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Review Article

# Use of heart rate variability in predicting frailty in older adults: a scoping review

## Uso da variabilidade da frequência cardíaca na predição da fragilidade em pessoas idosas: revisão de escopo

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**ABSTRACT**

**Objective:** to map the evidence on the use of heart rate variability as a predictor of frailty in older adults. **Methods:** scoping review conducted in eight national and international databases and two thesis and dissertation catalogs, with no time or language restrictions. Studies addressing older adults (population), heart rate variability (concept), and its application in the assessment or prediction of frailty (context) were included. Study selection was performed by independent reviewers, and the data were synthesized descriptively. **Results:** 15 studies were included, which highlighted the use of heart rate variability in association with other functional markers, as well as the increasing use of wearable sensors in frailty assessment. **Conclusion:** heart rate variability is a promising physiological marker for the early screening of frailty in older adults, with the potential to support more effective and timely care. **Contributions to practice:** the findings may support monitoring of older adults' health and the planning of patient-centered interventions in the context of frailty.

**Descriptors:** Frailty; Heart Rate; Aged; Scoping Review.

**RESUMO**

**Objetivo:** mapear as evidências sobre o uso da variabilidade da frequência cardíaca como preditor da fragilidade em pessoas idosas. **Métodos:** revisão de escopo realizada em oito bases de dados nacionais e internacionais e em dois catálogos de teses e dissertações, sem restrição temporal ou de idioma. Foram incluídos estudos que abordaram pessoas idosas (população), a variabilidade da frequência cardíaca (conceito) e sua aplicação na avaliação ou predição da fragilidade (contexto). A seleção dos estudos foi realizada por revisores independentes, e os dados foram sintetizados de forma descritiva. **Resultados**: foram incluídos 15 estudos, os quais evidenciaram o uso da variabilidade da frequência cardíaca associada a outros marcadores funcionais, bem como o crescente emprego de sensores vestíveis na avaliação da fragilidade. **Conclusão:** a variabilidade da frequência cardíaca configura-se como um marcador fisiológico promissor para a triagem precoce da fragilidade em pessoas idosas, com potencial para subsidiar um cuidado mais eficaz e oportuno. **Contribuições para a prática:** os achados podem apoiar o monitoramento da saúde da pessoa idosa e o planejamento de intervenções centradas no paciente no contexto da fragilidade.

**Descritores:** Fragilidade; Frequência Cardíaca; Idoso; Revisão de Escopo.

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## Introduction

Population aging results from social, political, and economic transformations initiated in the 20th century, reflected in reduced mortality and fertility rates, with direct impacts on the age structure and global epidemiological profile[1]. The proportion of older adults worldwide is estimated to increase from 10% to 22% between 2000 and 2050, reaching approximately 2 billion individuals aged 60 years or older. In Brazil, the 2022 Demographic Census indicates more than 32 million older adults, corresponding to a 56% increase compared with 2010, with a continuing growth trend in the coming decades[2].

From a physiological perspective, aging is a gradual, irreversible, and multifaceted process characterized by the progressive reduction of cell proliferation, differentiation, and function, with repercussions across several tissues and organs[3]. In addition to biological changes, it involves social and individual dimensions, resulting in different aging trajectories. This dynamic process compromises adaptive capacity and increases vulnerability to internal and external stressors, raising the risk of morbidities, hospitalizations, dependence, and death[3-4]. In this scenario, frailty syndrome stands out, marked by physical dysfunctions associated with sarcopenia and endocrine and neurological changes, expressed by a cycle of weight loss, exhaustion, reduced physical activity, decreased muscle strength, and slow gait, culminating in a higher risk of falls, hospitalizations, and mortality[5-7].

Severe frailty is associated with reduced resilience and adaptive capacity to environmental stressors, involving changes in homeostatic systems, especially the autonomic nervous system. Heart Rate Variability (HRV) is an indirect method for assessing autonomic modulation by analyzing variations between consecutive R–R intervals, reflecting the organism's adaptive capacity[7]. High HRV values indicate better autonomic adaptation, whereas reduced values suggest dysfunction or insufficient adaptation. In this context, it is plausible that HRV is altered in frail older adults, and the use of technologies such as wearable sensors has shown promise for monitoring and early detection of frailty risk, supporting more timely interventions[5-7].

In this sense, increased longevity poses a challenge to the health system to develop initiatives that enable the early detection of conditions related to functional vulnerability, such as frailty syndrome. To this end, it is essential that health professionals recognize new ways of providing care by adopting preventive approaches. In this scenario, growing interest has emerged in the use of HRV as a functional marker in older adults, especially due to advances in technologies that allow its measurement in a more accessible and noninvasive manner. Given this scenario, conducting a scoping review is appropriate because it allows the identification, mapping, and characterization of the available evidence, as well as the knowledge gaps on the topic.

It should be noted that a preliminary search was conducted in the Open Science Framework (OSF), the Database of Abstracts of Reviews of Effects (DARE), and the Cochrane Library, and no scoping review on a similar topic was identified. Therefore, the research protocol was registered in the OSF.

