38% of study participants did exceed 20 lb of UE force. Similarly, when healthy subjects used a 4-wheeled walker, Ishikura et al found the force put through the UE varied from 13-40% of one's body weight during a gait cycle [26].

This same trend has been observed in several previous studies that examined weight bearing through the lower extremities (and therefore inversely through a walker) during ambulation in patient populations. Fast and colleagues found that when patients used a standard walker to reduce weight bearing through the lower extremities, force through the walker was 20-49 lb, but when used for balance, the force through the walker was only 2-28 lb [27]. Because patients recovering from cardiac surgery with median sternotomy typically do not need to unweight the lower extremities, and use a walker primarily for balance stability, the latter values reported by Fast et al are similar to values in our study [27].

Studies examining compliance with touch down weight bearing (defined as < 25 lb) in patients with lower extremity trauma have found that placing too much weight through the involved side is common [28,29]. Hustedt and colleagues instructed healthy subjects to use touch down weight bearing with axillary crutches and found on average over 60 lb of weight was placed through the lower extremity [30,31]. Similarly, we found that study participants commonly applied too much UE force through a walker when given no feedback (see Figure 2). Also, it was uncommon for patients to use less than the 10 lb precautionary limit. It should be noted, however, that none of the previous studies have measured UE force through a walker while patients were instructed to "not place greater than 10 pounds through your arms," and were focused on limiting lower extremity weight bearing.

Ambulation using a front wheeled walker produced less UE force as compared to ambulation using a standard walker. This finding supports current sternal precautions and general clinical consensus that if an assistive device is needed for ambulation, a front wheeled walker is preferable for patients after median sternotomy [10]. A plausible explanation is that when using a standard walker, it must be lifted off the ground for a portion of the gait cycle and then placed back down, whereas a front wheeled walker remains on the ground throughout the gait cycle. Lifting a walker may result in less consistent force through the walker, creating cyclical peaks above the 10 lb limit. Previous studies have shown that lower extremity weight bearing (and therefore inversely UE weight bearing) varied throughout the gait cycle during ambulation with a 4-wheeled walker and standard walker [26,27,32]. Another possible explanation for the finding that in our study less UE weight was placed through the front wheeled walker as compared to the standard walker relates to the type of gait pattern employed. When patients ambulate using a standard walker they use a “step-to” pattern, but they use a “step-through” pattern with a front wheeled walker, so UE force is distributed more evenly throughout the gait cycle reducing peak forces. To date no previous studies have measured UE forces and compared a standard walker to a front wheeled walker.

Results indicate that UE weight bearing was highest during stand-to-sit transfers, and was significantly greater than during ambulation with a front wheeled walker. Although studies have examined UE forces during activities of daily living [17,18], little information is available on UE force during transfers. Similar to our study, Anglin et al reported higher maximal UE loads during stand-to-sit (179 N) than during sit-to-stand (154 N) [33]. 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 [34]. It is possible that patients feel the need to use more UE force during the eccentric control of the stand-to-sit movement than during the concentric muscle contractions required for the sit-to-stand movement.

The results of this study demonstrate that a brief feedback intervention can be effective in reducing UE force exerted during both ambulation with an assistive device and sit-to-stand transfers. Both visual and auditory feedback were utilized to provide participants information regarding force placed through their UE. A recent systematic review examining the efficacy of feedback for improving gait parameters found that visual (60%) and auditory (40%) feedback were most commonly employed [35]. In this study, a combination of both auditory (buzzer) and visual (force output on tablet screen) feedback was given to participants. This feedback was provided concurrently (during practice of the skill) as opposed to terminally (after practice of the skill) to best facilitate acquisition of a novel skill. Study participants were first given prescriptive (information on exactly how much weight was being placed through the walker) visual feedback while statically practicing UE weight bearing in standing or sitting. Then they were given descriptive (buzzer was sounded if force exceeded 10 lb limit) auditory feedback while practicing the whole task [35]. This method facilitated part-practice first followed by whole-practice, a principle of motor learning [36]. After feedback training, UE force was reduced during all functional tasks and on average was 10 lb or less, below the sternal precaution UE weight bearing threshold. Other studies have demonstrated that concurrent visual feedback training is effective in reducing lower extremity force when weight bearing is limited [28,30,31].

