

# Axillary Web Syndrome in Newly Diagnosed Individuals after Surgery for Breast Cancer: Baseline Results from the AMBER Cohort Study

Margaret L McNeely, PT, PhD<sup>1</sup>;\*<sup>†</sup> Kerry S Courneya, PhD<sup>2</sup>;‡ Mona M Al Onazi, BScPT, MSc;\* Qinggang Wang, PhD;<sup>§</sup> Stephanie Bernard, PT, PhD;\* Leanne Dickau, MSc;<sup>§</sup> Jeffrey K Vallance, PhD;<sup>¶</sup> S. Nicole Culos-Reed, PhD<sup>1</sup>;\*\*<sup>††</sup> Charles E Matthews, PhD<sup>1</sup>;‡‡ Lin Yang, PhD<sup>1</sup>;§<sup>§</sup> Christine M Friedenreich, PhD<sup>1</sup>;§<sup>§</sup>

## ABSTRACT

**Purpose:** To examine potential associations between post-surgical axillary web syndrome (AWS) and demographic, medical, surgical, and health-related fitness variables in newly diagnosed individuals with breast cancer. **Methods:** Participants were recruited between 2012 and 2019. Objective measures of health-related fitness, body composition, shoulder range of motion (ROM) and function, and AWS were performed within 3 months of breast cancer surgery. **Results:** AWS was identified in 243 (17.3%) participants and was associated with poorer shoulder ROM and function, and higher pain compared with women without AWS. Multivariable logistic regression analysis identified axillary lymph node dissection versus sentinel lymph node biopsy [OR = 3.97; 95% CI: 2.62, 6.03], mastectomy versus breast-conserving surgery [OR = 1.60, 95% CI: 1.17, 2.19], lower versus higher total percentage body fat [OR = 1.60; 95% CI: 1.10, 2.34], and earlier versus later time from surgery [OR: 1.56; 95% CI: 1.10, 2.23] as significantly associated with a higher odds of AWS. Higher cardiorespiratory fitness [OR = 1.04; 95% CI: 1.01, 1.08] and university or higher education [OR = 1.47; 95% CI: 1.1, 2.00] were also associated with higher odds of presenting with AWS. **Conclusions:** Findings highlight the need for increased awareness of AWS to facilitate early detection and physiotherapy intervention in the early post-surgical period.

**Key words:** axillary web syndrome; breast cancer; range of motion; shoulder; surgery.

## RÉSUMÉ

**Objectif :** examiner les associations potentielles entre le syndrome des cordelettes axillaires (SCA) postchirurgicales et les variables démographiques, médicales, chirurgicales et relatives à la forme physique liée à la santé chez des personnes qui viennent de recevoir un diagnostic de cancer du sein. **Méthodologie :** les chercheurs ont recruté les participantes entre 2012 et 2019. Ils ont procédé à des mesures objectives de la forme physique liée à la santé, de la composition corporelle, de l'amplitude de mouvement (AdM) et du fonctionnement des épaules et du SCA dans les trois mois suivant une opération du sein. **Résultats :** les chercheurs ont constaté un SCA chez 243 participants (17,3 %), associé à une AdM et un fonctionnement de l'épaule moins satisfaisants, de même qu'à une douleur plus marquée que chez les femmes sans SCA. L'analyse de régression logistique multivariable a établi que la dissection des ganglions axillaires plutôt que la biopsie d'un ganglion axillaire sentinelle (RC = 3,97; IC à 95 % : 2,62, 6,03), la mastectomie plutôt que la chirurgie de conservation du sein (RC = 1,60, IC à 95 % : 1,17, 2,19), une graisse corporelle totale plus faible plutôt que plus élevée (RC = 1,60; IC à 95 % : 1,10, 2,34) et une opération précoce plutôt que tardive (RC : 1,56; IC à 95 % : 1,10, 2,23) étaient associées de manière significative à un risque plus élevé de SCA. Une meilleure capacité cardiorespiratoire (RC = 1,04; IC à 95 % : 1,01, 1,08) et une formation universitaire ou plus poussée (RC = 1,47; IC

From the: \*Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada; †Supportive Care Services, Cancer Care Alberta, Alberta Health Services, Edmonton, Alberta, Canada; ‡Faculty of Kinesiology, Sport, and Recreation, College of Health Sciences, University of Alberta, Edmonton, Alberta, Canada; §Department of Cancer Epidemiology and Prevention Research, Cancer Care Alberta, Alberta Health Services, Calgary, Alberta, Canada; ¶Faculty of Health Disciplines, Athabasca University, Athabasca, Alberta, Canada; \*\*Department of Oncology, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada; ††Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada; ‡‡Division of Cancer Epidemiology and Genetics, US National Cancer Institute, Rockville, Maryland, USA.

