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Associations Among Muscular Strength, Aerobic Fitness, and Fatigue Resistance in Community-Dwelling Older Adults

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ABSTRACT: Community-dwelling older adults often experience concurrent declines in muscular strength, aerobic fitness, and tolerance to repeated physical effort, and these changes may undermine independence even before overt disability is apparent. This study examined the associations among muscular strength, aerobic fitness, and fatigue resistance in older men living independently in the community. In a cross-sectional analytical design, 156 men aged 60–84 years completed assessments of handgrip strength, 30-s chair-stand performance, 6-minute walk distance, estimated peak oxygen uptake, and a repeated sit-to-stand fatigue-resistance protocol, together with anthropometric and health screening procedures. Normality was evaluated using the Shapiro–Wilk test, group differences across fatigue-resistance tertiles were examined with one-way analysis of variance, and Pearson correlation and hierarchical multiple regression analyses were used to determine whether strength and aerobic fitness were independently associated with fatigue resistance. Participants with high fatigue resistance were younger and demonstrated greater handgrip strength (39.8 ± 4.2 kg), better chair-stand performance (14.3 ± 1.8 repetitions), longer 6-minute walk distance (549 ± 35 m), and higher estimated VO_2peak (26.1 ± 2.5 mL·kg^{-1}·min^{-1}) than those with low fatigue resistance (32.7 ± 4.5 kg, 11.4 ± 1.6 repetitions, 446 ± 37 m, and 21.6 ± 2.2 mL·kg^{-1}·min^{-1}, respectively; all $p < 0.001$). Fatigue resistance was inversely associated with handgrip strength ($r = -0.62$, $p < 0.001$), chair-stand performance ($r = -0.60$, $p < 0.001$), 6-minute walk distance ($r = -0.69$, $p < 0.001$), and estimated VO_2peak ($r = -0.69$, $p < 0.001$). In hierarchical regression, both handgrip strength ($\beta = -0.25$, $p = 0.003$) and 6-minute walk distance ($\beta = -0.38$, $p < 0.001$) remained independently associated with fatigue resistance after adjustment for age, body mass index, and comorbidity burden (model $R^2 = 0.58$). These findings suggest that muscular strength and aerobic fitness contribute in complementary ways to fatigue resistance in community-dwelling older men and support exercise strategies that integrate resistance and aerobic training to preserve daily function and physical resilience.

Keywords: muscular strength; aerobic fitness; fatigue resistance; older adults; handgrip strength; 6-minute walk test; physical function.

I. INTRODUCTION

Advancing age is accompanied by well-recognized changes in skeletal muscle function, cardiorespiratory capacity, and tolerance to sustained or repeated physical effort. These changes rarely appear in isolation. In many community-dwelling older adults, declining strength, reduced aerobic reserve, and earlier onset of task-related fatigue interact to narrow the margin of independence gradually. An individual may still be able to complete daily tasks, yet the work required to do so becomes progressively more effortful, less efficient, and more exhausting. For this reason, contemporary gerontological exercise research increasingly emphasizes multidimensional fitness rather than relying on a single physiological marker [1]–[4].

Muscular strength occupies a central role because many daily tasks in later life depend on the ability to generate and repeatedly express force. Standing from a chair, climbing stairs, carrying groceries, recovering from a perturbation, or walking across uneven ground all require force generation at a relative intensity that increases as strength declines. Even moderate decrements in strength may therefore alter task difficulty and accelerate functional fatigue. Classic work in older populations has shown that reduced lower-extremity performance and weak muscle function are strongly associated with disability, loss of mobility, and adverse health outcomes [5], [6]. Measures such as handgrip strength and the chair-stand test are practical because they capture global and lower-body strength capacity in ways that are clinically interpretable and ecologically relevant [7]–[9].

Aerobic fitness represents a second and complementary foundation of functional aging. Even when tasks are submaximal, their physiological cost depends in part on the cardiorespiratory reserve available to support them. Older adults with higher aerobic fitness usually tolerate ambulation, repeated transfers, and prolonged activity with lower relative strain, better recovery, and less dyspnea or exhaustion. Walking endurance and estimated aerobic capacity are therefore widely used as indicators of broader physical resilience in older adults [2], [4], [8], [10], [11]. The 6-minute walk test, in particular, has become an attractive field-based measure because it reflects integrated functional endurance while remaining feasible in community settings [8], [24].

Fatigue resistance is less frequently examined in observational studies, yet it may be among the most functionally meaningful constructs in older adulthood. A person may present with acceptable single-effort strength or moderate walking capacity and still struggle when a task must be repeated several times or sustained beyond a brief period. Fatigue resistance captures this ability to maintain performance in the face of accumulating physiological and perceptual strain. This construct is especially relevant in later life because many challenges to independent living do not arise from single maximal efforts but from repeated bouts of activity across the day—standing, walking, transferring, negotiating stairs, and recovering from interruptions in balance or pace [12]–[14].

