

ORIGINAL ARTICLE

## Greater muscle strength is associated with better hemodynamic parameters, physical, cognitive and kidney function in older nursing-home residents

Maior força muscular está associada a melhores parâmetros hemodinâmicos, função física, cognitiva e renal em idosos residentes em casas de repouso

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### KEYWORDS

Geriatric Assessment  
Cardiovascular  
Cognitive Performance  
Renal Function  
Muscular Strength

### ABSTRACT

**Objective:** To analyze hemodynamic parameters, kidney and cognitive function, and physical performance of institutionalized older adults with high- and low-strength. **Method:** Cross-sectional study. Twenty-one older adults (11 women, 10 men) participated in this study. Blood samples were collected for analysis of biochemical parameters. Cognitive function was evaluated using the mini-mental state examination (MMSE), clock drawing test (CDT), and verbal fluency test, while physical performance was assessed using the Short Physical Performance Battery (SPPB) and, blood pressure, heart rate, and Framingham Risk Score were evaluated. **Result:** Based on the median value, participants were divided into low-strength ( $81.63 \pm 3.03$  years) and high-strength ( $82.10 \pm 2.11$  years). The high-strength group showed significantly lower systolic ( $138.8 \pm 3.6$  vs.  $116.5 \pm 3.1$ ;  $p < 0.05$ ), diastolic ( $84.9 \pm 2.14$  vs.  $72.9 \pm 2.2$ ;  $p < 0.05$ ), mean blood pressure ( $102.2 \pm 2.4$  vs.  $87.4 \pm 2.4$ ;  $p < 0.05$ ), and cardiovascular risk ( $39.7 \pm 4.6$  vs.  $26.0 \pm 3.5$ ;  $p < 0.05$ ) than the low-strength group. In addition, the high-strength group had better HDL-c levels ( $27.4 \pm 1.7$  vs.  $35.6 \pm 3.4$ ;  $p < 0.05$ ), higher estimated glomerular filtration rate ( $51.5 \pm 4.9$  vs.  $86.2 \pm 5.5$ ;  $p < 0.05$ ), and lower creatinine ( $0.94 \pm 0.1$  vs.  $0.57 \pm 0.1$ ;  $p < 0.05$ ) than the low-strength group. For cognitive data (MMSE and CDT  $p < 0.05$ ) and physical performance (semi-tandem, tandem and walking speed  $p < 0.05$ ), the high-strength group had better scores compared to the low-strength group. **Conclusion:** Institutionalized older adults with high-strength has better hemodynamic parameters, physical performance, kidney and cognitive function than those with low-strength levels.

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**PALAVRAS-CHAVE**

Avaliação Geriátrica  
Cardiovascular  
Desempenho Cognitivo  
Função Renal  
Força Muscular

**RESUMO**

**Objetivo:** Analisar os parâmetros hemodinâmicos, a função física, cognitiva e renal de idosos institucionalizados com alta e baixa força. **Método:** Estudo transversal. Vinte e um idosos (11 mulheres, 10 homens) participaram do estudo. Foram coletadas amostras de sangue para análise de parâmetros bioquímicos. A função cognitiva foi avaliada por meio do minixame do estado mental (MEEM), do teste de desenho do relógio (TDR) e do teste de fluência verbal, enquanto o desempenho físico foi avaliado por meio da Short Physical Performance Battery (SPPB) e foram aferidas a pressão arterial, a frequência cardíaca e o escore de risco de Framingham. **Resultado:** Com base no valor da mediana, os participantes foram divididos em baixa força (81,63 ± 3,03 anos) e alta força (82,10 ± 2,11 anos). O grupo de alta força apresentou pressão arterial sistólica (138,8 ± 3,6 vs. 116,5 ± 3,1; p<0,05), diastólica (84,9 ± 2,14 vs. 72,9 ± 2,2; p<0,05), média (102,2 ± 2,4 vs. 87,4 ± 2,4; p<0,05) e risco cardiovascular (39,7 ± 4,6 vs. 26,0 ± 3,5; p<0,05) significativamente menores do que o grupo de baixa força. Além disso, o grupo de alta força apresentou melhores níveis de HDL-c (27,4 ± 1,7 vs. 35,6 ± 3,4; p<0,05), maior taxa de filtração glomerular estimada (51,5 ± 4,9 vs. 86,2 ± 5,5; p<0,05) e menor creatinina (0,94 ± 0,1 vs. 0,57 ± 0,1; p<0,05) do que o grupo de baixa força. Em relação aos dados cognitivos (MEEM e TDR, p<0,05) e ao desempenho físico (semi-tandem, tandem e velocidade de caminhada, p<0,05), o grupo de alta força apresentou melhores escores em comparação com o grupo de baixa força. **Conclusão:** Os idosos institucionalizados com altos níveis de força têm melhores parâmetros hemodinâmicos, desempenho físico, função renal e cognitiva do que aqueles com baixos níveis de força.

