**Title**: Physical Fitness is Related to Body Fat and Heart Rate Variability during Exercise in Community-Dwelling Older People: a cross-sectional study.

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## Abstract

**Background**: Physical fitness, body composition, and the autonomic response to exercise are important predictors of health-related outcomes in older adults, but their interplay is not fully understood, therefore, this study aims to assess the associations between these variables and possible mediating effects. **Methods**: an observational cross-sectional study was conducted in 81 community-dwelling older people, recruited by non-probabilistic sampling. To obtain body composition parameters, a bio-impedance analysis was made, then, the Short Physical Performance Battery (SPPB) was used to assess physical fitness, and the Heart Rate Variability (HRV) was recorded before, during and after the Two-Minute Step Test (TMST), to assess cardiac autonomic response to physical exercise. Geriatric depression and anxiety symptoms were assessed as secondary measures. Correlation and mediating effects analyses were carried out. **Results**: SPPB score was negatively related to body fat percentage (r = -0.273, p = 0.015), but positively related to SNS index during exercise (r = 0.313, p = 0.006). Also, a negative link existed between body fat and sympathetic activity: SNS index (r = -0.252, p = 0.030) and Stress index (r = 0.258, p = 0.027) during TMST. But a positive link with parasympathetic activity: RMSSD (r = 0.253, p = 0.029) and SDNN (r = 0.269, p = 0.020) **Conclusion**: the findings unveil a triangular relationship, where body fat percentage significantly impacts physical fitness and cardiac autonomic activity during exercise, while a greater sympathetic activity correlates with higher physical fitness. Additionally, physical fitness moderates the link between body fat and cardiac autonomic activity, emphasizing its importance for older adults’ health. Further research is needed to explore psychological variables’ moderating effects.

**Keywords**: Aged, Physical Functional Performance, Exercise Test, Body Composition, Autonomic Nervous System

# Introduction

The process of aging is accompanied by a multitude of physiological changes that have the potential to significantly impact people’s overall health and well-being (1,2). Body composition and cardiovascular function are particularly relevant, as they are closely associated with the aging process (3–7). In recent times, there has been a growing interest in comprehending the interplay between physical fitness, body composition, and cardiac autonomic response to exercise in older individuals, as these factors play pivotal roles in determining health outcomes within this age group.

Physical fitness has been classically defined as the ability to perform daily tasks with vigor and without undue fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies (8). Therefor, it is a crucial component of healthy aging. The term encompasses a multitude of aspects, typically including cardiorespiratory endurance, muscular endurance and strength, body composition, and flexibility (9). Numerous studies have demonstrated the positive impact of physical fitness on overall health and longevity, highlighting its role in reducing the risk of chronic diseases, and improving quality of life and functional independence in older adults (10–13)

Moreover, the alteration of body composition, specifically the proportion of body fat, is accompanied by significant changes with age, resulting in a tendency towards an increase in adiposity and a decrease in lean muscle mass (14,15). Excessive body fat accumulation, particularly visceral adiposity, has been associated with a higher risk of cardiovascular disease, metabolic disorders, and functional limitations in older individuals (16,17).

Autonomic nervous system (ANS) plays a critical role in regulating cardiovascular function, with sympathetic and parasympathetic branches exerting opposing effects on heart rate and vascular tone. Furthermore, during stressful situations, such as physical exercise, the ANS ensures a sufficient cardiac response to higher metabolic demands (18). The measurement of heart rate variability (HRV), serves as a non-invasive indicator of ANS activity and cardiovascular health (19,20). A reduction in rest HRV has been linked to various adverse outcomes, including cardiovascular events and morbidity, while insufficient HRV reduction during exercise may lead to impaired physical capacity (20–22).

However, HRV is not only influenced by physical and environmental stressors. Psychological factors such as anxiety and depression have also been linked to changes in ANS activity (23,24). Notably, older individuals may be more susceptible to these psychological factors, making it crucial to measure and control for their effects (25,26).

