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Response of heart rate variability after postural change and its relationship with determinants of frailty in hospitalized older adults

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ABSTRACT

Introduction: Frailty in the elderly causes significant functional impairments, increased hospitalizations, and changes in cardiac autonomic control. During hospitalization, these impairments may be aggravated. **Objective:** To identify frailty and assess the response of heart rate variability (HRV) and its relationship with factors that contribute to frailty in hospitalized elderly people. **Methods:** Cross-sectional study at a university hospital. Older adults aged ≥60 years, with preserved cognition, hemodynamic, and respiratory stability. Clinical data, HRV monitoring, Charlson and Barthel indices, International Physical Activity Questionnaire (IPAQ), Mini Nutritional Assessment (MNAr), Appendicular Skeletal Muscle Mass Index (ASMI), handgrip strength (HGS), and gait speed test (GST) were recorded. Shapiro-Wilk, One-Way ANOVA or Kruskal-Wallis, t-test or Mann-Whitney test, and Pearson or Spearman correlation were applied, adopting a $p \leq 0.05$. **Results:** Forty elderly individuals, aged 70.28±7.06 years, were evaluated; only 11 did not present frailty criteria (27.5%), 21 were characterized as pre-frail (52.5%), and 8 were frail (20%). The HRV response correlated with the GST (rs 0.88, p=0.01), Charlson (rs -0.56, p=0.02), MNAr (rs 0.81, p=0.02), and ASMI (rs 0.82, p=0.04). HRV was similar at rest and after postural change between the frailty subgroups. **Conclusion:** In this sample, the majority presented frailty criteria. HRV values at rest and after postural change were similar between the subgroups. The HRV response was associated with functionality, physical activity, nutrition, and mortality.

Keywords: frailty; heart rate determination; aged; hospitalization; muscle strength; functional status.

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INTRODUCTION

The life expectancy of the population has been increasing every year[1] and with aging, there is a progressive increase in risk factors and the incidence of chronic noncommunicable diseases (NCDs). In 2021, the Brazilian Ministry of Health warned that 57.25% of the Brazilian population was overweight, 22.35% was obese, 26.34% had systemic

arterial hypertension, and 9.14%[2,3] had diabetes. In addition, geriatric syndromes such as frailty are highly prevalent[4].

Functional capacity peaks at age 30, and from this age onwards, there is a progressive decline in strength and function. During aging, there is also a significant reduction in functionality, autonomy, independence, and quality of life[5]. The loss of muscle mass, strength, endurance, balance, and walking speed, as well as physical inactivity, are common conditions associated with aging and present in frailty syndrome in older adults. These conditions increase the vulnerability of the elderly population, leaving them susceptible to a higher incidence of falls and hospitalizations[6].

Frailty syndrome in older adults is considered a clinical syndrome of multifactorial nature, characterized by a decline in muscle mass and strength, endurance, balance, walking performance, and low activity levels. For the screening of frailty syndrome in older adults, a non-frail elderly person is considered to not meet any of the criteria mentioned above, a pre-frail person meets one or two of the criteria, and a frail elderly person meets three or more of the criteria[6].

The ability to engage in consistent physical activity can compensate for the decline in physical fitness during aging and consequently improve the cardiovascular system[7]. Thus, functional loss, physical deconditioning, and sedentary behavior present in frailty syndrome in older adults negatively interfere with cardiovascular capacity. There is evidence of improved heart rate variability (HRV) indices as physical activity increases in older adults, and the more sedentary the behavior, the worse the HRV indices[8].

Cardiac autonomic control can be assessed by heart rate variability (HRV), which monitors the variation between R-R interval distances over a given period of time. HRV monitoring is a valuable tool, with studies in various populations demonstrating a relationship with the risk of death and cardiovascular events[9,10].

When frail, older adults are 2 to 3 times more likely to develop cardiovascular disease[9]. It is known that individuals with this type of pathology have lower heart rate variability (HRV) indices[10]. A progressive worsening of HRV indices according to the severity of the clinical condition was found in hospitalized older adults[11], and an association between reduced HRV indices and increased risk of frailty in older adults has already been demonstrated[12]. A recent study demonstrated an inverse relationship between HRV index values and the presence of frailty syndrome in older adults[13].

However, the assessment of cardiac autonomic control in response to stress, such as postural change, in hospitalized older adults and its relationship with frailty determinants has not yet been fully explored. Given this, we hypothesize that hospitalized older adults, who tend to be frail, may have worse HRV responses to postural change and that this response may be associated with worse frailty determinants.

Thus, the objective of this study was to characterize hospitalized older adults according to frailty criteria and to evaluate the relationship between HRV indices after postural change and frailty criteria.

