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VALIDATION OF A 3-FACTOR MEASUREMENT MODEL OF DYSPNEA IN HOSPITALIZED ADULTS WITH HEART FAILURE

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The language used to characterize the sensory quality of dyspnea has been studied in numerous investigations,¹⁻²⁸ and it is generally accepted that dyspnea comprises a variety of distinct, potentially discriminable unpleasant respiratory sensations that vary in intensity.²⁹ However, only a few clinical studies of dyspnea sensory quality have involved patients with acute or exacerbated chronic dyspnea,^{13,22,23} only one of which focused on heart failure (HF),²² despite the fact that dyspnea is a major feature of emergency department visits³⁰⁻³³ and hospital admissions³³⁻³⁶ for HF.

Most studies of dyspnea sensory quality have used exploratory data analysis methods, such as open-ended interviews,^{2,16} cluster analysis,^{4,5,8,11,25} multidimensional scaling,^{3,17} or exploratory factor analysis^{22,23,28,37} to categorize groupings of related sensations. A major limitation of these methods is that they are essentially inductive (ie, descriptive, not hypothesis-driven); hence, there is no guarantee that results will generalize beyond the sample being described. Not surprisingly, results of these studies have varied widely in terms of the number of higher order groupings of descriptors identified and in the number and identity of descriptors said to characterize the various clusters or factors. The clinical usefulness of such findings has been hampered by a lack of replication or validation in independent samples.

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With respect to HF, a further limitation of most studies of dyspnea sensory quality has been either an exclusive^{12-14,23,37} or predominant^{2,5,8,11,25} focus on patients with chronic respiratory disease. Few studies of dyspnea sensory quality have focused on patients with HF.^{22,26} Although the need for valid clinical measures of dyspnea in acutely decompensated HF is recognized,^{35,36,38} so far, only unidimensional measures of dyspnea severity have been studied in that context.^{31,32,39,40} To date, no clinical studies have tested a specific, hypothesized measurement model of dyspnea sensory quality during acutely exacerbated HF, and no studies have attempted to validate a measurement model derived from patients of one diagnosis in patients of a different diagnosis using confirmatory factor analysis.

The purpose of this study was to validate a 3-factor measurement model of dyspnea sensory quality in adults hospitalized for HF using confirmatory factor analysis (CFA), a hypothesis-driven method in which a prespecified model is tested against data from an independent sample; evidence of good model fit implies that the model is reproducible.^{41,42} The model was originally derived from an exploratory factor analysis of dyspnea descriptor ratings (Table 1) during emergency department visits for chronic obstructive pulmonary disease (COPD).²³ The specified model consisted of 3 sensory quality factors (latent variables, UPPERCASE) characterized by 7 sensory quality descriptors (indicators / items, *lowercase italics*) with adequate reliability (internal consistency): SMOTHERING-AIR HUNGER (*smothering, suffocating, hunger for air*; Cronbach's $\alpha = .87$); WORK-EFFORT (*work, effort*; $\alpha = .87$), TIGHTNESS (*tight, constricted*; $\alpha = .74$).²³ In addition, exploratory analyses, based on having found 2 additional weaker (less internally consistent) factors pertaining to amount and depth of ventilation in the original COPD study,²³ were conducted with additional descriptors to determine whether other sensory quality factors were supported.

Methods

Design and Setting

The study used a prospective, longitudinal correlational design. Participants were adults admitted for treatment of new-onset or decompensated HF to an urban academic medical center or a Department of Veterans Affairs medical center (VAMC) in the southwestern United States. The ethical review bodies of both institutions approved the study, and signed informed consent was obtained from all participants.

Eligibility

Participants were at least 18 years of age, able to speak and understand English, and of sufficient cognitive capacity to give informed consent and participate in questionnaire administration. HF was either the admitting diagnosis or a major focus of inpatient medical management. Reasons for exclusion were admissions for pulmonary embolism, active malignant or metastatic cancer, trauma, pregnancy, or a B-type natriuretic peptide (BNP) level less than 100 pg/ml or N-terminal proBNP (NT proBNP) level less than 300 pg/ml. Patients admitted for ST-elevation myocardial infarction (STEMI) were excluded, as were patients with any other acute coronary syndrome who received percutaneous coronary intervention. In addition, any patients admitted or transferred to the cardiothoracic surgery service (eg, for coronary artery bypass or valve surgery) were excluded.

