Relationship Between Physical Performance and Peripheral Arterial Diseases in Different Age Groups of Chinese Community-Dwelling Older Adults

Xiya Fu1,2,3, Yiqiong Qi1,2,3, Peipei Han1,3, Xiaoyu Chen1,3, Feng Jin1,3, Zezhuo Shen3, Yikai Mou3, Zhengwei Qi3, Jiacheng Zhu3, Yangyi Chen3, Wenjing Zhou3, Yaqing Zheng4, Ziwei Zhang4, Ming Li5 and Qi Guo1,3

Aims: This study aimed to examine the relationship between physical performance and peripheral artery disease (PAD) in different age groups of Chinese older adults.

Methods: We enrolled 1357 relatively healthy ≥ 65 years old participants of Chinese ethnicity. We classified the participants into two age categories, the pre-old group (65–74 years, n=968) and the old group (≥ 75 years, n=389). We assessed the cross-sectional association of the ankle–brachial index (ABI), which is used for the classification of patients with PAD (ABI ≤ 0.9). Physical performance mainly focused on muscle strength, mobility, and balance, which were measured via hand grip, 4 m walking speed, and the Timed Up and Go Test.

Results: A total of 125 (9.2%) patients met the diagnostic criteria and were defined as having PAD. After multivariate adjustment, we found that grip strength and 4 m walking speed were correlated negatively with PAD (odds ratio (OR) 0.953, 95% confidence interval (CI) 0.919–0.989; OR 0.296, 95% CI 0.093–0.945) in pre-old participants, whereas balance (OR 1.058, 95% CI 1.007–1.112) was correlated positively with PAD only in older participants.

Conclusion: Our study further confirmed the association between physical performance and PAD in community-dwelling older Chinese adults. Muscle strength and mobility correlated negatively with PAD, and balance was positively associated with PAD in older participants. These findings might help with better early screening and management of PAD.

Key words: Peripheral artery disease, Grip strength, Timed Up and Go Test, 4-meter walking speed

Introduction

Population aging is a global phenomenon. Peripheral artery disease (PAD) is the third leading cause of atherosclerotic vascular morbidity after coronary heart disease1; however, PAD is the most underdiagnosed, underestimated, and undertreated atherosclerotic vascular disease and is often asymptomatic2. The PAD prevalence and incidence are both sharply age-related, and the prevalence in
old–old people is twice as high as that in young–old people. Physical function decreases as age increases, and a high prevalence of dysfunction and reduced potential for the enhancement of function is found among older individuals. Additionally, PAD is associated with higher cardiovascular morbidity and mortality and functional impairment in the lower limbs. Therefore, the prevention and early detection of PAD in the elderly are very important.

Patients with PAD should be advised and supported to exercise to improve their physical function. However, population-based studies have been inconclusive about the relationship between physical performance and PAD. The evaluation of the physical performance of older adults mainly focuses on mobility, balance, and muscle strength. Impaired blood flow and decreased oxygen and vascular pathologies may cause poor control and hamper the patient’s mobility and lead to weakness and poor physical function. However, some studies found that mobility did not correlate with PAD and that PAD was associated with muscle strength but only in nonhypertensive participants. Additionally, older age was consistently an important risk factor for PAD. Some studies reported that greater impairment in peripheral hemodynamic measurements occurs in older patients. The pre-old are generally active, and their functional capacity is usually conserved, whereas the older–old are mostly characterized by disability and dependency. However, Myers et al. showed that typical aging in the absence of ambulatory comorbidities may not result in a significant decline in function. In summary, it is unclear whether age has any effect on the physical function of patients with PAD.

Methods

Study Population

For the current study, we recruited residents from Chongming of Shanghai, China. All subjects were invited to participate in a comprehensive geriatric assessment and assessment. A total of 1473 community-dwelling older adults aged 65 years or older participated in the national free physical examination program from 2019 to 2020. Participants were excluded from this study if their measurements of physical performance were not conducted because of the following: leg pain and leg ulcers, history of lower extremity occlusive disease (n=18), lesions or amputations (n=1), and ankle–brachial index (ABI) (n=38) that was not measured. Those with ABI values higher than 1.40 were also excluded (n=59) because this level of ABI is consistent with poorly compressible leg arteries and the inability to accurately gauge arterial perfusion. Altogether, 1357 participants were analyzed. This study was approved by the Institutional Review Boards, and written informed consent was obtained from all participants.