In this context, this review sought to answer the following guiding question: What evidence is available on the measurement of HRV as a predictor of frailty in older adults? Based on this, the present study aimed to map the evidence on the use of heart rate variability as a predictor of frailty in older adults.

## Methods

### Study type

A scoping review was conducted in accordance with JBI recommendations[8] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)[9]. A research protocol was duly registered on the OSF platform under the following identification number: https://doi.org/10.17605/OSF.IO/Y3V4J.

## Research question

The research question was developed based on the Population, Concept, and Context (PCC) strategy: "What evidence is available on the measurement of HRV as a predictor of frailty in older adults?" P (population) was considered older adults; C (concept), heart rate variability; and C (context), frailty.

## Inclusion and exclusion criteria

Data collection was conducted between August and October 2024, with an additional refinement in March 2025 to update the results. The mapping process was carried out by two independent reviewers. As there was no disagreement between the reviewers, the intervention of a third reviewer to resolve possible discrepancies was not necessary.

Based on the PCC acronym, this scoping review included studies that investigated HRV as an instrument for assessing or predicting frailty in older adults. Studies with nonfrail, prefrail, or frail individuals were eligible, provided that frailty was measured using validated instruments or recognized criteria. There was no restriction regarding the theoretical model of frailty, as long as it was clearly defined and operationalized. Studies that used validated methods or technologies to measure HRV were included, with no restrictions on design, period, or language. Opinion studies, letters to the editor, preliminary notes, and studies unavailable in full text after an attempt to contact the corresponding author were excluded.

Additionally, a manual search was performed in the reference lists of the included studies after full-text reading, with the aim of identifying potentially relevant publications that had not been retrieved through the initial electronic search strategies. Studies identified through this complementary search were subjected to the same eligibility criteria and selection process applied to records from the databases.

## Selection of information sources and strategy for identifying, selecting, and extracting data

To develop a highly sensitive search strategy, controlled vocabularies aligned with the PCC mnemonic were identified from the Health Sciences Descriptors (DeCS), Embase Subject Headings (EMTREE), and Medical Subject Headings (MeSH), including descriptors and their synonyms in Portuguese, English, and Spanish. Subsequently, a preliminary pilot test was conducted in the Medical Literature Analysis and Retrieval System Online (MEDLINE), via PubMed, and Latin American and Caribbean Health Sciences Literature (LILACS), via the Virtual Health Library (VHL).

At this stage, the terms present in titles, abstracts, and descriptors were analyzed in order to identify related vocabulary. The search strategies were built by combining controlled vocabularies and free terms, with the aim of broadening sensitivity and specificity in study retrieval. Descriptors indexed in MeSH and DeCS were used, as well as terms from the controlled vocabulary specific to the Cumulative Index to Nursing and Allied Health Literature (CINAHL), while respecting the particularities of each database.

Searches were conducted across a broad spectrum of national and international databases and platforms: MEDLINE, SCOPUS, CINAHL, Scientific Electronic Library Online (SciELO), Web of Science, Excerpta Medica Database (EMBASE), LILACS, and the Nursing Database (BDENF).

Additionally, gray literature sources were consulted, such as the CAPES Theses and Dissertations Portal and the Brazilian Digital Library of Theses and Dissertations (BDTD) of the Brazilian Institute of Information in Science and Technology. Furthermore, potentially relevant studies were searched for in the references of the included articles.

The search strategies were adapted to the controlled vocabulary and indexing structure of each database, using MeSH descriptors in MEDLINE, Emtree in EMBASE, and DeCS in the Latin American databases. Controlled terms were combined with free keywords to increase search sensitivity. The searched fields included title, abstract, and descriptors, according to each database. In databases without standardized controlled vocabulary, such as SCOPUS and Web of Science, only free terms were used in the title, abstract, and keyword fields. The search strategies are detailed in Figure 1.