Sample

A total of 465 adult inpatients with a known history or admitting diagnosis of any type of HF, cardiomyopathy, or fluid overload were assessed for eligibility, of whom 260 (56%) were excluded (Figure 1). The most frequent exclusion was that HF was not a major focus of the hospitalization, based on clinical judgment and discussion between study personnel and

members of the cardiology service. The most common excluded diagnoses were dysrhythmias for which the focus of inpatient treatment was primarily rate or rhythm control (Figure 1). Other exclusions were for STEMI (or non-STEMI or unstable angina with percutaneous coronary intervention), syncope, cerebrovascular disease, hypertensive urgency, and noncardiac fluid overload (eg, chronic kidney disease, iatrogenic).

Of the 205 patients deemed eligible for participation (44% of all screened), 120 agreed to participate, one of whom subsequently withdrew, leaving a final sample of 119 (58% of eligible, 25.6% of all screened; Figure 1). Participants were enrolled as soon as possible after admission, consistent with their clinical condition and willingness to participate. The day of enrollment was considered Study Day 1.

Demographic and clinical characteristics of participants are shown in Table 2. There were no significant differences by sex in the relative numbers excluded versus eligible, or participating versus declining to participate. Proportions of Blacks and American Indians were similar across screened, excluded, eligible, participant, and declining groups (Figure 1). Proportions of Hispanics were similar between participants and those declining to participate ($P = .471$), but because only English-speaking patients were enrolled, a larger proportion of Hispanics was excluded (136/260; 52.3%) than deemed eligible (84/205, 40.9%), χ^2 ($df = 1$) = 5.46, $P = .019$ (Figure 1). Mean (SD) age of participants was 58.9 (13.7) years and was approximately 6 years younger than those who declined or were excluded ($P \leq .003$).

Measures

The dyspnea questionnaire included 16 sensory quality descriptor items (Table 1). Content validity of these descriptors was initially developed through interviews with healthy subjects exposed to unpleasant respiratory stimuli and patients with cardiopulmonary disease.^{4,5} In subsequent studies, content validity has been supported by frequency of endorsement from patients of various diagnoses^{5,11,13,22,23,25,26} and assessment of open-ended characterizations of dyspnea prior to checklist administration.^{22,23} In this study, participants were asked to rate each descriptor (sensation) as absent (*no*) or present (*yes*) and then to rate the intensity for any *yes* response (0 = *no* [absent]; 1 = *just barely noticeable*; 10 = *as intense or severe as possible*).^{22,23}

Participants completed the dyspnea questionnaire in a *today* version on Study Day 1 ($N = 119$) and up to 2 consecutive days thereafter (Study Days 2 and 3, $n = 114$ and 98, respectively). After enrollment of 22 participants, a protocol amendment was approved to add a recall version of the questionnaire pertaining to the day of admission (Study Day 0; $n = 97$) because it was evident that participants had already experienced very substantial dyspnea relief by the time of enrollment. The Day 0 questionnaire was administered on Study Day 1, immediately following the Day 1 version.

Statistical Analysis

Descriptive analyses included frequencies and percentages for nominal categorical data and estimates of central tendency and dispersion appropriate to the level of measurement and distribution of continuous variables. We used χ^2 tests to assess differences in proportions and Wilcoxon signed rank tests for paired comparisons of continuous variables. The criterion for statistical significance was $P < .05$.

Psychometric analysis included inter-item correlations and Cronbach's α for internal consistency of scaled questionnaire scores. CFA was conducted with Mplus, version 4.1 (Muthén & Muthén, Los Angeles, CA),⁴³ using a maximum likelihood χ^2 estimator with adjusted means and variances (MLMV). The MLMV estimator is robust to non-normally

distributed data and, for small samples, provides more appropriate standard error estimates, global and local tests of model fit, and parameter estimates than conventional maximum likelihood estimation.⁴⁴ In CFA, the overall model χ^2 test (in this case, the MLMV χ^2 test) is a goodness of fit test for which the null hypothesis is that the model fits the data (ie, $P > .05$ indicates good fit to the data). Additional indices of model fit included: relative χ^2 (ie, the model χ^2 divided by its degrees of freedom [df]), the comparative fit index (CFI) and non-normed fit index (NNFI), and the standardized root mean square residual (SRMR) and root mean square error of approximation (RMSEA). Criteria for good model fit include a relative $\chi^2 < 3.0$,⁴⁵ CFI and NNFI > 0.95 ,^{45,46} SRMR < 0.08 ,^{46,47} and RMSEA as small as possible: values $< .05$ indicate good fit, $\leq .08$ close fit, and $> .10$ poor fit.^{42,45-48}

We tested the 3-factor measurement model and several alternative models of up to 5-factors. Model testing used the Study Day 1 and Day 0 questionnaires only, because a majority of participants gave intensity ratings of zero to most descriptors by Study Day 2. Because the original COPD study²³ used a different estimation method (exploratory principal axis factor analysis with varimax rotation), those results were not directly comparable to the results of the present study. Therefore, we also reanalyzed, and report here for the first time, a secondary analysis of the original COPD data using the MLMV estimator.