Measurement of Ankle–Brachial Index

ABI is a simple, noninvasive diagnostic method recommended for the detection of symptomatic and asymptomatic PAD. Decreased ABI was defined as ABI ≤ 0.9. We measured ABI with a validated automatic device (BP-203PRE III, Omron, Kyoto, Japan), which automatically measured the blood pressure twice after the participants had rested for at least 5 min in the supine position. Using the higher value of the right or left brachial systolic blood pressure as the denominator, the ABI, the ratio of ankle systolic blood pressure to brachial systolic blood pressure, was calculated for the right and left legs. We selected the lowest ABI in cases of differences between the left and right ABI.

Physical Performance Assessment

Grip strength was measured to the nearest 0.1 kg using a handheld dynamometer (GRIP-D; Takei Ltd., Niigata, Japan). Participants were asked to exert their maximum effort twice using their dominant hand, and the average of two attempts was used for analysis.

Balance was assessed by the Timed Up and Go Test (TUGT), in which a participant was timed while rising from a chair, walking 3 m, turning around, walking back to the chair, and sitting on the chair. The time was recorded in seconds.

The 4 m walking test as an indicator of mobility was measured in a straight corridor with 6 m length...
marks on the ground. The participants were timed while walking 4 m at their usual pace, but we recorded the time to cover only the inner 4 m range to avoid the acceleration and deceleration stages of the participant’s walking. Participants completed the test twice, and the average gait speed (m/s) was used for analysis.  

Analysis of Blood Samples and Blood Pressure  
A blood sample was obtained from the antecubital vein of patients who fasted overnight for at least 10 h. The blood sample analysis and blood pressure collection methods have been explained in our previous studies.  

Definition of CKD  
To measure the estimated glomerular filtration rate (eGFR), a blood sample was collected via venipuncture after an overnight fast of at least 10 h. Serum creatinine (Scr) levels were measured in a certified central laboratory via a compensated Jaffe assay, traceable to IDMS (Roche Diagnostics, Mannheim, Germany). The eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation: eGFR (ml/min/1.73 m²) = \(141 \times \min(\text{Scr/k},1)^{1.154} \times \max(\text{Scr/k},1)^{-0.203} \times 0.993^{\text{age}} \times 1.018 \) if female and \(\times 1.159\) if black, where \(k=0.7\) if female, \(k=0.9\) if male, \(a=0.329\) if female, and \(a=-0.411\) if male. Additionally, Scr means the serum creatinine level, the \(\min\) is the minimum of or 1, and the \(\max\) is the maximum of \(\text{Scr/k}\) or 1. Participants were classified based on their eGFR levels by the National Kidney Foundation guidelines, and eGFR \(\geq 60\) ml/min/1.73 m² as not having CKD and eGFR \(< 60\) ml/min/1.73 m² as having CKD.  

Covariates  
All of the participants were invited to a face-to-face interview to answer a standardized questionnaire after they completed their medical examination. The questionnaire included questions about age, sex, education level, smoking habits, and drinking habits. Height and weight were recorded using a standard protocol. The short form of the International Physical Activity Questionnaire (IPAQ) was used to assess physical activity. A history of physical illness was evaluated based on participants’ responses to questions about their history, which included diabetes, hypertension, hyperlipidemia, stroke, heart failure, lower extremity occlusive disease, past diagnoses made by physicians, and current or historical medication regimens. Antihypertensive drugs include angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, beta-blockers, calcium channel blockers, diuretics, and alpha-blockers. Antidiabetic drugs include sulfonylureas, biguanide, \(\alpha\)-glucosidase inhibitors, nonsulfonylureas insulin secretors, thiazolidinediones, and insulin. Hypolipidemic drugs include statins, fibrates, and niacin bile acid chelators. Body mass index was calculated as weight in kilograms divided by height in meters squared. We also used electrical bioimpedance analysis (In-Body 720; Biospace Co., Ltd., Seoul, Korea) to estimate the participants’ body compositions, including appendicular skeletal mass. Cognitive assessment was completed using the Mini-Mental State Examination (MMSE) by trained investigators.  

