JETR

JOURNAL OF
EXERCISE THERAPY
AND REHABILITATION

Journal of Exercise Therapy and Rehabilitation. 2024;11(1):47-55. DOI: 10.15437/jetr.1092224

ORIGINAL ARTICLE

Effect of hypertension on muscle strength, balance, and mobility in older adults

Yaşlı erişkinlerde hipertansiyonun kas gücü, denge ve mobiliteye etkisi

Farzin HAJEBRAHİMİ[1,2], Devrim TARAKCI[3], Hanefi ÖZBEK[4], Miray BUDAK[3], Candan ALGUN[1]

Abstract

Purpose: Hypertension (HT) can exacerbate impaired blood pressure regulation and thus increase the risk of falls. The higher incidence of HT and impaired balance in older adults may lead to the hypothesis of an association between HT and physical function in older individuals. The purpose of this study was to investigate the effects of HT on muscle strength, balance, and mobility in older adults and the relationship between them.

Methods: Sixty-one older adults were included in the study and individuals with systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg formed the Hypertensive group (n=31), while the others formed the Normotensive group (n=30). Quadriceps Femoris (QF) muscle strength was evaluated with a hand-held dynamometer, mobility was evaluated with the Timed Up and Go Test (TUG), balance performance was evaluated with the Nintendo Wii Fit Balance Board (NWBB), and physiological age was evaluated with Wii Fit Age (WFA). The systolic and diastolic blood pressure were measured before the balance test.

Results: TUG and NWBB scores between groups were significantly better in the Normotensive group ($p<0.05$). In both Hypertensive and Normotensive groups, there was a negative correlation between QF muscle strength and TUG score, and a positive correlation between QF muscle strength and NWBB score ($p<0.05$).

Conclusion: HT may worsen mobility and balance in older adults. Further studies are required to better understand HT and establish better appropriate interventions for older hypertensive adults.

Keywords: Hypertension, Postural balance, Functional status, Frail elderly, Exergaming.

Öz

Amaç: *Hipertansiyon (HT), kan basıncı regülasyonunda bozulma ile şiddetlendirerek düşme riskini arttırabilmektedir. Yaşlı erişkinlerde daha yüksek HT insidansı ve bozulmuş denge, HT ile fiziksel fonksiyonlar arasında bir ilişki olduğu hipotezine yol açabilmektedir. Bu çalışmanın amacı, yaşlı erişkinlerde hipertansiyonun kas kuvveti, denge ve mobiliteye etkisini ve onlarla ilişkisini incelemekti.*

Yöntem: *Çalışmaya 61 yaşlı birey dahil edildi ve sistolik kan basıncı ≥140 mmHg veya diyastolik kan basıncı ≥90 mmHg olan bireyler Hipertansif grubu (n=31), diğerleri Normotansif grubu (n=30) oluşturdu. Quadriceps Femoris (QF) kas gücü dinamometre ile, mobilite Zamanlı Kalk ve Yürü Testi (ZKYT), denge performansı Nintendo Wii Fit Balance Board (NWBB) ve fizyolojik yaş Wii Fit Age (WFA) ile değerlendirildi. Denge testinden önce sistolik ve diyastolik kan basıncı ölçüldü.*

Bulgular: *Gruplar arasında ZKYT ve NWBB skorları, Normotansif grubunda anlamlı olarak daha iyiydi ($p<0,05$). Hem Hipertansif hem de Normotansif grubunda, QF kas kuvveti ile ZKYT skoru arasında negatif yönde, QF kas kuvveti ile NWBB skoru arasında pozitif yönde anlamlı ilişki bulundu ($p<0,05$).*

Sonuç: *HT, yaşlı erişkinlerde mobiliteyi ve dengeyi kötüleştirebilmektedir. HT'yi daha iyi anlamak ve yaşlı hipertansif yetişkinleri için daha uygun müdahaleler oluşturmak için daha fazla çalışmaya ihtiyaç vardır.*