**Correspondence to:** Margaret L. McNeely, PhD, Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta; 2-50 Corbett Hall, Edmonton, Alberta, T6G 2G4, Canada. Tel.: +1 780 248 1531; [mmcneely@ualberta.ca](mailto:mmcneely@ualberta.ca)

**Contributors:** MLM, KSC, JKV, SNC, CEM and CMF conceived of, and designed the study. LD, MLM, KSC, CMF collected the data. MLM, QW, MMO, and SB analyzed the data. MLM, MMO, SB drafted the manuscript. All authors reviewed the draft and approved the final version.

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à 95 %: 1,1, 2,00) étaient également liées à un plus fort risque de SCA. **Conclusions** : les résultats démontrent la nécessité d'être plus sensibilisé au SCA pour favoriser une détection précoce et une intervention physiothérapique au début de la période postchirurgicale.

**Mots-clés** : amplitude de mouvement; cancer du sein; chirurgie; épaule; syndrome des cordelettes axillaires

Breast cancer is the most prevalent cancer among females worldwide.<sup>1</sup> Upper-quadrant issues on the side of the breast cancer including pain, weakness, poor range of motion (ROM), and lymphedema are common following treatment.<sup>2</sup> Axillary web syndrome (AWS), also referred to as axillary cording, is a condition that has a negative impact on the early recovery of shoulder ROM and function after surgery for breast cancer.<sup>3</sup> AWS presents as a series of cord-like structures that are visible and palpable in the axillary region (Figure 1), and can extend down the upper arm past the elbow into the forearm and wrist.<sup>4,5</sup> In some cases, cords may present in the breast and chest wall region inferior to the axilla.<sup>6</sup> AWS is associated with pain and restrictions in shoulder range of motion, impairing activities of daily living.<sup>7</sup>

The etiology of AWS is unknown; however, it is thought to occur as a result of inflammation or occlusion of lymphatic and venous vessels as a result of axillary surgery.<sup>8,9</sup> Symptoms of AWS include insidious onset of intense pain and limitation in shoulder abduction ROM, especially when the arm is elevated overhead.<sup>9</sup> AWS most often appears within 8 weeks of surgery.<sup>4,10</sup> Reported risk factors include an increased number of lymph nodes removed at surgery, younger age, and lower body mass index.<sup>9</sup> In a recent review, the incidence of AWS was reported to range from 0.6% to 85.4%, with higher incidence rates found following axillary lymph node dissection (ALND) when compared with SNB.<sup>11</sup> Currently, there is controversy over the natural progression of AWS, with some authors reporting spontaneous resolution within 12 weeks of surgery<sup>4,12</sup> and others reporting cases of late-onset, recurrent, and unresolved AWS.<sup>7,9</sup>

A recent systematic review examining physiotherapy intervention for AWS concluded that interventions involving exercise and stretching are effective in restoring shoulder ROM and reducing upper extremity pain and

disability.<sup>13</sup> Given the negative impact of AWS on early postoperative upper limb function, and the potential for benefit from timely physiotherapy intervention, we aimed to explore AWS in individuals with breast cancer in the time following surgery, prior to adjuvant cancer treatment. The primary objectives of this study were to identify the potential impact of AWS on upper limb symptoms and function, and its associations with key demographic, medical, surgical, and health-related fitness variables.

