

# Association between interoception and self-care in individuals with cardiovascular disease

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## Aims

The aim of this study was to investigate the associations between interoceptive sensibility and self-care behaviours in individuals with cardiovascular disease (CVD).

## Methods and results

Adults with CVD were recruited for this cross-sectional descriptive study. Interoceptive sensibility was measured with the Multidimensional Assessment of Interoceptive Awareness. Self-care was measured with the Self-Care of Chronic Illness Inventory. Linear regression was used to describe the relationships between interoceptive sensibility and self-care dimensions. Hierarchical linear regression modelling was used to quantify additional explained variance in self-care beyond that of demographic and clinical characteristics. For this study, 387 participants were recruited through an online platform in America. Overall, interoceptive sensibility mostly explained the variance of self-care management ( $R^2 0.399$ ) (compared with the other self-care dimensions). Higher trust was associated with better self-care maintenance ( $P < 0.05$ ) and higher self-care confidence ( $P = 0.01$ ). Higher body listening was associated with better self-care in all dimensions (maintenance  $P = 0.025$ ; monitoring and management  $P = 0.000$ ; confidence  $P = 0.001$ ). Higher noticing was associated with greater self-care monitoring, management, and confidence ( $P = 0.01$ ,  $P < 0.05$ , and  $P = 0.01$ , respectively). Higher distraction was associated with worse self-care maintenance ( $P = 0.001$ ) and lower self-care confidence ( $P < 0.05$ ). Higher self-regulation was associated with worse self-care monitoring ( $P = 0.008$ ). Higher worrying was associated with worse self-care management ( $P = 0.002$ ).

## Conclusion

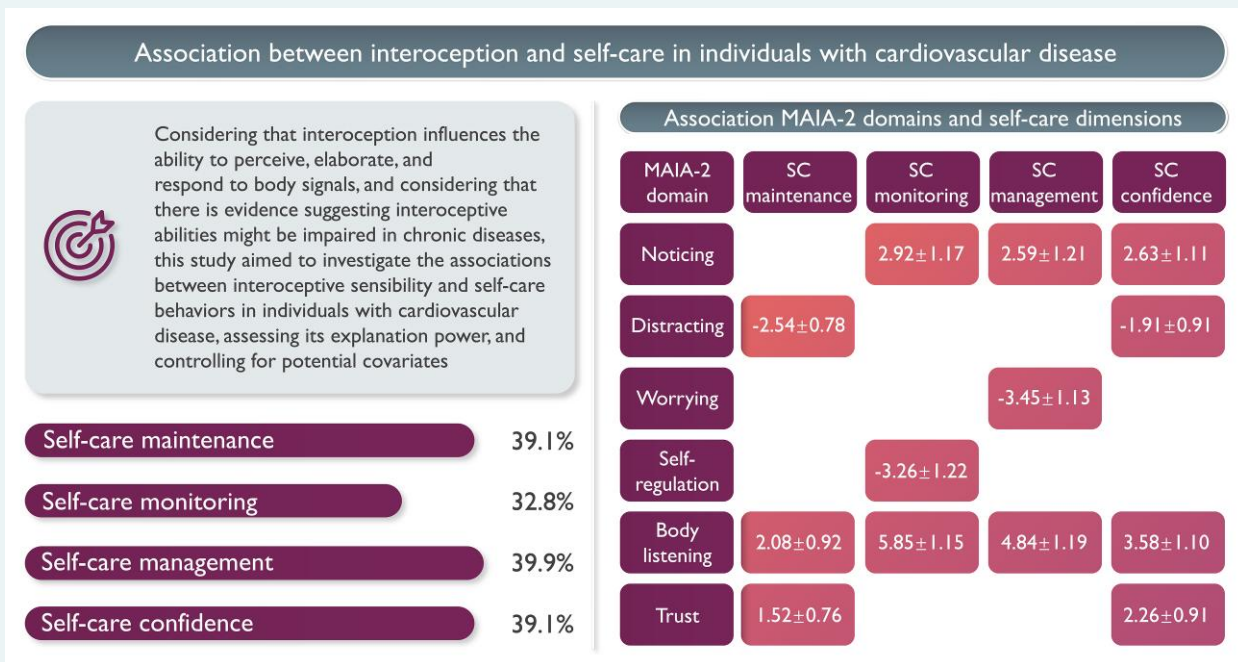
Interoceptive sensibility is associated with all self-care dimensions, especially management. Future studies should further explore these preliminary associations to examine causal relationships using longitudinal study designs, to examine the relationships by adding more potential covariates, and to examine whether changes in interoceptive sensibility led to changes in self-care using other study designs (e.g. Randomized Controlled Trial).