METHODS

This is a cross-sectional observational study. The assessments were carried out in the ward of a university hospital between October 2022 and September 2023.

The study was approved by the Research Ethics Committee (approval number 5,701,000) and complied with the ethical precepts of resolution no. 466 of 2012 of the CNS. Participation in the study only occurred after signing the informed consent form (ICF). Older adults aged ≥60 years were included, who had minimal cognition preserved by the Mini-Mental State Examination (MMSE)[14] for understanding the proposed assessments (cut-off values presented in the procedures and assessments), in addition to hemodynamic and respiratory stability. The presence of chronic respiratory failure, such as chronic obstructive pulmonary disease (COPD), in conditions for assessment was eligible. Older adults with end-stage chronic diseases, pacemakers, beta-blocker use, unhealed fractures that prevented functional assessments, and significant dementia were not included. Older adults who presented with untreated dyspnea on minimal exertion were excluded from the study. Older adults who developed unstable vital signs and dyspnea on minimal exertion, acute respiratory failure, and malignant arrhythmias were excluded from the study. There was no need to interrupt the assessments.

The sample size was calculated using GPower software (3.1.9.7), using the t-test family, based on the difference between two independent means, with a priori power analysis, an effect size of 0.83, Alpha (α) of 0.05, and Beta (β) of 0.80, resulting in a minimum sample size of 40 older adults. The HRV index, Alpha 1, which expresses the complexity of the ANS, was the primary variable. The sample size was similar to that used in a recent cross-sectional study that examined the effects of posture on HRV in non-frail and pre-frail individuals[15].

Procedures and evaluations

Older adults were evaluated within 72 hours of their hospital admission. To characterize the sample, clinical data were collected from medical records: diagnostic hypothesis, comorbidities, commonly used drugs, and drugs used during hospitalization.

Assessment of cardiac autonomic control

A heart rate monitor (H10, Polar Electro Co. Ltd., Kempele, Oulu, Finland) was used to monitor heart rate (HR) and variability between R-R intervals. The heart rate monitor was connected to an elastic strap positioned on the chest of the older adults, with the data being transmitted to the Elite HRV software (version 5.5.5). The data were collected in the supine and sitting positions for 10 minutes in each position. Data processing was performed using Kubios HRV Standard software (MATLAB, Kubios HRV Standard software, version 3.5, Kuopio, Finland), obtaining a section with 256 R-R intervals[16].

To evaluate the HRV response to postural change, the delta change in values between positions was calculated. Linear indices in the domains of time (HR, i-RR, SDNN, rMSSD, and PNN50) and frequency (HF and LF) were recorded and analyzed. The nonlinear indices were: Alpha 1, Alpha 2, SD1, SD2, ApEn, and SampEn[16].

Prediction of muscle mass

The Appendicular Skeletal Muscle Mass Index (ASMI) was used to predict muscle mass[17] using the following formula by Lee et al.[18]: ASMI = (0.244 x weight) + (7.8 x height) + (6.6 x gender) - (0.098 x age) + (ethnicity - 3.3)[18], (ethnicity: -1.2 for Asians, 1.4 for African Americans, and 0 for whites or Hispanics; gender: 0 for women and 1 for men, height in meters, and age in years).

The result of the formula was divided by height squared, and individuals with ≤6.75 kg/m² (men) and ≤10.75 kg/m² (women) were classified as having insufficient muscle mass[18].

Cognitive assessment

Screening for possible cognitive changes was performed using the Mini-Mental State Examination (MMSE)[14], with a maximum score of 30 points, with 20 points for illiterate individuals, 25 for those with up to 4 years of schooling, 26.5 for those with 5 to 8 years of schooling, 28 for those with 9 to 11 years of schooling, and 29 or 30 for those with >11 years of schooling[19]. Older adults with scores ≤20 were not included in the study.

Hospital mortality

The Charlson comorbidity index was used to assess morbidity and risk of in-hospital death in patients with multiple comorbidities. The score was determined by the sum of the listed comorbidities, with a risk of death ranging from 1 (lowest) to 6 (highest)[20].

Independence for performing daily life activities

The Barthel Index was used to assess independence in performing daily life activities, with scores ranging from 0 to 100, whereby the higher the score, the more independent the individual is[21].

Level of physical activity

The International Physical Activity Questionnaire (IPAQ) was used to estimate the population's level of physical activity[22]. The World Health Organization (WHO) recommends 150 minutes per week of moderate and/or vigorous activity. Values equal to or above this are considered sufficiently active, and values below this are considered insufficiently active[23].