| Database | Fields | Descriptors/keywords used |
|---|---|---|
| MEDLINE | MeSH + Title/ Abstract | (("Aged"[MeSH] OR "Aged, 80 and over"[MeSH] OR "Frail Elderly"[MeSH] OR older adult*[tiab] OR elderly[tiab] OR geriatric*[tiab] OR aging[tiab] OR aged[tiab]) AND ("Heart Rate Variability"[MeSH] OR heart rate variab*[tiab] OR HRV[tiab] OR "RR interval"[tiab] OR "R-R interval"[tiab] OR "beat-to-beat"[tiab] OR "cardiac autonomic"[tiab] OR "autonomic modulation"[tiab] OR vagal[tiab] OR sympathovagal[tiab]) AND ("Frailty"[MeSH] OR frail*[tiab] OR prefrail*[tiab] OR "frailty syndrome"[tiab] OR "physical frailty"[tiab] OR "frailty phenotype"[tiab] OR "frailty index"[tiab])) |
| EMBASE | Title/Abstract/ Keywords | ((TITLE-ABS-KEY("heart rate variab*" OR HRV OR "RR interval" OR "R-R interval" OR "beat-to-beat" OR "cardiac autonomic" OR "autonomic modulation" OR vagal OR sympathovagal)) AND (TITLE-ABS-KEY(frail* OR prefrail* OR frailty OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index")) AND (TITLE-ABS-KEY(elderly OR "older adult*" OR aged OR geriatric* OR aging))) |
| SCOPUS | TITLE-ABS-KEY | (TITLE-ABS-KEY("heart rate variab*" OR HRV OR "RR interval" OR "R-R interval" OR "beat-to-beat" OR "cardiac autonomic" OR "autonomic modulation" OR vagal OR sympathovagal) AND TITLE-ABS-KEY(frail* OR prefrail* OR frailty OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index") AND TITLE-ABS-KEY(elderly OR "older adult*" OR aged OR geriatric* OR aging)) |
| Web of Science | TS (Topic) | TS=(("heart rate variab*" OR HRV OR "RR interval" OR "R-R interval" OR "beat-to-beat" OR "cardiac autonomic" OR "autonomic modulation" OR vagal OR sympathovagal) AND (frail* OR prefrail* OR frailty OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index") AND (elderly OR "older adult*" OR aged OR geriatric* OR aging)) |
| CINAHL (EBSCOhost) | TI/AB + MH | ( (MH "Heart Rate Variability" OR TI ("heart rate variab*" OR HRV OR "RR interval" OR "R-R interval" OR "beat-to-beat" OR "cardiac autonomic" OR "autonomic modulation" OR vagal OR sympathovagal) OR AB ("heart rate variab*" OR HRV OR "RR interval" OR "R-R interval" OR "beat-to-beat" OR "cardiac autonomic" OR "autonomic modulation" OR vagal OR sympathovagal) ) AND (MH "Frailty" OR TI (frail* OR prefrail* OR frailty OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index") OR AB (frail* OR prefrail* OR frailty OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index") ) AND (MH "Aged+" OR TI (elderly OR "older adult*" OR aged OR geriatric* OR aging) OR AB (elderly OR "older adult*" OR aged OR geriatric* OR aging) ) ) |
| SciELO | Free text | ("variabilidade da frequência cardíaca" OR "variabilidade da frequencia cardiaca" OR "heart rate variability" OR HRV) AND (fragilidade OR frailty OR "síndrome da fragilidade" OR "frailty syndrome") AND (idoso OR idosos OR elderly OR "older adult" OR aged OR geriatric*) |
| LILACS | Tw (title/ abstract/ subject) | (tw:(idoso OR idosos OR "pessoa idosa" OR "população idosa" OR anciano OR ancianos OR elderly OR "older adult*" OR aged OR geriatric*)) AND (tw:("variabilidade da frequência cardíaca" OR "variabilidade da frequencia cardiaca" OR "heart rate variability" OR HRV OR "intervalo RR" OR "intervalo R-R" OR "intervalo R R" OR "batimento a batimento" OR "sistema nervoso autonômico" OR "modulação autonômica")) AND (tw:(fragilidade OR "síndrome da fragilidade" OR "fragilidade física" OR frailty OR frail* OR prefrail* OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index")) |
| BDENF | Tw (title/ abstract/ subject) | (tw:(idoso OR idosos OR "pessoa idosa" OR "população idosa" OR anciano OR ancianos OR elderly OR "older adult*" OR aged OR geriatric*)) AND (tw:("variabilidade da frequência cardíaca" OR "variabilidade da frequencia cardiaca" OR "heart rate variability" OR HRV OR "intervalo RR" OR "intervalo R-R" OR "intervalo R R" OR "batimento a batimento" OR "sistema nervoso autonômico" OR "modulação autonômica")) AND (tw:(fragilidade OR "síndrome da fragilidade" OR "fragilidade física" OR frailty OR frail* OR prefrail* OR "frailty syndrome" OR "physical frailty" OR "frailty phenotype" OR "frailty index")) |
| Gray literature | Free text | ("variabilidade da frequência cardíaca" OR "heart rate variability" OR HRV) AND (fragilidade OR frailty OR "síndrome da fragilidade") AND (idoso* OR elderly OR "older adult*" OR aged) |

TI/AB: Title/Abstract; TITLE-ABS-KEY: Title, Abstract, and Keywords; TS: Topic; Tw: Text word (terms in title, abstract, and subject/free text); MeSH/MH: Medical Subject Headings

**Figure 1** – Search strategies in databases. Campina Grande, PB, Brazil, 2026

### Selection of records

The selected studies were exported to the free online Rayyan Intelligent Systematic Review tool. Initially, duplicate articles were removed, and the eligibility screening process was carried out by reading titles, abstracts, and objectives, according to the inclusion and exclusion criteria.

After this stage, the studies addressing the topic were read in full. The sample consisted of articles freely available in full text, accessed through the Federated Academic Community (CAFe) of the CAPES Journal Portal. Regarding documents unavailable in full text, the authors of two articles were contacted by email; however, no response was received. The process of searching for and selecting the articles was documented by completing the PRISMA-ScR flow diagram[9].