## METHODS

### Study design, participants, and procedures

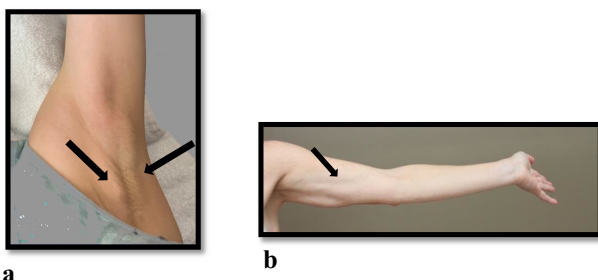
The Alberta Moving Beyond Breast Cancer (AMBER) study is a prospective cohort study examining the role of physical activity, sedentary behaviour, and health-related fitness in breast cancer treatment, recovery, and survivorship.<sup>14–16</sup> The present study reports the baseline data from the AMBER cohort for individuals undergoing surgery prior to, or at the start of adjuvant cancer treatments. Assessments were performed at baseline (soon after diagnosis), with 96% of assessments completed within 3 months. Participants were recruited between July 2012 and July 2019 in Edmonton and Calgary, Alberta, Canada. Individuals of female sex with newly diagnosed breast cancer were eligible if they had histologically confirmed stage I ( $\geq$ T1c) to stage IIIc breast cancer, were 18–80 years old, proficient in English, and not pregnant. In Calgary we identified potential participants through the Alberta Cancer Research Biobank, which approached individuals with breast cancer at the time of diagnosis, requested a blood sample, and obtained their consent to be contacted for future research studies. These individuals were contacted for the AMBER cohort study once their clinical and pathology results were available. In Edmonton eligible participants were identified through the Cross Cancer Institute's New Patient Breast Cancer Clinic and approached by their treating oncologist at their first visit.

### Ethical considerations and informed consent

Ethical approval was obtained through the Alberta Cancer Research Ethics Board and each participant completed a signed consent form. We have previously described the AMBER study design and methods<sup>15</sup> as well as the baseline characteristics of the full cohort.<sup>16</sup>

### Demographics

Participants self-reported sociodemographic characteristics such as age, marital status, ethnicity, education, income, employment, and comorbidities. Participants



**Figure 1** (a) Axillary web syndrome: Multiple visible cords in left axilla with the shoulder abducted; (b) Axillary web syndrome: Visible cords extending distally down the arm.

also self-reported lifestyle behaviours such as smoking, alcohol consumption, and physical activity. Clinical information about their cancer was extracted from medical charts by a trained study staff member and included date of diagnosis, disease stage, tumour grade, histology, and surgery type.

### Testing schedule

Most AMBER baseline testing occurred over two separate days about 1 week apart with lymphedema and ROM testing, hand grip strength, body composition assessments, and cardiorespiratory fitness testing taking place on day 1. At the end of day 1, participants were given questionnaires to complete. Day 2 testing consisted of upper and lower body muscular strength and endurance tests with about a 10-minute rest between the tests.

### Measures

Health-related fitness assessments, performed by Clinical Exercise Physiologists using standardized testing protocols and the same equipment at both sites, have been previously published.<sup>15</sup> Relative to upper limb morbidity, the assessments included: body composition (dual X-ray absorptiometry, body weight, height); grip strength; cardiorespiratory fitness (graded treadmill exercise test); and upper and lower body muscular strength (chest and leg press predicted one-repetition maximum [1-RM]) and endurance (multiple repetition maximum, based on 50% of predicted 1-RM for the chest press and 70% of predicted 1-RM for the leg press). Self-reported physical activity data were collected using the Past Year Total Physical Activity Questionnaire.<sup>17</sup>

AWS was determined through self-reporting, and standard physical assessment of both active and passive ROM measurements for the movements of shoulder forward flexion and abduction.<sup>11,18</sup> AWS was confirmed objectively and characterized as the presence of visible and/or palpable cords in the underarm, medial arm, antecubital space, or forearm on the side of the breast surgery at maximal passive shoulder abduction.<sup>18</sup>

Shoulder active and passive ROM were measured following standardized procedures using a traditional goniometer.<sup>19,20</sup> Each arm was measured separately for the movements of shoulder flexion and abduction. Active ROM was assessed with the participant in sitting or standing with their back in an upright position to prevent compensation by trunk muscles. Passive shoulder flexion and abduction movements were performed in the supine position. Self-reported arm function and pain were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) scale.<sup>21</sup>

Arm volume was measured using a perometer (Perosystems, Wippital, Germany). The perometer is an optoelectric limb volumeter that uses infrared technology to quantify limb volume and determine inter-limb dif-

ference. The perometer is a valid, reliable, and sensitive method for quantifying limb volume.<sup>22-24</sup>