Despite extensive research into physical fitness, body composition, and cardiovascular health in older adults, gaps persist in the understanding of their interrelationships and underlying mechanisms. One area of interest is the relationship between physical fitness, body fat percentage, and cardiac autonomic response to exercise in older individuals. Although previous studies have explored these factors independently, this study explore their collective influence on physical fitness in the aging population.

The conceptualization of this study is based on the recognition of the interplay between physical fitness, body composition, and autonomic cardiovascular regulation in aging. We aim to answer the following research question: How does physical fitness relate to body fat percentage and cardiac autonomic response to exercise in older people? By elucidating these correlations, we hope to gain valuable insights into the relationships that underlie age-related modifications in physical fitness and identify potential interventions to enhance health outcomes in older adults. Even more, we seek to understand the moderating effect of frequent psychological traits, such as geriatric depression and anxiety.

We hypothesize that physical fitness will be inversely related to body fat percentage and associated with cardiac autonomic response during exercise in older individuals. In our opinion, it will be essential for this population to have an optimal cardiac autonomic response, characterized by a shift towards sympathetic activity predominance, in order to achieve a grater performance during physical fitness testing.

The primary objective of this study is to investigate the relationship between physical fitness, body fat percentage, and cardiac autonomic response to exercise in older people. Even more, We aimed to assess the moderating effect of psychological variables on these relationships, with implications for cardiovascular health and functional capacity in aging.

# Methods

## Aims and Study design

A prospective observational, cross-sectional study was conducted in one data collection session, to determine the associations between physical fitness, body composition and cardiac autonomic response to moderate-intensity exercise.

## Setting

This study was conducted at the Centro Asistencial Docente e Investigación (Assistance, Teaching, and Research Center), belonging to the University of Magallanes (CADI-UMAG), in the city of Punta Arenas, Chile. All the assessments were made between 09:00 and 11:00 hours of the morning. The privacy and comfort of the subjects was ensured, the room temperature was set at 20°C and a white artificial lighting was used.

## Participants

81 community-dwelling older adults were recruited and selected by non-probabilistic sampling, from the Region of Magallanes and Chilean Antartica, Chile. They were included if: 65 years age or older; residents of the Region of Magallanes and Chilean Antartica, Chile; and being able to understand the study aims and instructions. But they were excluded in case of: diagnosis of congenital heart disease; consumption of beta-blocker drugs, taking stimulant substances within 24 h before assessments session; motor or cognitive disability; inability to understand instructions or written content; or presence of pain during cardiac or physical assessments.

All participating subjects gave their permission and provided informed consent before participation. The Ethics Committee of the University of Magallanes (N°XXX/YY/YEAR) approved this study following the regulations established by the Declaration of Helsinki on ethical principles in human beings.

## Procedures

During recruitment, the participants were instructed to avoid the use of psychoactive substances for the 24 hours prior to the assessment, and to sleep for at least 7 hours during the previous night. Upon arrival, participants were informed about the study aims and risks associated with their participation, and the socio-demographic and medical information was collected during the initial interview. Then, Body composition parameters were measured using bioimpedance analysis, and psychological questionnaires for anxiety and depression screening were applied by a supervised psychology undergraduate student.

Cardiac autonomic response to physical exercise was measured as previously validated for this age group (27). The protocol is briefly described below:

HRV was recorded through a non-invasive chest band, immediately before, during, and immediately after the execution of the two-minutes step test (TMST). Vital signs, including blood pressure, were monitored throughout the test, and participants’ well-being was visually checked to ensure they were comfortable and prepared. For resting HRV measurements (before and after the application of the TMST), the volunteers remained seated in a chair, with feet and back supported, ensuring avoiding to talk during the recordings. R-R intervals were recorded continuously during the last 10 min of rest, and were subsequently analyzed for 5 min in each occasion. The breathing rate was spontaneous. As part of the protocol, it was ensured that the participant needed to have a blood pressure less than 140/90 mmHg to start the HRV measurements.

Finally, after 15 minutes of resting from the TMST, the Short Physical Performance Battery (SPPB) was applied to the participants. Blood pressure, heart rate and general aspect of the subjects was verified before ending the session.

Physical and physiological assessments, as well as the initial interview, were made by professional physiotherapists.