Results

The median and modal hospital day on Study Day 1 was hospital day 1 (25th to 75th %ile: hospital day 1 to 2; range: hospital day 1 to 5). Cumulatively, 24% of the sample ($n = 29$) were enrolled on the day of admission, 72% ($n = 86$) by hospital day 1, 87% by hospital day 2 ($n = 104$), and 96% ($n = 114$) by hospital day 3. Only 5 participants (4%) were enrolled after hospital day 3 (4 on hospital day 4 and 1 on hospital day 5). All descriptors were endorsed by at least 60% of participants for Day 0 (Figure 2a) For each of the descriptors, the Day 1 scores were significantly lower than Day 0 scores (Wilcoxon signed rank test, $|z| > 6.5$, $P < .0001$ for all comparisons; Figure 2b).

CFA of the 3-Factor / 7-Indicator Model

Correlation matrices with item means and standard deviations for Study Day 1 and Study Day 0 are shown in Tables 3 and 4. Figures 3A-3C depict the factor loadings (standardized partial regression coefficients), interfactor correlations, and standardized residual (error) estimates for Study Day 1, Study Day 0, and the original COPD study data,²³ respectively.

The 3-factor / 7-indicator model fit the data for both Study Day 0 and Study Day 1, as well as for the reanalyzed COPD data ($P > .10$ for all). All fit indices were in satisfactory ranges (Table 5). Relative χ^2 values for each data set were all ≤ 1.7 , and all SRMR and RMSEA values were $\leq .08$.

Cronbach's alpha coefficients for the 7 items on Study Day 1 and Day 0 were $> .93$ and for each factor were all $> .87$ for both Study Day 1 and Day 0. For both Study Day 1 and Day 0, all estimated factor loadings (Table 6), covariances (Table 7), and variances (Table 8) were statistically significant ($P \leq 0.003$). For comparison, the corresponding MLMV parameter estimates from the reanalyzed COPD data are included in Tables 6, 7, and 8.

The WORK-EFFORT factor showed the greatest similarity across study days and diagnoses in terms of factor loadings (Figures 3A-3C; Table 6), as well as variance and standard error estimates (Table 8). For the other 2 factors, variance estimates, though not standard errors, were substantially larger for Study Day 0 compared with Study Day 1 and the COPD data (Table 8), and factor loadings were somewhat more variable across study days (Table 6; Figures 3A-3B) and diagnoses (Table 6; Figure 3C).

The most notable difference in the model across diagnoses was the substantially stronger interfactor correlations for HF ($r > .78$) compared with COPD ($r < .71$; Table 7). For Study Day 0 and the COPD study data, factor variances from largest to smallest were SMOTHERING-AIR HUNGER > TIGHTNESS > WORK-EFFORT. For Study Day 1, factor variances from largest to smallest were WORK-EFFORT > SMOTHERING-AIR HUNGER > TIGHTNESS (Table 8).

Exploratory Analyses of Alternative Factor Models

We conducted exploratory analyses to determine whether a model with 4 or 5 factors fit the HF data. Initial specification of a 5-factor model with 14 descriptors (Table 2) was: AMOUNT (*heavy, rapid, not out all the way*); DEPTH (*not enough air in, shallow*); TIGHTNESS (*tight, constricted*); and augmented SMOTHERING-AIR HUNGER (smothering, suffocating, hunger for air, could not breathe) and WORK-EFFORT (*work, effort, out of breath*) factors.²³ This model fit the original COPD data, as would be expected, but did not fit the HF data for Study Day 0 or Study Day 1.

We combined the putative AMOUNT and DEPTH of ventilation factors, above, into a single factor pertaining to awareness of ventilation. We examined several alternate specifications for this 4-factor model. We found a 4-factor / 15-indicator model (VENTILATION: heavy, rapid, not out all the way, not in all the way, shallow; SMOTHERING-AIR HUNGER: smothering, suffocating, hunger for air, could not breathe, not enough air in; and the same WORK-EFFORT and TIGHTNESS factors as in the preceding paragraph) demonstrated adequate fit to the Study Day 0 data, but fit poorly to the Study Day 1 data.

