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Body listening in the link between symptoms and self-care management in cardiovascular disease: A cross-sectional correlational descriptive study

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ABSTRACT

Objective: The aim of this study was to quantify relationships among symptoms, interoceptive sensibility (i.e. the conscious level of sensing, interpreting and integrating signals from the body), and self-care management behaviors (i.e. the response to symptoms when they occur) among adults with cardiovascular disease. We hypothesized that better interoceptive sensibility would increase the positive behavior-driving effects of symptoms on self-care management.

Methods: Adult patients with cardiovascular disease who experienced recent symptoms were recruited to participate in this cross-sectional correlational descriptive study. Patient-Reported Outcomes Measurement Information System measures were used to capture dyspnea, pain interference, fatigue, sleep disturbances, nausea and vomiting, anxiety and depressive symptoms. Interoceptive sensibility was measured using the Multidimensional Assessment of Interoceptive Awareness Version 2. The Self-Care of Chronic Illness Inventory was used to measure self-care management. Network analysis was used to identify domains of interoceptive sensibility that were most central. Linear regression with interaction terms was used to test the moderating effect of interoceptive sensibility on the relationship between symptoms and self-care management.

Results: The age of participants in the sample (n = 387) ranged from 18 to 88 years, a slight majority (53.5 %) were female, and a majority were Caucasian (66.4 %) or African American (32.0 %). Hypertension was the most common disorder (n = 238 (61.5 %)), followed by rhythm disorders (n = 124 (32.0 %)), coronary artery disease (n = 94 (24.3 %)), heart failure (n = 89 (23.0 %)), valve disease (n = 69 (17.8 %)), stroke (n = 62 (16.0 %)) and peripheral vascular disease (n = 49 (12.7 %)). Based on network analysis, body listening (i.e. active listening to the body for insights) was the most central interoceptive domain, and distracting (i.e. tendency to ignore or distract oneself from sensations of discomfort) was the least central. Noticing (i.e. greater awareness of body sensations), distracting, and body listening were significant in moderating relationships between dyspnea, sleep disturbances and anxiety and the outcome of self-care management behaviors (all $p < 0.001$). Better noticing and body listening were associated with better self-care management across symptoms, whereas ignoring or distracting oneself from discomfort was associated with worse self-care management behaviors.

Conclusion: Among adults with cardiovascular disease, interventions designed to augment the identified interoceptive sensibility domains like body listening, and mitigate the tendency to ignore or distract oneself from discomfort may support adults with cardiovascular disease through the development of future interventions that optimize patient behaviors in response to symptoms when they occur.

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What is already known

- In conditions like heart failure, better self-care management behaviors (i.e. the recognition and response to symptoms when they occur) are associated with better outcomes.

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- Among the domains of self-care, we know the least about self-care management in cardiovascular disease.
- We know very little about how interoceptive sensibility (i.e. the conscious level of sensing, interpreting and integrating body signals) may influence self-care management.

What this paper adds

- Among adults with cardiovascular disease, body listening (i.e. active listening to the body for insights) is most influential, and distracting (i.e. ignoring or distracting oneself from sensations of discomfort) is least influential to all other domains of interoceptive sensibility.
- Body listening, distracting, and noticing (i.e. awareness of body sensations) moderate relationships between dyspnea, sleep disturbances, and anxiety and the outcome of self-care behaviors in cardiovascular disease, making them reasonable targets for intervention.

1. Introduction

The prevalence of chronic cardiovascular disease is on the rise globally, with ischemic heart disease and stroke accounting for more disability-adjusted life years than other conditions (Diseases GBD, Injuries C, 2020). Self-care (i.e. the behaviors in which patients with chronic illness engage to maintain provider-prescribed therapies and stay in good health like engage in regular exercise (*self-care maintenance*), monitor for signs and symptoms of change in their underlying conditions (*self-care monitoring*), and recognize and respond to symptoms when they occur (*self-care management*)), is essential to chronic illness management in general (Riegel et al., 2012), and to the management of chronic cardiovascular disease in particular (Riegel et al., 2017; Heidenreich et al., 2022; McDonagh et al., 2021; Mancia et al., 2023; Schneider et al., 2020; Kleindorfer et al., 2021; Aboyans et al., 2018; Gerhard-Herman et al., 2017; Joglar et al., 2023; Hindricks et al., 2021). There have been great strides made in our theoretical and empirical understanding of self-care of chronic illness over the past 20 years (Riegel et al., 2021a; Jaarsma et al., 2020). But, interventions designed to improve self-care in cardiovascular disorders like coronary artery disease, heart failure and hypertension are only marginal in their efficacy in improving clinical outcomes (Lee et al., 2022). Moreover, most self-care studies including trials are focused on self-care maintenance and/or monitoring but not self-care management (Riegel et al., 2021b) – the behaviors about which we know the least in cardiovascular disease (Riegel et al., 2017). As such, there is significant room for improvement in our ability to intervene with self-care interventions in a clinically meaningful way, and in our ability to close a key knowledge gap related to self-care management behaviors in cardiovascular disease.

1.1. Self-care management behaviors in cardiovascular disease

Despite being studied separately in most instances, there are more commonalities than differences in self-care behaviors across cardiovascular disorders (Riegel et al., 2017). For example, there is 100 % overlap across cardiovascular disorders in recommended self-care management behaviors of linking symptoms to cardiovascular disease, having a plan for when changes in symptoms occur, taking dietary or medication action in response to symptoms, evaluating the effectiveness of self-initiated treatments, and knowing when and how to contact a provider (Riegel et al., 2017). We know that in conditions like heart failure, better self-care management behaviors are associated with better clinical and patient-oriented outcomes (Lee et al., 2018, 2015). We also know that worse physical symptoms like dyspnea and sleep disturbances (i.e. at a level where severity or burden are non-ignorable) (Auld et al., 2018) and worse affective symptoms like anxiety (i.e. perhaps by contributing to greater vigilance or hypervigilance) (Lee et al., 2015) tend to drive better self-care management behaviors. Theoretically, we also know that symptoms can either motivate self-care or blunt the ability to engage in self-care, and as such self-care management is challenging to study without also studying symptoms (Riegel et al., 2019a). Collectively, however, our understanding of self-care management behaviors is in its infancy both within and across cardiovascular disorders.

