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Upper arm anthropometrics versus DXA scan in survivors of acute respiratory distress syndrome

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KSC, MM and DMN conceived and designed the study. All authors contributed to the analysis plan. MM, CLH, EWE, PEM, ROH, DMN, and VDD acquired the data and LAF performed all analyses. All authors were involved in the interpretation of study results. KSC and MM drafted the manuscript and all authors critically revised it for important intellectual content and approved the final version to be submitted.

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Abstract

Survivors of acute respiratory distress syndrome (ARDS) experience severe muscle wasting. Upper arm anthropometrics can provide a quick, non-invasive estimate of muscle status, but its accuracy is unknown. This study examines the accuracy of upper arm percent muscle area (UAMA) with reference measures of lean mass from dual energy X-ray absorptiometry (DXA). Data are from 120 ARDS survivors participating in a multi-center national study. Receiver Operating Characteristic (ROC) Curves, by patient sex, demonstrated that UAMA did no better than chance in discriminating low appendicular skeletal muscle mass identified using DXA findings (c-statistics, 6m: 0.50-0.59, 12m: 0.54-0.57). Modest correlations of UAMA with DXA measures (whole-body: r=0.46-0.49, arm-specific: r=0.50-0.51, $p<0.001$) and Bland-Altman plots indicate poor precision. UAMA is not an appropriate screening measure for estimating muscle mass when compared to a DXA reference standard. Alternate screening measures should be evaluated in ARDS survivors.

Keywords

lean mass; anthropometrics; dual energy X-ray absorptiometry (DXA); critical illness survivors; acute respiratory distress syndrome (ARDS)

Introduction

Patients with acute respiratory distress syndrome (ARDS) experience substantial muscle wasting within the first week of admission to the intensive care unit(1). By hospital discharge, ARDS survivors had an 18% mean loss in body weight(2). Monitoring changes in body composition post-discharge is critical given the muscle loss and the associated functional impairments that are commonly observed in this population(3,4). Furthermore, evaluations of nutrition and exercise interventions aimed at improving muscle mass, strength, and physical functioning in these patients, require accurate measures of muscle mass.

Upper arm anthropometrics can provide quick, non-invasive screening measures of muscle area(5). However, it is unclear how well upper arm percent muscle area (UAMA) performs relative to measures of lean mass from reference standards, such as dual energy X-ray absorptiometry (DXA). If UAMA accurately replicates DXA measures, it can be a practical and valid option for monitoring muscle mass in ARDS survivors. Using data from a national, multicenter prospective cohort of ARDS survivors, this study examines the accuracy of UAMA relative to DXA-based estimates of lean mass.

Methods

Study Population

Data were collected as part of the ARDS Network (ARDSNet) Long-Term Outcome Study (ALTOS), a national multicenter prospective study that longitudinally evaluated survivors 6 and 12 months after ARDS. Supplemental funding (R01HL091760-02S1) provided for DXA scans at 5 ALTOS study centers Consent for DXA assessments were provided as part of written informed consent. Institutional review boards at Johns Hopkins University and participating study centers approved the study. The online methods supplement provides details on study population and DXA assessments.

Measurements

Dual energy X-ray absorptiometry—DXA-based percent lean mass for the whole body and right arm was evaluated at 6m and 12m. Of 120 ARDS survivors with ≥1 DXA scan, 97 had a scan at 6m and 91 at 12m. Appendicular skeletal muscle mass (ASMM), a DXA-based measure, was calculated as the sum of lean mass in the arms and legs (kg) divided by height squared (m^2). Low ASMM (<7.26 kg/m^2 in men and <5.45 kg/m^2 in women) has been used to indicate sarcopenia(6).

Percent Muscle Area[1]—UAMA(7) was calculated as the mean of three triceps skinfold measurements and three mid-arm circumference measurements, all made on the right arm. Research personnel underwent rigorous in-person training and ongoing quality assurance assessments for completing anthropometric assessment.

[1]Percent muscle area is calculated as UAMA/TUA where Upper Arm Muscle Area (UAMA) = $[C - (Ts \times \pi)]^2 / (4 \times \pi)$ and Total upper arm area (TUA) = $C^2/(4 \times \pi)$; C = mid-arm circumference, Ts = triceps skinfold.