Because the WORK-EFFORT and SMOTHERING-AIR HUNGER factors were highly correlated in the HF study data (especially for Study Day 0), we also conducted an unplanned exploratory analysis of a 2-factor / 7-descriptor model consisting of the 2-descriptor TIGHTNESS factor (*tight, constricted*) while combining the WORK-EFFORT and SMOTHERING-AIR HUNGER factors into a single factor (smothering, suffocating, hunger for air, work, effort). The fit of this 2-factor model was comparable to the 3-factor model for the HF Study Day 0 and Study Day 1 data, but the fit to the COPD study data was markedly worse. A single-factor model with all 7 descriptors fit the data very poorly across the HF Study Day 1 and Study Day 0 and the COPD data.

Discussion

Overall, the same 3-factor / 7-indicator measurement model fit the Study Day 1 and Day 0 data and the COPD data very satisfactorily and substantially better than any alternative model. All 3 factors had strong internal consistency reliability regardless of diagnosis or study day. To our knowledge, this is the first time that a specific measurement model of dyspnea sensory quality has been validated in an independent sample using CFA methods (which supports the internal validity of the 3-factor measurement model), and it also is the first time a model derived in patients of one diagnosis has been validated in patients of another diagnosis (which supports its external validity). External validity of the measurement model is further supported by replication of the WORK-EFFORT, SMOTHERING-AIR HUNGER, and TIGHTNESS factors in an independent sample^{41,42,45} among patients in a different geographic region than the original study. In addition, robustness of fit of the 3-factor model over successive days characterized by very substantial change in ratings supports its construct validity.

We considered whether coexisting HF and COPD might be a possible explanation for the model fitting data from patients of either diagnosis. However, we believe this is unlikely because less than 10% of our HF sample had a diagnosis of COPD, and, in all cases, we

confirmed that HF was the diagnosis driving the admission. In the earlier study, only 15% of participants had a history of HF in addition to COPD, but unless they were being treated with corticosteroids or beta-agonists (neither of which is indicated in HF), patients with HF were excluded.

As with any correlational method, CFA does not establish a causal basis for observed associations. Distinct sensory-perceptual mechanisms underlying effort perception, tightness, and air hunger are supported by substantial experimental and neuroimaging evidence.^{1,6,7,9,10,12,14,18-21,24,27,49-59} However, it would not be valid to infer that there are only three sensory quality factors or that only these three matter to patients with acute or exacerbated cardiopulmonary disease. The findings of this study also do not rule out the possibility that there may be other sensory quality factors that may be more diagnosis-specific. Rather, the 3-factor / 7-descriptor model represents sensory quality factors that can be reliably measured with relatively few items, at least for patients with exacerbated HF or COPD. Further research would be required to determine how well this measurement model fits other diagnoses.

A number of earlier studies focused on the possibility that certain combinations of sensory descriptor clusters might better characterize a particular diagnosis versus others and therefore might be useful in differential diagnosis.^{2,5,8,11} However, at least one study concluded that such clusters of descriptors may not be sufficiently specific for that purpose.²⁵ Regardless of diagnosis, the number of afferent pathways and subcortical to cortical brain regions involved in processing and awareness of respiratory sensations is finite.⁶⁰⁻⁶⁵ Which stimuli and which pathways predominate at any given time may differ between diagnoses or even within diagnoses as clinical condition changes, but there is no compelling evidence that afferent or higher central nervous system pathways differ by diagnosis in patients with cardiopulmonary disease.⁶⁶⁻⁷¹

Although few, if any, participants in the present study or the earlier COPD study spontaneously reported “air hunger” in open-ended statements prior to seeing the descriptor questionnaire, many patients in both samples endorsed the statement “*I feel [or felt] a hunger for air*” on the questionnaire, and ratings for that item correlated more strongly and consistently with ratings for *smothering* and *suffocating* than with the other descriptors. Numerous physiological investigations have focused on the sensation of “air hunger” in relation to increases in CO₂-mediated reflex inspiratory drive,^{6,7,18,49-52,54,59} or, more generally, when inspiratory drive exceeds a constrained ventilatory capacity.^{1,15,21,53,56,57} Few participants in either the HF or the COPD study had arterial blood gas measurements, and, of those who did, only a small number had elevated P_{CO₂}. Therefore, it seems likely that the confluence of ratings of *air hunger*, *smothering*, and *suffocating* in both samples was due to factors other than increased P_{CO₂}.