The aging literature has often examined muscular strength, aerobic fitness, and fatigability in separate disciplinary streams. Strength research has traditionally focused on sarcopenia, force loss, and function; aerobic research has emphasized endurance, mobility, or cardiometabolic health; and fatigability research has centered on symptom burden, perceived effort, or laboratory contraction paradigms. [3], [12], [15]–[18]

From a mechanistic standpoint, greater muscular strength may reduce the relative force demand of each functional task. In contrast, better aerobic fitness may reduce the metabolic and cardiorespiratory strain associated with repeated performance of that task. If both mechanisms operate simultaneously, older adults with favorable values in both domains may show a distinctly better fatigue-resistance profile than those with weakness, low aerobic reserve, or both. From a clinical and public-health perspective, such findings would support integrated exercise prescriptions rather than programs centered on a single component of fitness [2], [4], [11], [15], [16].

The present study focused on community-dwelling older men because this population often remains ambulatory and socially independent, yet shows substantial heterogeneity in physical capacity. Few community-based observational studies have simultaneously included pragmatic measures of upper-body strength, lower-body functional strength, walking-based aerobic fitness, and a repeatable fatigue-resistance outcome in the same sample of older men.

1. STUDY AIM

This study aimed to examine the associations among muscular strength, aerobic fitness, and fatigue resistance in community-dwelling older men. A secondary aim was to determine whether muscular strength and aerobic fitness would remain independently associated with fatigue resistance after adjustment for age, body mass index, and comorbidity burden.

2. STUDY HYPOTHESES

- Higher muscular strength would be associated with better fatigue resistance.
- Higher aerobic fitness would be associated with better fatigue resistance.
- Participants with favorable values in both strength and aerobic fitness would demonstrate the most favorable fatigue-resistance profile.

II. LITERATURE REVIEW

Exercise and aging research has repeatedly shown that no single fitness variable is sufficient to explain late-life physical performance. Position stands, and public-health recommendations emphasize both aerobic activity and muscle-strengthening exercise because the physiological demands of daily life in older age are multidimensional [1]–[4]. Large epidemiological and intervention studies have reinforced this position by showing that habitual activity, walking endurance, and strength are each tied to mobility, disability risk, and survival [5], [10], [11].

Muscular strength has long been recognized as a major determinant of physical function in older adults. Seminal work by Frontera and colleagues demonstrated that older men retain substantial adaptability when exposed to structured resistance training [12], and Fiatarone and colleagues extended this message dramatically by showing that even very old adults can improve strength and muscle function with appropriately supervised high-intensity resistance exercise [13]. Later intervention studies and meta-analytic reviews confirmed that progressive resistance training improves physical function and frailty-related outcomes in older populations [14]–[16]. These findings support the broader view that weakness is not simply an inevitable consequence of age, but a modifiable characteristic with functional consequences.

Handgrip strength remains popular because it is quick, inexpensive, and strongly associated with broader health and functional outcomes [9], [17]. At the same time, lower-body tests such as the 30-second chair-stand test provide an applied measure of functional strength that is closely aligned with transfers, chair rising, and stair negotiation [7].

Aerobic fitness is similarly central to functional aging. Even when tasks are not overtly athletic, they place repeated demands on oxygen transport, ventilation, circulation, and metabolic recovery. Older adults with greater aerobic fitness generally walk farther, recover more quickly, and tolerate longer periods of movement with less physiological strain [2], [4], [8], [10], [11]. The 6-minute walk test has become especially useful in this context because it reflects integrated walking endurance and functional exercise capacity while remaining safe for community assessment [8], [24].

The relationship between strength and aerobic fitness has also been highlighted empirically. For example, studies of home-dwelling older adults indicate that handgrip strength and 6-minute walk performance are positively related, suggesting that muscle fitness and walking-based aerobic capacity are not entirely separate domains [24], [25]. This overlap is logical: walking endurance depends not only on cardiovascular reserve but also on the ability to generate and absorb force across multiple gait cycles.

Eldadah argued that fatigue in older adults should not be treated merely as a vague symptom, but as a clinically meaningful signal with physiological, behavioral, and functional implications [18]. Avlund further proposed that fatigue may serve as an early indicator of the aging process, often emerging before overt disability [19]. More recent work on perceived and performance fatigability has shown that even mobility-intact older adults differ in how rapidly effort, slowing, and functional deterioration appear during standardized tasks [17], [18].

Aging does not always imply greater muscle fatigability. In some contraction paradigms, older adults appear more fatigue-resistant than younger adults [20], [21]. However, these findings often derive from tightly controlled neuromuscular tasks and do not map directly onto the repeated whole-body activities that characterize daily living in older adults. This discrepancy underscores the need to distinguish between isolated contractile fatigability and functional fatigue resistance in real-world populations.

Community-dwelling older adults live in the space between laboratory physiology and functional reality. Many maintain sufficient independence to avoid overt disability, yet they may still experience early declines in task tolerance, reduced reserve, and greater perceived effort during repeated daily activity. Understanding how strength and aerobic fitness relate to fatigue resistance in this population, therefore, has practical value for screening, exercise prescription, and early identification of functional vulnerability.

III. METHODS

This study used a cross-sectional analytical design. Participants were recruited from community centers, senior activity organizations, outpatient wellness programs, and local advertisements. Eligibility was confirmed through a brief screening interview and health questionnaire. Men were included if they were 60

years of age or older, lived independently in the community, and could ambulate without physical assistance. Exclusion criteria were unstable cardiovascular disease, recent major surgery, acute musculoskeletal injury, neurological disease that would substantially interfere with testing, and inability to understand or follow instructions.