### Statistical analyses

Descriptive statistics were used to present demographic, medical, surgical, and health-related fitness characteristics of the sample. T-tests were performed to explore the differences in outcomes of shoulder ROM, upper body function and pain (DASH score), upper limb strength and endurance, and grip strength among participants with and without AWS. We compared baseline characteristics across groups using relevant statistical tests (t-tests/analysis of variance [ANOVA] for continuous and  $\chi^2$  for categorical variables). Our multivariable analysis used a generalized logistic mixed model to control for the effect of location (Calgary/Edmonton) given the differences in the timing of upper limb assessments (Calgary: Median 52 days post-surgery; Edmonton: Median 60 days post-surgery). Independent baseline characteristics associated with the dependent variable at a statistically significant level ( $p < 0.05$ ) were entered into the final multivariable model. We handled missing data on covariates via multivariate imputations through chained equations, which includes all correlated covariates in regression models to avoid reducing the sample size.<sup>25</sup> All statistical tests were two-sided and the significance level was set at  $p < 0.05$ .

### RESULTS

Of the 3673 (25%) eligible individuals with breast cancer, we recruited 1528 (42%) in the AMBER cohort study. For the present analysis, of the 1528 AMBER participants we excluded 117 participants undergoing neoadjuvant chemotherapy, one participant not receiving cancer treatment, and eight participants missing data related to AWS, resulting in a final sample of 1402 participants who had undergone surgery prior to adjuvant cancer treatment. Of those, assessment for AWS was completed a median of 55 (inter-quartile range = 45–70) days post-surgery. Characteristics of the AMBER sample undergoing unilateral surgery are presented in [Table 1](#). Overall, 17.3% of participants presented with AWS. A lower prevalence was found in individuals who had undergone breast-conserving surgery with sentinel lymph node biopsy (SNB) (9.6%), and a higher prevalence in those who had undergone mastectomy with ALND (47.4%) ([Figure 2](#)). The mean age was 55.9 years (SD = 10.9), most were White (87.1%) and diagnosed with stage I (48.1%) or II (45.0%) breast cancer, 60.9% had breast-conserving surgery, and 83.0% had undergone a SNB.

### Association with ROM, pain, and function

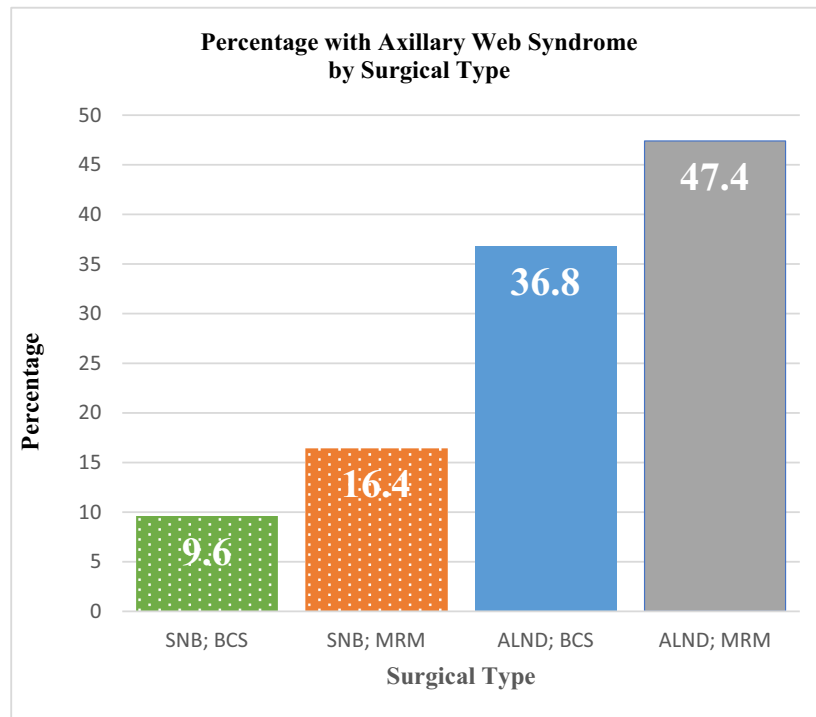
Compared with individuals without AWS, those with AWS had poorer ROM (i.e., a lower mean active abduction ROM of 11 degrees) and were more likely to present with ROM limitation below the threshold for function (i.e.,

**Table 1** Baseline Demographic and Medical Characteristics of the AMBER Cohort Study Participants, 2012–2019, *N* = 1402