Limitations of the present study include convenience sampling, a preponderance of male participants, and a relatively small sample size for CFA.⁴⁵ In addition, there was a lack of direct correspondence between study day and hospital day, and, in consequence, a variable recall interval for the day 0 ratings.

Convenience sampling is difficult to avoid in a clinical study with prospective data collection in an acute care setting. Recruitment was necessarily contingent on clinical condition and confirmation that HF was, indeed, a major focus of inpatient care. In addition, participation necessarily was limited to those who were willing to participate in an observational study that did not offer any prospect of direct clinical benefit. Although our sample was disproportionately male, there were no statistically significant differences by sex between those excluded versus eligible, nor, among the eligible, between those agreeing

versus those declining to participate. Excluding non-English speakers was a limitation, but, even so, nearly 40% of the sample was Hispanic.

The possible impact of the relatively small sample and non-normally distributed data on statistical analyses was mitigated by using a robust estimator appropriate for small samples in which multivariate normality cannot be assumed. We preferred this approach to statistical transformations of variables because transformation is generally ineffective when scores are constrained to a narrow range,^{72,73} and the model was robust to substantial differences in item scores and factor variances as well as the reversal in the direction of skewness from Study Day 0 to Study Day 1).

Despite the lack of one-to-one correspondence between study day and hospital day, the recall interval, though not standardized, was relatively short. In the original COPD study, test-retest reliability of recall descriptor ratings during an ED visit was strong.²³ In the present study, the changes in descriptor means and in the skewness of ratings between Day 0 and Day 1 reflect expected characteristics of score distributions in relation to aggressive, inpatient treatment over a relatively short interval.

Lastly, it is important to note that dyspnea encompasses multiple sensory qualities that vary not only in intensity,²⁹ but in their unpleasantness,⁷⁴ and in emotional responses (eg, overall distress and judgments about the seriousness and significance of what is felt).^{27,37,74-76} Thus, validation of a measurement model of dyspnea sensory quality in conjunction with ratings of descriptor intensity does not, by itself, capture the emotional dimension of the symptom. Research to address that limitation is ongoing.

Even with these limitations, this study demonstrates several strengths beyond using CFA. Confirmation of a diagnosis of HF among participants was essentially 100%. Any exclusions based on judgments that HF was not a major focus of inpatient management were made prospectively, based on clinical information available during rounds and through discussion with members of the cardiology services of the 2 facilities. There were no post hoc exclusions. Moreover, we did not exclude on the basis of presumed mechanism of HF (systolic vs. diastolic dysfunction) or functional consequence (eg, reduced vs. preserved ejection fraction), because HF is a heterogeneous condition, and ejection fraction and the underlying pathophysiology of HF may not always be ascertainable at the time of admission.

Our results have several notable clinical and research implications. First, nearly all currently available dyspnea measures have been developed and tested primarily in ambulatory settings.^{29,77,78} Therefore, their construct validity is uncertain with respect to patients in an acute care setting. Secondly, many such measures are diagnosis-specific, but in the context of an emergency department visit or hospital admission, the underlying diagnosis is not always immediately known, and chronic pulmonary and cardiac conditions frequently coexist. Our findings suggest that diagnosis-specific measures may not be necessary to reliably assess changes in dyspnea in response to treatment of exacerbated chronic cardiopulmonary disease in acute care settings.

Conclusion

This study demonstrates that intensity ratings for 3 sensory quality factors can be measured consistently and reproducibly with only a few descriptors both across diagnoses and across time points within a diagnosis. Although a single-item rating of intensity or distress has demonstrated responsiveness to clinical change in acute HF syndromes,^{31,39,40} using a single-item assumes that differences in sensory quality are irrelevant to feeling better or worse. As far as we are aware, such an assumption has never been rigorously tested, and risks underestimating clinically meaningful change or missing it altogether. For example, in

asthma sensations of tightness differ mechanistically from sensations of work,^{20,24} and tightness responds more rapidly than sensations of work or effort to bronchodilator treatment.¹³ The extent to which different sensory qualities of dyspnea in diseases other than asthma may also have different time-courses of response to acute treatment has not been studied. Whether home-monitoring of sensory qualities of dyspnea might predict deterioration or exacerbation of previously stable HF or COPD has also never been studied. Both of those possibilities are worthwhile areas for future investigation. Lastly, given the heterogeneity of both HF and COPD, it would be reasonable to hypothesize in a future study that this 3-factor measurement model may also fit other diagnoses.