### Extraction and analysis of the evidence

Data extraction was performed using a structured instrument developed by the reviewers in accordance with JBI recommendations, covering bibliographic and methodological information such as year of publication, journal, country, and study design. Specific clinical and methodological data were also collected, including characteristics of the older adult population, the method used to assess heart rate variability, and the main outcomes related to the association between HRV and frailty. The instrument was previously submitted to a pilot test that included three studies in order to verify its clarity, consistency, and adequacy, and it was adjusted before final application. No critical appraisal of methodological quality or risk of bias of the studies included in this scoping review was performed.

The Patterns, Advances, Gaps, Evidence for Practice, and Research Recommendations (PAGER) framework was used as a strategy to synthesize the findings of this scoping review. The PAGER framework is a tool developed to systematize, assess, and report information from scoping reviews in a more organized manner[10].

### Presentation, interpretation of results, and summary of evidence

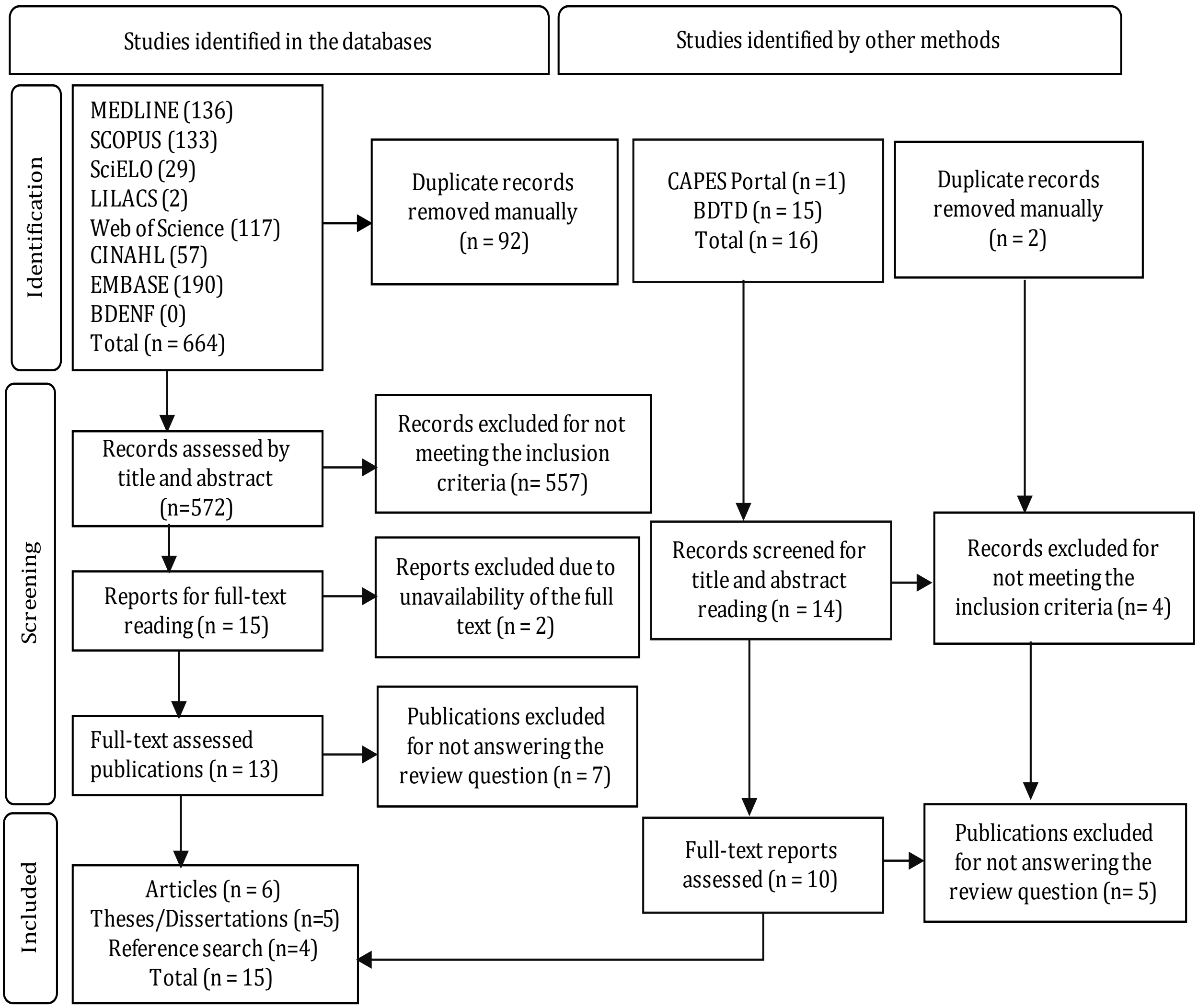
The results were presented in figure format. For organizational and presentation purposes, the selected articles were numbered and sequentially identified as E1 to E15. The main bibliographic and methodological information was categorized by year, journal, country, main results, and method (Figure 3).

### Ethical considerations

It should be emphasized that the investigation respected ethical principles, and all authors were properly referenced and cited. As this was a review study, ethics committee approval was not required.