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## Graphical Abstract



## Keywords

Cardiovascular disease • Chronic disease • Interoception • Self-care

## Novelty

- Interoceptive sensibility is associated with all self-care dimensions, especially management.
- The various domains of interoceptive sensibility are differently associated with all self-care dimensions.

## Introduction

Cardiovascular diseases (CVDs) include a set of chronic diseases, such as heart failure and coronary heart disease, and are the leading cause of death worldwide.<sup>1</sup> Although improvements in the management of CVDs, patients still experience poor outcomes such as high mortality and rehospitalization rates,<sup>2</sup> poor quality of life, as well as burdening physical and psychological symptoms.<sup>3–6</sup> These health outcomes,<sup>7,8</sup> myocardial stress, systemic inflammation,<sup>9</sup> and health-care costs<sup>10</sup> can be addressed and improved by appropriate self-care practices.<sup>11,12</sup>

Self-care includes self-care maintenance, self-care monitoring, and self-care management behaviours. Self-care maintenance involves health-promoting practices (e.g. regular physical activity); self-care monitoring refers to active body listening; and self-care management focuses on addressing signs and symptoms when they arise.<sup>13</sup> Although self-care can improve several outcomes,<sup>11,12</sup> there are barriers that can impair the adoption of appropriate self-care behaviours. One of these barriers may be represented by deficits in interoceptive abilities. Interoception is the ability of the body to perceive and respond to internal bodily signals (e.g. symptoms).<sup>14</sup> Interoception has three dimensions: interoceptive accuracy (i.e. how accurate a person is in detecting her internal body signals); interoceptive sensibility (i.e. how good a person believes to be in

detecting and responding to her body signals); and interoceptive awareness (i.e. the degree to which the other two interoceptive dimensions match).<sup>15</sup> As per these definitions, interoception seems to be highly related to the abilities of body listening, symptom perception, interpretation, and assessment, which particularly recall self-care monitoring and management. Although the literature in this area is still scarce, there is evidence of altered interoception in adults with chronic conditions,<sup>14</sup> which, in turn, has been documented to be associated with altered symptom perception<sup>14,16</sup> and decision-making<sup>17</sup> (both of which are essential elements of self-care). Few studies targeted interoceptive sensibility to improve patient outcomes in chronic conditions, but some showed that, for example, a mindfulness-based intervention improved emotional awareness and self-regulation (which are interoceptive sensibility domains) and, at the same time, such intervention led to a reduction of depression and pain in patients with chronic pain and comorbid depression.<sup>18</sup> Similarly, another study in patients major depressive disorder showed that a brief mindfulness training could improve interoceptive sensibility while reducing depressive symptoms.<sup>19</sup> In patients with chronic low back pain, a study showed that a physical intervention (i.e. Feldenkrais method) led to an improvement in interoceptive sensibility and a concurrent reduction in pain.<sup>20</sup>

The study of interoception in the area of CVD is rather recent, and more evidence is needed to clearly understand how to target this

variable to ultimately improve patient outcomes.<sup>21</sup> Although scarce, some evidence suggests that greater interoceptive sensibility is associated with lower symptom burden in chronic physical illness,<sup>14</sup> and this is crucial because symptom perception and management are key dimensions of self-care. Additionally, interoceptive sensibility and self-care are both self-reported measures, thus allowing a comparison between subjective perceptions of individual processes. In that regard, previous studies suggested that individuals who are more interoceptively sensitive might be more likely to perceive arousal stimuli and communicate them in self-reported processes (e.g. self-care measurement) even if those changes are not so evident in explicit reports<sup>22</sup> (e.g. interoceptive accuracy tests or signs assessment). Interoceptive sensibility is a nascent area of science in CVD, and thus, new insights are needed to understand which elements of interoceptive sensibility could be worth targeting and how such interventions could help in improving self-care.<sup>21</sup>

Considering that interoception influences the ability to perceive, elaborate, and respond to body signals (i.e. self-care behaviours) and considering that there is evidence suggesting interoceptive abilities might be impaired in chronic diseases, we aimed to investigate the associations between interoceptive sensibility and self-care behaviours in individuals with CVD, assessing its explanation power, and controlling for potential covariates (i.e. demographic and clinical characteristics).