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Figure 1. Assessed for eligibility, exclusions, eligible to participate, and agreed versus declined to participate. M = male; F = female; HF = heart failure; STEMI = ST-elevation myocardial infarction; ACS = acute coronary syndrome; Ca = cancer.

a

b

Figure 2. Dyspnea descriptor percent endorsement and mean ratings for Study Day 1 and Study Day 0. (2A) Percentage of participants endorsing dyspnea descriptors (rating > 0); (2B) Mean

intensity ratings for dyspnea descriptors (All Day 0 to Day 1 comparisons, $|z| > 6.5$, $P < .0001$, paired Wilcoxon test)

A

B

Figure 3.

Standardized estimates for 3-factor / 7-indicator model. (3A) Heart failure, Study Day 1 (N = 119). (3B) Heart failure, Study Day 0 (n = 97). (3C) Chronic obstructive pulmonary disease (data from ref. 23; N = 100). Ovals = factors (latent variables); rectangles = indicators (measured variables, descriptors); circles = unique measurement error; capital letters = factor names; SMOTHERING = SMOTHERING-AIR HUNGER factor; lowercase letters = variable (descriptor) names (see Table 1 for complete items); double-headed curved arrows = correlations between factors; single-headed arrows from factors to indicators = factor loadings (standardized partial regression coefficients, ie, β -weights); single-headed arrows from errors to indicators = standardized residuals.

TABLE 1
Variable Names and Corresponding Questionnaire Items^a

Variable name	Questionnaire item
<i>constrict</i>	My chest feels/felt constricted
<i>smother</i>	I feel/felt I am/was smothering
<i>notout</i>	My breath does not/did not go out all the way
<i>tight</i>	My chest feels/felt tight
<i>shallow</i>	My breathing is/was shallow
<i>couldnot</i>	I feel/felt that I cannot/could not breathe
<i>work</i>	My breathing requires/required work
<i>notin</i>	My breath does not/did not go in all the way
<i>oob</i>	I feel/felt out of breath
<i>hunger</i>	I feel/felt a hunger for air
<i>heavy</i>	My breathing is/was heavy
<i>effort</i>	My breathing requires/required effort
<i>More^b</i>	I feel/felt I am/was breathing more
<i>rapid</i>	I feel/felt my breathing is/was rapid
<i>suffocate</i>	I feel/felt that I am/was suffocating
<i>notenough</i>	I cannot/could not get enough air in

^a All descriptors scaled from 0-10 (0 = *no* [absent]; 1 = *just barely noticeable*; 10 = *as intense or severe as that sensation could possibly be*). **Bold type** = descriptors included in 3-factor / 7-indicator measurement model.

^b Deleted from factor analyses because of questionable item performance (cf. Ref. 23).

Table 2
Demographic and clinical characteristics (N = 119)

Sex	n	%
Male	84	70.6
Female	35	29.4
Ethnicity		
Hispanic	46	38.7
Not Hispanic	73	61.3
Race		
Black	10	8.4
American Indian	8	6.7
White (not Hispanic)	55	46.2
Other admitting diagnoses		
Hypertension	20	16.8
Dysrhythmias	19	16.0
SOB / respiratory distress	11	9.2
COPD	9	7.6
Unstable angina	7	5.9
Pneumonia	6	5.0
NSTEMI	5	4.2
Renal failure	5	4.2
	Median	(25th, 75th %ile)
LV ejection fraction (%)	34.5	(20, 45)
BNP (pg/ml)	1143	(741, 1,756)
NT-proBNP (pg/ml)	3815	(2,020, 12,000)

SOB = shortness of breath; COPD = chronic obstructive pulmonary disease; NSTEMI = non ST-elevation myocardial infarction; LV = left ventricular; BNP B-type natriuretic peptide; N NT-proBNP = N-terminal prohormone BNP

TABLE 3

Correlation Matrix, Means, and SDs for Study Day 1^a (N = 119)

	<i>constrict</i>	<i>smother</i>	<i>tight</i>	<i>work</i>	<i>hunger</i>	<i>effort</i>	<i>suffocate</i>
<i>smother</i>	.682						
<i>tight</i>	.789	.604					
<i>work</i>	.722	.723	.612				
<i>hunger</i>	.662	.697	.717	.630			
<i>effort</i>	.700	.693	.650	.787	.696		
<i>suffocate</i>	.645	.789	.579	.693	.646	.701	
Mean	2.03	1.29	1.68	2.29	1.77	2.49	1.11
SD	2.88	2.91	2.73	3.16	3.14	3.24	2.77

P < .001 for all correlation coefficients^aStudy Day 1 = day of enrollment in study.