## Results

A total of 664 studies were initially identified through the electronic databases. After removal of 92 duplicate records, 572 studies were screened by reading titles and abstracts. At this stage, 557 records were excluded for not meeting the inclusion criteria, resulting in 15 publications eligible for full-text assessment. After full-text reading, 11 studies met the review objectives and were included. Additionally, backward reference searching of the selected studies resulted in the inclusion of four publications. Thus, the final sample of this scoping review comprised 15 studies. The reasons for exclusion at each stage of the process are described in the flow diagram, in accordance with PRISMA-ScR recommendations (Figure 2).




BDTD: Brazilian Digital Library of Theses and Dissertations

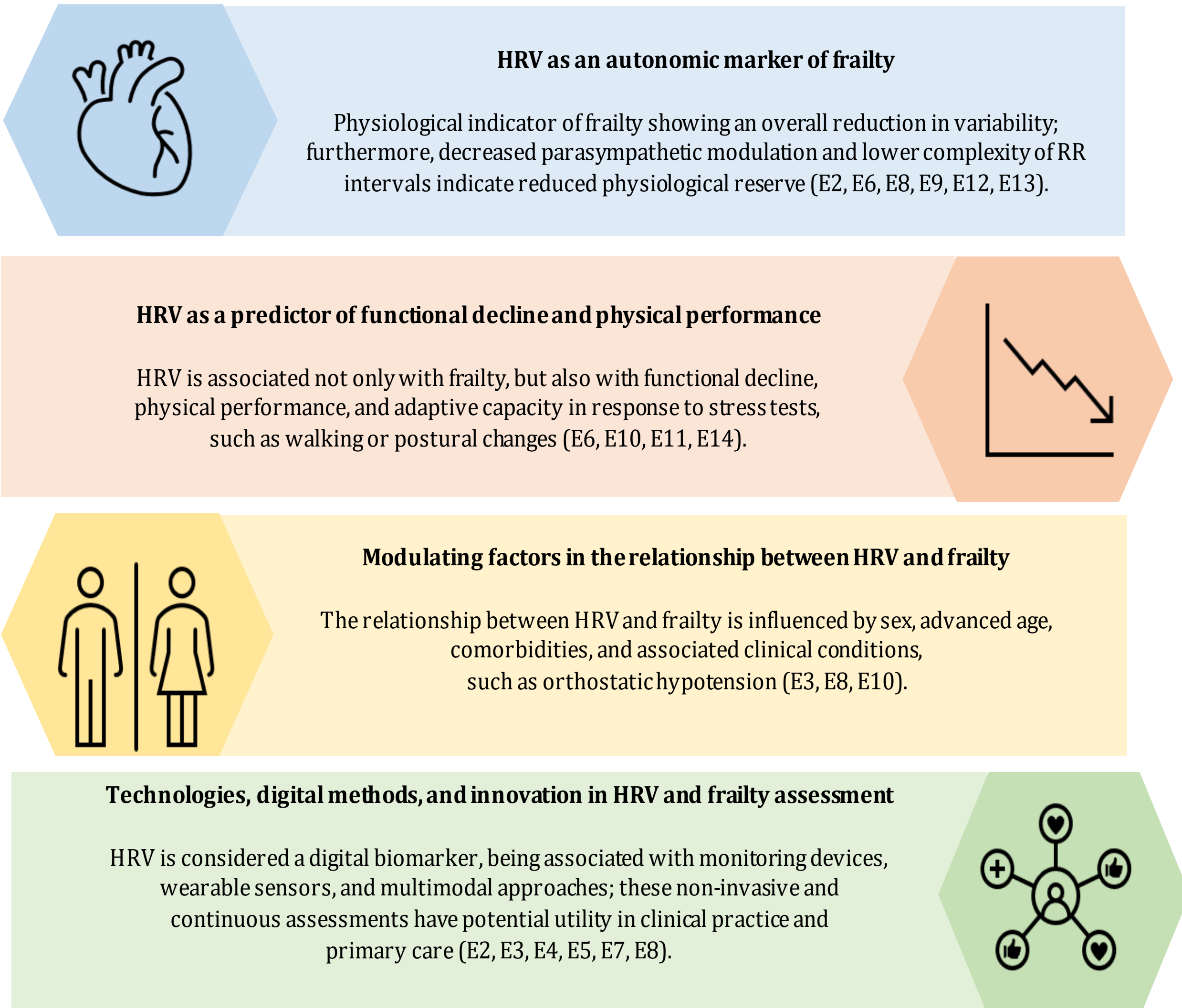
**Figure 2** – Study selection flow diagram, adapted from PRISMA-ScR. Campina Grande, PB, Brazil, 2026

The 15 studies in the sample were published between 2008 and 2025. Most of the studies were retrieved from the MEDLINE database, totaling 8 (53.3%), followed by 4 from the Brazilian Digital Library of Theses and Dissertations (26.7%), and 3 publications from SCOPUS (20%).

Regarding country of origin, 5 studies (33.3%) were conducted in Brazil (E3, E4, E9, E11, and E13), followed by 3 (20%) from the United States of America (USA) (E8, E14, and E15). There were also studies conducted in Hong Kong (E1), India (E2), China (E5), Mexico (E6), Germany (E7), and Ireland (E10).