Nutritional assessment

The Mini Nutritional Assessment (MNAr) was used to assess nutritional status. This is a nutritional status screening tool derived from the Mini Nutritional Assessment (MNAr). The MNAr is a quick and practical clinical application tool. Nutritional status is considered normal (12 to 14 points), at nutritional risk (8 to 11 points), or malnourished (0 to 7 points)[24].

Peripheral muscle strength

Hand grip strength (HGS) was measured using a hydraulic dynamometer (JAMAR - Sammons Preston, Warrenville, United States). Cut-off values of <27 kgf in men and <16 kgf in women were considered indicative of peripheral muscle weakness[25].

Functional capacity

The Walking Speed Test (WST) was used to assess functional capacity. The distance covered (meters) was divided by the time (seconds), considering ≤0.8 m/s as poor physical performance[26]. The inability to perform the test was recorded, and the speed was considered zero for data analysis.

Frailty Screening

Following the criteria for frailty screening, adapted from Fried et al.[6], the gait speed test (GST performance ≤0.8 m/s), handgrip strength (HGS <27 kgf in men and <16 kgf in women), level of physical activity (IPAQ <150 minutes per week of moderate and/or vigorous activity) and nutritional status (MMSE ≤11 points or loss of 4.5 kg or 5% of body weight in the last year) to characterize frailty syndrome in older adults, with non-frail older adults being those who did not meet any of the criteria, pre-frail older adults being those who met one or two criteria, and frail older adults being those who met three or more criteria.

Data analysis

SPSS software (IBM SPSS Statistics, version 20) was used to perform statistical tests. The normality of the sample was tested using the Shapiro-Wilk test, and the choice of tests (parametric or nonparametric) was based on the nature of the data. Data analysis was performed by subgroups: non-frail group (NFG), pre-frail group (PFG), and frail group (FG). For intergroup comparison, the One Way ANOVA or Kruskal-Wallis tests were used, and the T or Mann-Whitney tests were used for comparison between two groups, Pearson's or Spearman's correlation, also using the amplitude of the correlation coefficient (*r* or *rs*, respectively, according to the nature of the tests used), such as small |0 to 0.25|, low |0.26 to 0.49|, moderate |0.50 to 0.69|, high |0.70 to 0.89| and very high |0.90 to 1|[27].

RESULTS

The sample consisted of 40 older adults (Figure 1), of whom only 11 did not meet the criteria for frailty, 21 were characterized as pre-frail, and eight as frail. The distribution among the subgroups was: NFG with 11 older adults (27.5%), PFG with 21 older

adults (52.5%), and FG with eight older adults (20%). The main causes of hospitalization were: gastrointestinal and abdominal disorders (10), renal disorders (9), cardiovascular diseases (9), various infections (8), COPD (5), hydroelectrolytic disorders (4), eating disorders (2), neoplasms (2), varicose veins in the lower limbs (2), unspecified encephalopathy (1), erysipelas (1), and sepsis (1). Data on the general characteristics of the Frailty subgroups are presented in table 1.

The PFG showed a significant positive correlation between the Alpha 1 index delta and GST (m/s) (rs 0.88; p=0.01) (Figure 2A and Table 2), suggesting that the greater the functional capacity, the greater the complexity of the ANS. The SD2 delta and Charlson (rs -0.56; p=0.02) showed a significant negative correlation, suggesting that the higher the number of comorbidities and the risk of mortality, the lower the complexity of the ANS (Figure 2B and Table 2). No correlation was found between the variation deltas of the HRV indices and the other instruments in the NFG.

FG showed a significant positive correlation between the delta variation of the i-RR index and MNAr (rs 0.81; p=0.02) (Figure 3A and Table 2), suggesting that the better the nutritional status, the higher the HRV. The delta of Alpha 1 and ASMI (rs 0.82; p=0.04) also showed a significant positive correlation, suggesting that the greater the muscle mass, the greater the complexity of the ANS (Figure 3B and Table 2).

The resting HRV data comparing the Frailty groups are described in table 3. No significant differences were found between the resting values in the subgroups analyzed.

The postural variation deltas of HRV indices were compared between the Frailty subgroups and are presented in table 3. Among them, no significant difference in HRV indices was found.

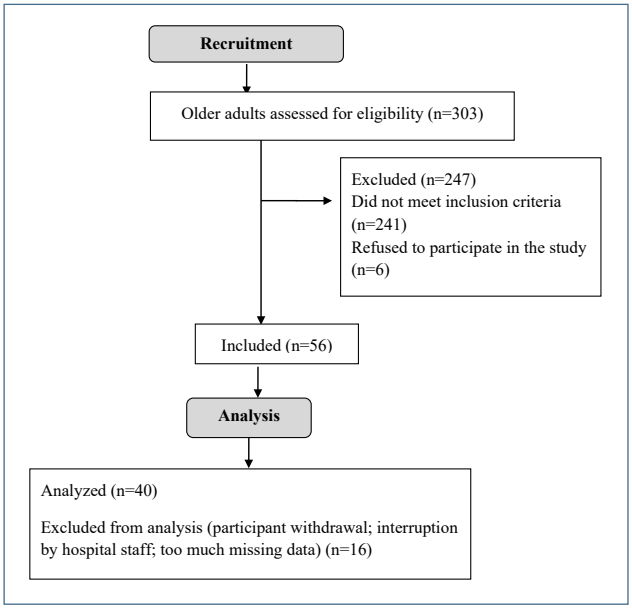

Figure 1: Study flowchart.