## Methods

### Study design

This is a secondary analysis of a cross-sectional descriptive study<sup>21</sup> that primarily aimed to examine the interplay between physical and affective symptoms, interoceptive sensibility, and self-care management in adults with CVD across the USA. The original study was approved by the Boston College Institutional Review Board (protocol no. 2323501).

### Participants and recruitment

The sample included adults having at least one chronic CVD (i.e. hypertension, rhythm disorders, coronary artery disease, heart failure, valve disease, stroke, or peripheral vascular disease), being at least 18 years old, experiencing recent symptoms (e.g. dyspnoea, pain, nausea, fatigue, or sleep disturbances), being reachable by email, and having computer and internet access. The exclusion criteria included not having recent symptoms, not having at least one of the CVDs above mentioned, or not being on cardiovascular medications.

Participants in this study were recruited via ResearchMatch.org, which is an American platform where researchers can select potential available participants based on inclusion and exclusion criteria and solicit their interest in participating in specific studies. Eligible participants received a study summary and potential participants indicated if they were interested in the study. Those who were interested were sent a unique link to complete pre-consenting procedures and, if actually eligible, completed informed consent and the survey via REDCap.

In the primary study, we estimated that a sample size of at least 302 individuals would have been sufficient to detect a Cohen's  $f^2$  as low as 0.04 (small effect size) as being statistically significant. This estimation was based on hierarchical regression modelling, with an assumed power of 0.80 and an alpha level of 0.01. More details on the sample and sampling procedures can be found in the original study.<sup>21</sup>

### Measurements

Sociodemographic characteristics (i.e. age, gender, marital status, race, ethnicity, education, and employment) were self-reported. The original study collected several variables, but, for the present analysis, we focused on self-care and interoceptive sensibility. More details on all the instruments used for the overall data collection can be found in the original study.<sup>21</sup>

Self-care was measured with the Self-Care of Chronic Illness Inventory (SC-CII) (v.4c), which is a psychometrically sound scale.<sup>23</sup> The SC-CII assesses

self-care maintenance (i.e. illness-related and health-promoting behaviours, seven items), self-care monitoring (i.e. body listening behaviours, five items), and self-care management (i.e. autonomous and consulting behaviours to manage the illness signs and symptoms, seven items). Additionally, the SC-CII assesses self-care confidence that is the level of one's confidence in performing self-care behaviours (10 items). Each of these scales is scored separately and then standardized 0–100 with higher scores indicating better self-care. A total score of  $\geq 70$  indicates adequate self-care.<sup>24</sup> Self-care maintenance subscale has sufficient reliability (global reliability index = 0.67) and excellent factorial validity (comparative fit index = 0.97, Tucker and Lewis index = 0.95, root mean square error of approximation = 0.035, standardized root mean square residual = 0.036).<sup>23</sup> Self-care monitoring subscale has sufficient reliability (global reliability index = 0.81) and almost perfect factorial validity (comparative fit index = 1.00, Tucker and Lewis index = 1.01, root mean square error of approximation = 0.00, standardized root mean square residual = 0.012).<sup>23</sup> Self-care management subscale has sufficient reliability (global reliability index = 0.71) and adequate 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).<sup>23</sup> Self-care confidence subscale has a good reliability (Raykov's composite reliability coefficient = 0.938), partial metric invariance, and partial scalar invariance in a US population.<sup>25</sup> In this study, alphas ranged from 0.78 (self-care management) to 0.92 (confidence).