**INTRODUCTION**

Aging is a continuous and complex phenomenon marked by the gradual accumulation of several degenerative biological processes. Depending on the extent of these processes, they can lead to chronic diseases and diminish physical performance, cognitive function, and overall quality of life in older individuals<sup>1</sup>. The 20<sup>th</sup> century went through a remarkable global increase in life expectancy, more than doubling the number of people reaching old age. This trend is expected to continue at least through the middle of the 21<sup>st</sup> century<sup>2</sup>. As a result, a substantial portion of the population will experience aging, which will demand active measures to deal with this demographic change.

As individuals age, there is often a decrease in muscle mass and strength, particularly during the latter half of life<sup>3</sup>. This decrease can be attributed to lifestyle choices and external factors<sup>3</sup>, and are closely linked to frailty, significantly raising the likelihood of various adverse consequences, including dependence, fractures, hospitalization, institutionalization, and death<sup>4</sup>. Furthermore, some studies have seemed to demonstrate a close association of declining strength and/or muscle mass with cognitive decline<sup>5</sup>.

In addition, several studies have provided a strong association between the decrease in kidney function and the worsening of hemodynamic parameters, physical performance, and cognitive function<sup>6</sup>. This connection can be attributed, at least in part, to the aging and worsening complacency of blood vessels throughout the body, decline of glomerular filtration rate, and increase in chronic inflammation<sup>6</sup>. This causes possible degeneration in the kidney, and in the physical and cognitive function<sup>6</sup>.

Previous studies showed a negative relationship between muscular strength levels and hemodynamic parameters<sup>7</sup>, physical and cognitive performance in older individuals<sup>8</sup>, including nursing-home residents<sup>9</sup>. However, the relationship between physical and cognitive

performance, hemodynamic parameters, and renal function in institutionalized older adults is still unclear. Therefore, the objective of the present study was to analyze hemodynamic parameters, physical, cognitive and kidney function of older adults with high and low muscular strength who lived in a nursing home.

**METHODS***Ethical approval*

This cross-sectional study is part of a larger study approved by the Human Research Ethics Committee of the University Center - UDF (protocol number: 5.376.435) and was conducted according to the Declaration of Helsinki (National Council of Health, Resolution 466/2012). Furthermore, all subjects provided written informed consent before participation after all procedures had been clearly explained.

*Participants*

Elderly people were recruited by convenience between January and May 2022 from a private nursing home located in Brasília, DF, Brazil. The nursing home was private-owned, with accommodations, kitchen, dining and TV rooms, nursing and rehabilitation units, areas for leisure and celebrations, and a psychological stimulation room. Its residents typically come seeking better care and/or assistance with cognitive and physical disabilities. The rooms in which patients are housed were assigned based on gender and health status. Residents commonly wake up around 6:00 a.m., were monitored by nurses, and attended the rehabilitation unit according to their self-will. Physiotherapists offered analgesia, massages, and physical stimulation without overload in individual sessions of up to 45min. In the afternoon and/or evening, patients watched movies, engaged in artwork, received visitors,

or spent time in the garden. Meals were offered six times per day, following specific nutritional recommendations (e.g., protein consumption).