TABLE 4
Correlation Matrix, Means, and SDs for Study Day 0^a (N = 97)

	<i>constrict</i>	<i>smother</i>	<i>tight</i>	<i>work</i>	<i>hunger</i>	<i>effort</i>	<i>suffocate</i>
<i>smother</i>	.726						
<i>tight</i>	.841	.626					
<i>work</i>	.670	.839	.639				
<i>hunger</i>	.671	.720	.711	.726			
<i>effort</i>	.665	.819	.595	.792	.691		
<i>suffocate</i>	.603	.743	.521	.701	.707	.642	
Mean	5.59	5.57	5.15	6.53	5.91	6.70	5.17
SD	3.86	4.04	3.87	3.26	3.87	3.18	4.29

P < .001 for all correlation coefficients

^aStudy Day 0 = day admitted to hospital (recall rating).

TABLE 5
Three-Factor / 7-Indicator Measurement Model: CFA χ^2 Statistics and Fit Indices

Diagnosis	Study Day	n	Model χ^2	df^b	p	Relative χ^2	CFI	NNFI	SRMR	RMSEA
HF	1	119	7.91	7	0.34	1.13	0.99	0.99	0.03	0.03
HF	0	97	9.92	6	0.13	1.65	0.98	0.97	0.03	0.08
COPD ^a	ED	100	10.00	6	0.12	1.67	0.96	0.94	0.05	0.08

CFA, confirmatory factor analysis; HF, heart failure; COPD, chronic obstructive pulmonary disease; ED, emergency department; Study Day 1, dyspnea ratings on day of HF study enrollment; Study Day 0, recall dyspnea rating for day of admission obtained on Study Day 1; df , degrees of freedom for model χ^2 ; relative χ^2 , model χ^2/df ; CFI, comparative fit index; NNFI, non-normed fit index; RMSEA, root mean square error of approximation.

^aData from ref 23.

^bThe df for the maximum likelihood mean- and variance-adjusted (MLMV) χ^2 are estimated and rounded to the nearest integer; hence, the df for the same model can vary.

TABLE 6
Regression Weights and Standard Errors for 3-Factor / 7-Indicator Model in Patients with Heart Failure and Chronic Obstructive Pulmonary Disease

<i>Item</i> → FACTOR	HF: Study Day 1 (N = 119)			HF: Study Day 0 (n = 97)			COPD (n = 100)^a					
	B	SE	CR^b	β	B	SE	CR^b	β	B	SE	CR^b	β
<i>work</i> → EFFORT	<i>c</i>	<i>d</i>	<i>d</i>	0.89	<i>c</i>	<i>d</i>	<i>d</i>	0.91	<i>c</i>	<i>d</i>	<i>d</i>	0.89
<i>effort</i> → EFFORT	1.03	0.06	18.14	0.89	0.94	0.09	10.67	0.87	0.90	0.09	10.26	0.87
<i>tight</i> → TIGHTNESS	<i>c</i>	<i>d</i>	<i>d</i>	0.85	<i>c</i>	<i>d</i>	<i>d</i>	0.88	<i>c</i>	<i>d</i>	<i>d</i>	0.69
<i>constrict</i> → TIGHTNESS	1.16	0.14	8.03	0.93	1.10	0.09	12.40	0.96	1.31	0.20	6.58	0.86
<i>smother</i> → SMOTHER	<i>c</i>	<i>d</i>	<i>d</i>	0.89	<i>c</i>	<i>d</i>	<i>d</i>	0.93	<i>c</i>	<i>d</i>	<i>d</i>	0.87
<i>suffocate</i> → SMOTHER	0.92	0.07	12.61	0.86	0.90	0.07	12.92	0.79	1.15	0.10	11.69	0.87
<i>hunger</i> → SMOTHER	0.97	0.10	9.56	0.80	0.84	0.07	12.90	0.81	0.90	0.10	9.26	0.78

HF, heart failure; COPD, chronic obstructive pulmonary disease; Study Day 1, day enrolled in study (today rating); Study Day 0, day of admission (recall rating, obtained immediately after Study Day 1 rating); B, unstandardized regression weights; SE, standard error; CR, critical ratio (B/SE); β, standardized regression (beta-) weights.