This may suggest a poorer ANS response to stressors in the studied population.

The comparison of questionnaire and test scores between the Frailty subgroups is shown in table 4. Significant differences were found in the IPAQ (p=0.03), MAN-r (p=0.01), and Handgrip Strength (p=0.01).

When comparing the instruments between the NFG and PFG groups, MNAr and HGS showed lower values (p<0.05) for the PFG group. When comparing these variables between the NFG and FG groups, MANr and HGS showed lower values (p<0.05) for the FG group. Among the PFG and FG groups, IPAQ and HGS showed lower values (p<0.05) for the FG group.

DISCUSSION

Main findings

In the sample evaluated, we observed a high incidence of frailty criteria (8 frail older adults (20%), 21 pre-frail (52.5%), and 11 non-frail (27.5%)). No association was found between HRV indices and frailty determinants in non-frail older adults, whereas in pre-frail older adults, an association was found between better ANS complexity (Alpha 1) and better functionality (GST), as well as worse ANS complexity (SD2) and higher mortality (Charlson).

In frail older adults, an association was found between greater HR variability (iRR) and better nutritional status (MNAr), better ANS complexity (Alpha 1), and better muscle quality (ASMI). No statistically significant difference was found in HRV indices at rest and after postural change when compared between frailty groups. Finally, in the sample evaluated, a difference was found between the level of physical activity (IPAQ), nutritional status (MNAr), and handgrip strength (HGS) among the frailty groups, indicating progressive worsening in these indicators in older adults with the presence of frailty syndrome in older adults.

HRV, functional capacity, morbidity and mortality, nutritional status, and body composition

In our study, a positive correlation was found between the Alpha 1 index and GST, suggesting a relationship between better ANS complexity and better functionality, a finding similar to a recent study that demonstrated the association between greater mobility and better cardiac autonomic function[28].

The results of our study showed a negative correlation between the SD2 index and the Charlson index, suggesting a relationship between greater complexity of the ANS and a higher number of comorbidities and in-hospital mortality. This relationship can be explained by the fact that, as we age, there is a progressive loss of the compensatory physiological reserve of the ANS in response to harmful stimuli, leaving individuals more vulnerable to the incidence of diseases[29] that have the potential to increase mortality[30].

In this study, the iRR index correlated positively with MNAr, suggesting a correlation between greater HR variability and better nutritional aspects. It is well established that eating habits rich in minerals and vitamins have the potential to increase HRV, while the opposite occurs when there is high consumption of carbohydrates and fats[31,32].

The relationship between the Alpha 1 index and ASMI indicates that the better the body composition, the greater the complexity of the ANS, consistent with recent findings that men with lower levels of visceral and body fat had higher HRV indices[33]. The combination of poor body composition and low peripheral muscle