Interoceptive sensibility was measured with the Multidimensional Assessment of Interoceptive Awareness (MAIA-2)<sup>26</sup> which is a psychometrically sound questionnaire that showed good validity (comparative fit index = 0.860; Tucker and Lewis index = 0.845; root mean square error of approximation = 0.055, standardized root mean square residual = 0.064) and adequate internal consistency reliability (Cronbach's alphas ranged between 0.64 and 0.83).<sup>26</sup> The MAIA-2 has 37 items assessing eight subdomains of noticing, distracting, worrying, attention regulation, emotional awareness, self-regulation, body listening, and trust. *Noticing* refers to body awareness and the ability to notice body sensations (e.g. When I am tense, I notice where the tension is located in my body). *Distracting* indicates the tendency to ignore or distract oneself from body sensations (e.g. I distract myself from sensations of discomfort). *Worrying* indicates emotional distress with negative body sensations (e.g. When I feel physical pain, I become upset). *Attention regulation* measures the ability to sustain and control attention to body sensations (e.g. I can pay attention to my breath without being distracted by things happening around me). *Emotional awareness* measures the ability to attribute physical sensations to emotions (e.g. I notice how my body changes when I am angry). *Self-regulation* measures the ability to regulate distress by paying attention to body sensations (e.g. When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing). *Body listening* indicates the tendency to actively listen to the body for insights (e.g. I listen to my body to inform me about what to do). *Trust* measures the perception of one's own body as safe and trustworthy (e.g. I trust my body sensations).<sup>26,27</sup> Scores for each domain range from 0 to 5, where higher values indicate more of the trait being measured. Please note that we did not reverse the two original domains of 'not worrying' and 'not distracting' as it is sometimes done; thus, our scoring simply reflects the conceptual domains of distracting and worrying. In this study, alphas ranged from 0.65 (not worrying) to 0.93 (attention regulation) with all scales except not worrying over 0.80.

### Statistical analysis

The sample was described using means and standard deviations or frequencies and percentages based on the levels of measurement. Simple linear regression was used to describe the unadjusted relationships between the eight MAIA-2 domains and self-care (maintenance, monitoring, management, and confidence). The results are reported in regression coefficients  $\pm$  standard error and explained variance (i.e.  $R^2$ ). Hierarchical linear regression modelling was used to quantify additional  $R^2$  in self-care controlling for demographic and clinical characteristics (i.e. age, gender, marital status, race, education, employment, CVD, and comorbidity) in adjusted analysis. The results are reported in regression coefficients  $\pm$  standard error, and additional explained variance is reported as  $\Delta$  in  $R^2$  (as well as the associated  $F$  statistic and  $P$ -value) and Cohen's  $f^2$  (i.e. the ratio of the change in  $R^2$  by adding the eight MAIA-2 domains in a second block of the model to the  $R^2$  of the first block of the model that included demographic and clinical characteristics). In hierarchical regression modelling, Cohen's  $f^2$  of 0.1,

0.25, and 0.4 is considered small, medium, and large, respectively.<sup>28</sup> Alpha of <0.05 was considered statistically significant in all models. All analysis was completed in Stata (v18MP), College Station, TX, USA.

## Results

Participants in our sample ( $n = 387$ ) had a mean age of 50.2 years; a majority were female (53.5%), married (66.4%), and white (66.4%). Among them, a plurality had bachelor's degrees (37%) and were working full-time (40.3%) (Table 1). The most common CVD in our sample was hypertension (61.5%), and most participants (66.7%) had a mild Charlson comorbidity risk category. Among the interoceptive sensibility domains, participants rated *noticing* the highest and *distracting* the lowest. Overall, self-care behaviours in our sample were adequate.

### Unadjusted relationships between interoception and self-care

The unadjusted results of the MAIA-2 domains in explaining self-care are presented in Table 2. Collectively, the MAIA-2 domains explained 39.1, 32.8, 39.9, and 39.1% of the variance in self-care maintenance, monitoring, management, and confidence, respectively. Higher distraction was associated significantly with worse self-care maintenance, whereas higher trust was significantly associated with better self-care maintenance behaviours. Higher noticing and body listening were significantly associated with better self-care monitoring, whereas higher self-regulation was significantly associated with worse self-care monitoring behaviours. Higher distraction and worrying were significantly associated with worse self-care management behaviours, whereas better body listening was significantly associated with better self-care management behaviours. Finally, higher levels of noticing, body listening, and trust were significantly associated with higher confidence in self-care.