Statistical Analysis

We examined the cross-sectional correlation of DXA whole body and right arm percent lean mass with UAMA. Additionally, Bland-Altman plots, comparing UAMA with corresponding DXA right arm percent lean mass, was created to assess measurement bias and accuracy. We used Receiver Operating Characteristic (ROC) Curves to evaluate, by patient sex, the ability of UAMA to discriminate between clinically different groups: survivors with vs. without low ASMM, which represents one aspect of sarcopenia. C-statistic of 1.0 indicates perfect discrimination; 0.5 reflects poor discrimination. Analyses were repeated for each follow-up and by baseline obesity status (obese = BMI ≥30). SAS® 9.4 was used for all analyses.

Results

Survivors with low ASMM were older, primarily white, had lower BMI, and longer hospital length of stay (Table 1). Correlation was modest between both UAMA and DXA percent lean mass of whole body (6m: r=0.46, 95%CI: 0.28, 0.61; 12m: r=0.49, 95%CI: 0.31, 0.64) and of the right arm (6m: r=0.50, 95%CI: 0.32, 0.65; 12m: r=0.51, 95%CI: 0.32, 0.66). Bland-Altman plots confirm the low accuracy of UAMA for replicating DXA right arm percent lean mass, with wide 95% limits of agreement for the mean difference between these methods. DXA estimates were higher than UAMA estimates (6m: 7.7, 95%CI: -12.0, 27.5; 12m: 6.8, 95%CI: -14.1, 27.7), although this bias was not significant at either follow-up. Bland-Altman plots and scatterplots are provided in the online data supplement (Appendix Figure A1-2).

ROC analysis indicated that UAMA performed no better than chance (c-statistics: 6m=0.50-0.59; 12m=0.54-0.57) in identifying survivors with low ASMM for either males or females (Figure).

Findings were similar by obesity status, with modest correlations (obese: r=0.46-0.55; non-obese: r=0.48-0.60) and low accuracy for UAMA based on Bland-Altman plots. We did not conduct ROC analysis by subgroup as there were too few obese patients with low ASMM. See online data supplement Appendix B for full results.

Discussion

In our multi-center national study of 120 ARDS survivors, UAMA did not accurately replicate whole-body or arm-specific estimates from DXA, a reference method for assessing lean mass. These findings indicate that UAMA, despite its practicality, does not provide an adequate estimate of muscle mass in ARDS survivors.

Concerns regarding the accuracy and reproducibility of muscle area anthropometric measures have been raised in studies of elderly patients(8). Our findings suggest that alternative measures of muscle mass are also needed for ARDS survivors. Our multi-center sample, while typical of ARDS survivors, was generally younger with a higher BMI than samples included in the prior review(8). Although we found similar correlations between UAMA and DXA measures in both obesity groups, there were too few obese survivors with

low ASMM for valid ROC analysis. Future studies should investigate whether similar findings would be observed in other populations of critical illness survivors, including obese patients. Finally, all body composition assessment methods, including DXA, have limitations when used during non-steady state conditions, which could not be confirmed in our study.

Our findings have practical implications. BMI and UAMA based on anthropometric measurements are commonly used in dietetic practice to assess malnutrition risk and changes in body composition. While practical tools are necessary for dietetic assessments, our findings suggest caution is needed in interpreting UAMA as indicators of ARDS survivors' muscle status.