Statistical Analysis  
All statistical analyses were performed using IBM SPSS v25.0 software (SPSS Inc., Chicago, IL, USA). The significance level in the current research was set as 0.05. Baseline sociodemographic and health-related characteristics were compared between participants in two age groups: pre-old people and old people with and without PAD using an independent \(t\) test for numerical variables and a chi-square test for categorical variables. Data with a normal distribution are expressed as the mean±SD; categorical variables are expressed as proportions; and continuous nonnormal distribution variables, such as IPAQ, are expressed as the median and quartile. Associations between PAD and grip strength, TUGT, and walking speed were evaluated via binary logistic regression, which was constructed using stepwise and backward elimination algorithms. The results are presented as odds ratios (ORs), 95% confidence intervals (CIs), and corresponding \(p\) values. Model adjusted variables included age, sex, BMI, smoking, drinking, education, heart disease, hypertension, diabetes, hyperlipidemia, stroke, osteoarthritis, CKD, and MMSE.  

Results  
Characteristics of the Participants  
A total of 1357 participants (968 pre-old and 389 old) were included in the analysis. A total of 125 (9.2%) met the diagnostic criteria and were defined as having PAD, including 64 old people and 61 pre-old people. The characteristics of the participants in the different age groups are shown in Table 1. Compared with those in the non-PAD group, the pre-old participants in the PAD group were on average older, had a slower walking speed, were less educated, had a worse cognitive function, were more frequently women and smokers, had higher systolic blood pressure, and had suffered from hypertension.
To those in the old non-PAD group. diabetes, and stroke. Moreover, old people with PAD were older, were more frequently smokers, had worse balance, and most suffered from heart disease relative
Relationship between Physical Performance and PAD

The relationship between physical performance and PAD is shown in Table 2. When we stratified all adults by age, we found that grip strength was not associated with PAD (OR=0.978, 95% CI=0.939–1.005; OR=1.003, 95% CI=0.967–1.033) in all participants, and 4 m walking speed was negatively correlated with PAD (OR=0.184, 95% CI=0.061–0.551) in pre-old participants. Balance was positively associated with PAD in older participants (OR=1.050, 95% CI=1.003–1.107) in older participants. In the fully adjusted model, we found that grip strength and 4 m walking speed were correlated negatively with PAD (OR=0.953, 95% CI=0.919–0.989; OR=0.296, 95% CI=0.093–0.945) in pre-old participants; greater strength and faster walking speed were protective factors against PAD. However, in older participants, the balance remained significantly associated with PAD (OR=1.058, 95% CI=1.007–1.112).

**Discussion**

This study examined the relationship between physical performance and PAD in different age groups. The results demonstrated that muscle strength and mobility correlated negatively with PAD in pre-old participants, and only balance was positively associated with PAD in old participants.

Relationship between Muscle Strength and PAD

Previous studies have also reported an association between muscle strength and PAD. A large study found that arterial stiffness was not associated with hand grip strength in hypertensive Indian men and hypertensive women in both India and Japan 14, which was similar to the results of this study. We observed no association between PAD and grip strength when we stratified all adults by age. In this population, people with PAD suffered from hypertension. A hypertensive-induced endothelial injury might not always induce atherosclerosis, and endothelial injury could induce atherosclerosis and angiogenesis (increased collateral blood flow), which leads to the maintenance of grip strength 26, 27. However, we found the grip strength correlated negatively with pre-old PAD patients in the fully adjusted model. Several possible explanations exist for the mechanism underlying the relationship between grip strength and PAD. Several studies have reported inflammatory cytokines and markers (interleukin‐6, tumor necrosis factor-alpha, C‐reactive protein) to be inversely associated with muscle strength 28. Inflammatory cytokines can alter blood vessel dynamics, which in turn can alter muscle metabolism and skeletal muscle breakdown 29. However, McDermott et al. showed significant associations between ABI and handgrip or knee extension isometric strength. This result matched that of our recent study, which found that there was no association between PAD and grip strength, suggesting that greater global weakness in persons with PAD affects both upper and lower extremity strength 4, 30. We also found that the muscle mass of pre-old persons was higher than that of old persons. This finding indicates an accelerated loss of whole-body muscle mass in individuals with age. We believe the different results may be due to the specific populations, and the results of our study need to be validated in other populations in the future.