To be eligible for inclusion in the study, nursing-home residents had to meet the following criteria: (a) 60 years of age or older, (b) adequate physical and cognitive abilities to complete all measurements as per the protocol, and (c) receive physician approval to participate. Those who had uncorrected visual deficit or color blindness were taking hormone replacement therapy or psychotropic drugs or had experienced a cardiovascular event (such as a myocardial infarction) or any complications in the previous six months were excluded.

### General procedures

All volunteers underwent a thorough assessment, including anamnesis, body mass and height and blood pressure measurements. Blood samples were collected and centrifuged to isolate serum for biochemical analysis. Cognitive function was evaluated using the mini-mental state examination (MMSE), clock drawing test (CDT), and verbal fluency test, while physical performance was assessed using the Short Physical Performance Battery (SPPB). Following the initial assessment and general procedures, the volunteers were divided into two groups based on their strength in the sit-to-stand test. The group with low-strength comprised 11 participants, while the high-strength group consisted of 10 participants.

### Clinical characteristics

Clinical characteristics were measured for sample characterization. Body mass and height were measured using an analog weight scale with a Filizola® (Brazil) stadiometer. Subsequently, the body mass index (BMI) was calculated. Additionally, data regarding disease conditions, medication, drinking and smoking habits, educational background, and duration of institutionalization were collected through a combination of self-report and careful review of medical charts.

### Hemodynamic parameters

Blood pressure (BP) was assessed following the guidelines of the VII Joint National Committee on High Blood Pressure (JNC7)<sup>10</sup>. The evaluation was conducted with participants seated comfortably in a room with artificial lighting. Automated oscillometric equipment (BP 3BTOA, Microlife AG, Widnau, Switzerland) was used to blindly measure BP and heart rate (HR) in the left arm<sup>11</sup>. Systolic BP (SBP), diastolic BP (DBP), and HR were automatically recorded at the end of each measurement. Mean arterial pressure (MAP) was calculated using the recorded values. We calculated a Framingham Risk Score<sup>12</sup> to estimate the cardiovascular disease risk for each participant. A 10-year cardiovascular risk (%) was then determined.

### Biochemical parameters

All participants underwent an 8-hour fasting state for venous blood sample collection (BD Vacutainer®, Chicago, IL, USA). Triglycerides, high-density lipoprotein (HDL-c),

total cholesterol (TC), creatinine and blood glucose were determined using an automated chemistry analyzer (COBAS c111 system; Roche Diagnostics, Switzerland). Low-density lipoprotein (LDL-c) was determined using Friedewald's formula<sup>13</sup>. Kidney function was assessed by estimated glomerular filtration rate (eGFR), which requires the creatinine serum values to be applied to the equation provided by Delgado et al.<sup>14</sup>.

### Cognitive function

Cognitive tests were administered face-to-face in a private silent room by a trained researcher. Global cognitive function was assessed using the mini-mental state examination<sup>15</sup>, clock drawing test<sup>16</sup>, and verbal fluency test (colors and animals)<sup>17</sup>.

### Physical performance

The physical performance tests were conducted by a team of experienced exercise physiologists and physiotherapists who were responsible for administering the tests and ensuring the safety of the participants. One of the examiners was responsible for explaining the test procedures to the participants, demonstrating it, quantifying performance, and evaluating motor patterns, while the other examiner provided occasional verbal and/or tactile cueing to ensure the safety of the participants. To prevent fatigue, the participants were asked to verbally explain the tests before each one. The tests were conducted twice, and the better result was used for analysis. A 2–5 min rest interval was given between each test. The physical performance was assessed using Short Physical Performance Battery, as follows: (i) balance tests (side-by-side, semi-tandem, and tandem); (ii) sit and stand five times; and (iii) gait speed (4 m)<sup>18</sup>.