1.2. Potential role of interoceptive sensibility in self-care management behaviors

Interoception is the complex and multidimensional process by which the nervous system senses, interprets and integrates signals originating from within the body (Forkmann et al., 2016). *Interoceptive sensibility* is the conscious level of this process that can be measured by self-report (Mehling et al., 2018). We do not know much about interoceptive sensibility in the context of cardiovascular disease; but, conceivably better interoceptive sensibility would be associated with better symptom recognition if not also the behavioral responses thereto. We do know that adults with chronic physical illness in general have lower *interoceptive accuracy* (i.e. objective accuracy in detecting bodily changes) compared with healthy individuals, and that greater interoceptive sensibility is associated with less symptom burden in chronic physical illness (Locatelli et al., 2023). We also know that greater *interoceptive awareness* (i.e. the metacognitive awareness of one's own level of interoceptive accuracy) is associated with anxiety among patients with chronic mood disorders (Dunn et al., 2010). We have far more insights into interoceptive sensibility in the context of mental health where, as an example, it has been shown that depression is associated with worse interoceptive sensibility (Dunne et al., 2021), and interoceptive sensibility is frequently the target of intervention (Khoury et al., 2018; Heim et al., 2023). But, there is very limited evidence about the relationship between interoceptive sensibility and self-care management behaviors directly (Locatelli et al., 2023), or how interoceptive sensibility may influence known pathways between symptoms and self-care management. There is emerging interest in interoception as a target of intervention (Loucks et al., 2023; Rominger et al., 2021); but, interoceptive sensibility is a nascent area of science in cardiovascular disease. As such, we need more preliminary insights before thinking about which elements of interoceptive sensibility to target, and what the effectiveness of such interventions might be in terms of improving self-care management.

1.3. Purpose

The goal of this study was to quantify relationships among physical and affective symptoms, interoceptive sensibility, and self-care management behaviors among adults living with cardiovascular disease. Since the measurement of interoceptive sensibility is relatively new in the context of chronic cardiovascular disease, we first explored relationships among the interoceptive sensibility domains using network analysis. We then tested the moderating effect of interoceptive sensibility on the relationship between symptoms and self-care management behaviors under the primary hypothesis that greater interoceptive sensibility would increase the positive effects of symptoms on self-care management behaviors (i.e. worse symptoms motivating better self-care management (Riegel et al., 2019a)).

2. Methods

2.1. Design and setting

This was a cross-sectional, correlational, descriptive study that was conducted between August and November of 2023 across the United States.

2.2. Participants

The sampling frame for this study was adults living with chronic cardiovascular disease. Inclusion criteria included being 18 years of age or greater, having at least one chronic cardiovascular condition (i.e. hypertension (hypertension, hypertensive heart disease without congestive heart failure, essential hypertension, or moderate or high blood pressure), rhythm disorders (cardiac arrhythmia, bradycardia or cardiac arrhythmia, tachycardia, atrial fibrillation/flutter or chronic atrial fibrillation/flutter), coronary artery disease (coronary artery disease or multi vessel coronary artery disease/disorder), heart failure (congestive heart failure, acute or congestive heart failure, chronic right or left sided congestive heart failure), valve disease (heart valve diseases, mitral valve disease, tricuspid valve disease, aortic or subaortic stenosis, calcific or supra-valvar aortic stenosis, sub-valvular or aortic stenosis, non-rheumatic or subaortic stenosis, membranous or idiopathic hypertrophic subaortic stenosis, mitral valve prolapse or tricuspid valve prolapse), stroke (stroke, mini stroke, acute stroke, embolic stroke, lacunar stroke, ischemic stroke, cerebellar stroke, thrombotic stroke, hemorrhagic stroke), or peripheral vascular disease (peripheral vascular disease or peripheral artery disease)), experiencing recent symptoms (e.g. shortness of breath, pain, nausea, fatigue, or sleep disturbances), being reachable by email, and having computer and internet access to complete study procedures. Exclusion criteria included not having current or recent symptoms, not having one of the above listed cardiovascular disorders, and/or not being on any cardiovascular medication.

2.2.1. Sample size estimation

Our primary hypotheses involved moderation testing. Using hierarchical regression modeling, assuming power of 0.80, alpha of 0.01 (to correct for family-wise false discovery), a set of up to 10 predictors in block A, and the interaction term tested in block B, we estimated that a sample size of at least 302 adults would be sufficient to detect a Cohen's f^2 as low as 0.04 (small effect size) as being statistically significant. Although our network analysis of interoceptive sensibility domains was exploratory, sample sizes of 350 or less have been shown to be sufficient in generating networks with 20 or fewer nodes (Constantin et al., 2023).

2.3. Recruitment

Participants in this study were recruited via ResearchMatch.org, a National Institutes of Health-sponsored platform established to link research teams with potential participants based on their medical history. Researchers are able to select potential participants based on inclusion and exclusion criteria. Potential participants who are eligible received a brief study summary and indicated if they are interested in learning more. Those who selected that they may be interested agreed to have their contact information shared with the research team via the secure platform along with limited information on demographics, medical conditions, and medications. Potential participants were then sent a unique and non-transferable link to complete pre-consenting procedures (i.e. confirmation of eligibility) and if eligible continued in completing the survey via REDCap, a secure web application for managing electronic surveys that also is supported by the U.S. National Institutes of Health. This study was not open to the public and not otherwise advertised at any time. Approximately 15,000 potential participants met these inclusion criteria. ResearchMatch.org limits potential participant contacts to 1500 every two weeks. As such, recruitment occurred in five waves of simple random sampling (up to 1500 randomly selected potential participants from the remaining eligible pool sampled approximately every two weeks) in ResearchMatch.org. For participants who selected that they may be interested and agreed to have their contact/limited clinical information shared with the research team, we performed an additional confirmation of eligibility to ensure that participants listed one of our cardiovascular conditions of interest, and that they were on a medication used in the management of cardiovascular disease (e.g. any class of antihypertensive agent for those indicating they had hypertension). Potential participants who met these prescreening criteria were sent a unique link to complete screening. Screening entailed the potential participant verifying that they met the age criterion, selecting which cardiovascular condition(s) they had, verifying that they had recent symptoms, and verifying that they were reachable by email and had computer access sufficient to complete the survey. Participants who met the inclusion criteria in screening were asked to proceed to review the consent form and provide informed consent if they were willing; participants who did not meet inclusion criteria did not progress to consenting procedures and were thanked for their consideration. Participants who completed the survey were offered a US$25 electronic gift card to compensate them for their time spent in participation.

2.4. Measurement

2.4.1. Sociodemographic and clinical information

Sociodemographics (i.e. age, gender, marital status, race, ethnicity, education and employment) were collected via self-report. The Charlson Comorbidity index was used to measure self-reported comorbid illness burden; data on individual conditions were weighted and calculated into categories of mild, moderate and high (Charlson et al., 1987).

2.4.1.1. Symptoms. Patient-Reported Outcomes Measurement Information System (PROMIS®) measures were used to capture physical and affective symptoms. Dyspnea was captured using the 10-item PROMIS Dyspnea Severity (version 10a) measure (Choi et al., 2011). Pain interference was captured using the 8-item PROMIS pain interference (version 4a) measure (Amtmann et al., 2010). Fatigue was captured using the 6-item PROMIS fatigue (version 4a) measure (Stone et al., 2015). Sleep disturbances were captured using the 8-item PROMIS sleep disturbances (version 4a) measure (Yu et al., 2011). Nausea and vomiting were captured using the 4-item PROMIS gastrointestinal nausea and vomiting (short form version 4a) measure (Spiegel et al., 2014). Depression/sadness was captured using the 8-item PROMIS depression/sadness (version 4a) measure (Pilkonis et al., 2011). Anxiety/fear was captured using the 8-item PROMIS anxiety/fear (version 4a) measure (Schalet et al., 2016). All PROMIS measures were U.S. population-normalized to a mean of 50 and standard deviation of 10 using online scoring (https://www.assessmentcenter.net/ac_scoringservice). All PROMIS measures are scored such that higher levels equal more of the trait being measured (i.e. worse symptoms in this case). In this study, internal consistency reliability of the PROMIS measures ranged from 0.77 (nausea and vomiting) to 0.97 (pain interference).