The studies investigated the relationship between HRV and frailty in older adults. A predominance of cross-sectional design was observed, adopted by most studies, 9 (60%), including E2, E5, E6, E8, E9, E12, E13, E14, and E15. One investigation had a quasi-experimental design (E7). One publication was classified as a mixed-methods study, combining a scoping review and a cross-sectional design (E3). In addition, one systematic review with meta-analysis was identified (E1). Two studies were observational cross-sectional studies (E4 and E11), and one study used a longitudinal design (E10).

The literature indicates that HRV, when considered in isolation, has limitations and should be interpreted together with other functional markers, such as mobility and muscle strength, as well as with data obtained from technological devices used for its measurement (E1, E6, E9, E10, E11, E12, E13, E14, and E15). Figure 3 illustrates the main results of the articles.




HRV: Heart Rate Variability

**Figure 3** – Main findings in the literature. Campina Grande, PB, Brazil, 2026

Finally, 6 studies (E2, E3, E4, E5, E7, and E8) highlighted the potential of digital and noninvasive technologies for the clinical application of HRV in frailty assessment, especially in rehabilitation or home-monitoring contexts. The main purposes, characteristics, and conclusions of the studies are presented in Figure 4.

| ID* | Journal, year, and country | Results | Method |
|---|---|---|---|
| E1[11] | Arch Gerontol Geriatr 2025, Hong Kong | Both short-term and long-term models indicated lower heart rate variability (HRV) in prefrail/frail individuals compared with nonfrail individuals, although there was no heterogeneity in the data. | Systematic review and meta-analysis |
| E2[12] | Aging Med 2024, India | Frail older adults had lower parasympathetic HRV parameters ($p<0.05$), with no differences in sympathovagal balance ($p>0.05$). Frailty was negatively correlated with HRV ($p<0.001$). | Cross-sectional |
| E3[13] | BDTD, 2024, Brazil | The smartwatch was able to identify components of frailty: step count was associated with muscle weakness and physical activity level, and sleep data showed that more time spent in light sleep was linked to the presence of exhaustion. | Mixed methods (scoping review and cross-sectional study) |
| E4[14] | BDTD, 2024, Brazil | HRV behavior in sarcopenic and frail older adults showed significant correlation with the Appendicular Skeletal Muscle Mass Index (Spearman correlation coefficient [rs] = 0.82; p = 0.04), Barthel Index (rs = 0.83; p = 0.01), Maximum Speed Test (rs = 0.88; p = 0.01), Handgrip Strength (rs = 0.67; p = 0.04), International Physical Activity Questionnaire (rs = 0.92; p = 0.01), Mini Nutritional Assessment–short form (rs = 0.79; p = 0.01), and Charlson Index (rs = −0.59; p = 0.04). | Cross-sectional |
| E5[15] | BMC Geriatr 2023, China | Nonfrail patients showed HRV variations between postures ($p<0.05$), unlike prefrail patients ($p>0.05$). In the nonfrail group, Root Mean Square of the Successive Differences (RMSSD) and High Frequency (HF) were higher in the supine position (p=0.003; p=0.001), whereas Low Frequency (LF) and LF/HF were higher in the seated position (p=0.024; p=0.011). | Cross-sectional |
| E6[16] | Int J Environ Res Public Health 2022, Mexico | HRV parameters proved to be potential frailty markers, especially low frequency and the time required to reach maximum heart rate. | Cross-sectional |
| E7[17] | Gerontol 2022, Germany | Early geriatric rehabilitation resulted in improved HRV parameters, indicating possible recovery of cardiac autonomic modulation; photoplethysmography was able to identify HRV modulations, with moderate to high association with electrocardiography. | Quasi-experimental |
| E8[18] | BMC Geriatr 2022, USA | Prefrail and frail individuals showed 47% lower HRV variations during and after the Upper-Extremity Function test compared with nonfrail individuals ($p<0.01$). | Cross-sectional |
| E9[19] | BDTD, 2019, Brazil | Women showed higher values of High Frequency (HF - parasympathetic) and Sample Entropy (complexity) compared with men. | Cross-sectional |
| E10[20] | CMAJ, 2015, Ireland | Reduced HRV is associated with a higher risk of functional decline in older adults, affecting daily activities regardless of sex, age, or heart disease. | Longitudinal |
| E11[21] | BDTD, 2015, Brazil | HRV and systolic blood pressure variability, when assessed in isolation, do not change in the presence of frailty. | Cross-sectional |
| E12[22] | Aging Clin Exp Res 2015, Brazil | The frail group showed greater sympathetic modulation and lower parasympathetic modulation compared with the other groups. | Cross-sectional |
| E13[23] | BDTD, 2015, Brazil | All groups reduced complexity when standing up, but frail individuals were not worse than the others. | Cross-sectional |
| E14[24] | J Gerontol A Biol Sci Med Sci 2009, USA | Parameters related to age, frailty, and mortality highlight the relationship between frailty and cardiac autonomic dysfunction reflected in HRV. | Cross-sectional |
| E15[25] | J Am Geriatr Soc 2008, USA | Frail participants had lower cardiac entropy than nonfrail participants (p=0.02), indicating lower cardiac complexity. Low cardiac entropy values and reduced HRV, even after adjustments, were associated with frailty. | Cross-sectional |