* Data from ref 23.

^b $P < 0.0001$ for all estimates.

^c Scaling constant (one constant required per factor; value set to 1.0).

^d Not estimated.

TABLE 7
Inter-Factor Covariances, Standard Error Estimates, Critical Ratios, and Correlations for 3-Factor / 7-Indicator Model in Patients with Heart Failure and Chronic Obstructive Pulmonary Disease

Factor covariances	HF: Study Day 1 (N = 119)				HF: Study Day 0 (n = 97)				COPD (n = 100) ^d			
	COV	SE	CR ^b	r	COV	SE	CR ^b	r	COV	SE	CR ^c	r
EFFORT ↔ SMOTHERING	6.56	1.44	4.56	0.91	10.86	1.11	9.76	0.99	5.13	1.26	4.07	0.71
EFFORT ↔ TIGHTNESS	5.49	1.08	5.09	0.85	7.75	1.22	6.35	0.78	4.28	0.97	4.42	0.69
SMOTHERING ↔ TIGHTNESS	4.99	1.20	4.15	0.84	10.29	1.30	7.90	0.82	4.57	1.16	3.92	0.63

HF, heart failure; COPD, chronic obstructive pulmonary disease; Study Day 1, day enrolled in study (today rating); Study Day 0, day of admission (recall rating, obtained immediately after Study Day 1 rating); COV, unstandardized covariance estimate between factors; SE, standard error, CR, critical ratio (COV/SE, *t*-statistic); *P*, *P* value for *t*-statistic with *df*, *n*-1; *r*, interfactor correlation (standardized covariance estimate).

^aData from ref 23.

^b*P* < .0001 for all estimates.

^c*P* < .0002 for all estimates.

TABLE 8
Factor and Residual (Error) Variances, Standard Errors, Critical Ratios, and Standardized Estimates for 3-Factor / 7-Indicator Model in Patients with Heart Failure and Chronic Obstructive Pulmonary Disease

Factors	HF: Study Day 1 (N = 119)					HF: Study Day 0 (n = 97)					COPD (n = 100) ^a				
	VAR	SE	CR	P	Std ^b	VAR	SE	CR	P	Std ^b	VAR	SE	CR	P	Std ^b
EFFORT	7.77	1.37	5.68	c		8.63	1.36	6.35	c		6.19	1.59	3.90	c	
TIGHTNESS	5.32	1.27	4.19	c		11.39	1.68	6.76	c		6.19	1.66	3.74	c	
SMOTHERING	6.65	1.77	3.77	c		13.87	1.32	10.54	c		8.47	1.72	4.93	c	
Residuals	VAR	SE	CR	P	SR	VAR	SE	CR	P	SR	VAR	SE	CR	P	SR
<i>work</i>	2.11	0.54	3.93	c	0.21	1.86	0.64	2.92	c	0.18	1.64	0.83	1.99	.05	0.21
<i>effort</i>	2.19	0.66	3.32	c	0.21	2.37	0.66	3.62	c	0.24	1.59	0.46	3.46	c	0.24
<i>right</i>	2.09	0.45	4.67	c	0.28	3.47	1.15	3.03	c	0.23	6.86	1.64	4.17	c	0.53
<i>constrict</i>	1.09	0.49	2.22	c	0.13	1.12	0.52	2.14	c	0.08	3.78	1.53	2.48	.02	0.26
<i>smother</i>	1.77	0.57	3.09	c	0.21	2.29	0.66	3.50	c	0.14	2.76	1.08	2.54	.01	0.25
<i>suffocate</i>	2.03	0.62	3.27	c	0.27	6.93	1.48	4.67	c	0.38	3.66	1.14	3.22	c	0.25
<i>hunger</i>	3.55	0.87	4.11	c	0.36	5.02	0.78	6.42	c	0.34	4.32	1.24	3.50	c	0.39

HF, heart failure; COPD, chronic obstructive pulmonary disease; Study Day 1, day enrolled in study (today rating); Study Day 0, day of admission (recall rating, obtained immediately after Study Day 1 rating); VAR, variance estimate; SE, standard error, CR, critical ratio (VAR/SE); P, P value for CR (t-statistic) with df, n-1; Std, standardized variance; SR, standardized residual.

^a Data from ref 23.

^b Value standardized to 1.0 (ie, not estimated).

^c P ≤ .004