Demographic/medical characteristic	Full cohort <i>N</i> = 1402		No AWS <i>n</i> = 1159 (82.7%)		AWS <i>n</i> = 243 (17.3%)	
	Mean/ <i>n</i>	SD/%	Mean/ <i>n</i>	SD/%	Mean/ <i>n</i>	SD/%
Age at diagnosis, mean, SD	55.9	10.9	56.6	10.6	53.1	10.4
Location						
Calgary	826	58.9%	707	61.0%	119	49.0%
Edmonton	576	41.1%	452	39.0%	124	51.0%
Race/Ethnicity						
White	1221	87.1%	1005	86.7%	216	88.9%
Asian	96	6.8%	81	7.0%	15	6.2%
Asian: Indian	29	2.1%	27	2.3%	2	0.8%
Black	8	0.6%	6	0.5%	2	0.8%
Latin American or Hispanic	17	1.2%	11	0.9%	6	2.5%
First Nations	12	0.9%	12	1.0%	0	0.0%
Don't know/missing	14	1.0%	13	1.1%	1	0.4%
Marital status						
Married or common-law	1040	74.2%	864	74.5%	176	72.4%
Divorced, separated, widowed	265	18.9%	217	18.7%	48	19.8%
Single (never married)	97	6.9%	78	6.7%	19	7.8%
Highest level of education						
High school or less	317	22.6%	282	24.3%	35	14.4%
College or trade school	436	31.1%	365	31.5%	71	29.2%
University undergraduate degree/nursing school	356	25.4%	279	24.1%	77	31.7%
University graduate degree	257	18.3%	204	17.6%	53	21.8%
Missing	36	2.6%	29	2.5%	7	2.9%
Income						
≤\$50,000	206	14.7%	181	15.6%	25	10.3%
>\$50,000–\$100,000	400	28.5%	336	29.0%	64	26.3%
>\$100,000–\$150,000	295	21.0%	253	21.8%	42	17.3%
>\$150,000	369	26.3%	280	24.2%	89	36.6%
Missing	132	9.4%	109	9.4%	23	9.5%
Charlson Comorbidity Index*, median, Q1, Q3	0.5	0.0, 1.5	0.5	0.0, 1.5	0.5	0.0, 1.5
Menopausal status						
Premenopausal	555	39.6%	440	38.0%	115	47.3%
Postmenopausal	847	60.4%	719	62.0%	128	52.7%
Body mass index category						
<18.5	12	0.9%	10	0.9%	2	0.8%
18.5–24.9	514	36.7%	391	33.7%	123	50.6%
25–29.9	484	34.5%	403	34.8%	81	33.3%
30–39.9	350	25.0%	317	27.4%	33	13.6%
>40	42	3.0%	38	3.3%	4	1.6%
Breast cancer stage						
I	674	48.1%	603	52.0%	71	29.2%
II	631	45.0%	500	43.1%	131	53.9%
III	97	6.9%	56	4.8%	41	16.9%
Breast cancer affected side						
Right	697	49.7%	569	49.1%	128	52.7%
Left	704	50.2%	589	50.8%	115	47.3%
Bilateral	1	0.1%	1	0.1%	0	0.0%
Breast cancer surgery						
Unilateral	1228	87.6%	1024	83.4%	204	84.0%
Bilateral	174	12.4%	135	11.6%	39	16.0%

36% of those with AWS presented with ROM limitation below 130 degrees flexion). Participants with AWS were also found to have a higher frequency and severity of pain, and worse upper limb function. For example, moderate or greater pain was reported by 13.4% of those without AWS compared with 21.5% of those with

AWS, and the mean DASH score was 4.1 points higher (indicating worse functioning) in those with AWS (Table 2). No statistically significant differences were found in the number of individuals presenting with an arm volume difference of more than 200 millilitres, indicative of potential lymphedema.



**Figure 2** Prevalence of Axillary Web Syndrome by Surgical Type.

ALND: Axillary lymph node dissection; BCS: Breast-conserving surgery; MRM: Modified radical mastectomy; SNB: Sentinel lymph node biopsy.

**Unadjusted univariate associations**

Associations between independent variables and the prevalence of AWS are reported in Supplementary Table S1. Prior to data analyses, an examination of test assumptions indicated that multicollinearity did not present a significant problem in the analyses. Related to the prevalence of AWS, statistically significant unadjusted univariate associations were found with demographic (age, education), medical (cancer stage, positive lymph

node status), surgical (mastectomy, axillary node dissection, reconstruction, time from surgery), and health-related fitness variables (higher cardiorespiratory fitness, higher lower body strength, higher lower body endurance, and lower % fat mass) variables.