A total of 171 men were screened, 156 met the eligibility criteria and completed all testing procedures, and all 156 were included in the final analysis. The final sample had a mean age of 68.8 ± 5.0 years and a mean body mass index of 27.6 ± 3.2 $kg \cdot m^{-2}$. All procedures were carried out in accordance with the Declaration of Helsinki, and written informed consent was obtained before data collection.

Testing was performed during a single standardized assessment session in the following order: anthropometry and health screening, muscular strength testing, aerobic fitness testing, and fatigue resistance testing. Participants were instructed to take their usual medications unless advised otherwise by their physician, avoid unusually strenuous activity for 24 h before testing, and consume a light meal at least 2 h before attendance.

1. MUSCULAR STRENGTH ASSESSMENT

Muscular strength was assessed using handgrip dynamometry and the 30-second chair-stand test. Handgrip strength was measured with a calibrated handheld dynamometer according to standardized procedures. Participants completed two maximal trials with each hand while seated with the elbow flexed at 90°, and the highest value obtained from either hand was retained for analysis. The chair-stand test was used as a complementary measure of lower-body functional strength. Participants were instructed to rise to full standing and return to the chair as many times as possible within 30 s while keeping their arms folded across their chest. The total number of correctly completed repetitions was recorded [7], [9].

2. AEROBIC FITNESS ASSESSMENT

Aerobic fitness was assessed with the 6-minute walk test conducted on an indoor flat course. Participants were instructed to cover as much distance as possible in 6 min at a self-paced, maximal-sustainable speed. Standardized encouragement was provided at regular intervals, and the total distance walked was recorded in meters. Estimated VO_2peak was derived from 6-minute walk performance using an established field-based prediction approach to provide an additional cardiorespiratory-fitness indicator [8], [10], [24], [25].

3. FATIGUE RESISTANCE ASSESSMENT

Fatigue resistance was assessed using a repeated sit-to-stand protocol designed to capture functional performance decline over repeated bouts. Participants completed five 30-second sit-to-stand bouts, each separated by 60 s of seated recovery. The number of successful repetitions in each bout was recorded. A fatigue resistance index was then calculated as the percentage decline between the first and fifth bouts. Lower values indicated better fatigue resistance because they reflected smaller performance loss across the repeated-task sequence. This operational definition was selected because it reflects repeated-task tolerance in a movement that is directly relevant to daily function.

4. COVARIATES

Age, body mass index, and comorbidity burden were included as covariates because each may influence both fitness and fatigue. Comorbidity burden was quantified as the number of physician-diagnosed chronic conditions reported during screening. Weekly physical activity was also recorded descriptively to contextualize the sample.

5. STATISTICAL ANALYSIS

Data are presented as mean ± standard deviation (SD). Normality of the principal continuous variables was examined using the Shapiro–Wilk test and visual inspection of Q–Q plots. Participants were divided into tertiles of fatigue resistance for descriptive group comparisons. One-way analysis of variance (ANOVA) was used to compare participant characteristics and physical-performance variables across fatigue-resistance tertiles, with Bonferroni-adjusted post hoc comparisons where appropriate. Pearson correlation coefficients

were calculated to examine the associations among muscular strength, aerobic fitness, and fatigue resistance. Hierarchical multiple regression was then used to determine whether handgrip strength and 6-minute walk distance remained independently associated with fatigue resistance after adjustment for age, body mass index, and comorbidity burden. Statistical significance was accepted at $p < 0.05$.

IV. RESULTS

Shapiro–Wilk testing indicated no serious departure from normality for the principal variables used in the main analyses (all $p > 0.05$), and inspection of Q–Q plots supported the use of parametric statistics. Participants were then categorized into tertiles of fatigue resistance according to the repeated sit-to-stand fatigue index. Lower fatigue index values indicated better resistance to performance decline. Participant flow is shown in Figure 1.

1. PARTICIPANT CHARACTERISTICS BY FATIGUE-RESISTANCE GROUP

Table 1. Participant characteristics and principal outcome variables across fatigue-resistance tertiles.

Variable	High fatigue resistance (n = 52)	Moderate fatigue resistance (n = 52)	Low fatigue resistance (n = 52)	p value
Age (years)	66.4 ± 4.3	68.0 ± 4.9	72.1 ± 4.2	<0.001
BMI (kg·m^{-2})	27.4 ± 3.5	27.6 ± 2.8	27.8 ± 3.2	0.709
Handgrip strength (kg)	39.8 ± 4.2	36.9 ± 3.8	32.7 ± 4.5	<0.001
Chair-stand repetitions (30 s)	14.3 ± 1.8	12.8 ± 1.6	11.4 ± 1.6	<0.001
6-min walk distance (m)	549 ± 35	496 ± 31	446 ± 37	<0.001
Estimated VO_2peak (mL·kg^{-1}·min^{-1})	26.1 ± 2.5	24.3 ± 2.1	21.6 ± 2.2	<0.001
Fatigue resistance index (%)	16.6 ± 2.3	20.9 ± 0.9	24.6 ± 1.5	<0.001

Table 1 shows a clear gradient across fatigue-resistance tertiles. Men in the high-fatigue-resistance group were younger and demonstrated stronger handgrip performance, better chair-stand capacity, longer 6-minute walk distance, and higher estimated VO_2peak than those in the low-fatigue-resistance group. The between-group differences were especially pronounced for handgrip strength, chair-stand repetitions, and walking-based aerobic fitness, all of which differed significantly across tertiles ($p < 0.001$). Body mass index did not differ significantly among the groups, suggesting that the observed performance pattern was not driven simply by body size.