### Adjusted hierarchical models of the relationship between interoception and self-care

The adjusted results of adding the MAIA-2 domains to hierarchical linear regression models explaining self-care behaviours and confidence are presented in Table 3. The eight MAIA-2 domains significantly increased explained variance in self-care maintenance beyond that explained by demographic and clinical characteristics ( $\Delta R^2 = 0.271$ ;  $F = 23.28$ ,  $P < 0.001$ ; Cohen's  $f^2 = 0.577$ ). Higher levels of distraction were significantly associated with worse self-care maintenance ( $P = 0.001$ ), whereas higher levels of body listening and trust were significantly associated with better self-care maintenance behaviours ( $P = 0.025$  and  $P < 0.05$ , respectively).

The eight MAIA-2 domains significantly increased explained variance in self-care monitoring beyond that explained by demographic and clinical characteristics ( $\Delta R^2 = 0.235$ ;  $F = 16.36$ ,  $P < 0.001$ ; Cohen's  $f^2 = 0.411$ ). Higher levels of noticing and body listening were significantly associated with better self-care monitoring behaviours ( $P = 0.01$  and  $P = 0.000$ , respectively), whereas higher levels of self-regulations were significantly associated with worse self-care monitoring behaviours ( $P = 0.008$ ).

The eight MAIA-2 domains significantly increased explained variance in self-care management beyond that explained by demographic and clinical characteristics ( $\Delta R^2 = 0.207$ ;  $F = 15.15$ ,  $P < 0.001$ ; Cohen's  $f^2 = 0.386$ ). Higher levels of noticing and body listening were significantly associated with better self-care management behaviours ( $P < 0.05$  and  $P = 0.000$ , respectively), whereas higher levels of worrying were significantly associated with worse self-care management behaviours ( $P = 0.002$ ).

The eight MAIA-2 domains significantly increased explained variance in self-care confidence beyond that explained by demographic and clinical

**Table 1** Sociodemographic and clinical characteristics of the sample ( $n = 387$ )

Characteristic	mean $\pm$ SD or n(%)
Age (in years)	50.2 $\pm$ 17.1
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)
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)
Charlson comorbidity categories	
Mild	258 (66.7)
Moderate	103 (26.6)
Severe	26 (6.7)
Interoceptive sensibility: MAIA-2 (range 0–5, higher = more of trait)	
Noticing	3.5 $\pm$ 1.1
Distracting	1.7 $\pm$ 1.1

Continued

**Table 1 Continued**

Characteristic	mean±SD or n(%)
Worrying	2.6 ± 0.9
Attention regulation	3.0 ± 1.2
Emotional awareness	3.3 ± 1.2
Self-regulation	2.9 ± 1.5
Body listening	2.8 ± 1.4
Trust	3.2 ± 1.4
Self-Care of Chronic Illness Inventory (range 0–100, higher = better)	
Self-care maintenance	73.3 ± 17.4
Self-care monitoring	75.7 ± 19.3
Self-care management	69.9 ± 21.3
Self-care confidence	72.2 ± 19.4

SD, standard deviation; MAIA, Multidimensional Assessment of Interoceptive Awareness.

characteristics ( $\Delta R^2 = 0.230$ ;  $F = 17.72$ ,  $P < 0.001$ ; Cohen's  $f^2 = 0.431$ ). Higher levels of noticing, body listening, and trust were significantly associated with higher confidence in self-care ( $P = 0.01$ ,  $P = 0.001$ , and  $P = 0.01$ , respectively), whereas higher levels of distracting were significantly associated with lower confidence in self-care ( $P < 0.05$ ).

## Discussion

In this study, we aimed to examine the associations between interoceptive sensibility and self-care behaviours in people with CVD. We found that interoceptive sensibility explained the variance of self-care management the most and of self-care monitoring the least. Additionally, we found that interoceptive sensibility domains were differently associated with self-care dimensions. Notably, aspects of interoceptive sensibility, such as trust, body listening, and noticing, were positively associated with self-care, while distraction, self-regulation, and worrying were associated with poorer self-care behaviours. These findings highlight the complexity of interoceptive sensibility in shaping self-care dimensions, suggesting potential targets for interventions aimed at ultimately improving self-care in individuals with CVDs.