## Instruments

### Short physical performance battery

SPPB consists of a physical test used to measure three components of physical fitness, described below (28):

Balance: to achieve the maximal score (4 points), the subject should be able to stay balanced for at least 10 seconds in side-by-side stand (feet together), semi-tandem stand and tandem stand.

Usual gait speed: the subjects are asked to walk normally a 4 meters distance. Two chances are given and the best of both is registered. To achieve the maximal score (4 points), they should obtain 4.82 sec. or less.

Lower body fitness: The subjects are asked to perform 5 chair stands without using their arms and time upon complete is registered. A time lower or equal 11.19 sec. gives the maximal score (4 points).

To obtain the final score, the summing of the three components is calculated, with a maximal total score of 12 points.

### Body composition

Body mass (kg) and total body fat (%) were assessed by bioimpedance using the Tanita BC-558 Ironman Segmental Body Composition Monitor (Tanita Ironman, Arlington Heights, IL 60005, USA), with a concordance of 89.3% compared to the Dual X-ray Absorption test using standard measurement protocols (29).

### Cardiac autonomic activity

Cardiac autonomic activity was assessed using R-R interval recordings (HRV) obtained through the Polar Team2 system (Polar®) application. Artifacts and ectopic heartbeats, which did not exceed 3% of the recorded data, were excluded (30). Time-domain parameters considered for analysis included the square root of the mean squared differences of successive R-R intervals (RMSSD, expressed in ms) as an index of parasympathetic activity (31), and the standard deviation of RR intervals (SDNN), reflecting total variability encompassing both sympathetic and parasympathetic contributions to cardiac autonomic function (32,33). Additionally, the Stress Index (SI) and Parasympathetic and Sympathetic Nervous System Index (PNS and SNS, respectively) were computed. The PNS Index, indicative of total vagal stimulation, was derived from mean R-R intervals, RMSSD, and Poincaré Plot Index SD1 in normalized units (linked to RMSSD), representing deviations from normal population averages (32,34). The SNS Index, reflecting total sympathetic stimulation, was derived from mean R-R intervals, Baevsky’s Stress Index (positively related to cardiovascular system stress and cardiac sympathetic activity), and the Poincaré Plot Index SD2 in normalized units (related to SDNN) with interpretation similar to the PNS Index (32,34). The SI serves as an indicator representing the ANS control system’s workload (35), normalized by the square root of Baevsky’s SI (36). All analyses conducted to compute HRV related indices were performed using Kubios HRV® software (Kuopio, Finland).

### Two-Minutes Step Test

The TMST is a sub-test from the Senior Fitness Test, demanding a low to moderate intensity (27,37). The test consists of a two-minute assessment designed to evaluate cardiorespiratory fitness. Participants are instructed to raise their right knee to a marked point on a wall as many times as possible within the given time frame, ensuring that each raise reaches at least a 70° angle at the thigh-femoral joint. The number of valid steps were recorded for each subject.

### Geriatric Depression Scale

The 30-questions Geriatric Depression Scale (GDS-30) was employed to assess subject’s depressive symptoms (38). It consists of a 30 dichotomous questionnaire, where participants are asked about their past-week feelings in reference to depressive symptoms (for instance, “Do you feel that your life is empty?”), with higher scores (i. e., “yes” responses) representing more depressive symptoms. It was first developed by Yesavage and colleagues (39) and is currently widely used (40). The spanish version, employed in this study, has been previously validated, with a Cronbach alpha coefficient of 0.82 (41).

### Beck Anxiety Inventory

The Beck anxiety Inventory was employed to assess anxiety symptoms. It consists of a 21-items questionnaire based on usual anxiety symptoms and a 4-options Likert scale from 0 (“Not at all”) to 3 (“Severely”), meaning the severity reported by the subject in each one. It was originally developed by Beck and colleagues (42). In this study, the spanish version is used, which has demonstrated a high internal consistency in older people (α = 0.94) (43).