### Statistical analysis

Data normality was assessed with the Shapiro-Wilk test. Data were expressed as mean ± standard deviation (SD). Independent samples t-tests were conducted to compare all variables between groups, expressed as t value (df). Furthermore, Cohen's d was used to verify the effect size of the comparisons<sup>19</sup>. The following classification to measure the magnitude of effect size was used: small,  $d = 0.2$  to  $0.49$ , moderate,  $d = 0.5$  to  $0.79$ , and large,  $d > 0.8$ . The significance level was set at  $p < 0.05$ . All procedures were performed using SPSS 26 (IBM Corporation, New York, NY, USA).

## RESULTS

The characteristics of the sample are presented in Table 1. Both groups did not differ significantly in clinical characteristics such as age, body mass, height, and BMI. However, the low-strength group had lower formal education (1 year) than the high-strength group. There was no difference in the time of institutionalization between the two groups. Hypertension, osteoarthritis, diabetes, and anxiety were more prevalent in the low-strength group, while Parkinson's disease and depression were more common in the high-strength group.

**Table 1** – Main characteristics of the study participants.

	Low strength (n = 11)	High strength (n = 10)	t value (df)	p value	Cohen's d
<b>Clinical characteristics</b>					
Age (years)	81.6 ± 3.0	82.1 ± 2.1	0.12 (17.50)	0.90	-0.18
Gender (female/male)	6/5	4/6	-	-	-
Body mass (kg)	62.5 ± 2.91	60.7 ± 3.6	-0.39 (17.65)	0.69	0.56
Height (m)	1.59 ± 0.02	1.62 ± 0.02	0.84 (18.61)	0.40	-1.50
BMI (kg·m <sup>-2</sup> )	24.6 ± 1.1	23.0 ± 1.5	-0.86 (16.98)	0.40	1.20
Schooling (years)	8.9 ± 5.4	9.8 ± 4.8	-	-	-
Time of institutionalization (years)	1.8 ± 0.4	1.4 ± 0.3	-0.89 (18.70)	0.38	1.26
<b>Comorbidities</b>					
Hypertension (%)	72.7	10.0	-	-	-
Osteoarthritis (%)	18.2	0	-	-	-
Diabetes (%)	27.3	20.0	-	-	-
Parkinson's disease (%)	0	10.0	-	-	-
Anxiety (%)	27.3	0	-	-	-
Depression (%)	18.2	30.0	-	-	-

BMI = Body Mass Index.

The high-strength group showed significantly lower ( $p < 0.05$ ) systolic blood pressure ( $d = 6.407$ ), diastolic blood pressure ( $d = 5.478$ ), mean arterial pressure ( $d = 6.223$ ), and risk of cardiovascular disease ( $d = 3.363$ ) than the low-strength group. Moreover, the high-strength group had higher levels of HDL-c ( $d = -3.103$ ), higher estimated glomerular filtration rate ( $d = -6.263$ ) and lower creatinine ( $d = 4.123$ ) than the low-strength group ( $p < 0.05$ ). In terms of cognitive function, as indicated by the Mini-Mental State Examination ( $d = -4.260$ ) and Clock Drawing Test ( $d = -4.780$ ), and physical performance, as indicated by balance (semi-tandem and tandem;  $d = -3.618$  and  $d = -3.656$ , respectively) and walking speed ( $d = -3.677$ ), the high-strength group demonstrated higher performance ( $p < 0.05$ ). There were no significant differences between groups for heart rate, TC, LDL-c, triglycerides, blood glucose, creatinine, verbal fluence, and normal balance ( $p > 0.05$ ), with moderate and large effect size for many variables (see Table 2 for details).

## DISCUSSION

In this study, we assessed the differences between low and high strength on hemodynamic parameters, kidney, cognitive and physical function of older adults who lives in a nursing home. The main findings were: 1) High-strength older adults have better hemodynamic parameters than low-strength older adults; 2) Higher levels of HDL-c and better kidney function in high-strength older adults compared to low strength older adults; 3) better cognitive function and physical performance in high-strength older adults compared to low-strength older adults and; 4) Low-strength older adults have less educational background and higher prevalence of aging-associated diseases compared to high strength older adults.