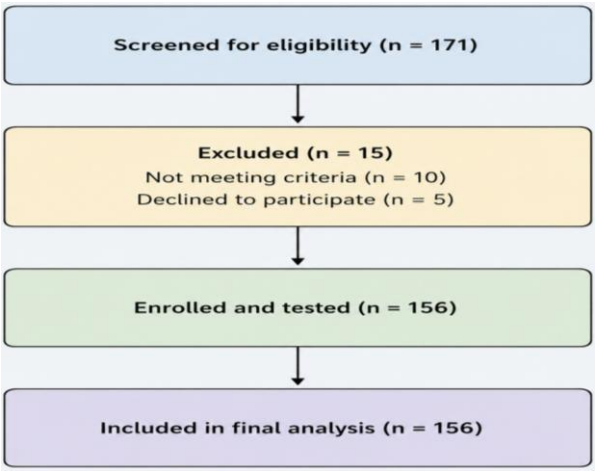

FIGURE 1. Participant flow diagram.

Figure 1 is important because it confirms that the final analytical sample represented the great majority of screened volunteers and that attrition was minimal. In observational studies of older adults, this type of diagram helps the reader judge whether the sample was formed systematically and whether exclusions were likely to introduce major bias.

2. CORRELATION ANALYSES

Table 2. Pearson correlation matrix for the principal study variables. *** $p < 0.001$.

Variable	Handgrip strength	Chair-stand test	6-min walk distance	Estimated VO_2peak	Fatigue resistance index
Handgrip strength	1.00	0.73***	0.77***	0.78***	-0.62***
Chair-stand test	0.73***	1.00	0.72***	0.78***	-0.60***
6-min walk distance	0.77***	0.72***	1.00	0.80***	-0.69***
Estimated VO_2peak	0.78***	0.78***	0.80***	1.00	-0.69***
Fatigue resistance index	-0.62***	-0.60***	-0.69***	-0.69***	1.00

As shown in Table 2, both muscular strength and aerobic fitness were significantly associated with fatigue resistance. Handgrip strength demonstrated a moderate-to-strong inverse association with the fatigue resistance index ($r = -0.62$, $p < 0.001$), indicating that stronger men exhibited less performance loss across repeated sit-to-stand bouts. The 6-minute walk distance showed an even stronger inverse association with fatigue resistance ($r = -0.69$, $p < 0.001$), suggesting that better walking-based aerobic fitness was linked to more stable repeated-task performance. Estimated VO_2peak demonstrated a similarly strong relationship ($r = -0.69$, $p < 0.001$), reinforcing the interpretation that cardiorespiratory fitness was not merely tangential but centrally related to fatigue resistance.

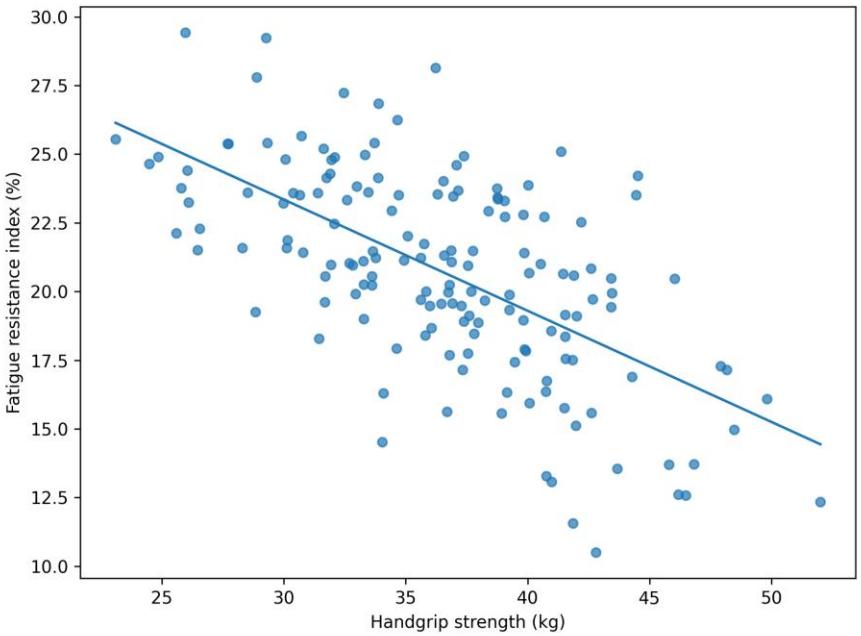

FIGURE 2. Relationship between handgrip strength and fatigue resistance index.