Anahtar kelimeler: *Hipertansiyon, Postür dengesi, Fonksiyonel durum, Kırılgan yaşlılar, Exergaming.*

1: Istanbul Medipol University, School of Health Sciences, Department of Physical Therapy and Rehabilitation, Istanbul, Türkiye.
2: Istanbul Medipol University, Institute of Health Sciences, Department of Physical Therapy and Rehabilitation, Istanbul, Türkiye
3: Istanbul Medipol University, School of Health Sciences, Department of Ergotherapy, Istanbul, Türkiye.
4: Bakircay University, School of Medicine, Department of Medical Pharmacology, Izmir, Türkiye.
Corresponding Author: Farzin Hajebrahimi: fhajebrahimi@medipol.edu.tr
ORCID IDs (order of authors): 0000-0002-5286-4981;0000-0001-9804-368X;0000-0002-8084-7855;0000-0003-0552-8464;0000-0002-2476-6567
Received: March 23, 2022. Accepted: January 10, 2023.

INTRODUCTION

High blood pressure is a common condition seen mostly in older adults.[1] As a result of aging, a linear increase in systolic blood pressure (SBP) occurs as a result of increasing stiffness in the arteries. Similarly, diastolic blood pressure (DBP) is observed to be plateaued or decreased gradually by aging.[2] Hypertension (HT) is the detection of SBP≥140 mmHg or DBP≥90 mmHg for at least three times, and this definition does not vary depending on age.[3]

Mobility is known as a critical feature of the independent function.[4] Although HT has silent symptoms, it can cause significant symptoms that increase the likelihood of reduced physical activity.[5] Due to the effect of HT on white matter hyperintensities in the brain, cerebrovascular dysfunction, general lean muscle mass, and inflammation or changes in the renin-angiotensin system, the above symptoms can be alleviated in patients with HT.[6] In particular, white matter hyperintensities are closely related to HT and have been associated with impaired mobility.[7]

Maintaining postural balance is one of the most important capabilities to prevent falls in the elderly population.[8] However, sensory and motor control of postural balance is often affected with aging.[9] Cho et al.[10] stated that postural balance control is necessary for mobility as well as stability during functional activities. In addition, they noted that lack of balance depending on loss of muscle strength may lead to falls in older adults. Therefore, a better understanding of the relationship between HT and postural balance control in older adults may help to better determine the risk of falls.[8] Hausdorff et al.[11] evaluated the gait and balance in hypertensive older adults in their study, and although they suggested that HT may increase fall risk by affecting the control of gait and balance, they did not evaluate the relationship between HT and gait and balance in hypertensive and normotensive older adults.

In recent years, video game consoles have become very popular as a means of evaluation and intervention.[12] Nintendo Wii Fit is one of the systems used to assess weight-bearing asymmetry (WBA) in people with impaired balance.[13] The Nintendo Wii Fit Balance Board (NWBB) can provide clinicians with a new way to evaluate the WBA. The sensors on the balance board measure the center of pressure of the user and the amount of weight-bearing on each foot.[14]

To the best of our knowledge, there is no study evaluating the relationship between muscle strength, balance, and mobility in hypertensive and normotensive older adults. The primary purpose of this study was to evaluate the effects of HT on muscle strength, balance, and mobility in older adults, and the secondary aim was to investigate the relationship of HT with these parameters.

METHODS

Study sample

The study was conducted with older adults who followed-up in the internal medicine outpatient clinic of Istanbul Medipol University Hospital. An oral and written informed consent in accordance with the procedures was obtained from each participant before inclusion in the study. This study was approved by the Istanbul Medipol University Non-Invasive Clinical Research Ethics Committee with the approval number 108400987-297. This study is a single-blind (evaluators) cross-sectional study.

Ninety elderly people followed-up in the internal medicine outpatient clinic of Istanbul Medipol University Hospital were evaluated for eligibility for the study. Sixty-one older adults who met the inclusion criteria were included in the study and divided into two groups as Hypertensive Group (n=31) and Normotensive Group (n=30). The flow diagram of the study is shown in Figure 1.