The worse hemodynamic parameters in the low-strength condition compared to high-strength in older adults can be attributed to low-strength indicators are closely linked to sarcopenia and frailty, and these conditions increase the stiffness of the arterial walls,<sup>7</sup> decreasing compliance and increasing the chance of cardiovascular disease<sup>7</sup>. One possible explanation is that low strength, a greater tendency for Sarcopenia, and physical inactivity can increase the amount of inflammatory markers, in a chronic and low-grade way<sup>20</sup>, increasing the expression of pro-inflammatory cytokines in the blood levels and gene expression, decreasing the bioavailability of nitric oxide, increasing arterial stiffness, the formation of atherosclerotic plaques and increasing endothelial dysfunction, which can worsen hemodynamic parameters<sup>7</sup>.

Vascular aging is part of the aging process, it affects the kidneys, blood vessels, and even cognition<sup>6</sup>. The mechanism behind this association is due to the change in mean arterial pressure resulting from aging<sup>21</sup>. Vascular aging causes veins and arteries to decrease their contractile capacity, causing systolic, diastolic, and mean arterial pressure to increase<sup>22</sup>. This, in turn, affects the veins and arteries, including those of the kidneys and brain, to greater pulsatile circumferential tension and longitudinal shear stress<sup>23</sup>. Both the kidney and the brain are highly vascular organs with a strongly autoregulated blood flow, and this changes from aging<sup>24</sup>, being more accentuated when exposed to constant stress scenarios and lower levels of physical activity<sup>25</sup>. Furthermore, hypoxia, chronic inflammation, and other mechanisms that promote vascular aging can lead to end-organ damage clinically manifested by impaired renal function, functional status, and cognition<sup>6</sup>. Improving strength may be a viable strategy for the improvement of these conditions. Previous studies have reported that following training protocols

**Table 2** – Hemodynamic and biochemical parameters, cognitive function and physical performance of low and high strength older adults.

	Low strength (n = 11)	High strength (n = 10)	t value (df)	p value	Cohen's d
<b>Hemodynamic parameters</b>					
SPB (mmHg)	136.8 ± 3.6	116.5 ± 3.1	-4.19 (18.85)	<b>&lt;0.001</b>	6.407
DBP (mmHg)	84.9 ± 2.1	72.9 ± 2.2	-3.86 (18.80)	<b>0.001</b>	5.478
MAP (mmHg)	102.2 ± 2.4	87.4 ± 2.4	-4.38 (18.96)	<b>&lt;0.001</b>	6.223
HR (bpm)	67.6 ± 2.7	66.3 ± 2.4	-0.36 (18.97)	0.719	0.519
Framingham risk score (%)	39.7 ± 4.6	26.0 ± 3.5	-2.37 (18.01)	<b>0.031</b>	3.363
<b>Biochemical parameters</b>					
TC (mg·dL <sup>-1</sup> )	116.8 ± 10.6	148.6 ± 18.9	1.43 (14.30)	0.157	-2.071
HDL-c (mg·dL <sup>-1</sup> )	27.2 ± 1.7	35.6 ± 3.4	2.25 (13.46)	<b>0.036</b>	-3.103
LDL-c (mg·dL <sup>-1</sup> )	73.6 ± 8.8	97.8 ± 16.2	1.37 (13.98)	0.185	-1.897
Triglycerides (mg·dL <sup>-1</sup> )	82.0 ± 12.9	78.5 ± 9.2	-0.22 (17.69)	0.829	0.316
Blood glucose (mg·dL <sup>-1</sup> )	82.4 ± 4.9	78.5 ± 3.8	-0.61 (18.27)	0.546	0.883
Creatinine (mg·dL <sup>-1</sup> )	0.94 ± 0.10	0.57 ± 0.05	-3.00 (14.36)	<b>0.007</b>	4.123
eGFR (mL·min <sup>-1</sup> ·1.73m <sup>-2</sup> )	51.5 ± 4.9	86.2 ± 5.5	4.73 (18.47)	<b>&lt;0.001</b>	-6.263
<b>Cognitive function</b>					
MMSE (points)	13.3 ± 1.9	19.7 ± 0.9	2.90 (13.98)	<b>0.009</b>	-4.260
CDT (points)	1.0 ± 0.3	3.0 ± 0.5	3.42 (14.65)	<b>0.003</b>	-4.780
VF animal (words)	6.5 ± 1.0	7.1 ± 0.8	0.50 (18.31)	0.618	-0.720
VF color (words)	5.9 ± 1.5	5.8 ± 0.9	-0.06 (16.64)	0.952	0.082
<b>Physical performance</b>					
Normal balance (s)	4.1 ± 1.5	8.0 ± 1.3	1.96 (18.97)	0.064	-2.810
Semi tandem balance (s)	3.2 ± 1.4	8.0 ± 1.3	2.53 (18.97)	<b>0.021</b>	-3.618
Tandem balance (s)	2.9 ± 1.4	7.8 ± 1.3	2.55 (18.99)	<b>0.019</b>	-3.656
WS (m/s)	0.22 ± 0.02	0.36 ± 0.05	2.57 (12.65)	<b>0.018</b>	-3.677