Table 1: General characteristics of the sample - Fragility

	NFG (n=11)	PFG (n=21)	FG (n=8)	p-value
Age (years)	66.50±6.87	70.62±7.07	74.13±5.41	0.04
Weight (kg)	78.36±17.89	67.15±16.18	69.23±17.53	0.26
Height (meters)	1.64±0.09	1.64±0.08	1.64±0.08	0.78
BMI (kg/m²)	26.53±9.77	24.85±5.74	26.10±8.28	0.26
Female, n (%)	7 (63.63%)	9 (42.85%)	4 (50%)	0.37
Male, n (%)	4 (36.36%)	12 (57.14%)	4 (50%)	0.37
Oxygen therapy, n (%)	0 (0%)	3 (14.28%)	1 (12.50%)	0.37
MMSE	22.60±4.03	22±5.20	21±2.65	0.73
Clinical				
HR (bpm)	76.40±8.69	80.52±18.72	80±8.94	0.76
RR (breaths/min)	17.70±2.79	20.42±4.50	17±3	0.14
SpO_2 (%)	94.60±1.90	93.05±2.48	95±1.58	0.12
SBP (mmHg)	120±19.44	119.47±16.15	126±23.02	0.93
DBP (mmHg)	74±17.76	67.37±9.91	68±8.37	0.59
MAP (mmHg)	89.33±18.32	84.73±12.04	87.33±13.25	0.37
Previous comorbidities (n)				
SAH	2	9	3	
DM	2	6	2	
Cancers	1	3	1	
Liver disorders	1	2	2	
Kidney disorders	0	3	1	
Heart disease	1	2	1	
Previous AMI	0	4	0	
COPD	0	2	1	
Obesity	2	1	0	
Intestinal disorders	2	0	1	
Hypothyroidism	1	1	1	
Eye disorders	0	2	1	
AIDS	1	0	1	
Esophageal varices	1	0	1	
Gastric disorders	0	1	1	
Depression	0	1	0	
Peripheral vascular insufficiency	1	0	0	
Rheumatism	0	1	0	
Pulmonary fibrosis	0	1	0	
Macrocytic anemia	0	0	1	
Psoriasis	0	0	1	
Most commonly administered medications (n)				
Losartan potassium (12.5 mg)	2	4	2	
Furosemide (2 mg/kg)	1	4	2	
Isosorbide dinitrate (5 mg)	0	3	1	
Metformin (500 mg)	1	2	1	
Omeprazole (20 mg)	2	2	1	
Levothyroxine (50 mcg)	0	3	2	
Amlodipine besylate (5 mg)	2	2	2	
Enoxaparin sodium (1.5 mg/kg)	0	4	0	
Heparin sodium (150 IU/kg)	1	1	2	

Data are presented as mean and standard deviation. Kruskal-Wallis test for intergroup analysis with a significant difference of $p<0.05$. kg: kilogram; BMI: body mass index; m^2: square meter; MMSE: Mini-Mental State Examination; HR: heart rate; bpm: beats per minute; RR: respiratory rate; irm: respiratory incursions per minute; SpO_2: peripheral oxygen saturation; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; mmHg: millimeters of mercury; SAH: systemic arterial hypertension; DM: diabetes mellitus; AMI: acute myocardial infarction; COPD: chronic obstructive pulmonary disease; AIDS: acquired immunodeficiency syndrome; mg: microgram; mg/kg: microgram per kilogram; mcg: microgram; UI/kg: microliter per kilogram.

strength contributes to loss of functionality and an increase in the incidence of cardiovascular diseases[34] which, when present, worsen cardiac autonomic control[29,30].

HRV and frailty

The behavior of HRV indices during aging has raised several questions in light of controversial findings, as some studies point to an improvement in indices in the first decades of aging and reductions in the final decades of life[35], while a reduction in indices during aging has also been found[36] and all this divergence may be directly related to the heterogeneity of aging, which may or may not be healthy.

Table 2: Correlations between HRV index responses and frailty determinants.

	Rs	p-value
Pre-Fragile Group (PFG)		
Alpha 1 and GST	0.88	0.01
SD2 and Charlson	-0.56	0.02
Fragile Group (FG)		
iRR and MNAr	0.81	0.02
Alpha 1 and ASMI	0.82	0.04

Spearman's correlation for correlation analysis with a significant difference of $p<0.05$. Correlation coefficient range (Rs): small |0 to 0.25|, low |0.26 to 0.49|, moderate |0.50 to 0.69|, high |0.70 to 0.89|, and very high |0.90 to 1|. Alpha 1: short-term scale of a time series of RR-i, GST: gait speed test, SD2: continuous variability at each heartbeat, iRR: average distance between R waves in ms, MNAr: mini nutritional assessment reduced, ASMI: appendicular skeletal muscle mass index.