**Adjusted multivariable associations**

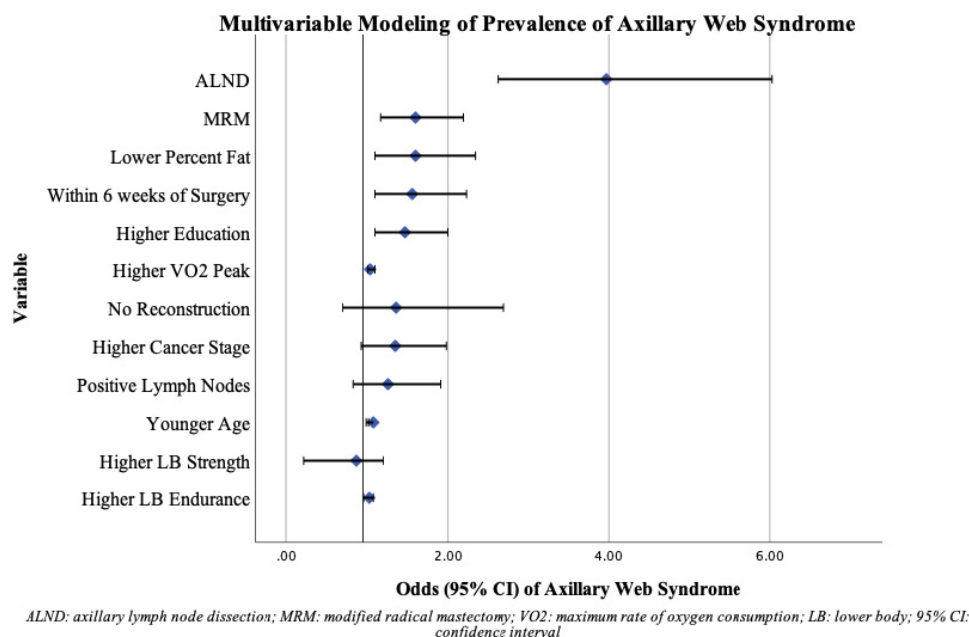
Figure 3 presents the findings of the generalized logistic mixed model analyses examining the association between

**Table 2** Range of Motion, Pain, Function and Strength Outcomes, AMBER cohort study, 2012–2019, N = 1402

Outcome	Category	No AWS n = 1157 mean/n	SD/%	AWS n = 242 mean/n	SD/%	p-value
Flexion ROM	Passive ROM degrees	161.7	16.4	155.7	17.5	<b>p &lt; 0.001</b>
	Active ROM degrees	146.2	17.4	141.3	18.5	<b>p &lt; 0.001</b>
Abduction ROM	Passive ROM degrees	165.5	24.1	151.7	30.0	<b>p &lt; 0.001</b>
	Active ROM degrees	150.0	24.0	139.0	26.3	<b>p &lt; 0.001</b>
Pain	Functional ROM 130+ degrees; n, %	941	85.9%	155	64.0%	<b>p &lt; 0.001</b>
	ROM Limitation, <130 degrees; n, %	216	18.7%	87	36.0%	
	No pain	640	57.6%	92	39.7%	<b>p &lt; 0.001</b>
Pain with activity	Mild pain	322	29.0%	90	38.8%	
	Moderate or greater pain	149	13.4%	50	21.5%	
	No pain	627	56.4%	78	33.5%	<b>p &lt; 0.001</b>
Upper limb function	Mild pain	309	27.8%	93	39.9%	
	Moderate or greater pain	175	16.8%	62	26.6%	
	DASH score/100	10.5	11.0	14.6	13.6	<b>p &lt; 0.001</b>
Lymphedema	Arm volume >200 ml difference	44	3.8%	7	2.9%	p = 0.485
Upper limb strength	1-RM kg	35.5	10.1	34.5	9.4	p = 0.124
Upper limb endurance	Number of repetitions × 50% 1-RM	475	212	477	210	p = 0.869
Grip strength	Combined, kg	54.8	12.2	56.0	12.2	p = 0.138

DASH = Disabilities of the Arm, Shoulder and Hand (lower scores reflect better functioning); 1-RM: One-repetition maximum; ROM: Range of motion.