Figure 2 shows that the association between muscular strength and fatigue resistance was continuous rather than driven only by extreme values. The negative slope indicates that as handgrip strength increased, the percentage decline across repeated sit-to-stand bouts became smaller. This figure is important because it shows that strength was not merely a descriptive characteristic of the most robust participants; it was systematically related to fatigue resistance across the full sample.

FIGURE 3. Relationship between 6-minute walk distance and fatigue resistance index.

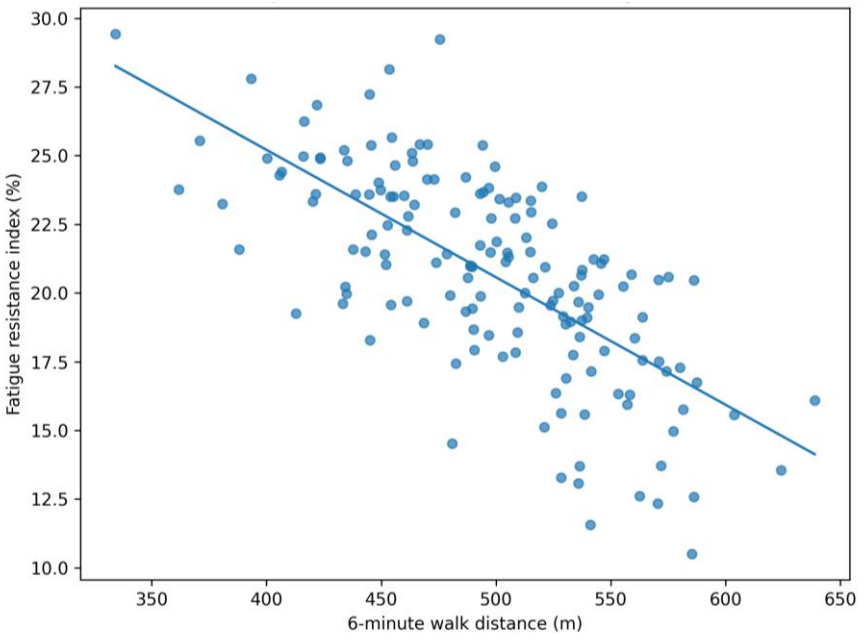

Figure 3 complements the strength finding by showing a similarly graded relationship between aerobic fitness and fatigue resistance. Men who covered a greater distance during the 6-minute walk test tended to show less decline in repeated sit-to-stand performance. This figure is especially valuable because it links a practical, widely used field-based endurance measure to a repeated-task fatigue outcome directly relevant to everyday function.

3. HIERARCHICAL REGRESSION ANALYSIS

Table 3. Final hierarchical regression model predicting fatigue resistance index (model $R^2 = 0.58$, adjusted $R^2 = 0.57$, $p < 0.001$).

Predictor	B	SE	Beta	p value
BMI (kg·m^{-2})	0.11	0.06	0.10	0.070
Comorbidity burden	0.58	0.17	0.19	0.001
Handgrip strength (kg)	-0.17	0.06	-0.25	0.003
6-min walk distance (m)	-0.03	0.01	-0.38	<0.001

Hierarchical multiple regression showed that the associations observed in the unadjusted analyses remained meaningful after statistical control. Age, body mass index, and comorbidity burden explained 27% of the variance in fatigue resistance. Adding handgrip strength increased the explained variance to 53%, and the final model, including 6-minute walk distance, explained 58% of the total variance. In the fully adjusted model, handgrip strength ($\beta = -0.25$, $p = 0.003$) and 6-minute walk distance ($\beta = -0.38$, $p < 0.001$) both remained independently associated with fatigue resistance, whereas body mass index was not a significant predictor. These results suggest that muscular and aerobic fitness each contributed unique explanatory value rather than merely reflecting the same underlying trait.

FIGURE 4. Fatigue resistance by combined strength-fitness profile.

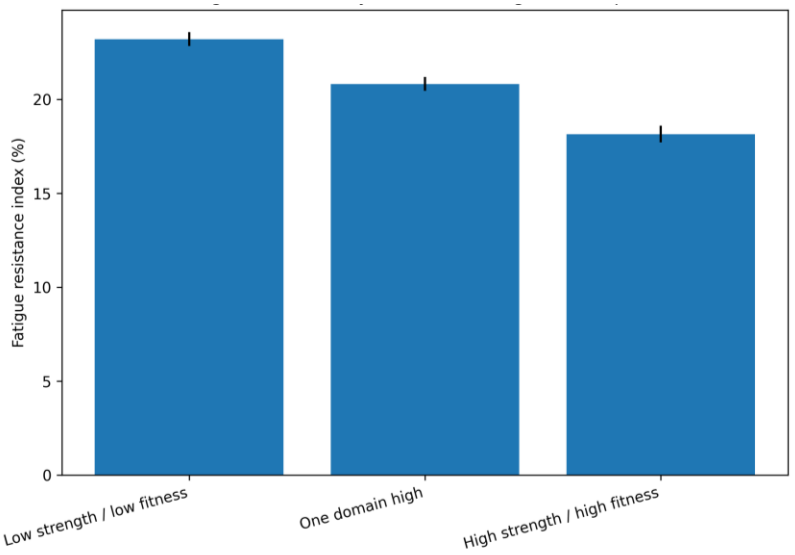

Figure 4 illustrates the combined effects of strength and aerobic fitness in practice. Participants classified as high in both strength and aerobic fitness demonstrated the lowest fatigue resistance index, whereas those low in both domains demonstrated the poorest profile. This figure is important because it shows that the two predictors are best understood as complementary contributors to functional resilience rather than competing explanations.