The interoceptive sensibility domains of the MAIA-2 seem to reflect aspects of both self-care monitoring and management behaviours. Indeed, aspects such as body listening and noticing explore how prone a person is in listening to their body and monitoring body sensations (i.e. self-care monitoring<sup>13,29</sup>), while aspects such as self-regulation, distraction, and worrying explore how a person reacts to body signals (i.e. self-care management<sup>23,29</sup>). In our sample, we observed that interoceptive sensibility explained the variance of self-care management the most. This suggests that the interoceptive sensibility domains of the MAIA-2 can inform on how much a person is aware of her body signals and prone to listen to them (i.e. self-care monitoring), but they can inform even more on how a person intentionally engages to emotionally and pragmatically embrace and respond to them (i.e. self-care management). Thus, these results suggest that interoceptive sensibility as measured by the MAIA-2 should be seen not only as assessing self-care monitoring, but also especially self-care management behaviours. This is important because it provides novel evidence on the association between interoception and self-care management, as most of the existing studies so far have explored the association between interoceptive domains and symptom perception, but not between interoception and

symptom management and/or self-care management.<sup>14</sup> Since one ultimate goal is to improve symptoms through improvements in self-care, based on the results of study, it would be very meaningful to test interventions targeting interoceptive sensibility to improve self-care management and, ultimately, improve symptom perception and reduce symptom burden.

Some interventions such as meditation techniques, yoga, breathing exercises, and physical exercises<sup>30–32</sup> have been suggested as being able to improve interoceptive abilities and, eventually, clinical outcomes including pain, cardiovascular, and psychological symptoms.<sup>14,30</sup> Mindfulness, in particular, has been shown to produce neuroplasticity effects by modulating the insula (i.e. the area of the brain responsible for interoception), by cultivating sustained attention to bodily sensations, eventually resulting in improved interoception.<sup>31</sup> Such results may support interoceptive sensibility as the hypothesized link between mindfulness and enhanced self-care,<sup>18,33</sup> and in that regard, the results of the present study add evidence to such hypothesized link by showing the association between interoceptive sensibility and self-care in chronic disease.

Based on that, it might be tempting to try increasing interoception at all costs. However, it is important to remember that the ultimate goal of any future intervention should not simply be to increase interoception but also to improve self-care skills.<sup>21</sup> Indeed, solely augmenting interoceptive abilities (and not also self-care abilities at the same time) might cause distress especially in population suffering from higher anxiety,<sup>34</sup> or with neurodivergent or psychiatric conditions.<sup>35</sup> Indeed, it has been shown that, for example, in people with anxiety, enhanced, exaggerated/distorted interoceptive abilities led to over-reacting and taking risky decisions when anticipating negative stimuli (e.g. a symptom) or facing challenging situations.<sup>36,37</sup> Furthermore, in chronic disease, an overactive insula could lead to distorted or exaggerated perceptions of bodily sensations<sup>38</sup> as well as to altered decision-making because of its role in estimating the magnitude and probability of expected outcomes in relation to bodily signals.<sup>38,39</sup> For these reasons, future interventions should not simply aim to improve interoception alone (i.e. without addressing self-care at the same time) or all interoceptive domains (i.e. accuracy, sensibility, and awareness) in the same way,<sup>40,41</sup> or equally for every population (e.g. individuals with a chronic physical disease or individuals with a psychiatric condition).<sup>35</sup> Instead, researchers should aim to personalize interoceptive domains training<sup>21</sup> and to concurrently improve other abilities to allow patients to elaborate and interpret body sensations in a self-regulatory and adaptive way<sup>31</sup> and, in general, to perform appropriate self-care management whenever needed.<sup>21,42</sup>

The specific associations between the MAIA-2 domains and self-care monitoring and management should be further investigated because they may vary among different populations. First, there might be a difference in how much interoceptive sensibility explains self-care monitoring and/or management based on the stage of the disease. For example, those suffering from chronic disease for a longer time may have developed more of a specific trait of interoceptive sensibility. For example, these patients may tend to automatically respond to symptoms they have become used to, without even paying much attention to listening to their body. Second, there might be a difference between physical and psychological conditions. In psychological conditions, interoceptive sensibility can play a more relevant role in individuals' ability to regulate their emotions and psychological symptoms<sup>43</sup> (i.e. management), but these patients might start engaging in body listening (i.e. monitoring) which could, however, trigger higher emotional distress<sup>44</sup> leading to suspending subsequent management behaviours. In physical conditions (e.g. heart failure), instead, interoceptive sensibility has been shown to be more associated with the process of symptom perception (i.e. monitoring)<sup>45</sup> and a meta-analysis on patients with chronic pain reported higher levels of attention to bodily sensations (i.e. monitoring) and lower on emotional regulation (i.e.