2.4.1.2. Interoceptive sensibility. Interoceptive sensibility was measured using the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2); a 37-item measure with an 8-factor structure corresponding to the conceptual domains of noticing, distracting, worrying, attention regulation, emotional awareness, self-regulation, body listening, and trust (Mehling et al., 2018). In the original psychometric evaluation, internal consistency reliability ranged from 0.64 (noticing) to 0.83 (attention regulation and trust) (Mehling et al., 2018). MAIA-2 scores are calculated (range 0–5) such that higher levels indicate more of the trait being measured – our scoring reflects the conceptual domains of distracting and worrying as opposed to the "not worrying" and "not distracting" that are sometimes used with the MAIA-2 (i.e. these two domains were not reverse scored but instead kept in their direct scoring form). The MAIA-2 domains, interpretation thereof, and internal consistency reliability as observed in this study are presented in Table 1.

2.4.1.3. Self-care management behaviors. The Self-Care of Chronic Illness Inventory (v4c) was used to measure the behavioral domain of self-

Table 1
MAIA-2 interoceptive sensibility domains.

Domain	Interpretation	Cronbach's α
Noticing:	Higher values indicate greater awareness of body sensations	0.82
Distracting:	Higher values indicate greater tendency to ignore or distract oneself from sensations of discomfort	0.86
Worrying:	Higher values indicate greater emotional distress or worry with sensations of discomfort	0.66
Attention regulation:	Higher values indicate greater ability to sustain and control attention to body sensations	0.93
Emotional awareness:	Higher values indicate greater awareness of the connection between body sensations and emotions	0.89
Self-regulation:	Higher values indicate greater ability to regulate psychological distress by attention to body sensations	0.91
Body listening:	Higher values indicate more active listening to the body for insights	0.91
Trusting:	Higher values indicate more favorable appraisal of experiencing one's body as safe and trustworthy	0.89

Abbreviation: MAIA-2, Multidimensional Assessment of Interoceptive Awareness, Version 2.

care management (i.e. participants' ability to recognize and respond to symptoms when they occur) (Riegel et al., 2018). The Self-Care of Chronic Illness Inventory has three behavioral domains (maintenance, monitoring, and management); but, only self-care management was used in this analysis. The 7 self-care management items focus on how quickly respondents recognize symptoms as related to their health conditions, how likely they are to engage in several management behaviors in response to symptoms (i.e. change what they eat or drink, change their activity level, take a medication, tell their healthcare provider at the next visit, and/or call their provider for guidance), and their evaluation of the self-initiated treatment effectiveness. In the original psychometric evaluation, the self-care management scale had sufficient reliability (global reliability index = 0.71) and sufficient factorial validity (comparative fit index = 0.93, Tucker and Lewis index = 0.88, root mean square error of approximation = 0.07, standardized root mean square residual = 0.05) (Riegel et al., 2018). Self-care management scores are calculated to range from 0 to 100, with higher values indicating better self-care management. A score of ≥70 is considered, albeit theoretically, as being adequate in self-care management (Riegel et al., 2019b). In this study, internal consistency reliability of the 7-item self-care management scale was 0.79.

2.5. Statistical analysis

All analyses were performed in StataMP (v.18.0, College Station, TX) except where noted. Descriptive statistics (mean and standard deviations or cell size and percentages) were used to describe the sample. Given the nature of these survey data, there was limited missingness (max 2.1 % on any key independent or independent variable), and no discernable pattern of missingness could be identified. As such, missingness was handled using multiple imputation with incremental chained equations (i.e. the mi impute chained command).

2.5.1. Network analysis

Our use of individual network analysis entailed quantifying conditional associations and interdependencies among the 8 MAIA-2 domains collected at a single point in time, translating those interdependencies into connected nodes, and weighing the strength and direction of associations among nodes (Borsboom et al., 2021). Centrality of nodes was based on three domains: a) betweenness - the number of times a node falls on the shortest path between two others, b) closeness - the average distance from one node to all others, and c) strength - how strongly a node is connected to all others in the network (Epskamp et al., 2018). Network analysis and visualizations were generated using the open source program JASP (v0.18.1; the Netherlands).

2.5.2. Preliminary multivariate modeling

Multivariate regression modeling was used to quantify relationships between symptoms, and the domains of interoceptive sensibility and the dependent outcome of self-care management. Results are reported in adjusted slope coefficients ± standard errors and their associated p-values.

2.5.3. Moderation testing and visualization

Significant relationships from multivariate regression modeling were moved forward into moderation testing (i.e. testing the statistical interaction between a symptom and an interoceptive sensibility domain in predicting self-care management). Moderation was confirmed by examining the statistical significance of interaction terms (e.g. dyspnea * body listening), the statistical significance of each component of the interaction term (e.g. dyspnea and body listening independently), and the significance of the increase in explained variance (R^2) by adding the interaction term in hierarchical regression (Baron and Kenny, 1986). In cases of significant moderation, marginal means prediction (i.e. the margins command) was use to estimate self-care management across all possible permutations of combined information on each component of the interaction – these results were represented visually using continuous by continuous variable interaction graphs generated in StataMP.

2.6. Ethical approval

This study was reviewed, approved, and monitored by the Boston College Institutional Review Board (Protocol Number: 23.235.01).

3. Results

Of the 6782 potential participants who met inclusion criteria in ResearchMatch and were selected via random sampling to be send information on our study, 536 agreed to be contacted directly by our team to learn more (see Supplemental Data for study flow and U.S. geographical distribution). 30 potential participants were screened out during eligibility verification because they were not on a cardiovascular medication or did not have a cardiovascular disorder included in their condition list. 448 potential participants completed pre-consenting procedures; 60 potential participants indicated that they were ineligible because they did not have current or recent symptoms, and 1 potential participant indicated they did not have cardiovascular disease at that point. 387 participants met inclusion criteria, provided informed consent to participate in the study, and completed the survey.

3.1. Characteristics of the sample

The age of participants in the sample ranged from 18 to 88 years, and a slight majority (53.5 %) of participants identified as being female (Table 2). A majority of participants were married (66.4 %), and a majority identified as being White or Caucasian (66.4 %) followed in frequency by being Black or African American (32.0 %). A plurality of participants had a Bachelor's degree (37.0 %), and a plurality were employed full-time (40.3 %). The most common cardiovascular condition was hypertension (61.5 %), followed in prevalence by rhythm disorders, coronary artery disease, heart failure, valve disease, stroke and peripheral vascular disease. A majority of participants (66.7 %) had a mild Charlson comorbid illness risk category.