Relationship between mobility and PAD

A correlation was found between 4 m walking speed and PAD (OR=0.265, 95% CI=0.083–0.843) in pre-old PAD patients. Our results are in line with previous studies 31 showing positive associations of lower ABI or a clinical diagnosis of PAD with objective measurements of impaired physical function. Among all LIFE participants, lower ABI values were significantly associated with slower 4 m walking velocity 31. This likely reflects that lower extremity atherosclerosis results in inadequate oxygen supply to

---

**Table 2. Logistic Regression Analysis of Physical Performance and PAD**

<table>
<thead>
<tr>
<th>Variables</th>
<th>65-74</th>
<th>≥ 75</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude</td>
<td>Adjusted</td>
</tr>
<tr>
<td></td>
<td>OR (95%CI) p</td>
<td>OR (95%CI) p</td>
</tr>
<tr>
<td>Grip strength</td>
<td>0.978 (0.939-1.005) 0.079</td>
<td>0.953 (0.919-0.989) 0.010</td>
</tr>
<tr>
<td>4-metre walking test</td>
<td>0.184 (0.061-0.551) 0.002</td>
<td>0.296 (0.093-0.945) 0.040</td>
</tr>
<tr>
<td>TUGT</td>
<td>1.035 (0.987-1.093) 0.214</td>
<td>0.968 (0.891-1.052) 0.444</td>
</tr>
</tbody>
</table>

Adjusted by age, sex, BMI, smoking, drinking, education, heart disease, hypertension, diabetes, hyperlipidaemia, stroke, osteoarthritis, chronic kidney disease, MMSE.
lower extremity skeletal muscle during walking. Consistent with these results, a prior cross-sectional study shows that PAD participants who are always asymptomatic have smaller calf muscle areas and lower calf muscle density and have higher rates of mobility loss as compared with participants without PAD. Several studies have shown an association of muscle strength with gait speed, which could explain why gait speed was not associated with PAD in older persons. The results of the current study support the earlier findings of McDermott and colleagues. Among asymptomatic patients with PAD, self-directed walking exercise performed at least three times weekly is associated with a significantly less functional decline during the subsequent year. In our study, there were significant differences in activities of daily living between pre-old and old people. We believe that differences in lower extremity physical performance among PAD patients of different ages are primarily due to differences in physical activity level rather than to PAD severity. Given the evidence that physical inactivity is a major risk factor for coronary heart disease, it stands to reason that physical activity inactivity is a major risk factor for coronary heart due to differences in physical activity level rather than among PAD patients of different ages are primarily differences in lower extremity physical performance between pre-old and old people. We believe that significant differences in activities of daily living between pre-old and old people. We believe that differences in lower extremity physical performance among PAD patients of different ages are primarily due to differences in physical activity level rather than to PAD severity. Given the evidence that physical inactivity is a major risk factor for coronary heart disease, it stands to reason that physical activity should have a major influence on the primary prevention of PAD. Thus, physical inactivity should be listed as an additional modifiable risk factor for PAD, although the precise quantitative impact has not been studied.