SBP = systolic blood pressure. DBP = diastolic blood pressure. MAP = mean arterial pressure. HR = heart rate. TC = total cholesterol. HDL = high density lipoprotein. LDL = low density lipoprotein. eGFR = estimated glomerular filtration rate. MMSE = mini mental state examination. CDT = clock drawing test. VF = verbal fluency. WS = walking speed.

that increased participants' strength improved glomerular filtration rate<sup>26</sup>, improved hemodynamic parameters<sup>9</sup>, lipid/metabolic profile<sup>27</sup> and cognitive function<sup>28</sup>.

Several factors explain the results of this research on cognitive function and educational background. Older adults with higher strength have higher cognitive function, physical performance, and educational background than older adults with lower strength<sup>9</sup>. Hypotheses from previous studies corroborate that older adults who are more physically active and have more strength<sup>29</sup>, and also with a longer educational background have their physical and cognitive function preserved for longer<sup>30</sup>, including a decrease in the integrity of the brain functions, such as executive function. Another hypothesis is the cognitive reserve<sup>31</sup>, which despite aging, brain plasticity can be preserved and can be influenced by educational factors (higher educational levels), specific and non-specific physical activity, and higher socioeconomic status<sup>30</sup>. Therefore, older people who are stronger and have "trained their brains" have better cognitive function.

Some limitations of the present study should be mentioned and addressed in future studies for a better understanding of the relation between low and high muscle strength, cognitive and kidney functions, and hemodynamics parameters in older nursing-home residents, including our limited sample size, several cognitive and physical performance evaluations, which avoid us to perform more robust statistical analysis, like logistic and multiple regressions. Despite these limitations, our study has its strengths. It elucidates the importance of maintaining strength for a better quality of life for the older adults. It outlines the possible outcomes related to a state of low strength and high strength and can be of great value to researchers, health care providers and public policy programs for health promotion, including for the older adults, and more specifically, the older adults living in nursing homes.

## CONCLUSION

In conclusion, older adults who lives in a nursing home with higher strength have better hemodynamic parameters,

physical performance, kidney and cognitive function than those with lower strength levels. These findings highlight the importance of strength maintenance in older adults, particularly for nursing-home residents.

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Study conception and design: EMA, VSS, VMCB, RXCO, SSA

Data collection: EMA, VSS, VMCB, RXCO, SSA

Data analysis and interpretation: EMA, SSA

Manuscript writing: EMA, SSA

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Final approval of the manuscript\*: EMA, VSS, VMCB, RXCO,

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