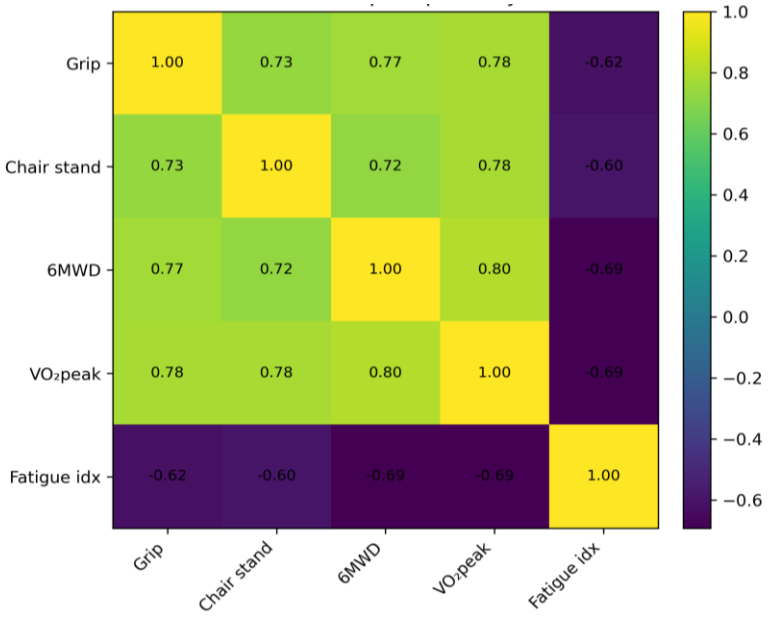

FIGURE 5. Correlation matrix of the principal study variables.

Figure 5 provides a concise overview of how the study variables clustered. The heatmap highlights the strong positive relationships among strength and fitness measures and the uniformly negative relationships between those variables and the fatigue resistance index. It is included because it helps the reader appreciate the coherence of the data structure before turning to the multivariable interpretation.

V. DISCUSSION

The purpose of this study was to examine the associations among muscular strength, aerobic fitness, and fatigue resistance in community-dwelling older men. The main finding was straightforward: men with greater strength and better aerobic fitness also demonstrated better resistance to fatigue during a repeated functional task. Importantly, both domains remained independently associated with fatigue resistance after adjustment for age, body mass index, and comorbidity burden. This suggests that fatigue resistance in older adults is not adequately explained by a single aspect of fitness but instead emerges from the combined influence of neuromuscular and cardiorespiratory capacity.

The strength findings are consistent with the long-standing view that muscle weakness increases the relative demand of everyday tasks [5]–[7], [12]–[16]. In practical terms, standing from a chair repeatedly requires a larger fraction of available force when absolute strength is low. When each repetition consumes a greater proportion of the individual's maximum capacity, the task becomes more difficult to sustain, and performance is more likely to deteriorate across repeated bouts. The present results fit that interpretation well. Participants with stronger handgrip and better chair-stand performance showed smaller declines in repeated-task output, indicating that better force-producing capacity translated into greater task tolerance.

The 6-minute walk distance and estimated VO_2peak both showed strong inverse associations with the fatigue resistance index, and 6-minute walk distance remained a significant predictor even in the fully adjusted model. This finding suggests that fatigue resistance in older adults is not only a matter of how much force can be produced, but also of how effectively physiological strain can be supported and recovered between repeated efforts. Older men with higher aerobic fitness likely performed the sit-to-stand bouts at a lower relative metabolic cost, which may have allowed them to preserve movement quality and repetition rate more effectively across the sequence.

Figure 4 showed that men who were high in both strength and aerobic fitness had clearly better fatigue resistance than those who were low in both domains, whereas those high in only one domain fell in the intermediate range. This pattern supports a complementary model in which strength and aerobic fitness make distinct, albeit partly overlapping, contributions to functional endurance. Strength may reduce the mechanical burden of each repetition, whereas aerobic fitness may support recovery and energy supply across repeated efforts. When both are favorable, fatigue resistance appears strongest.

These results align with broader aging research emphasizing multidimensional exercise programming [1]–[4], [14]–[16]. Resistance training improves force-generating capacity and can reverse important aspects of functional decline even in very old adults [12], [13]. Aerobic training improves walking endurance, exercise tolerance, and mobility reserve [2], [4], [10], [11], [15]. The present findings suggest that these benefits should not be viewed in isolation. In community-dwelling older men, the ability to resist fatigue during repeated functional activity appears to depend on both domains.

If an older adult presents with poor fatigue resistance, it may be insufficient to evaluate only one component of fitness. A person with acceptable walking capacity may still struggle if strength is low, and a person with reasonable strength may still fatigue early if aerobic reserve is poor. Multidimensional assessment may therefore help explain functional complaints that appear disproportionate when judged against a single test result.