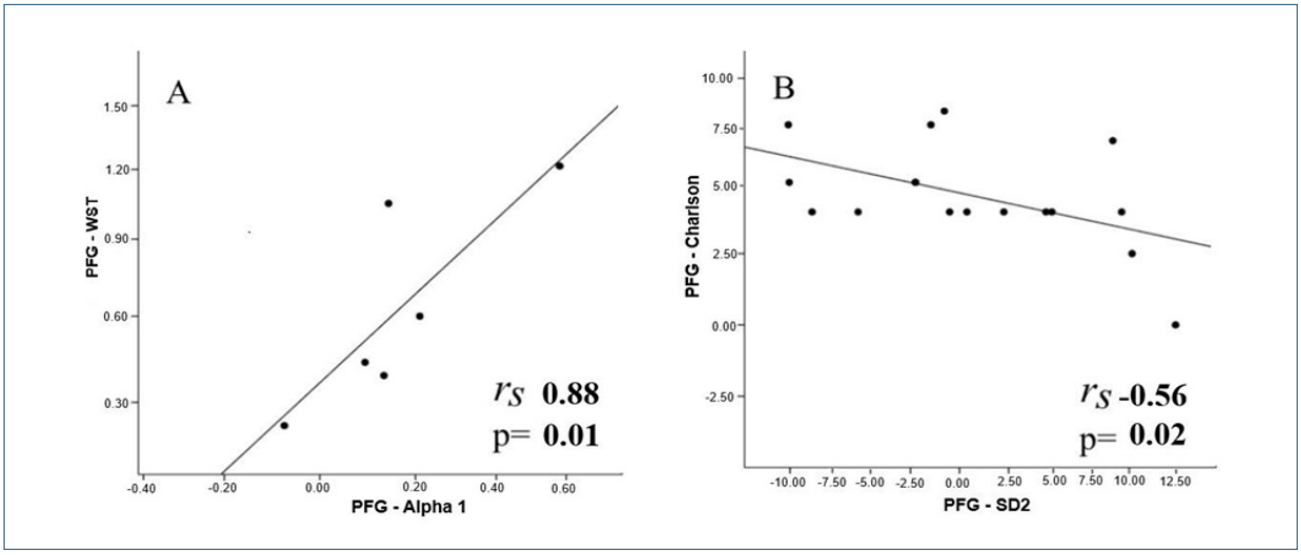

Figure 2: Correlation between Alpha 1 indices (short-term scale of a time series of R-R intervals) and the Walking Speed Test (WST) in meters per second (A), SD2 (continuous variability at each heartbeat), and Charlson (B) in the pre-frail group (PFG).

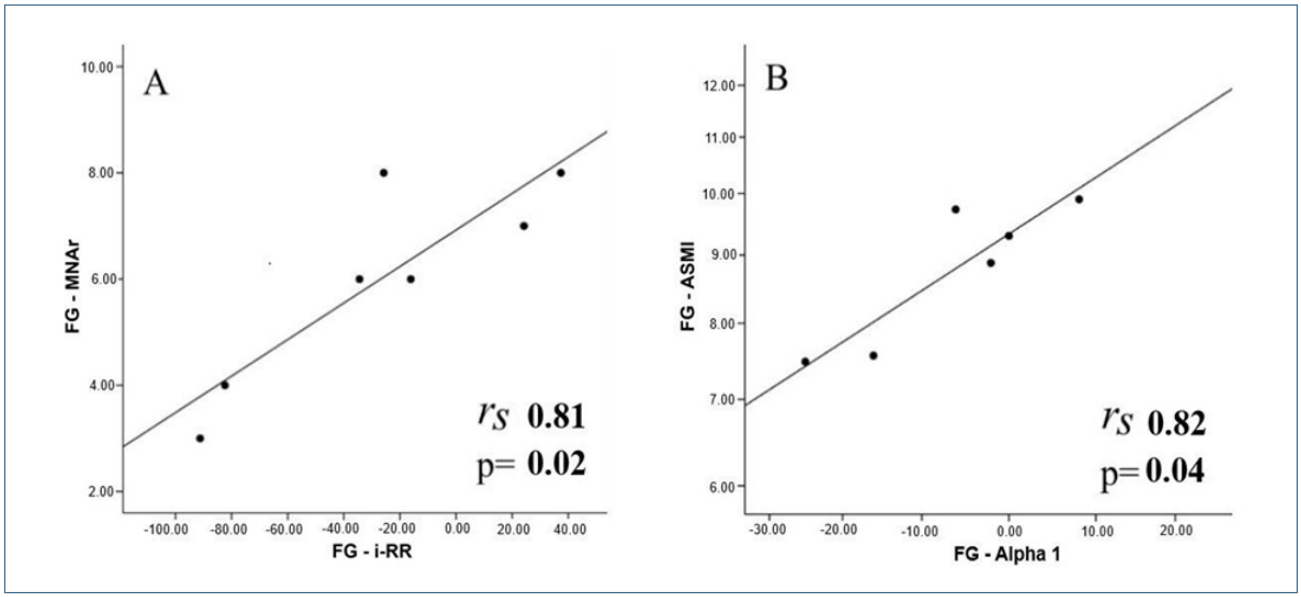

Figure 3: Correlation between iRR indices (average distance between R waves in milliseconds) and reduced Mini Nutritional Assessment (A), Alpha 1 (short-term scale of a time series of R-R intervals), and Appendicular Muscle Mass Index in kilograms per square meter (B) in the frail group (FG).

Table 3: Linear and nonlinear HRV indices among frailty subgroups.