## Statistical analysis

We used mean and standard deviation (SD) to describe continuous variables, absolute and relative frequencies to describe discrete variables. In order to assess the relationship between variables, we used Pearson’s product-moment correlation (r), and to assess differences between groups we used standardized mean difference (SMD) and 95% confidence intervals (CI95%).

As a way of controlling for the influence of psycho-physiological variables on the cardiac autonomic response of the subjects to exercise, we assess the average causal mediation effect (ACME), the average direct effect (ADE) of the main effects after taking into account the effect of moderator variables into the observed relationships and the proportion of the effect that its mediated by these variables (44). To assess the significance of moderating variables, we used non overlapping CI95%, estimated based on non parametric bootstrapping by using Monte Carlo resampling, and bias-corrected and accelerated CI95%, using the *mediation* R package to this end (45).

We defined a type I error rate at 5% ( = 0.05) as our threshold for null hypothesis significance testing, and non-overlapping CI95% over the null effect for sex differences and mediation analyses. All analyses were computed using the *R* programming language for statistical computing, (46).

# Results

## Sample characteristics

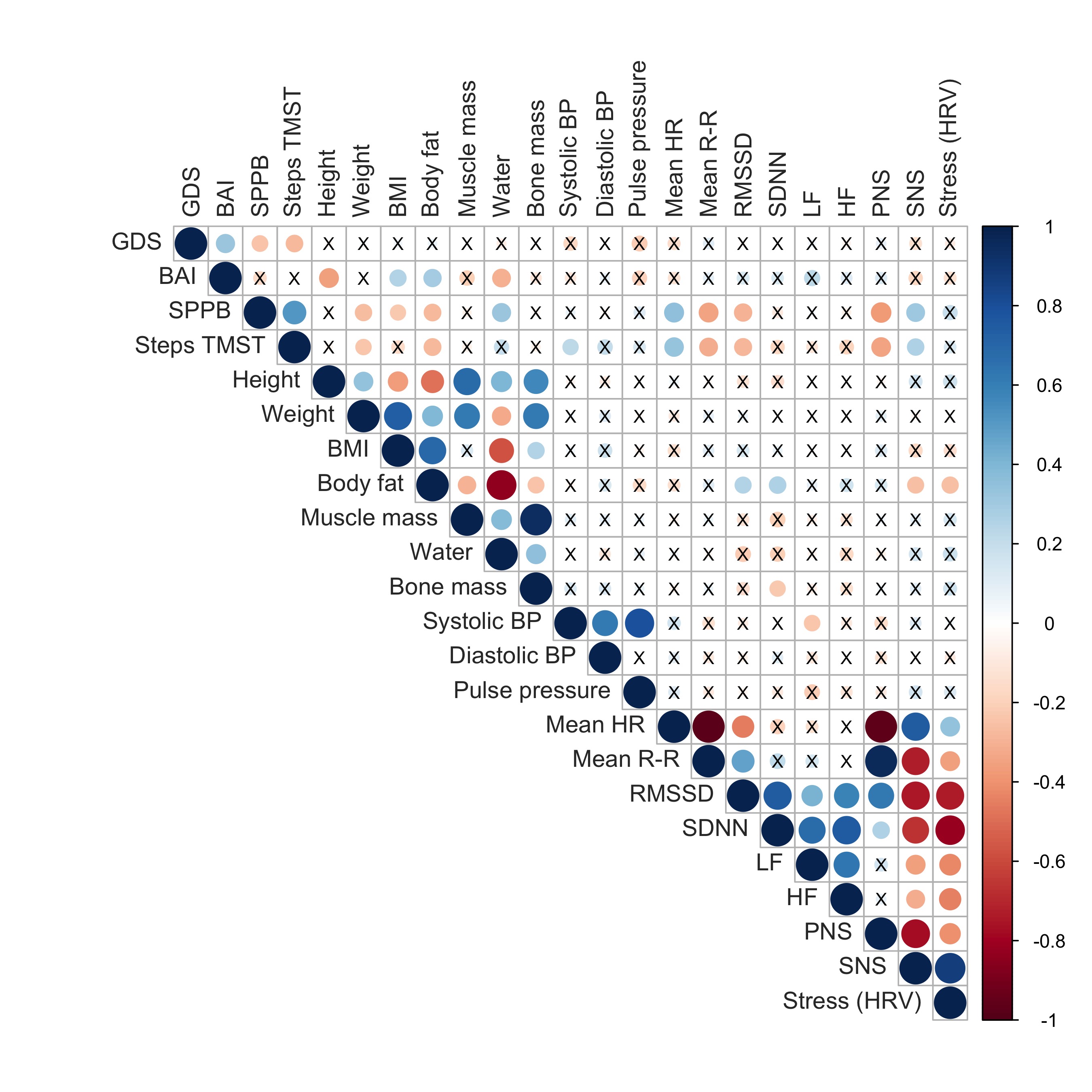
The sample assessed consisted on 81 adults (age: 71.1 ± 6.2 years old, BMI: 31 ± 6.2 kg/m2), of whom 67 (82.7%) were females. Sociodemographic and anthropometric characteristics of the sample can be seen in table 1.