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**Figure 3** Findings from the Multivariable Modeling of Prevalence of Axillary Web Syndrome.

statistically significant univariate variables and odds of developing AWS. In terms of independent associations, participants who had undergone ALND had 3.97-times higher odds [OR = 3.97; 95% CI: 2.62, 6.03] of AWS when compared with those participants undergoing SNB. Participants who had undergone mastectomy had 1.60-times higher odds [OR = 1.60; 95% CI: 1.17, 2.19] when compared with those undergoing breast-conserving surgery; while those with a total percentage body fat less than 40% had 1.60-times higher odds [OR = 1.60; 95% CI: 1.10, 2.34] when compared with those with a body fat percentage equal to or higher than 40%. Participants who were assessed within 6 weeks of surgery had 1.56-times higher odds [OR = 1.56; 95% CI: 1.10, 2.23] when compared with those assessed more than 6 weeks postoperatively. Findings from the multivariable adjusted analysis also indicated that higher cardiorespiratory fitness [OR = 1.04; 95% CI: 1.01, 1.08] and university or higher education [OR = 1.47; 95% CI: 1.1, 2.00] were associated with higher odds of presenting with AWS.

## DISCUSSION

To our knowledge, the AMBER study is the largest prospective cohort study to report on the prevalence of AWS in the first 3 months after breast cancer surgery, in the time between surgery and adjuvant cancer treatment.<sup>11,13,26</sup> Our findings provide insight into the factors related to the wide range of prevalence reported in the literature.<sup>11</sup> Consistent with prior reports, undergoing an ALND was most strongly associated with the prevalence of AWS.<sup>7,10,18,27,28</sup> Given our large cohort, however, we were able to examine prevalence more specifically across

surgical types, and in subgroups involving combinations of the type of breast cancer surgery and lymph node dissection procedure. For example, we detected AWS in 12.4% of individuals who had undergone SNB, a rate that falls within the range (1%–25%) reported in a systematic review by Yeung and colleagues.<sup>11</sup> In contrast, the prevalence rate of our participants who had undergone ALND (43.5%) was higher than the range reported in this review (5%–36%).<sup>11</sup> Importantly, our findings support a lower prevalence in individuals who had undergone breast-conserving surgery with SNB (9.6%) and a higher prevalence in those who had undergone mastectomy with ALND (47.4%) in comparison to rates reported in this review.

A primary reason for the variability in reported prevalence rates is likely attributable to the more commonly self-reported measures used across studies of AWS. In AMBER, AWS was identified using both self-report and a standardized, objective clinical assessment method proposed by Bergmann and colleagues.<sup>18</sup> Several prior studies used self-reported symptoms alone to identify potentially affected individuals, leading to possible over- or under-diagnosing of the condition.<sup>11</sup> Thus, the AMBER study contributes to our understanding of the burden of AWS through evaluation of a large sample of individuals with breast cancer inclusive of all possible surgical procedures and combinations, and by using a standardized objective measurement method to detect AWS.

Findings of a systematic review support that AWS is most commonly first identified in the first 3 months after surgery, with a majority of studies reporting AWS occurrence within the first 8 weeks.<sup>11</sup> A recent large-scale co-

hort study examined the time course for the development of AWS and followed participants for a median of 24.3 months. The authors report a similar 3-month AWS prevalence rate (~15%) to that of AMBER; however, their cumulative incidence rate of 31% at 24 months suggests that AWS is not solely an early postoperative and self-limiting condition. While our current AMBER findings consider only the early time period following surgery and support a higher prevalence of AWS in the earlier weeks, further follow-up of participants over time will help inform the overall prevalence and natural progression of AWS.

It is well-recognized that arm and shoulder morbidity commonly occur following surgery for breast cancer.<sup>29–31</sup> We found that individuals with AWS had worse shoulder ROM, as well as more pain at rest when compared with those without AWS. Similar to our findings, greater restrictions have been reported for shoulder abduction ROM when compared with restrictions in shoulder flexion ROM.<sup>11</sup> Less commonly reported in the literature is the functional impact of AWS.<sup>11</sup> AMBER participants with AWS were more likely to present with shoulder ROM below the threshold for function,<sup>32</sup> and worse upper limb function than those without AWS. In contrast to our findings, a prior small study ( $N = 36$ ) reported no difference in function, based on DASH scores, between AWS and non-AWS groups.<sup>33</sup> However, in support of our findings, another large-scale cohort study reported higher odds of functional limitations among those with AWS.<sup>27</sup> Although AWS may resolve spontaneously in some cases, early detection and timely physiotherapy are essential to relieve pain and prevent the long-term impact of this condition on the individual's functional ability.<sup>7,13,27</sup>