Summary data on symptoms, interoceptive sensibility, and self-care management behaviors are presented in Table 3. Overall, participants

Table 2
Sociodemographic and clinical characteristics of the sample (n = 387).

Characteristic	Mean ± SD or n (%)
Age (in years)	50.2 ± 17.1
Age (in categories):	
18–34 years	82 (21.2 %)
35–49 years	126 (32.6 %)
50–64 years	70 (18.1 %)
65+ years (sample maximum 88)	109 (28.2 %)
Gender:	
Female	207 (53.5 %)
Male	176 (45.5 %)
Other	4 (1.0 %)
Marital status:	
Married/partnered	257 (66.4 %)
Single	57 (14.7 %)
Divorced/separated	51 (13.2 %)
Widowed	22 (5.7 %)
Ethnicity (Spanish, Hispanic or Latino)	24 (6.2 %)
Race (not mutually exclusive):	
White or Caucasian	257 (66.4 %)
Black or African American	124 (32.0 %)
Other	8 (2.1 %)
American Indian/Alaskan Native	5 (1.3 %)
Asian	3 (0.8 %)
Native Hawaiian/Pacific Islander	0 (0.0 %)
Highest level of education:	
High school or less	9 (2.3 %)
Some college	64 (16.5 %)
Associates degree	37 (9.6 %)
Bachelor's degree	143 (37.0 %)
Masters/professional degree	116 (30.0 %)
Doctoral degree	18 (4.7 %)
Current employment:	
Full-time	156 (40.3 %)
Retired	92 (23.8 %)
Part-time	57 (14.7 %)
Quit/retired due to health	54 (14.0 %)
Unemployed	24 (6.2 %)
Looking for work	4 (1.03 %)
Cardiovascular disease (not mutually exclusive):	
Hypertension	238 (61.5 %)
Rhythm disorder	124 (32.0 %)
Coronary artery disease	94 (24.3 %)
Heart failure	89 (23.0 %)
Valve disease	69 (17.8 %)
Stroke	62 (16.0 %)
Peripheral vascular disease	49 (12.7 %)
Number of cardiovascular diseases	1.9 ± 1.1
Charlson chronic conditions:	
Heart disease (e.g. heart failure, coronary artery disease)	255 (65.9 %)
Arthritis/rheumatism	176 (45.5 %)
Asthma/chronic obstructive pulmonary disorder/chronic bronchitis	119 (30.7 %)
Diabetes mellitus	91 (23.5 %)
Digestive problems (e.g. ulcer, colitis)	76 (19.6 %)
Stroke	62 (16.0 %)
Cancer (in the past 3 years)	39 (10.1 %)
Kidney disease	32 (8.3 %)
Liver disease (e.g. cirrhosis)	30 (7.8 %)
HIV/AIDS	8 (2.1 %)
Charlson comorbidity categories:	
Mild	258 (66.7 %)
Moderate	103 (26.6 %)
Severe	26 (6.7 %)

Abbreviations: AIDS, acquired immunodeficiency syndrome; HIV, human immunodeficiency virus; PROMIS, Patient-Reported Outcomes Measurement Information System; SD, standard deviation.

Table 3
Independent and dependent variables.

Patient-reported outcome	Mean ± SD	95 % CI
PROMIS measure (mean of 50, SD of 10, higher = more of trait):		
Dyspnea	53.0 ± 10.3	(51.95–54.02)
Pain interference	59.7 ± 8.9	(58.85–60.64)
Fatigue	59.4 ± 9.0	(58.46–60.27)
Sleep disturbances	57.5 ± 4.1	(57.08–57.89)
Nausea and vomiting	54.9 ± 10.2	(53.93–55.97)
Depression/sadness	57.4 ± 10.4	(56.34–58.43)
Anxiety/fear	58.8 ± 10.6	(57.69–59.81)
Interoceptive sensibility: MAIA-2 (range 0–5, higher = more of trait):		
Noticing	3.5 ± 1.1	(3.38–3.61)
Distracting	1.7 ± 1.1	(1.59–1.81)
Worrying	2.6 ± 0.9	(2.53–2.72)
Attention regulation	3.0 ± 1.2	(2.89–3.14)
Emotional awareness	3.3 ± 1.2	(3.22–3.46)
Self-regulation	2.9 ± 1.5	(2.81–3.09)
Body listening	2.8 ± 1.4	(2.65–2.95)
Trust	3.2 ± 1.4	(3.01–3.29)
Self-care of chronic illness inventory (range 0–100, higher = better):		
Self-care management	69.9 ± 21.3	(67.54–71.84)

Abbreviations: CI, confidence interval; MAIA-2, Multidimensional Assessment of Interoceptive Awareness, Version 2; PROMIS, Patient-Reported Outcomes Measurement Information System; SD, standard deviation.

experienced more pain interference, fatigue and anxiety compared with other symptoms. Notably, participants in this study experienced more of all symptoms compared with the general population. Noticing was the interoceptive sensibility domain rated the highest among participants, and distracting was rated the lowest. On average, participants reported self-care management just below the margin of adequacy.

3.2. Network analysis among interoceptive domains

Results from the network analysis of interoceptive sensibility domains are presented in Fig. 1. Based on betweenness, closeness and strength of association with other domains, body listening was the most central interoceptive domain, meaning it had the strongest positive association with other domains. Distracting was the least central interoceptive domain, meaning it had the strongest negative association with other domains.

3.3. Multivariate modeling of self-care management

Multivariate regression models of the influence of symptoms and interoceptive sensibility domains on self-care management are presented in Table 4. Among physical symptoms, dyspnea and sleep disturbances were statistically significant in their association with self-care management (model $R^2 = 0.054$, $p = 0.001$). Among affective symptoms, only anxiety was statistically significant in its association with self-care management (model $R^2 = 0.022$, $p = 0.017$). Among interoceptive domains, noticing, distracting, worrying, and body listening were statistically significant in their association with self-care management (model $R^2 = 0.41$, $p < 0.001$).

3.4. Moderation testing

Moderation testing between symptoms and interoceptive sensibility domains in their association with self-care management behaviors are presented in Figs. 2 through 5. Of particular note, worrying was not statistically significant in interaction with any symptom in predicting self-care management behaviors (all $p > 0.05$, *data not shown*).

3.5. Dyspnea, noticing and distracting

At higher levels of dyspnea, low noticing was associated with poor self-care management, and high noticing was associated with better self-care management (all $p < 0.001$) (Fig. 2). Higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors, especially at higher levels of dyspnea (all $p < 0.001$).