ASMI: Appendicular Skeletal Muscle Mass Index; MST: Maximum Speed Test; HGS: Handgrip Strength; IPAQ: International Physical Activity Questionnaire; MNA-SF: Mini Nutritional Assessment – Short Form; IPPG: Imaging Photoplethysmography; BDTD: Brazilian Digital Library of Theses and Dissertations

**Figure 4 –** Characterization of the studies according to year, country, journal, main results, and method. Campina Grande, PB, Brazil, 2026

Patterns, advances, gaps in the literature, evidence for practice, and research recommendations were presented according to the PAGER framework (Figure 5).

| Patterns | Advances | Gaps | Evidence for practice | Research recommendations |
|---|---|---|---|---|
| Inverse correlation[11-12,18,23] | Analysis of HRV in different older adult populations | Need for studies with larger and more heterogeneous samples | Reduced HRV is associated with frailty and functional decline | Use HRV as a marker for early frailty screening |
| HRV measurement technologies[12-15,17-18] | Noninvasive devices and combined approaches | Validation and standardization of these methods | Usefulness in monitoring frailty risk | Incorporate accessible technologies into geriatric assessment |
| Postural change and exertion[15-16] | Cross-sectional studies analyzing postural change and post-exertion response | Insufficient detection of autonomic dynamics in different postures and after activities | Differences in autonomic response between groups | Consider posture and exertional exercise in HRV-based frailty assessment |
| Influence of sex and advanced age[22,25] | Analyses stratified by sex and age group | Limited exploration across different sexes | More reliable interpretation of HRV indices | Develop robust analyses by sex and age |
| Reduction in HRV values with aging[16,19-21,24] | Inclusion of multiple HRV domains | Lack of a clinical threshold for HRV | Identification of older adults with low autonomic reserve | Define reference HRV values for older adults |

HRV: Heart Rate Variability

**Figure 5** – PAGER framework for the scoping review. Campina Grande, PB, Brazil, 2026

## Discussion

Technological advances have promoted fundamental transformations in health care, improving diagnostic and treatment methods as well as the organization of services. Consequently, with increasing life expectancy, the demand grows for technological tools that support healthy aging as well as the early identification of negative clinical outcomes[23,26].

In this scenario, instruments aimed at maintaining functionality and rehabilitating individuals affected by frailty stand out. It is well known that frail older adults have reduced physiological reserves and greater vulnerability to health problems, which compromises autonomy and independence. In view of this, technological devices are allies in health monitoring, prevention of adverse events, and self-care, making it possible to implement interventions that meet the demands of this population[25-26].

The studies reveal that such resources favor autonomous and active aging. Digital resources such as heart rate measurement cameras, Holter monitors, and mobile applications also stand out. In addition, wearable sensors appear as an accessible alternative for assessing cardiac and motor functions, such as HRV measurement[13,17,24].

The development of wearable technologies enables the monitoring of physiological parameters, such as HRV, allowing the early identification of negative outcomes in older populations. Moreover, HRV analysis, combined with computational algorithms and artificial intelligence, supports preventive and individualized interventions in the health care of older adults[27-28].

Noninvasive assessment emerges as a methodological alternative for older adults with physical limitations, which may compromise the applicability of conventional methods. In this context, devices equipped with integrated sensors enable continuous monitoring of physiological parameters, such as sleep patterns, physical activity level, and muscle strength[16,18].

Photoplethysmography, used in wearable sensors, demonstrates the ability to identify changes in autonomic modulation associated with a positive prognosis. Thus, the usefulness of assistive technologies and noninvasive monitoring as initiatives to promote the health and functionality of older adults in the context of frailty is evident. Furthermore, this technological resource proved effective in detecting different degrees of frailty, highlighting its relevance in follow-up and interventions aimed at geriatric rehabilitation[17].

In this way, the use of digital biomarkers stands out as a tool in the multidimensional assessment of frailty in older adults. Physiological and behavioral signals, when analyzed together, help predict clinical changes, which reinforces the importance of incorporating technology into clinical practice and health surveillance for older adults[16,18].

HRV, understood as the oscillation between heartbeat intervals, reflects autonomic nervous system activity, since high values suggest greater adaptive capacity of the organism, whereas reduced values indicate vulnerability to stressors and lower functional reserve[5,17,29]. Studies show that frail older adults have lower HRV than nonfrail older adults, reinforcing its association with frailty. In this regard, HRV analysis can be performed using linear and nonlinear methods, providing data on sympathetic and parasympathetic system activity[12,15-16].

HRV can be assessed using linear and nonlinear methods. Linear methods include time-domain analysis, which evaluates intervals between beats through indicators such as Standard Deviation of NN intervals (SDNN), Root Mean Square of Successive Differences (RMSSD), Number of pairs of successive NN intervals that differ by more than 50 ms (NN50), Proportion derived by dividing NN50 by the total number of NN intervals (PNN50), and frequency-domain analysis, which examines the contribution of different spectral bands to autonomic modulation, including High Frequency (HF), Low Frequency (LF), the low-to-high frequency ratio (LF/HF), and Very Low Frequency (VLF)[16,19,29-30].