Groups	NFG (N= 11)	PFG (N= 21)	FG (N= 8)	*p-value*
At rest (supine position)				
Linear analysis				
HR-i	80.84 (70.63 – 89.34)	83.32 (73.93 – 90.90)	73.84 (66.67 – 85.53)	0.81
RR-i	744.20 (683.78 – 850.17)	720.37 (681.75 – 830.72)	812.57 (702.40 – 892.08)	0.73
SDNN	12.70 (7.66 – 26.99)	12.78 (7.51 – 34.66)	19.53 (8.71 – 39.35)	0.78
RMSSD	15.09 (8.45 – 26.36)	13.35 (6.91 – 46.36)	25.91 (3.75 – 60.97)	0.79
PNN50	0.97 (-0.92 – 9.04)	0.58 (-2.03 – 16.09)	7.84 (-5.43 – 32.75)	0.7
LF	50.89 (44.45 – 64.36)	45.65 (40.02 – 61.51)	50.52 (25.02 – 76.41)	0.52
HF	49.09 (35.35 – 55.47)	54.19 (38.38 – 59.82)	49.39 (23.59 – 74.48)	0.53
LF/HF	1.05 (0.73 – 2.20)	0.84 (0.82 – 2.57)	1.04 (0.03 – 3.22)	0.53
Nonlinear analysis				
Alpha 1	0.93 (0.83 – 1.02)	0.75 (0.67 – 0.98)	0.81 (0.44 – 1.41)	0.13
Alpha 2	0.41 (0.35 – 0.61)	0.49 (0.42 – 0.67)	0.37 (0.20 – 0.54)	0.5
SD1	10.69 (5.98 – 18.68)	9.45 (4.89 – 32.85)	18.35 (2.66 – 43.19)	0.79
SD2	14.46 (8.97 – 33.34)	13.98 (9.15 – 35.96)	20.55 (12.08 – 35.72)	0.92
ApEn	1.03 (0.87 – 1.09)	1.01 (0.95 – 1.04)	1.03 (0.97 – 1.07)	0.75
SampEn	1.96 (1.35 – 2.16)	1.64 (1.41 – 1.90)	1.68 (1.50 – 1.85)	0.61
Variation from supine to sitting position				
Linear analysis				
HR-i	3.56 (-1.61 – 14.56)	0.75 (-0.27 – 3.50)	3.21 (-1.08 – 7.52)	0.15
RR-i	-34.34 (-93.08 - -1.42)	-7.41 (-42.53 – 0.56)	-25.76 (-71.78 – 17.96)	0.28
SDNN	-0.40 (-14.25 – 32.51)	0.08 (-2.10 – 4.38)	-3.71 (-11.52 – 5.61)	0.41
RMSSD	-1.00 (-11.87 – 33.22)	-0.44 (-3.94 – 6.26)	-3.53 (-19.00 – 13.70)	0.53
PNN50	0.00 (-4.59 – 22.13)	0.00 (-1.34 – 5.05)	0.00 (-13.77 – 14.09)	0.74
LF	0.13 (-10.22 – 15.31)	2.16 (-0.56 – 16.05)	1.38 (-7.56 – 10.48)	0.63
HF	-0.21 (-15.40 – 10.44)	-2.26 (-16.10 – 0.37)	-1.37 (-10.31 – 7.72)	0.56
LF/HF	-0.06 (-0.78 – 1.60)	0.05 (-0.30 – 1.66)	0.12 (-1.31 – 3.97)	0.75
Nonlinear analysis				
Alpha 1	0.00 (-0.18 – 0.26)	0.11 (0.00 – 0.18)	-0.02 (-0.15 – 0.05)	0.12
Alpha 2	0.20 (-0.02 – 0.25)	-0.01 (-0.07 – 0.07)	-0.01 (-0.29 – 0.08)	0.14
SD1	-0.71 (-8.41 – 23.53)	-0.32 (-2.79 – 4.44)	-2.51 (-13.46 – 9.70)	0.53
SD2	-0.81 (-19.44 – 39.16)	0.11 (-1.91 – 4.28)	-4.71 (-9.01 – 0.83)	0.18
ApEn	-0.04 (-0.12 – 0.14)	0.01 (-0.02 – 0.03)	0.02 (-0.05 – 0.05)	0.68
SampEn	-0.22 (-0.62 – 0.09)	-0.11 (-0.22 – 0.00)	0.01 (-0.17 – 0.27)	0.22

Data are presented as median and interquartile range. Kruskal-Wallis test for intergroup analysis with a significant difference of $p<0.05$. Non-frail group (NFG), pre-frail group (PFG), and frail group (FG). HR-i: mean heart rate in milliseconds; RR-i: mean distance between R waves in ms; SDNN: standard deviation of all normal R-R intervals; RMSSD: square root of the mean square of the differences found between normal RR-i; PNN50: percentage of consecutive R-R intervals whose difference between them is greater than 50 ms; Hz: hertz; LF: variation between 0.04 and 0.15 Hz; HF: variation between 0.15 and 0.4 Hz; Alpha 1: short-term scale of a time series of RR-i; Alpha 2: long-term scale of an iR-R time series; SD1: instantaneous variability at each heartbeat; SD2: continuous variability at each heartbeat; ApEn: approximate entropy; SampEn: simple entropy.