|  | | **Sex** | |  | |
| --- | --- | --- | --- | --- | --- |
| **Characteristic** | **Overall**, N = 811 | **Female**, N = 671 | **Male**, N = 141 | **Difference**2 | **95% CI**23 |
| Age (years) | 71.1 ± 6.2 | 71.0 ± 6.4 | 71.9 ± 5.5 | -0.15 | -0.73, 0.43 |
| Hypertension | 33 (41%) | 26 (39%) | 7 (50%) |  |  |
| Diabetes | 12 (15%) | 9 (13%) | 3 (21%) |  |  |
| Body weight (kg) | 74.6 ± 13.2 | 72.8 ± 12.6 | 85.0 ± 12.7 | -0.98 | -1.6, -0.33 |
| Height (cm) | 155.8 ± 9.2 | 153.3 ± 7.6 | 167.8 ± 6.3 | -2.1 | -2.8, -1.4 |
| BMI (kg/m2) | 31.0 ± 6.2 | 31.2 ± 6.5 | 29.7 ± 3.2 | 0.28 | -0.36, 0.92 |
| BMI category |  |  |  |  |  |
| Normal | 7 (9%) | 6 (9%) | 1 (9%) |  |  |
| Overweight | 35 (45%) | 29 (43%) | 6 (55%) |  |  |
| Obese | 36 (46%) | 32 (48%) | 4 (36%) |  |  |
| Muscle mass (kg) | 43.9 ± 8.2 | 41.0 ± 4.3 | 59.9 ± 6.5 | -3.5 | -4.4, -2.7 |
| Fat mass (%) | 37.5 ± 9.3 | 39.5 ± 8.3 | 26.2 ± 6.4 | 1.8 | 1.2, 2.5 |
| Bone mass (%) | 2.3 ± 0.4 | 2.2 ± 0.2 | 3.1 ± 0.3 | -3.6 | -4.5, -2.8 |
| Water (%) | 47.0 ± 6.7 | 45.4 ± 5.6 | 55.8 ± 5.0 | -2.0 | -2.7, -1.3 |

**Table 1**. Main sample characteristics. Body composition and sociodemograpic variables are displayed for the overall sample and aggregated by sex. Differences between males and females are displayed as SMD and CI95% for continuous variables.

## Body composition and autonomic response

We observed that body fat percentage was linked to a lower SNS (r = -0.252, p = 0.030) and Stress index (r = 0.258, p = 0.027) response during the TSMT. In addition, body fat percentage was positively correlated with time domain HRV during exercise, more specifically RMSSD (r = 0.253, p = 0.029) and SDNN (r = 0.269, p = 0.020). No other body composition variables were found to influence the cardiac autonomic response to exercise.

 **Figure 1**. Main correlations among psychological, cardiac autonomic and performance variables. Non-significant correlations (i.e., p > 0.05) were crossed with and “X”. The more intense the color the stronger the correlation, either positive or negative. GDS, Geriatric Depression Scale; BAI, Beck Anxiety Inventory; SPPB, Short Physical Performance Battery; TMST, Two-Minutes Step Test; BMI, Body Mass Index.