Results of this study suggest that PM muscle activation is small during functional mobility, and that feedback 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. There have been no previous studies examining PM muscle EMG activity during ambulation with a walker or during sit-stand transfers. A few studies have measured PM muscle EMG activity during similar activities. Pectoralis major muscle EMG activity was 13.0-14.4% MVIC while pushing a 4 kg weight forward on tracks, although in a different shoulder position (at shoulder height vs arms at side) than in our study [22]. Pectoralis major muscle EMG activity in the “prayer” position (kneeling with hands on floor in front of knees) was 7% MVIC, also a different shoulder position than used in our study [37]. Difference in arm position during bilateral UE movements can alter PM muscle EMG activity [38].

Overall, our findings suggest that use of an instrumented walker and feedback training would be beneficial in clinical practice to help patients more accurately follow weight bearing instructions. Most previous studies have used bathroom scales [30,31], force plates / pressure sensing mats [26,33], or foot pressure sensors [28,30,31] to measure weight bearing through the lower extremities. Others have described use of an instrumented walker to measure force placed through the assistive device but commonly this was accomplished with sensors placed in the legs and not the handles [25,27]. The instrumented walker used in this study had force transducers incorporated into the handles which Khodadadi et al found results in easier installation and less error compared to installation on circular vertical walker legs [39]. An inexpensive, lightweight walker without bulky add-ons for the measurement and display of force would have multiple clinical applications for providing feedback to patients who need to limit weight bearing through the upper or lower extremities. In addition to patients recovering from median sternotomy, an instrumented walker and feedback training would be useful for patients who need to limit weight through a lower extremity, for example following a fracture [28,29]. In this study, weight bearing was equal bilaterally through the UE indicating that possibly only a single walker handle needs to be instrumented, although this may not be the case for patients with unilateral extremity disorders [32].

Study results demonstrated that the relationship between PM muscle activity and UE weight bearing force is weak between subjects but strong within subjects. Muscle activation in this study was monitored via EMG, which measures the degree of muscle activation (motor neuron recruitment) by quantifying the number of action potentials; as such, EMG is an indirect indicator of muscle force production. It is not surprising that inter-subject correlations were small because even though EMG data were expressed relative to MVIC, there were differences between study participants' muscle mass. David and colleagues found a wide range of inter-subject correlations (r = 0.21-0.95) between EMG activity and strength in other shoulder muscles [40]. Intra-subject correlations were strong (most >75%) suggesting that estimating UE force using PM muscle EMG values for a given patient might be possible. For example, if a patient should only use force equivalent to 10 lb of UE weight bearing, then measuring PM muscle EMG values at that level may provide a good estimation of force.

Several limitations need to be considered when generalizing the results of this study. Healthy study participants were utilized in order to evaluate the safety of the instrumented walker and to reduce variability due to other factors, such as pain and impaired cognition that can occur after surgery. It would be expected that this functionally independent population should be better able to use only 10 lb or less of UE weight bearing force than populations with functional limitations and/or that use an assistive device for mobility. Leung and Yeh found that during sit-stand transfers using a walker, older adults who did not ambulate with a walker used less vertical arm force than those who did ambulate with a walker [41]. In addition, force through the UE does not necessarily equal force across the sternum. McQuade and colleagues found that although patients put 46% of their body weight through a walker during ambulation, compressive forces at the UE joints were only 20% of body weight, were greatest at the wrist, and decreased proximally [32]. Lastly, this study found benefits of feedback training on modulation of weight bearing immediately after the feedback. Therefore, conclusions about long term retention cannot be made. Hustedt and colleagues [42] found improvements in weight bearing were maintained up to 24 hours following feedback training, although others have not found good retention of acquired skills after feedback training [43].

CONCLUSION

In conclusion, the results of this study suggest that patients may not be good at estimating UE force during weight bearing activities. Specifically, patients recovering from median sternotomy most likely are not limiting arm force to 10 lb or less during daily activities, which puts them at risk for delayed bone healing and complications. But, a combination of visual and auditory feedback was effective at reducing UE weight bearing and PM muscle EMG activity. Objective feedback training while using an assistive device would be useful for patients recovering not only from median sternotomy, but also from lower extremity fractures and/or surgeries that require limiting weight placed through a leg.

Conflicts of interest: None

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