Table 1 demonstrates that the fatigue-resistance groups differed not merely in the outcome itself but across a broad functional profile. Table 2 shows that the associations were not trivial and extended across several related variables. Table 3 demonstrates that the independent contributions of strength and aerobic fitness persisted after adjustment. Figures 2 and 3 make clear that the key associations were graded and continuous, while Figure 4 translates the multivariable findings into an applied format meaningful to clinicians and exercise professionals.

Several limitations should be acknowledged. First, the cross-sectional design does not permit causal inference. Although greater strength and better aerobic fitness were associated with greater fatigue resistance, the present analyses cannot determine the direction of causality. Second, the sample included only community-dwelling older men, which improved comparability but limits direct generalization to women or more medically complex populations. Third, fatigue resistance was operationalized through a repeated sit-to-stand protocol. This definition is functionally meaningful, but other fatigue paradigms may produce somewhat

different association patterns. Fourth, aerobic fitness was estimated using a field-based approach rather than directly measured gas exchange testing.

Even with these limitations, the internal coherence of the results strengthens the overall interpretation. The same participants who performed better on strength and walking-endurance tests also showed less decline in performance across repeated functional effort, and these relationships persisted in multivariable analysis. That consistency is important because it suggests the findings reflect a meaningful pattern in physical function rather than isolated statistical artifacts.

Future studies should extend this work in several directions. Longitudinal designs could determine whether changes in strength and aerobic fitness predict changes in fatigue resistance over time. Intervention trials could test whether combined resistance and aerobic training yields greater improvements in fatigue resistance than single-modality programs. It would also be valuable to include women, older adults with chronic disease, and more direct measures of aerobic capacity and neuromuscular fatigability. Finally, combining objective performance metrics with perceived fatigability scales may offer a richer account of how older adults experience and express fatigue in daily life [17]–[20].

VI. CONCLUSION

In community-dwelling older men, muscular strength and aerobic fitness were each positively associated with fatigue resistance. Men with stronger handgrip performance, better lower-body functional strength, and greater walking-based aerobic fitness showed smaller declines in performance during a repeated sit-to-stand task. These associations remained meaningful after adjustment for age, body mass index, and comorbidity burden.

The findings suggest that fatigue resistance should not be interpreted solely as a symptom of aging or generalized deconditioning. Instead, it appears to reflect the combined functional influence of neuromuscular and cardiorespiratory capacity. This has practical implications for exercise screening and exercise prescription in community settings, where preserving independence often depends on sustaining repeated daily activity rather than achieving isolated maximal performance.

Accordingly, older-adult exercise programs may be most effective when they integrate both resistance and aerobic conditioning. Improving only one component of fitness may leave an important part of the fatigue-resistance profile unchanged. In contrast, combined improvements in strength and aerobic fitness may offer a broader and more durable protection against functional decline.

Third, future studies should incorporate women, ethnically diverse community samples, and older adults with more complex disease profiles. These groups may show different interaction patterns among strength, fitness, and fatigue. Fourth, integrating objective performance outcomes with perceived fatigability scales, accelerometer-derived activity patterns, or direct physiological testing could clarify whether the experience of fatigue and the expression of fatigue resistance follow the same pathways. This would move the field toward a more comprehensive understanding of physical resilience.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