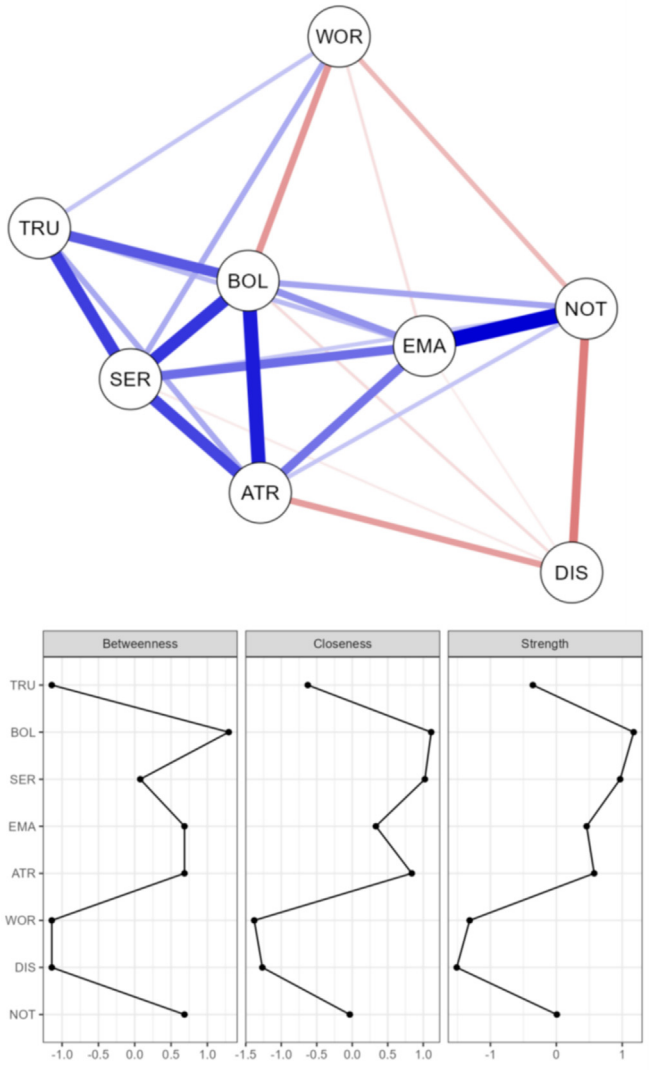


Fig. 1. Network analysis and centrality metrics of interoceptive sensibility. Blue lines indicate positive associations whereas red lines indicate negative associations. Bolder lines indicate stronger relationships, and lighter lines indicate weaker relationships. Abbreviations: ATR = attention regulation, BOL = body listening, DIS = distracting, EMA = emotional awareness, NOT = noticing, SER = self-regulation, TRU = trust, WOR = worrying.

3.6. Sleep disturbances, noticing and distracting

At low levels of sleep disturbances, low noticing was associated with poor self-care management and high noticing was associated with better self-care management (all $p < 0.001$) (Fig. 3). With above average sleep disturbances, higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors (all $p < 0.001$).

3.7. Anxiety, noticing and distracting

With higher levels of anxiety, low noticing was associated with poor self-care management and high noticing was associated with better self-care management (all $p < 0.001$) (Fig. 4). At higher levels of anxiety, higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors (all $p < 0.001$).

Table 4
Multivariate regression models of self-care management on symptoms and interoceptive sensibility.

	Self-care management	
	β ± SE	p-Value
Physical symptoms		
Dyspnea	0.470 ± 0.154	0.002
Pain interference	0.188 ± 0.184	0.308
Fatigue	−0.126 ± 0.170	0.459
Sleep disturbances	0.731 ± 0.295	0.014
Nausea/vomiting	−0.049 ± 0.128	0.704
Affective symptoms		
Depression/sadness	−0.123 ± 0.177	0.487
Anxiety/fear	0.380 ± 0.173	0.028
Interoceptive sensibility domains		
Noticing	2.830 ± 1.158	0.015
Distracting	−2.233 ± 0.952	0.020
Worrying	−3.998 ± 1.028	<0.001
Attention regulation	0.488 ± 1.297	0.707
Emotional awareness	0.493 ± 1.220	0.686
Self-regulation	−0.673 ± 1.236	0.586
Body listening	4.989 ± 1.133	<0.001
Trust	1.109 ± 0.931	0.234

Abbreviation: SE, standard error.

3.8. Body listening and dyspnea, sleep disturbances and anxiety

Body listening (the interoceptive domain most central in relation to others) was associated with better self-care management across most ranges of dyspnea, sleep disturbances, and anxiety (all $p < 0.001$) (Fig. 5). At the highest levels of dyspnea, sleep disturbances, and anxiety, however, self-care management behaviors were high irrespective of the degree of body listening.

4. Discussion

In this sample of 387 adults living with cardiovascular disease, we used network analysis to characterized interoceptive sensibility (i.e. the conscious level of sensing, interpreting and integrating body signals) and determined for the first time that active listening to the body for insights (i.e. body listening) is the most central domain, and the tendency to ignore or distract oneself from sensations of discomfort (i.e. distracting) is the least central domain in relation to others. We found in moderation testing that greater awareness of body sensations (i.e. noticing) and body listening were associated with better self-care management behaviors across most ranges of dyspnea, sleep disturbances and anxiety. Additionally, we found that distracting was associated with worse self-care management behaviors across most ranges of dyspnea, sleep disturbances and anxiety. To the best of our knowledge, this is the first evidence that domains of interoceptive sensibility are significant moderators of the relationship between physical and affective symptoms and self-care management behaviors in the context of chronic cardiovascular disease.

We found that better body listening a) was most central in its association with other interoceptive sensibility domains, b) was associated positively with self-care management, and c) beneficially moderated the relationship between key physical and affective symptoms and self-care management behaviors. Greater noticing, although not as central in relation to other interoceptive domains also was positively associated with self-care management, and beneficially moderated the relationship between physical and affective symptoms and self-care management behaviors. At the same time, we observed that greater distraction a) was least central in its association with other interoceptive sensibility domains, b) was associated negatively with self-care management, and c) detrimentally moderated the relationship between physical and affective symptoms and self-care management behaviors. Our findings suggest that educational/interventional programs designed to help patients better listen to their body sensations including