**Table 2** Unadjusted model of interoceptive sensibility and self-care in individuals with cardiovascular disease

MAIA-2 domains	Maintenance	Monitoring	Management	Confidence
Noticing	1.31 ± 0.97	<b>2.64 ± 1.14</b>	2.06 ± 1.15	<b>2.48 ± 1.07</b>
Distracting	<b>-1.78 ± 0.82</b>	-1.41 ± 0.95	<b>-2.04 ± 0.97</b>	-1.21 ± 0.90
Worrying	1.35 ± 0.87	1.26 ± 1.01	<b>-4.07 ± 1.04</b>	-0.24 ± 0.97
Attention regulation	1.64 ± 1.08	1.90 ± 1.26	-0.42 ± 1.31	2.14 ± 1.21
Emotional awareness	0.36 ± 0.102	0.90 ± 1.19	1.12 ± 1.22	0.01 ± 1.14
Self-regulation	1.84 ± 1.03	<b>-2.90 ± 1.20</b>	-0.91 ± 1.24	-0.45 ± 1.15
Body listening	1.21 ± 0.95	<b>5.16 ± 1.12</b>	<b>5.49 ± 1.14</b>	<b>3.04 ± 1.05</b>
Trust	<b>2.50 ± 0.78</b>	0.74 ± 0.91	0.93 ± 0.95	<b>3.11 ± 0.87</b>
R <sup>2</sup>	0.391	0.328	0.399	0.391

Significant results are reported in bold.

MAIA, Multidimensional Assessment of Interoceptive Awareness; R<sup>2</sup> = R squared, coefficient of determinants.

**Table 3** Results from the adjusted hierarchical modelling of interoceptive sensibility and self-care in individuals with cardiovascular disease

MAIA-2 domains	Maintenance	Monitoring	Management	Confidence
Noticing	1.38 ± 0.95	<b>2.92 ± 1.17</b>	<b>2.59 ± 1.21</b>	<b>2.63 ± 1.11</b>
Distracting	<b>-2.54 ± 0.78</b>	-1.61 ± 0.95	-1.79 ± 0.99	<b>-1.91 ± 0.91</b>
Worrying	0.50 ± 0.87	0.35 ± 1.07	<b>-3.45 ± 1.13*</b>	-0.26 ± 1.04
Attention regulation	1.36 ± 1.06	0.95 ± 1.29	-0.34 ± 1.37	1.61 ± 1.26
Emotional awareness	0.57 ± 0.98	1.40 ± 1.21	1.32 ± 1.27	0.34 ± 1.71
Self-regulation	1.94 ± 1.00	<b>-3.26 ± 1.22</b>	-1.44 ± 1.29	-0.51 ± 1.20
Body listening	<b>2.08 ± 0.92</b>	<b>5.85 ± 1.15</b>	<b>4.84 ± 1.19</b>	<b>3.58 ± 1.10</b>
Trust	<b>1.52 ± 0.76</b>	0.54 ± 0.93	1.22 ± 0.98	<b>2.26 ± 0.91</b>
ΔR <sup>2</sup> /Cohen's f <sup>2</sup>	0.271/0.577	0.235/0.411	0.207/0.386	0.230/0.431
Total R <sup>2</sup>	0.529	0.428	0.464	0.466

Significant results are presented in bold. The variables that were controlled for in this adjusted hierarchical modelling were age, gender, marital status, race, education, employment, cardiovascular disease, and comorbidity.