AMBER is the first study to examine the relationship between AWS and objectively collected measures of body composition and physical fitness.<sup>18,34,35</sup> Individuals with a lower body fat percentage were found to have higher odds of developing AWS. This finding aligns with previous research showing higher prevalence among individuals with lower BMI,<sup>11</sup> and lower prevalence among those who have a BMI  $\geq 30$ .<sup>18,36</sup> It has been suggested that detecting AWS in individuals with a higher BMI may be more challenging due to increased subcutaneous adipose tissue, leading to potential underestimation of the condition.<sup>7,37,38</sup> A second theory proposed in the literature is that AWS is part of the body's natural response to lymphatic injury.<sup>7,37,38</sup> When the lymphatic system is injured, the immune system plays a critical role in lymphangiogenic response and collateralization, which may lead to the formation of cords.<sup>39</sup> Koehler and colleagues theorize that the lymphatic response may be suppressed in individuals with a higher BMI due to poor wound healing associated with obesity.<sup>40</sup> This theory may help explain why individuals who are obese appear to be at a lower risk of AWS but at a higher risk for developing lymphedema.<sup>41,42</sup>

We also found that individuals with better cardiorespiratory fitness and those with university or higher education had higher odds of developing AWS. These factors, along with body composition, are highly related, and may reflect the better overall health status of the individual.<sup>43–45</sup> Prior to data analysis, we performed an examination of test assumptions, and findings indicated that multicollinearity did not present a significant problem in the analysis. However, conducting multicollinearity diagnostics does not solve the problem of the overlapping information these variables may share as markers of health, and thus, a more careful interpretation of the data is warranted related to these variables.<sup>46</sup>

Although AWS occurs frequently after surgery for breast cancer, it remains poorly understood and under-recognized.<sup>9,47</sup> A recent systematic review involving nine studies reported benefit from early physiotherapy intervention in addressing pain, limitations in ROM, and functional deficits related to AWS.<sup>13</sup> As there is a growing need for physiotherapists to serve as primary providers of cancer rehabilitation services, an increased awareness of AWS among those working in both public and private practice settings will help to facilitate appropriate and timely management.<sup>9,47</sup>

Strengths of our study include the large sample size, the collection of post-surgical data prior to, or at the start of adjuvant cancer treatments, and the comprehensive and objective assessments of AWS, health-related fitness, and body composition. The primary limitation of our study was the lack of collection of data on the extent of AWS in terms of the cord number, thickness, location, and associated symptoms; however, no standardized grading system for AWS currently exists.<sup>11</sup> Moreover, AWS may have been present in those without a visible or palpable cord, resulting in an underestimation of the prevalence. Further limitations include the cross-sectional design, a younger, predominantly White, and relatively healthier breast cancer sample.<sup>16</sup> Future analyses of the AMBER cohort objective and self-reported data at 1- and 3-year follow-ups, and self-reported data at the 5-year follow-up, will allow us to examine findings related to the natural progression of AWS over time.

## CONCLUSION

AWS is prevalent among individuals undergoing more extensive breast cancer surgical procedures. Consequences of AWS include ROM restriction, pain, and functional limitation. Our findings highlight the need for preoperative physiotherapy education and closer attention to individuals undergoing ALND and mastectomy, and in those who are leaner. Early identification of individuals with AWS will facilitate timely physiotherapeutic treatment to improve upper limb mobility and function, and decrease associated pain.<sup>11,13</sup>

## KEY MESSAGES

### What is already known on this topic

The reported incidence of postoperative breast cancer-related AWS ranges from 0.6% to 85.4%. Although largely considered a self-limiting condition, more recent research suggests that AWS can persist and may reoccur after resolution. Early physiotherapy intervention is helpful to reduce upper extremity pain and restore shoulder ROM and function.

### What this study adds

AWS is prevalent among individuals undergoing more extensive surgical procedures and results in significant shoulder ROM restriction, pain, and upper extremity functional limitation. Our findings highlight the need for targeted preoperative education and early detection to support timely physiotherapy intervention, particularly in those who appear to be at greater risk.

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