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Examining upper limb kinematics and dysfunction of breast cancer survivors in functional dynamic tasks

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ABSTRACT

Background: Comorbidities within the breast cancer population can reduce quality of life. Current breast cancer survivor upper limb kinematic strategies unfortunately lack robust connection with performing important activities of daily living.

Methods: Accordingly, fifty breast cancer survivors performed 88 dynamic tasks (divided into range of motion-reach, range of motion-rotate, activity of daily living, and work tasks). Humerothoracic and scapulothoracic angles were extracted from motion capture data. Bilateral differences existed for range of motion, and maximal and minimal scapulothoracic and humerothoracic angles.

Findings: Generally, the affected side used less range of motion across task types. Humerothoracic angles on the affected side experienced 6.7° less range of motion in plane of elevation in range of motion-reach ($p < 0.01$), 2.3° less elevation angle range of motion in range of motion-rotate ($p = 0.01$), and 7.1° more internal rotation range of motion in range of motion-rotate ($p < 0.01$). Scapulothoracic angles on the affected side had 2° more anterior/posterior tilt range of motion in work tasks ($p = 0.03$), 3.4° less maximal protraction in activity of daily living tasks ($p = 0.01$), and 3.5° less minimum downward rotation in range of motion-rotate ($p < 0.01$).

Interpretation: A reduced range of motion on the affected side suggests the breast cancer population had less varied movement strategies, keeping movements in narrower ranges to avoid disability, pain, or subacromial impingement. This investigation produced an unprecedentedly diverse collection of three-dimensional humerothoracic and scapulothoracic kinematics for a breast cancer population. Documentation of physical capability, dysfunction, and adaptive strategies is a crucial step towards developing targeted strategies for enhancing functional recovery in breast cancer survivors.

1. Introduction

Breast cancer is the most common cancer among females in Canada. Breast cancer constitutes 25.9% of new cancer cases each year for females, and 1 in 9 Canadian females will be diagnosed in their lifetime (CCS, 2015). Continued research on breast cancer population (BCP) prevention and care has produced positive results, and 5-year survivorship has reached ~90% in women aged 40–79 (CCS, 2015). Patients typically undergo surgical treatments, with adjuvant therapy following surgery to ensure removal of the cancerous cells. Mastectomies continue to be the most common surgical treatment, representing 45% of total surgical procedures, followed by breast conserving treatment and axillary node dissection in more advanced tumours (Courneya et al., 2002; Markes et al., 2006; Nemoto et al., 1980). Radical mastectomies are the most effective surgical treatment with only a 4.4% relapse rate (van der Sangen et al., 2011), but involve removal of the breast tissue, overlying skin, pectoralis muscle and extensive lymph node dissection (Dalberg et al., 2010). Improvements in imaging have led to increased popularity of modified radical mastectomies, which involve the removal of pectoral fascia, but leave the muscle intact (Dalberg et al., 2010).

This removal of muscle and tissue from surgery and adjuvant treatment generates a substantial volume and range of comorbidities. Range of motion (ROM) defects and/or lymphedema complications exists in 4 out of 5 patients receiving radical mastectomies (Sugden et al., 1998). While modified radical mastectomies reduce lymphedema risk and improves range of motion compared to radical mastectomies, 35% of patients still had range of motion restriction in one or more directions (Lauridsen et al., 2008). Across the BCP, treatment-related sequelae affects 30–82% of patients, and commonly include reduced range of motion, weakness, pain, numbness and swelling (Kwan et al., 2002; Lauridsen et al., 2008; Maycock et al., 1998; Rietman et al.,

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Fig. 1. Motion capture setup. Motion capture markers were placed over bony landmarks of the torso and upper extremity, with acromion clusters placed directly over the flat part of the acromion.

2004). The duration of these side effects vary across symptoms and between individuals, and can last from days to years (Schmitz et al., 2010). These upper limb morbidities can limit or interfere with activities of daily living (ADL), negatively affecting return to work and quality of life (Markes et al., 2006; Rietman et al., 2003).

Detailed knowledge surrounding upper limb functional ability of the BCP is limited. Accurate documentation of upper limb morbidity in the BCP is rare, and relationships between impairments, disability, task performance and quality of life are scarce (Rietman et al., 2003, 2004; Thompson et al., 1995). Various fundamental shoulder movements appear to be affected differentially, exacerbating the problem. Mean restrictions in abduction and forward flexion compared to the unaffected side have been reported at 21° and 12°, respectively (Kuehn et al., 2000), while other research quantified decreases in range of motion from 1 to 67° (Lee et al., 2008). Treatment strategy affects outcomes, with mastectomy patients reporting reduction in arm function more often (77%) than those with breast conserving therapy (33–39%), and reductions in flexion, abduction and external rotation more prominent in those who received mastectomies (Ebaugh et al., 2011; Harrington et al., 2013; Lauridsen et al., 2008; Nesvold et al., 2008; Sugden et al., 1998). Ability in these fundamental motions may not correlate effectively to motions of activities of daily living, and assessments of the BCP performing these tasks are incomplete. Systematic BCP evaluation is critical, as specific and effective preventative and treatment strategies do not exist to promote return to function and work. A prerequisite for creating these treatment strategies is rigorous quantification of the physical capabilities typical within the BCP for practical activities. This study describes the upper limb capacities and dysfunctions in female breast cancer survivors in terms of scapulothoracic and humerothoracic kinematics during range of motion, activities of daily living and simulated work activities. We hypothesize that the BCP have reduced humeral angle of elevation and external rotation ranges of motion, but increased scapular protraction on the affected side compared to the contralateral limb.

2. Methods

Anthropometrics and a brief medical history were recorded for 50 breast cancer survivors, who then performed 88 dynamic functional tasks during which motion capture was recorded.

2.1. Participants

Participants included 50 female breast cancer survivors (59.4 (SD 9.7) years, range 31–83 years; stature 1.7 (SD 0.1) m, range 1.5–1.8 m; body mass 71.7 (SD 11.8) kg, range 51.4–97.7 kg) who were previously diagnosed with stages I, II or III unilateral breast cancer. Participants had completed cancer therapies including surgery, radiation and/or chemotherapy at least 3 months prior to participation, and were predominantly right handed (n = 47). Cancer was on the left breast for 27 participants. Twenty-seven participants had mastectomies (16 prophylactic bilateral); 34 had lumpectomies and 48 had axial node dissection surgeries. Thirty-four participants received hormone replacement therapy, 34 had received chemotherapy and 37 had received radiation treatments. The average time since diagnosis was 74.9 (SD 59.6) months; range 12–228 months. All participants provided informed consent prior to data collection, and this study received ethics clearance through the institutional Office of Research Ethics.

2.2. Instrumentation

Motion capture was collected for both arms and the torso during each of the dynamic tasks. Three-dimensional motion was tracked using an 8-camera Vicon MX20 system (Vicon, Oxford, UK). Individual markers were placed over palpable anatomical landmarks: bilaterally over the radial and ulnar styloids, medial and lateral epicondyles and acromion, as well as the suprasternal notch, xiphoid process, and spinous processes of C7 and T8. Additional marker clusters were secured to rigid plates positioned on the upper arm and over the acromion (Fig. 1). The acromial marker cluster was placed over the flat part of the posterior-lateral acromion, just medial to the origin of the deltoid when