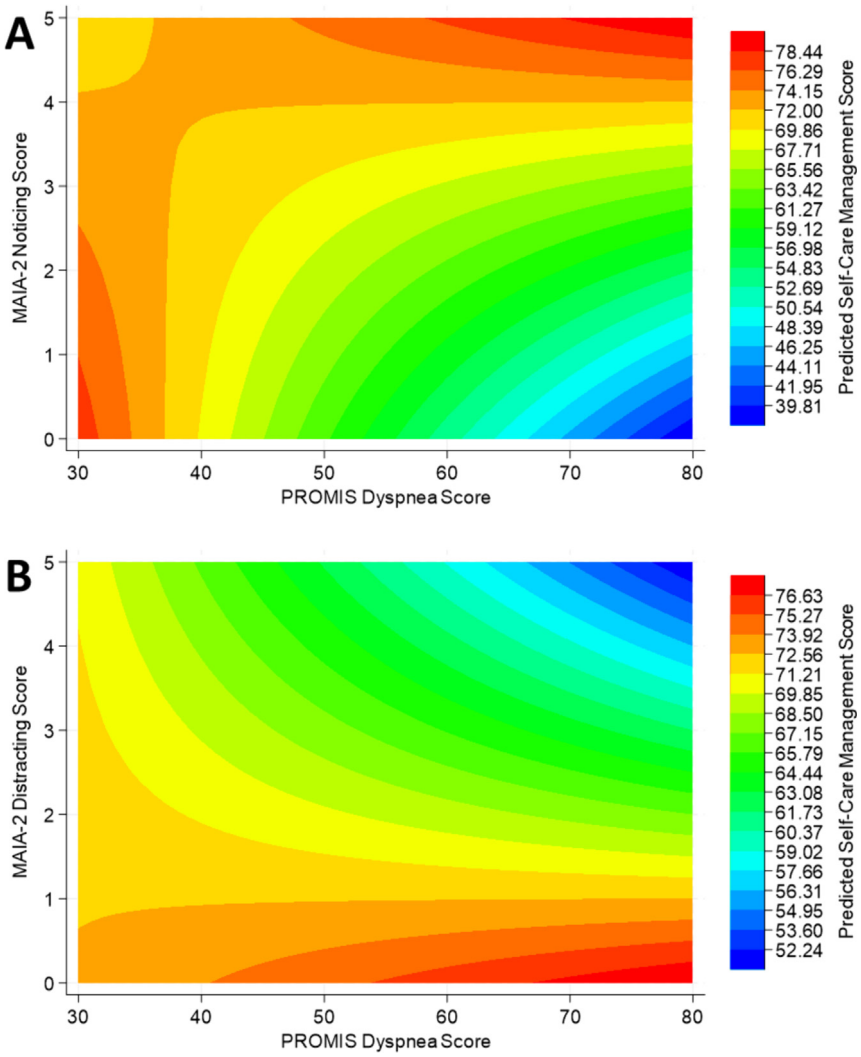


Fig. 2. Moderation between interoceptive sensibility domains and dyspnea on self-care management behaviors. Panel A presents the moderation between noticing and dyspnea in predicting self-care management behaviors. With lower levels of dyspnea any degree of noticing (i.e. *awareness of body sensations*) was associated with adequate-to-higher self-care management. At higher levels of dyspnea, low noticing was associated with poor self-care management whereas high noticing was associated with better self-care management. Panel B presents the moderation between distracting (i.e. *the tendency to ignore or distract oneself from sensations of discomfort*) and dyspnea in predicting self-care management behaviors. Higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors, especially with higher levels of dyspnea.

symptoms they are experiencing, and to help patients develop alternative strategies to ignoring or distracting oneself from sensations of discomfort may be key to improving self-care management behaviors in cardiovascular disease. There are neural, behavioral, and psychological pathways that can be helpful in improving interoception at large. For example, vagus nerve simulation (a neural intervention) may improve pulmonary interoception by regulating autonomic tone or by influencing neuroplasticity, and guided slow breathing (a behavioral intervention) may help improve pulmonary interoception by modulating cardiopulmonary baroreflexes and regulating parasympathetic tone (Weng et al., 2021). Critical questions that stem from our findings center on how best to intervene, and in whom to intervene when considering how to improve interceptive sensibility in cardiovascular disease.

4.1. Interventions with great potential

Mindfulness-based interventions (where body awareness and listening are among key components) have been shown in meta-analyses to improve affective symptoms and perceived stress in cardiovascular disease (Scott-Sheldon et al., 2020). But, in addition to improving symptoms mindfulness-based interventions may also be a particularly useful approach to improve interoceptive sensibilities (e.g. improve noticing and body listening while also targeting distraction) and to improve self-management (Schuman-Olivier et al., 2020). Mindfulness-based interventions may improve interoception by helping regulate autonomic tone and activating networks involved with attention and executive function (Weng et al., 2021). Interventions such as mindfulness-based cognitive therapy provide both psychoeducational and experiential learning opportunities over the course of eight sessions related to interoceptive domains (e.g. noticing, body awareness, emotional awareness self-regulation, etc.), and have been used successfully across studies to manage both chronic physical illnesses (e.g. chronic pain) (Pei et al., 2021) and psychological disorders (e.g. depression) (Piet and Hougaard, 2011). Other mindfulness-based interventions, including brief interventions may also improve interoceptive sensibilities (Khoury et al., 2018; Lima-Araujo et al., 2022). Finally, mindfulness training for primary care programs that include elements of behavioral change in self-care in addition to mindfulness-based cognitive therapy and stress reduction has been shown to improve self-care action plan initiation (Gawande et al., 2019a, 2019b).