## Body composition and physical fitness

In addition, greater SPPB score was observed in leaner (r = -0.273, p = 0.015) and individuals with lower BMI values (r = -0.225, p = 0.047). Similar findings were observed between total steps from the TMST and body fat percentage (r = -0.279, p = 0.013) and bodyweight (r = -0.232, p = 0.041). Not enough evidence was observed to suggest a correlation between total muscle mass with either total SPPB score (r = -0.063, p = 0.584) or total number of steps in TMST (r = -0.070, p = 0.541).

## Physical fitness and cardiac autonomic response to exercise

Physical fitness, reflected through SPPB total score and total steps in TMST, was positively correlated with a greater sympathetic activity during exercise, which was reflected by SNS index (SPPB score, r = 0.313, p = 0.006; TMST steps, r = 0.265, p = 0.022), mean HR (SPPB score, r = 0.355, p = 0.002; TMST steps, r = 0.338, p = 0.003) and its inverse counterpart mean R-R (SPPB score, r = -0.35, p = 0.002; TMST steps, r = -0.311, p = 0.007). Total number of steps from TMST was also inversely correlated with parasympathetic indices during exercise like RMSSD (r = -0.285, p = 0.014) and PNS index (r = -0.344, p = 0.003).

However, this appears to be accompanied by an proportional decrease in parasympathetic drive during exercise with increasing levels of physical fitness displayed in the SPPB, which was denoted by the inverse correlation of the later with PNS index during (r = -0.375, p = 0.001) and after exercise (r = -0.229, p = 0.049), in addition to RMSSD during exercise (r = -0.294, p = 0.010)

## Mediation analysis

Mediation analyses suggest many potential influential effects for the relationships for body composition and parasympathetic indices. In this context, the average direct effect (ADE) of body fat percentage on RMSSD during exercise (ADE = 0.088, CI95%[-0.005, 0.200], p = 0.077) was accentuated when considering the influence of SPPB score (ACME = 0.0289, CI95%[0.003, 0.110], p = 0.057; Total effect = 0.117, CI95%[0.028, 0.240], p = 0.012). Similar findings were observed when considering the mediation effect of TMST steps into account (ACME = 0.0283, CI95%[0, 0.07], p = 0.079; Total effect = 0.117, CI95%[0.028, 0.240], p = 0.012). No other parasympathetic indicators were influenced or mediated by fitness or psychological related measures.

Additionally, and in the case on sympathetic indicators, the effect of body fat on SNS index during exercise (ADE = -0.050, CI95%[-0.107, 0.01], p = 0.077) was influenced by SPPB score in similar way as with RMSSD, potentiating the original main observed effect (ACME = -0.016, CI95%[-0.049, 0], p = 0.041; Total effect = -0.066, CI95%[-0.125, -0.010], p = 0.016). Similar effects were observed with TMST steps in this regard (ACME = -0.015, CI95%[-0.042, 0], p = 0.050; Total effect = -0.066, CI95%[-0.125, -0.010], p = 0.016). No other sympathetic indices were notoriously modified in the presence of either SPPB score, TMST steps or psychological variables.

When assessing potential mediators for the effect of body composition on fitness related measures, we found that the effect of body fat percentage on SPPB score (ADE = -0.075, CI95%[-0.123, -0.020], p = 0.007) is partially diminished when considering the influence of total muscle mass (ACME = 0.011, CI95%[0, 0.040], p = 0.107; Total effect = -0.064, CI95%[-0.111, -0.010], p = 0.014). Similar mediation effects of total muscle mass were observed (ACME = 0.118, CI95%[0.005, 0.350], p = 0.075) when assessing the effect of body fat percentage on TMST steps (ADE = -0.773, CI95%[-1.193, -0.300], p = 0.001; Total effect = -0.655, CI95%[-1.084, -0.210], p = 0.004). No other mediating effects were observed for any of the psychological measures for any of the relationships between body composition and physical fitness measures.

# Discussion

This study aimed to investigate the relationship between physical fitness, body fat percentage, and cardiac autonomic response to exercise in older people. Through correlational analyses, we aimed to elucidate the interplay between these factors and their implications for cardiac autonomic function during physical efforts.