Study design

Inclusion criteria were age 65 and older, scoring 6 points on Katz Basic Activities of Daily Living Scale;[15] and scoring >24 on the Mini-Mental State Examination (MMSE) Test.[16] Individuals with a systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg formed the Hypertensive Group, while the others formed the Normotensive Group. Patients with neurological disorders with continuing disabilities, psychiatric disorders requiring medication, cardiovascular diseases, active cancer, kidney or liver disease, acute diseases, or diabetes requiring insulin or hypoglycemic drugs were excluded from the study. 10 subjects who had psychiatric disorders requiring medication, 12 subjects who had cardiovascular diseases, and 7 subjects who had diabetes requiring insulin were excluded from

the study. The study was completed with 61 participants.

All hypertensive subjects were diagnosed with HT by a cardiologist and were receiving two or fewer anti-hypertensive medications for approximately 5 years under the control of a cardiologist.

Outcome measurements

Participants were evaluated in terms of Quadriceps Femoris (QF) muscle strength, mobility, balance performance, and physiological age. The SBP and DBP were measured before the balance test.

Isometric muscle strength was assessed in both QF muscles with the hand-held dynamometer. The strength of the QF is one of the intrinsic factors that has been shown to affect knee joint function. It is clear that lower extremity strength plays an important role in knee joint shock attenuation during weight-bearing activities. So we measured the QF muscle for lower extremity isometric muscle strength. Evaluations were made using a standard seat. The back of the seat was angled backwards by 105° to allow 75° flex in the body. The knee was positioned at a 60° angle and secured with bands around the body, waist, hip, and ankle. Each participant was asked to hold the sides of the seat with both hands during the test, but attention was paid to compensation. QF isometric muscle strength was measured with three 10-second maximum isometric contractions. Rest periods of 3 seconds were given between each contraction. Verbal encouragement was given throughout the whole test to obtain maximum strength from the participants. The test was performed by applying force to the lower extremity. The measurements were repeated three times, and the mean values were taken.

Mobility was measured with the Timed Up and Go Test (TUG). The test consists of different mobility tasks such as walking with a straight head, turning, sit to stand and stand to sit which require controlling balance. The participant will sit on a standard chair, and then he/she will stand up and walk in the line of 3 meters, then will turn around and walk back to the chair and sit down. The test starts when the examiner says "go" and stops with the participant's buttocks touching the seat. The time of this action was recorded in seconds.[17]

The balance performance was assessed with the NWBB (Figure 2).[17,18] During the Nintendo Wii measurement, a general analysis of the body was performed when the participant stood relaxed looking forward to the screen with both arms in a neutral position on the NWBB. The center of pressure was measured during this step to detect the percentage of weight-bearing distributed to each foot. Then, the participants were asked to stand on one leg to assess their single-leg standing balance. Since the dominant leg in all the participants was the right leg, the single-leg balance test was performed only on the left leg. The situation and the duration of the test were explained to the participants, and all the participants were instructed to stand with their right leg raised but not touching their left leg or the balance board. All the participants were barefoot and were asked to complete the 30-second test but no encouragement was given to them. This balance performance was reported in percentages after finishing the test and performance score was assigned to participants who completed all 30 seconds. At the end of the test, the scores for the "single-leg balance duration (seconds- SLB-S)", the "single-leg balance performance (SLB-P)" and the "Wii Fit Age (WFA)" were obtained.[19] WFA was calculated according to the balance test results, taking into account the actual age of the individual.[20] Additionally, after all participants rested for 5 minutes in the lying position, their blood pressure in sitting position was measured 3 times consecutively and their mean values were taken.