Table 4: Results of questionnaires and tests between groups - Frailty.

Groups	NFG (N= 11)	PFG (N= 21)	FG (N= 8)	*intergroup p-value*
Questionnaires				
Charlson	3.00 (2.04 – 4.35)	2.00 (1.95 – 3.92)	2.00 (1.23 – 4.19)	0.45
Barthel	90.00 (62.71 – 98.19)	75.00 (56.06 – 79.17)	80.00 (37.00 – 85.49)	0.06
IPAQ (min)	-	498.50 (111.16 – 898.83)	110.00 (35.98 – 159.01)‡	0.03
MNAr	12.00 (11.48 – 13.71)	5.00 (4.25 – 8.54)*	6.00 (3.60 – 7.39)†	0.01
Equation				
ASMI	10.20 (6.46 – 10.98)	8.67 (7.64 – 9.24)	8.88 (7.53 – 9.63)	0.76
Functional assessments				
HGS (Kgf)	29.50 (22.05 – 37.14)	20.00 (18.25 – 24.79)*	13.00 (10.22 – 19.27)† ‡	0.01
GST (ms)	1.21 (-2.09 – 4.51)	0.74 (0.55 – 1.11)	0.78 (0.51 – 0.94)	0.21

Data are presented as median and interquartile range. Kruskal-Wallis test for intergroup analysis with a significant difference of $p<0.05$. Mann-Whitney test for comparisons between two groups. Non-frail group (NFG), pre-frail group (PFG), and frail group (FG), IPAQ: International Physical Activity Questionnaire; min: minutes; MNAr: Mini Nutritional Assessment; ASMI: Appendicular Skeletal Muscle Mass Index; HGS: Handgrip Strength; Kgf: kilogram force; GST: Gait Speed Test; Ms: milliseconds; Significant difference: *$p<0.05$ between NFG and PFG; †$p<0.05$ between NFG and FG; ‡$p<0.05$ between PFG and FG.

Longer distances between R-R intervals mean greater parasympathetic activity, lower heart rate, and higher HRV, indicating better adaptability and response of the ANS to different situations experienced by the individual, such as exercising, changing position, among others. The opposite is also true[16].

Changes in the ANS may influence the progression of frailty in older adults[37]. Some studies have shown that frail older women have lower HRV indices, which is believed to be due to low cardiovascular reserve and ANS impairment in this population[38]. An experimental study using older adult mice with an experimental model of frailty identified a reduction in HRV in accordance with the progressive increase in frailty severity and age when the analysis was performed in subgroups. However, when analyzed without this stratification, this reduction was not found[39].

Level of physical activity, nutritional status, and peripheral muscle strength of the sample

Given the high incidence of older adults with characteristics of frailty, it is reasonable to assume that this is accompanied by low muscle strength and nutritional issues, which together can act synergistically to reduce physical activity levels. Poor muscle composition, disability, and poor nutrition are closely linked to the occurrence of frailty syndrome in older adults[40].

Clinical implications

Few studies have evaluated HRV in frail older adults in a hospital setting. In these studies, correlations between HRV indices and tools that assess functionality, body composition, nutritional aspects, and mortality were presented, suggesting that cardiac autonomic control may accompany the decline of these variables, opening up possibilities for future research, such as performing linear regression analysis to find what influences these declines. Knowing that older adults with better functional aspects have better cardiac autonomic control reinforces the importance of prevention and rehabilitation programs, such as physical therapy follow-up, even after hospital discharge, for this population.

Limitations of the Study

The environment, even though standardized for all older adults during HRV monitoring, was susceptible to interference inherent to hospital routine, which could interfere with the signals captured. Although bedridden patients were excluded, not all patients were able to perform the GST. With the aim of using tools accessible in everyday life, established tools such as computed tomography, electrical bioimpedance, and dual-energy X-ray absorptiometry were not used to quantify muscle mass. Therefore, this quantification was performed using a predictive equation validated for the Brazilian population. Finally, cross-sectional studies do not allow for the proposal of cause-and-effect relationships because they do not follow the sample over time.

Conclusion

In this sample of hospitalized older adults, most met the criteria for frailty syndrome in older adults. HRV index values at rest and after postural change were similar among the frailty subgroups. The best HRV response was associated with greater functional capacity, level of physical activity, and nutritional aspects, while worse responses were associated with a higher number of comorbidities and increased risk of mortality.

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