It was hypothesized that a higher body fat percentage would be inversely correlated to physical fitness. Our results aligns with this hypothesis and with those of previous research regarding body composition and physical performance, with a proportional decrease in aging individuals (47,48).

Furthermore, greater body fat percentage was related to a reduced sympathetic drive and higher parasympathetic activity during the TMST, as hypothesized. Throughout the course of physical efforts, the ANS is expected to shift into a sympathetic state, ensuring an efficient response to greater metabolic demands (49). However, aged individuals may present an impaired ANS response to physical exercise (27). In that sense, our results support that body composition may play a pivotal role in that response, generating novel insights for potential interventions.

Nonetheless, the moderating effect of physical fitness related measures on the relationship proposed earlier, suggests that greater physical activity could potentially counteract the negative effects of a high body fat percentage on cardiac autonomic response to exercise, possibly, at the same extent as seen in leaner individuals. This result highlights the importance of promoting a physically active lifestyle and favor the maintenance of physical capacity, regardless of nutritional status (50,51).

Regarding the link between physical fitness and cardiac autonomic response to exercise, our results evidenced that individuals with a high sympathetic drive while exercising, had greater physical fitness. Additionally, previous research had demonstrated the utility of HRV and exercise-induced responses in those metrics as a potential marker of cardiorespiratory fitness in these individuals (22), supporting the current hypothesis that a greater sympathetic drive facilitates performance and its related measures during moderate intensity physical activities. Even more, it has been previously demonstrated that physically active individuals have an enhanced autonomic response to exercise, playing a pivotal role strengthening this hypothesis (52,53).

Our results provide evidence to support the interplay between physical fitness, body fat, and cardiac autonomic response to exercise in older individuals. Physical fitness is negatively affected by higher body fat percentage, while also being associated with impaired cardiac autonomic response to exercise, characterized by decreased sympathetic drive and increased parasympathetic tone. Additionally, this altered autonomic response is related to lower physical performance in older individuals, both variables being important predictors of health outcomes in this population (54,55). Overall, our findings underscore the triangular and bidirectional relationship among these variables.

However, our results did not evidence a moderating effect of either GDS-30 or BAI scores, challenging our initial hypothesis. These finding suggests a nuanced interplay between psychological variables and physical/physiological measures in older people, underscoring the need for further research to elucidate underlying mechanisms and variables beyond depression and anxiety. While the lack of evidence suggesting any moderating effects does not diminish the significance of psychological factors in aging, it highlights the complexity of their influence.

In addition to the potential strengths of this cross-sectional study, it is not without limitations. First, our study design prevents us from making causal inferences about the direction of the relationships, highlighting the relevance of experimental and longitudinal research exploring causal relations between our variables and potential underlying mechanisms. Second, a relatively small sample was included, limiting generalizability and statistical power of the analysis. Furthermore, the sample consisted mainly of women (82.7%), limiting our ability to make sex comparisons and decreasing the representativeness of the sample. It should also be noted that the relationships between physical fitness and cardiac autonomic response to exercise were not made within the same instrument, due to the possible lack of SPPB to generate an adequate physical stress, and of TMST to inform general physical fitness of the participants. Further research could investigate the impact of cardiac autonomic response on performance during the same task, in this age group.

# Conclusion

The results highlighted a structural bidirectional relationship among variables. Body fat percentage was inversely correlated to both physical fitness and cardiac autonomic activity during exercise, with sympathetic drive associated with physical fitness in older people. Furthermore, physical fitness may mediate the effect of body fat on cardiac autonomic activity during exercise, highlighting its pivotal role in older people’s health. However, further research is needed to elucidate moderating effects of psychological variables in this field.

# Author Contributions

All authors listed have made a substantial, direct and intellectual contribution to the work and approved it for publication.

# Funding

[…].

# Institutional Review Board Statement

[…].

# Informed Consent Statement

[…]

# Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

# Conflicts of interests

The authors declare that the research was conducted without any commercial or financial relationships construed as a potential conflict of interest.

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