Accurate estimates of muscle mass, along with muscle function (e.g, strength), is important for determining functional sarcopenia(9). More reliable and practical tools are needed to help identify survivors who may benefit from nutrition and rehabilitation interventions and improve outcomes of ARDS survivors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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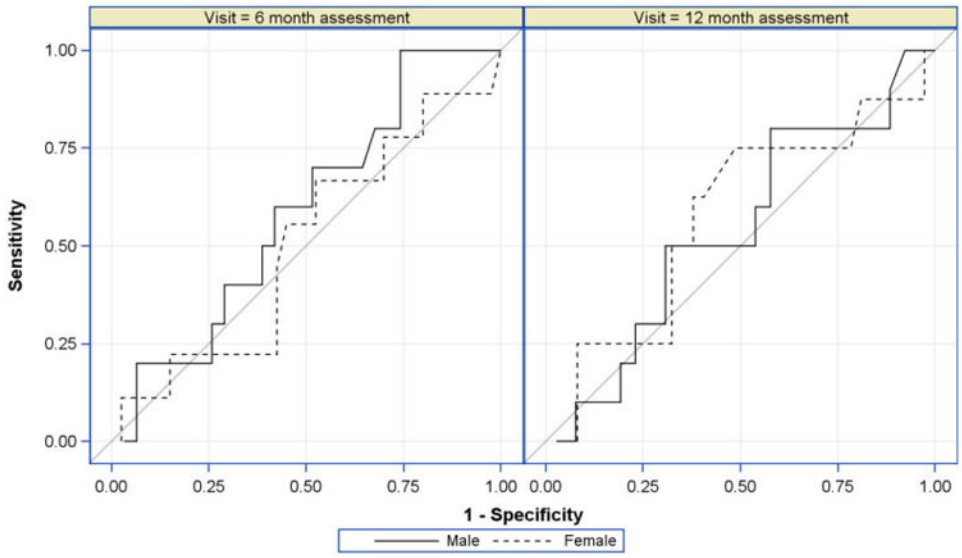

Figure.

Ability of Percent Upper Arm Muscle Area (UAMA) to Discriminate Low ASMM, Receiver Operating Characteristic Curves by Patient Sex at 6m and 12m Follow-up. Male (6m: N=41, 12m: N=36), Female (6m: N=49, 12m: N=45).

Table 1

Participant Characteristics

Variables	Total N=120	Low ASMM† N=30	Normal ASMM N=50	p-value
Demographics				
Age, mean (sd)	50 (15)	57 (14)	46 (14)	<.001
Male, n (%)	57 (48)	15 (50)	20 (40)	0.383
White Race, n (%)	103 (86)	29 (97)	38 (76)	0.015
Comorbidities and Baseline Status				
Charlson Comorbidity Index, mean (sd)	1.2 (1.7)	1.2 (1.3)	1.1 (1.7)	0.769
Functional Comorbidity Index, mean (sd)	1.9 (1.5)	1.6 (1.3)	1.9 (1.4)	0.294
COPD, n (%)	6 (5)	4 (13)	0 (0)	0.008
Rheumatologic comorbidity*, n (%)	5 (7)	2 (11)	1 (3)	0.322
Neurologic comorbidity, n (%)	9 (8)	3 (10)	6 (12)	0.784
BMI in hospital WHO category, n (%)				<.001
< 18.5	1 (<1)	1 (3)	0 (0)	
18.5 - < 25	20 (17)	9 (30)	5 (10)	
25 - <30	37 (31)	16 (53)	12 (24)	
≥30	62 (52)	4 (13)	33 (66)	
Normalized SF-36 PF, mean (sd)	44 (13)	42 (13)	45 (13)	0.229
ICU and Hospital Exposures				
APACHE III severity of illness score, mean (sd)	86 (28)	90 (30)	81 (26)	0.206
Days with organ failure, mean (sd)	0.7 (0.1)	0.7 (0.2)	0.7 (0.1)	0.508
Ever used steroids, n (%)	53 (44)	15 (50)	22 (44)	0.602
Ever used neuromuscular blockade, n (%)	30 (25)	8 (27)	12 (24)	0.790
ICU length of stay, mean (sd)	15 (11)	17 (11)	14 (10)	0.175
Hospital length of stay, mean (sd)	22 (15)	27 (16)	19 (11)	0.020

COPD= *Chronic Obstructive Pulmonary Disease*, BMI= body-mass index, ICU=Intensive Care Unit, WHO=World Health Organization, SF-36 PF= Short Form-36 physical function, APACHE= Acute Physiologic Assessment and Chronic Health Evaluation;

† Low appendicular skeletal muscle mass (ASMM) was used to reflect low muscle mass, which is one component of sarcopenia.30 patients had low ASMM at either 6m or 12m follow-up and 50 patients had normal ASMM at either follow-up.

* Rheumatologic comorbidity data not collected in the SAIL study, percentage based on N=74.