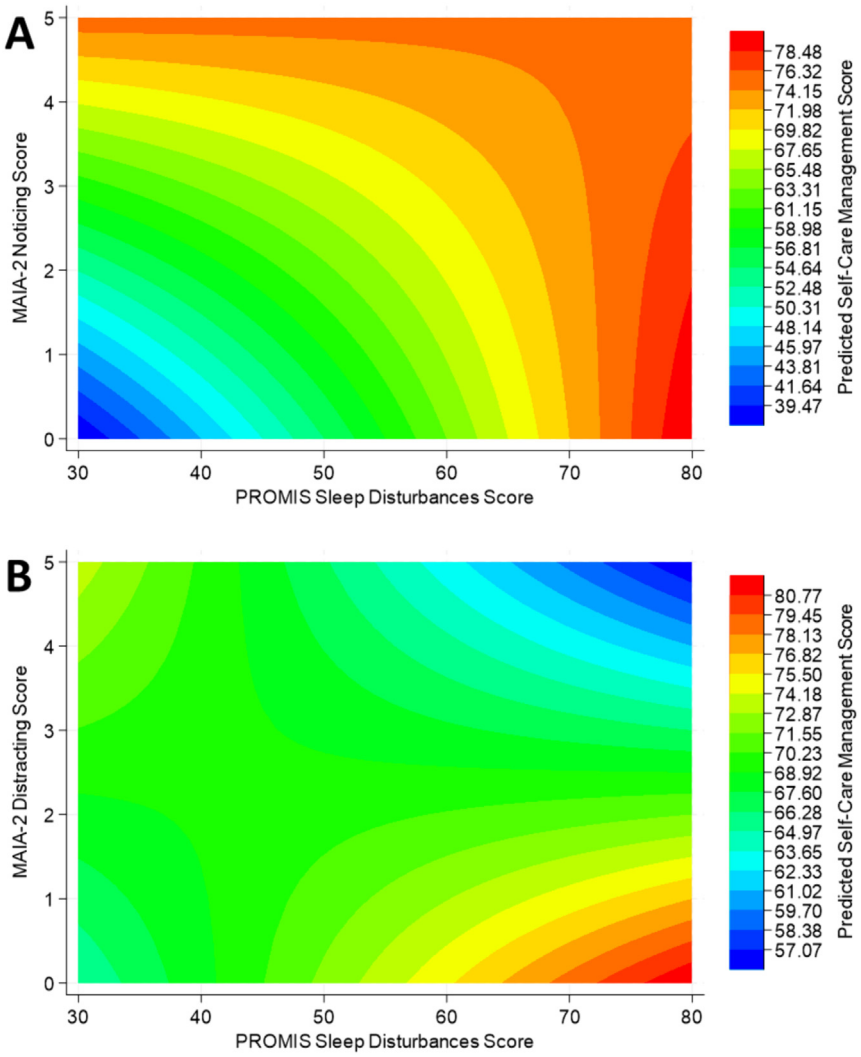


Fig. 3. Moderation between interoceptive sensibility domains and sleep disturbances on self-care management behaviors. Panel A presents the moderation between noticing (i.e. *awareness of body sensations*) and sleep disturbances in predicting self-care management behaviors. At low levels of sleep disturbances, low noticing is associated with poor self-care management whereas high noticing is associated with better self-care management. With higher levels of sleep disturbances, any degree of noticing is associated with adequate-to-higher self-care management. Panel B presents the moderation between distracting (i.e. *the tendency to ignore or distract oneself from sensations of discomfort*) and sleep disturbances in predicting self-care management behaviors. With above average sleep disturbances, higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors.

4.2. Concerns about intervening on interoceptive sensibility

A concern about enhancing interoceptive sensibility as a means of improving self-care management behaviors is the potential to cause distress. For example, in the presence of anxiety increased interoceptive sensibility is associated with greater physiological reactivity to internal changes that may in turn cause distress (Mehling, 2016; Mallorqui-Bague et al., 2014). Caution must therefore be exercised when attempting to improved interoceptive sensibility to also foster greater ability to interpret and attend to body sensations in a self-regulatory and adaptive way (Gibson, 2019). Put simply, the end goal should not be to simply increase interoceptive sensibility or enhance reactivity but also to build skills in self-care (Scott-Sheldon et al., 2020; Cohen et al., 2015). Greater interoceptive sensibility, but not other aspects of interoception like interoceptive accuracy or interoceptive awareness (i.e. the meta-cognitive awareness of one's own interoceptive accuracy), has been shown to be associated with better well-being (Ferentzi et al., 2019). As such, by improving interoceptive sensibility we may indeed make patients feel better; but, we must acknowledge that in doing so we may not be influencing interoceptive accuracy or interoceptive awareness. Finally, it has been argued that distracting oneself from body sensations may be an effective coping style (Huffziger and Kuehner, 2009). In chronic illness, however, it has been shown that listening to the body and paying attention to sensations are even more effective than distraction in reducing symptoms and improving mental health (de Jong et al., 2016). Hence, it is likely that reducing distraction would foster effective adaptation in chronic illness as opposed to propagate maladaptive behavior.

4.3. In whom to intervene

Our findings provide novel insights into when it may be best to intervene with interventions that enhance interoceptive sensibility. For example, greater noticing was associated consistently with better self-care management at levels of dyspnea above 40, greater body listening was associated consistently with better self-care management at levels of dyspnea below 70, and greater distraction was associated consistently with worse self-care management at all levels of dyspnea. Accordingly, intervention elements that focus on reducing distraction may work for all patients whereas those focusing on noticing may be less effective in patients with lower levels of dyspnea, and those focusing on body listening may be less effective in patients with higher levels of dyspnea. Alternatively, one can imagine tailoring the interoceptive sensibility elements of an intervention to match a patient's particular degree of dyspnea.

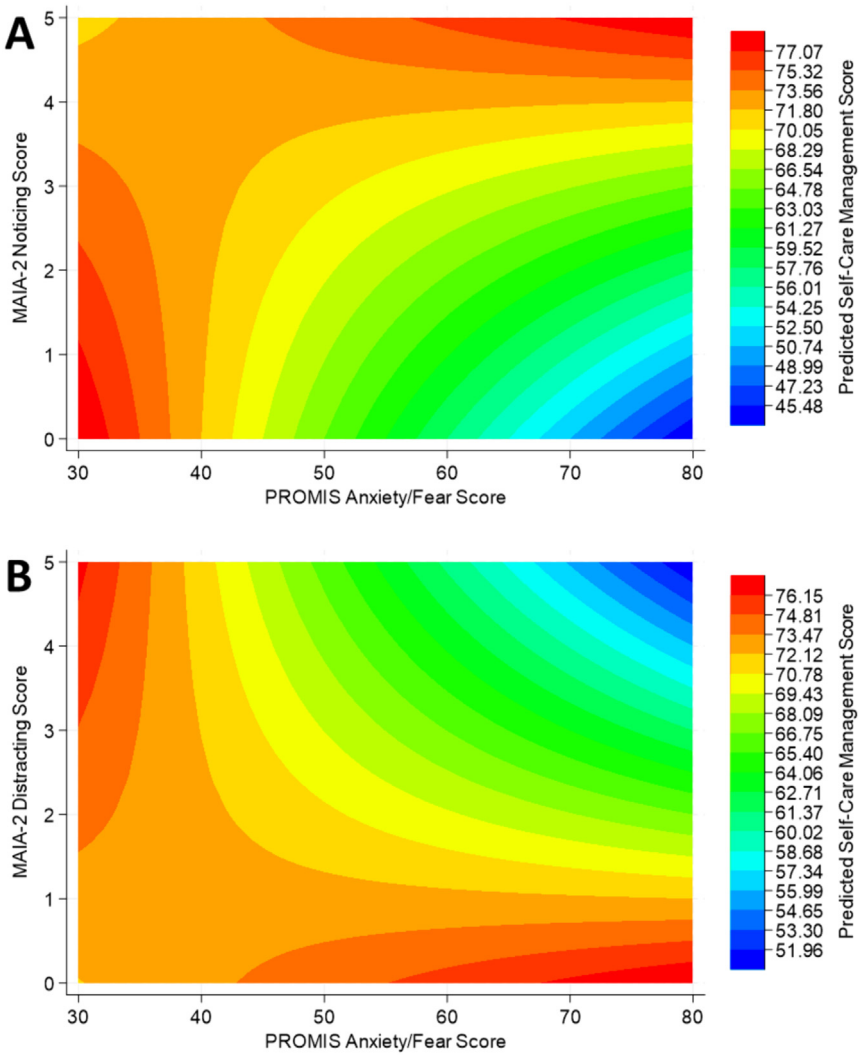


Fig. 4. Moderation between interoceptive sensibility domains and anxiety/fear on self-care management behaviors. Panel A presents the moderation between noticing (i.e. *awareness of body sensations*) and anxiety in predicting self-care management behaviors. At low levels of anxiety, any degree of noticing is associated with adequate-to-higher self-care management. With higher levels of anxiety, low noticing is associated with poor self-care management whereas high noticing is associated with better self-care management. Panel B presents the moderation between distracting (i.e. *the tendency to ignore or distract oneself from sensations of discomfort*) and anxiety in predicting self-care management behaviors. With lower levels of anxiety, any degree of distraction is associated with self-care management in the adequate range. At higher levels of anxiety, higher levels of ignoring or distracting oneself from sensations were associated with worse self-care management behaviors.