REFERENCES

1. R. S. Mazzeo, P. Cavanagh, W. J. Evans, M. Fiatarone, J. Hagberg, E. McAuley, and J. Startzell, "Exercise and physical activity for older adults," Med. Sci. Sports Exerc., vol. 30, no. 6, pp. 992–1008, 1998, doi: 10.1097/00005768-199806000-00033.
2. M. E. Nelson, W. J. Rejeski, S. N. Blair, P. W. Duncan, J. O. Judge, A. C. King, C. A. Macera, and C. Castaneda-Sceppa, "Physical activity and public health in older adults: recommendations from the American College of Sports Medicine and the American Heart Association," Med. Sci. Sports Exerc., vol. 39, no. 8, pp. 1435–1445, 2007, doi: 10.1249/mss.0b013e3180616aa2.
3. W. J. Chodzko-Zajko et al., "Exercise and physical activity for older adults," Med. Sci. Sports Exerc., vol. 41, no. 7, pp. 1510–1530, 2009, doi: 10.1249/MSS.0b013e3181a0c95c.
4. D. H. Paterson and D. E. R. Warburton, "Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines," Int. J. Behav. Nutr. Phys. Act., vol. 7, art. 38, 2010, doi: 10.1186/1479-5868-7-38.
5. J. M. Guralnik, E. M. Simonsick, L. Ferrucci, R. J. Glynn, L. F. Berkman, D. G. Blazer, P. A. Scherr, and R. B. Wallace, "A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission," J. Gerontol., vol. 49, no. 2, pp. M85–M94, 1994, doi: 10.1093/geronj/49.2.M85.
6. S. Studenski et al., "Gait speed and survival in older adults," JAMA, vol. 305, no. 1, pp. 50–58, 2011, doi: 10.1001/jama. 2010.1923.
7. R. E. Rikli and C. J. Jones, "The reliability and validity of a 6-minute walk test as a measure of physical endurance in older adults," J. Aging Phys. Act., vol. 6, no. 4, pp. 363–375, 1998, doi: 10.1123/japa. 6.4.363.
8. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, "ATS statement: guidelines for the six-minute walk test," Am. J. Respir. Crit. Care Med., vol. 166, no. 1, pp. 111–117, 2002, doi: 10.1164/ajrccm. 166.1.at1102.
9. R. W. Bohannon, "Hand-grip dynamometry predicts future outcomes in aging adults," J. Geriatr. Phys. Ther., vol. 31, no. 1, pp. 3–10, 2008, doi: 10.1519/00139143-200831010-00002.
10. E. F. Binder, K. B. Schechtman, A. A. Ehsani, K. Steger-May, M. Brown, D. R. Sinacore, K. E. Yarasheski, and J. O. Holloszy, "Effects of exercise training on frailty in community-dwelling older adults: results of a randomized, controlled trial," J. Am. Geriatr. Soc., vol. 50, no. 12, pp. 1921–1928, 2002, doi: 10.1046/j.1532-5415.2002.50601.x.
11. M. Pahor et al., "Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial," JAMA, vol. 311, no. 23, pp. 2387–2396, 2014, doi: 10.1001/jama. 2014.5616.
12. W. R. Frontera, C. N. Meredith, K. P. O'Reilly, H. G. Knuttgen, and W. J. Evans, "Strength conditioning in older men: skeletal muscle hypertrophy and improved function," J. Appl. Physiol., vol. 64, no. 3, pp. 1038–1044, 1988, doi: 10.1152/jappl. 1988.64.3.1038.
13. M. A. Fiatarone, E. C. Marks, N. D. Ryan, C. N. Meredith, L. A. Lipsitz, and W. J. Evans, "High-intensity strength training in nonagenarians: effects on skeletal muscle," JAMA, vol. 263, no. 22, pp. 3029–3034, 1990, doi: 10.1001/jama.1990.03440220053029.
14. C. J. Liu and N. K. Latham, "Progressive resistance strength training for improving physical function in older adults," Cochrane Database Syst. Rev., no. 3, CD002759, 2009, doi: 10.1002/14651858.CD002759.pub2.
15. D. T. Villareal et al., "Aerobic or resistance exercise, or both, in dieting obese older adults," N. Engl. J. Med., vol. 376, no. 20, pp. 1943–1955, 2017, doi: 10.1056/NEJMoa1616338.
16. R. Cooper, D. Kuh, and R. Hardy, "Objectively measured physical capability levels and mortality: systematic review and meta-analysis," BMJ, vol. 341, c4467, 2010, doi: 10.1136/bmj.c4467.
17. N. W. Glynn, A. J. Santanasto, E. M. Simonsick, R. M. Boudreau, S. R. H. Beach, R. Schulz, and A. B. Newman, "The Pittsburgh fatigability scale for older adults: development and validation," J. Am. Geriatr. Soc., vol. 63, no. 1, pp. 130–135, 2015, doi: 10.1111/jgs. 13191.
18. E. M. Simonsick, J. A. Schrack, N. W. Glynn, and L. Ferrucci, "Assessing fatigability in mobility-intact older adults," J. Am. Geriatr. Soc., vol. 62, no. 2, pp. 347–351, 2014, doi: 10.1111/jgs. 12638.
19. B. A. Eldadah, "Fatigue and fatigability in older adults," PM&R, vol. 2, no. 5, pp. 406–413, 2010, doi: 10.1016/j.pmrj.2010.03.022.
20. K. Avlund, "Fatigue in older adults: an early indicator of the aging process?" Aging Clin. Exp. Res., vol. 22, no. 2, pp. 100–115, 2010, doi: 10.1007/BF03324782.
21. I. R. Lanza, D. W. Russ, J. R. Kent-Braun, "Age-related enhancement of fatigue resistance is evident in men during both isometric and dynamic tasks," J. Appl. Physiol., vol. 97, no. 3, pp. 967–975, 2004, doi: 10.1152/japplphysiol. 01351.2003.
22. E. S. Rawson, M. P. Clarkson, and M. J. Tarnopolsky, "Enhanced fatigue resistance in older adults during repeated sets of intermittent contractions," J. Strength Cond. Res., vol. 24, no. 1, pp. 251–256, 2010, doi: 10.1519/JSC.0b013e3181a8f7cf.
23. Q. Zhang, H. Lu, S. Pan, Y. Lin, K. Zhou, and L. Wang, "6MWT performance and its correlations with VO_2 and handgrip strength in home-dwelling mid-aged and older Chinese," Int. J. Environ. Res. Public Health, vol. 14, no. 5, art. 473, 2017, doi: 10.3390/ijerph14050473.
24. P.-J. Pan, M.-J. Lin, J.-Y. Lee, and Y.-C. Cheng, "Physical fitness and its correlation with handgrip strength in active community-dwelling older adults," Sci. Rep., vol. 12, art. 20695, 2022, doi: 10.1038/s41598-022-21736-w.
25. M. Brown, D. R. Sinacore, E. F. Binder, and W. M. Kohrt, "Physical and performance measures for the identification of mild to moderate frailty," J. Gerontol. A Biol. Sci. Med. Sci., vol. 55, no. 6, pp. M350–M355, 2000, doi: 10.1093/gerona/55.6.M350.