Nonlinear methods use indicators capable of capturing complex patterns of cardiac dynamics, such as Standard deviation 1 (SD1), Standard deviation 2 (SD2), the short- to long-term variability ratio (SD1/SD2), Approximate Entropy (ApEn), and Sample Entropy (SampEn)[16]. The integrated analysis of these parameters has proven useful for differentiating degrees of frailty in older adults. Particular emphasis should be placed on the LF/HF ratio, which shows an inverse relationship with frailty stages and makes it possible to discriminate between frail and nonfrail individuals. In general, frail older adults present reduced values of SDNN, RMSSD, HF, and LF/HF, reflecting lower heart rate variability and reduced parasympathetic activity[19,31-33].

Reduced HRV indicates that the organism is not able to adapt to stressors. In summary, autonomic modulation showed changes in response to postural changes in older adults, such as transitions among standing, sitting, and supine positions. These postural variations require adjustment mechanisms of the organism, which are commonly preserved in nonfrail older adults. However, in prefrail individuals, this regulatory capacity is deficient, which is reflected in changes in HRV parameters[15]. The ability to modulate heart rate in response to physiological stimuli, such as performing an activity, is limited in older adults with frailty. This functional reduction, in turn, compromises the post-exertional chronotropic response, which implies lower HRV indices[16].

Among older women classified as frail, greater sympathetic modulation and lower parasympathetic modulation were observed when compared with nonfrail and prefrail women. This implies lower adaptive capacity to stress, higher cardiovascular risk, and a negative functional prognosis[22]. Thus, HRV is associated with functional decline in older adults, reinforcing its use as an early, noninvasive biomarker of frailty[20]. However, it should be clarified that measurement during a single visit did not prove effective, highlighting the importance of longitudinal HRV monitoring as a preventive measure against the vulnerability of the older population[32].

Furthermore, the integration between digital technologies and care has expanded the scope of longitudinal monitoring of older adults. In this regard, remote monitoring of physiological parameters makes clinical safety feasible and favors evidence-based decision-making, contributing to personalized care and high-quality assistance[33-34].

In the context of population aging, the introduction of technological tools in health care emerges as an initiative capable of optimizing functional assessment and care management. From this perspective, the use of devices favors the detection of vulnerabilities, supports preventive actions, and strengthens person-centered care for older adults[12,35].

In addition, functional assessment associated with digital technologies is fundamental for promoting healthy aging. The use of objective measurement methods allows greater clinical precision and can contribute to the planning of more effective interventions, especially in contexts of continuous and home care[21,36].

Moreover, incorporating technologies into the care of older adults should involve articulation with the nursing work process, emphasizing comprehensive care and multidimensional assessment. Thus, the application of technological tools in care makes it possible to identify vulnerabilities earlier, improves care planning, and reinforces practices centered on the functionality and autonomy of older adults. In this context, integrating different technologies into care expands the alternatives for clinical monitoring and favors a more systematized approach adapted to the needs of population aging[37].

It should be emphasized that, in the context of nursing practice, the findings of this review indicate that HRV may constitute a relevant complementary tool for the care of older adults through patient-centered care planning, with a focus on preserving functionality, preventing adverse events, and strengthening self-care. The growing incorporation of noninvasive technologies into the nursing work process aligns with the contemporary demands of population aging.

## Study limitations

As limitations of this review, the predominance of studies with cross-sectional design and small samples stands out, which restricts the methodological diversity of the evidence available on the topic. In addition, there is a shortage of research exploring autonomic dynamics in situations such as postural changes or responses to physical exercise. Moreover, although wearable devices are emerging technologies, they still require validation and standardization for clinical use.

## Contributions to practice

The use of heart rate variability as a functional marker may support nursing practice by enabling continuous monitoring of older adults' physiological responses to clinical and functional stressors, which may favor the early identification of frailty and contribute to the planning of individualized interventions.

## Conclusion

It is concluded that measuring heart rate variability constitutes a noninvasive and promising strategy for frailty screening in older adults, since the reduction in autonomic parameters is associated with different degrees of frailty, especially when used in an integrated manner with other functional markers.

However, the consolidation of heart rate variability as a clinical marker of frailty requires greater methodological homogeneity and the adoption of longitudinal designs that allow understanding of the dynamics of autonomic modulation over time. Moreover, technologies such as wearable sensors are viable alternatives, despite limitations related to their use in clinical practice and the need for continuous validation and standardization processes.

## Author contributions

Conceptualization and design or analysis and interpretation of data: **Inácio EDAS**. Manuscript writing or critical review of relevant intellectual content: **Silva AMR, Abdala EAR, Alves KCA, Ramos SAA**. Final approval of the version to be published: **Cabral JVB, Barbosa KTF.** Agreement to be accountable for all aspects of the manuscript, ensuring that questions related to the accuracy or integrity of any part are appropriately investigated and resolved: **Barbosa KTF**.

## Data availability

The authors declare that the raw data from data collection are available upon request from the corresponding author.

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