Greater noticing and body listening were associated consistently with better self-care management at levels of sleep disturbances below 70, and greater distraction was associated consistently with better self-care management with levels of sleep disturbances above approximately 55. Intervention elements centered on noticing and body listening alone may therefore be most effective among patients with sleep disturbances in the moderate-high range (although this is 2 standard deviations above the average), and those focused on minimizing distraction may be most effective in improving self-care management behaviors at average or above ranges of sleep disturbances. Additionally, one could imagine interventional elements shifting from enhancing noticing and body listening to minimizing distraction in the event that sleep disturbances worsen over time.

Greater noticing was associated consistently with better self-care management behaviors at levels of anxiety above approximately 45, better body listening was associated consistently with better self-care management at nearly all levels of anxiety, and greater distraction was associated consistently with worse self-care management at levels of anxiety above approximately 45. With respect to anxiety, intervention elements that focus on improving noticing and reducing distraction may be most effective at levels of anxiety above average, whereas those focused on improving body listening may be effective across all levels of anxiety. Collectively, these data provide insight into interventional elements that may be most effective in patients experiencing a range of physical and affective symptoms, and help support the hypothesis that interoceptive sensibility is an important link between symptoms and self-care (Locatelli et al., 2023; de Jong et al., 2016).

4.4. Limitations

There are several limitations to this study that must be taken into consideration when interpreting our results. First, this report represents the primary aim of a cross-sectional correlational descriptive study designed to provide preliminary insights into the role of interoceptive sensibility in the relationship between symptoms and self-care in cardiovascular disease. As such, we can neither comment on causal relationships nor speculate about trajectories of illness and how they may help us further understand interoceptive sensibility in this domain. Second, the wide distribution of age in our sample may limit external validity. That is, the results of this study may not translate to future observations in samples exclusively comprised of older adults. Although

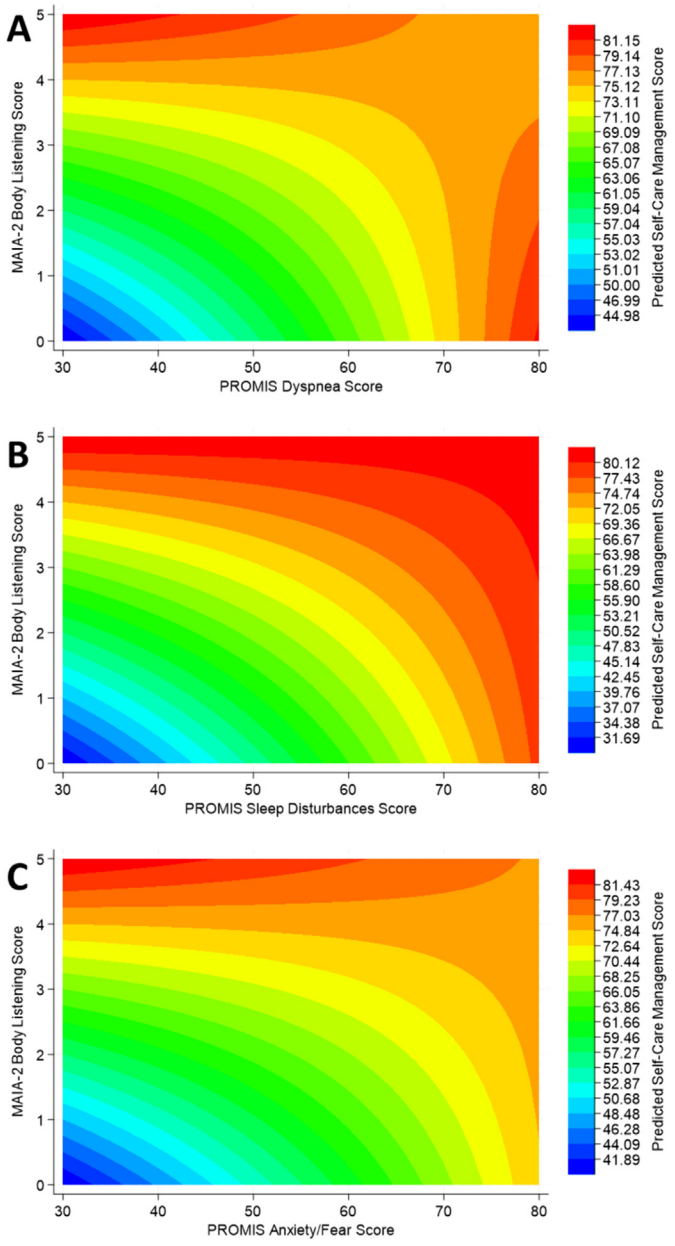


Fig. 5. Moderation between body listening and dyspnea (A), sleep disturbances (B), and anxiety/fear (C) on self-care management behaviors. Better body listening (i.e. *active listening to the body for insights*) was associated with better self-care management across most ranges of dyspnea, sleep disturbances, and anxiety/fear. The highest levels of dyspnea and sleep disturbances were associated with better self-care management irrespective of the degree of body listening.

our sample is diverse in some ways such as gender and self-identified race, it is homogeneous in others such as ethnicity and comorbidity burden – this issue may further limit external validity. Third, our hypotheses focused on self-care management and not other aspects of self-care. It has been shown by others that in chronic illness self-care monitoring behaviors directly influence some self-care management behaviors (Riegel et al., 2022). As such, there is a future need to conceptually clarify or disambiguate relationships between self-care monitoring behaviors and interoceptive sensibility. Finally, chronic conditions, including those that were inclusion criteria, were collected by pre-disclosure via ResearchMatch and by self-report. More objective means of confirming and examining the severity of chronic illnesses should be employed in future studies to build upon this preliminary research.

5. Conclusion

Among the domains of interoceptive sensibility, body listening and noticing are key elements to enhance, and distraction is a key element to minimize in order to improve self-care management behaviors among adults with cardiovascular disease. Mindfulness-based interventions may be a great way to improved interoceptive sensibility in cardiovascular disease and in so doing enhance self-care management. More research is needed to understand areas of intersection among interoceptive sensibility and other aspects of self-care including self-care monitoring.

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CRediT authorship contribution statement

Christopher S. Lee: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sang Hui Chu:** Writing – review & editing, Methodology, Conceptualization. **Julie Dunne:** Writing – review & editing, Methodology, Conceptualization. **Elise Spintzyk:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Data curation, Conceptualization. **Giulia Locatelli:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Viktoriya Babicheva:** Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Data curation, Conceptualization. **Louisa Lam:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Kelly Julio:** Writing – review & editing, Writing – original draft, Project administration. **Summer Chen:** Writing – review & editing, Writing – original draft, Project administration. **Corrine Y. Jurgens:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Data availability

Selected data are available upon request to the corresponding author.

Declaration of Competing Interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnurstu.2024.104809.

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