MAIA, Multidimensional Assessment of Interoceptive Sensibility.

management).<sup>46</sup> However, in this study on patients with CVD, we found a stronger association between interoceptive sensibility and self-care management. Furthermore, in a previous study on this CVD sample,<sup>21</sup> we also found that (i) higher interoceptive sensibility was associated with higher self-care management and (ii) in the case of psychological symptoms (e.g. anxiety), higher interoceptive sensibility had a protective role because at low levels of anxiety corresponded high self-care management, but at high level of anxiety corresponded poor self-care management, unless interoceptive sensibility was high. Additionally, a previous systematic review reported that higher interoceptive sensibility was associated with lower symptom burden across chronic conditions.<sup>14</sup> Thus, the results of the present study, together with all this prior knowledge, can suggest that higher interoceptive sensibility entails higher body listening and better detection of body changes, as well as potentially greater ability to emotionally process those signals without over-worrying and over-reacting, which, in turn, can lead to greater chances to practically manage those changes through self-care management. In that regard, we indeed found that higher worrying was associated with worse self-care management.

In this study, we found that higher distraction from body sensations was associated with worse self-care management and lower confidence

in self-care abilities. This interestingly adds up to previous evidence showing that (i) paying attention to body sensation is key to adaptively manage body signals, even the most distressing ones like the symptoms of a burdening chronic disease,<sup>19</sup> (ii) higher attention to body sensation, instead of distracting, can result in greater symptom relief,<sup>14,47</sup> and (iii) higher distraction negatively moderates the association between symptoms and self-care management.<sup>21</sup> Thus, this might suggest that higher interoceptive sensibility (and, in particular, lower distraction, or, in other words, higher ability of not distracting from body sensations) can lead to better self-care management and to greater symptom relief.

Interoceptive sensibility, by definition, reflects how much a person believes to be able to process body signals. Through the MAIA-2, it is possible to assess how well they believe they are doing this. This aspect clearly entails aspects of confidence in one's own ability to do so. The results of this study suggest that (i) the more one trusts his/her body and the relevance of the signals it generates (i.e. *trust* domain of the MAIA-2), the more confident the person will be in his/her abilities to detect and process them (i.e. self-care confidence); (ii) the more one believes to be able to listen to his/her body and notice body changes (i.e. *body listening* and *noticing* domains of the MAIA-2), the more confident the person will feel about his/her self-care abilities (indeed, we

found that both body listening and noticing were positively associated with self-care confidence); and (iii) the more one believes to distract from his/her body sensations, the less confident that person will feel in his/her self-care abilities (to process and respond to potential body changes).

## Limitations

This study has some limitations. First, it is a cross-sectional study, so it does not allow to investigate causal relationships nor changes of the patterns over time. Second, the relatively young age of participants in our sample may reduce generalizability of the results to other older populations. In fact, studies reported that the elderly can experience changes in adrenergic function which leads to decline in interoceptive abilities<sup>48</sup> and higher tendency to distract from body sensations.<sup>49</sup> However, our sample was heterogeneous in terms of gender and race, which can enhance external validity. Third, potential psychosocial factors that could affect self-care have not been taken enough into consideration in this analysis. Finally, chronic conditions and their severity were self-reported, while more objective collection of this information could enhance accuracy in future studies to build upon the results of this research. Besides that, this study provides initial and innovative evidence on the relationship that exists between interoceptive sensibility and self-care dimensions.

## Conclusions

Interoceptive sensibility domains are associated with all the self-care dimensions, especially management. Greater interoceptive sensibility entails better body listening and detection of body changes, as well as potentially greater ability to emotionally regulate without over-worrying, which, in turn, can lead to better self-care management. Thus, paying attention to body sensation is key to adaptively process and manage body signals, but patients should also be given knowledge on how to perform appropriate self-care management.

This is particularly important because it can suggest that targeting interoceptive sensibility might be a way to improve self-care management. Further research should examine the causal relationships between interoceptive sensibility and self-care behaviours in chronic disease by adopting other study designs (such as longitudinal designs or randomized controlled trials) and by including more potential covariates affecting self-care (e.g. psychosocial variables). This could help further deepening our understanding of how interoceptive sensibility influences self-care practices and could inform future interventions more comprehensively.

To summarize, different domains of interoceptive sensibility played different roles in the relationships to different types of self-care and self-care confidence. Thus, this suggests that tailored interventions need to be provided to individuals with CVDs, considering those domains of interoceptive sensibility and dimensions of self-care, to improve self-care and self-care confidence and ultimately reduce symptoms.

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## Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

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