Relationship between Balance and PAD

This study found a correlation between balance and PAD (OR=1.058, 95% CI=1.007–1.112) in older people. This was consistent with the results of previous studies. The TUGT has been endorsed by the US Centers for Disease Control and Prevention as a clinically useful tool for evaluating gait, strength, and balance in determining fall risk in elderly patients. Lanzarin et al. found that there was a change in the anterior–posterior stability in patients as a result of functional impairment and loss of motor control of the muscles. Previous studies have shown that asymptomatic PAD was associated with slower walking velocity and poorer standing balance score. Because the problems caused by PAD are more distally located and lead to atrophic muscles, fewer muscle fibers, and demyelination of peripheral nerves, vascular pathologies may cause poor balance control. However, these explanations cannot explain why we observed an association between PAD and balance only in older adults. Previous studies have emphasized that there is a fear of falling in PAD patients. We found that older people had slower gait speeds and longer TUGT times than pre-old people. It is assumed that older people’s physical abilities decrease due to the fear of falling and that they restrict functional activity by developing various adaptations. Lower extremity physical performance is not significantly compromised until disease severity has reached a critical level of impaired blood flow in pre-old individuals. A study found that the TUGT could be used as a longitudinal monitoring tool to identify individuals at risk of subclinical atherosclerosis; atherosclerosis is an independent predictor of functional limitation at 1 year in older adults. Therefore, more studies are needed in the future to explore the relationship between balance and PAD, considering the physical and psychological risk factors for patient’s fear of falling. It is possible that balance training can better prevent the symptoms and occurrence of PAD in older people.

Asymptomatic PAD is an easily overlooked form of atherosclerotic disease and the outcome is irreversibly improved. However, loss of physical activity can be easily detected, alerting patients to prevent the onset of PAD. Patients with PAD can also maintain their health by improving their physical activity and slowing the progression of the disease.

Strengths and Limitations

To the best of our knowledge, this study is the first to examine how the relationship between PAD and physical performance varies according to different age groups. Recruited participants from a suburban area led a more physically active lifestyle, differentiating them from participants in other geographical areas. There are many diagnostic methods for PAD, such as doppler ultrasound, ABI, and TBI. Our study subjects were asymptomatic PAD, and we excluded severe individuals. Although doppler ultrasound is more accurate, we chose to use ABI data for screening PAD. Because doppler is difficult to perform in a community screening and a high level of specificity (83.3%–99.0%) and accuracy (72.1%–89.2%) was reported for an ABI ≤ 0.90 in detecting ≥50% stenosis. The test of ABI ≤ 0.90 can be a simple and useful tool to identify PAD with serious stenosis and may be substituted for other noninvasive tests in clinical practice. In the future, we will consider adding data of moderate and severe patients and other diagnostic indicators for the study. Our study was cross-sectional, making it difficult to find a causal relationship between the various factors. Future work will need to increase the sample size, perform follow-up in this population to further verify the causal relationship, and validate these findings in other populations.
Conclusions

Our study further confirmed the association between physical performance and PAD in community-dwelling older Chinese adults. Muscle strength and mobility correlated negatively with PAD in pre-old participants, and balance was positively associated with PAD in older participants. The findings of this study might provide basic scientific and theoretical support for strategies aimed at maintaining or improving physical performances in the elderly, which might help slow down their decline in their physical condition and prevent PAD.

Conflicts of Interest

None.

Financial Support

This research was supported by the funding of National Natural Science Foundation of China (82172552) and Scientific Research Foundation of SUMHS (SSF-21-03-005).

References

9) McDermott MM, Fried L, Simonick E, Ling S, Guralnik JM. Asymptomatic peripheral arterial disease is independently associated with impaired lower extremity functioning: the women’s health and aging study. Circulation, 2000; 101: 1007-1012
15) Kuwardhani RAT, Suastika K. Age and homocystein were risk factor for peripheral arterial disease in elderly with type 2 diabetes mellitus. Acta Med Indones, 2010; 42: 94-99
16) Gardner AW. Claudication pain and hemodynamic responses to exercise in younger and older peripheral arterial disease patients. J Gerontol, 1993; 48: M231-M236
42) Curcio C-L, Gomez F, Reyes-Ortiz CA. Activity restriction related to fear of falling among older people in the Colombian Andes mountains: are functional or psychosocial risk factors more important? J Aging Health, 2009; 21: 460-479