Sample size planning

The sample size was determined using the G*power sample size calculator.[21] The required sample size was 58 with a 85% power and 15.05% confidence interval (α=0.05), considering the minimal clinically detectable change of 0.96 (0.93-0.98) points in the TUG.[22]

Statistical analysis

IBM SPSS (Statistical Package for Social Science) 25.0 for Windows program was used for statistical analysis.[23] The normal distribution of the variables was determined by the Kolmogorov-Smirnov Test. Parametric tests were applied because it was determined that they showed normal distribution. The difference

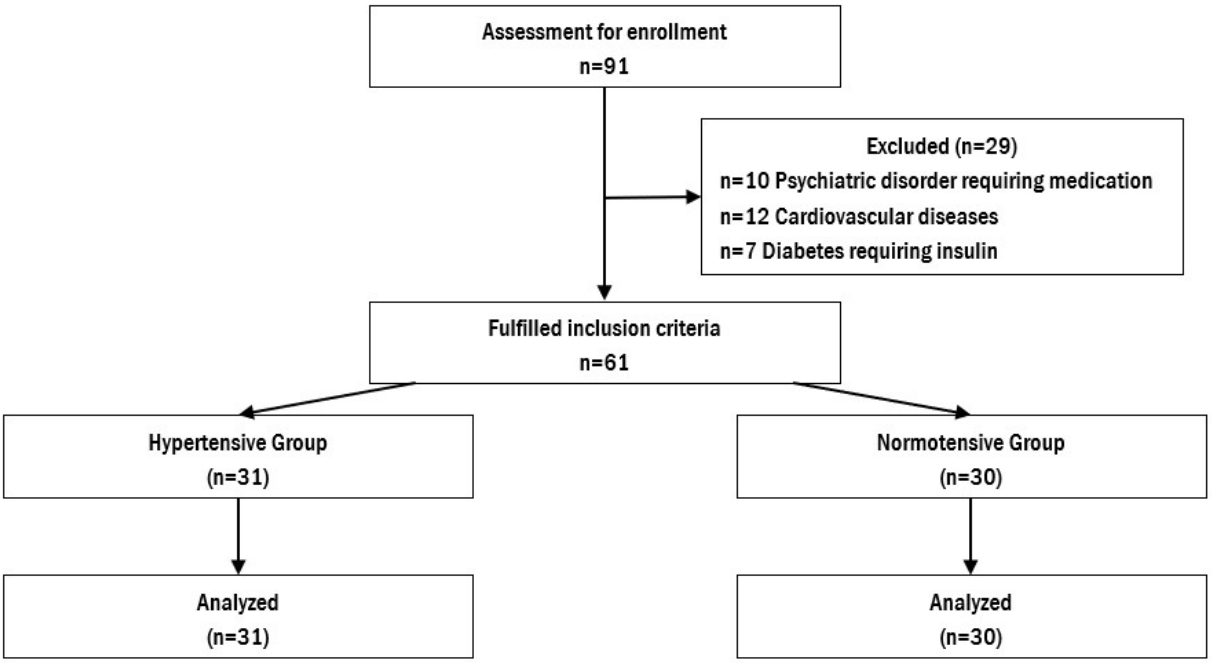

Figure 1. STROBE (Strengthening the Reporting of Observational Studies in Epidemiology Statement) Flow Diagram.

between the groups was analyzed by the Independent Sample t Test. The correlation between the data was evaluated by Pearson Correlation Test. As for cut-off values, the -1.0 correlation was considered a perfect negative correlation, and the 1.0 correlation was considered a perfect positive correlation. Significance value for all tests applied to variables with normal distribution $p<0.05$. It was aimed to enroll at least 60 participants considering the drop-outs.

RESULTS

Sixty-one participants (32 female, 29 male) were included in this study. There was a statistically significant difference in terms of age, SBP, and DBP between groups ($p<0.05$). The distribution of demographic and clinical data was shown in Table 1.

The TUG score, SLB-S time, SLB-P time, and WFA scores were found statistically significant in favor of the Normotensive Group ($p<0.05$). There was no statistically significant

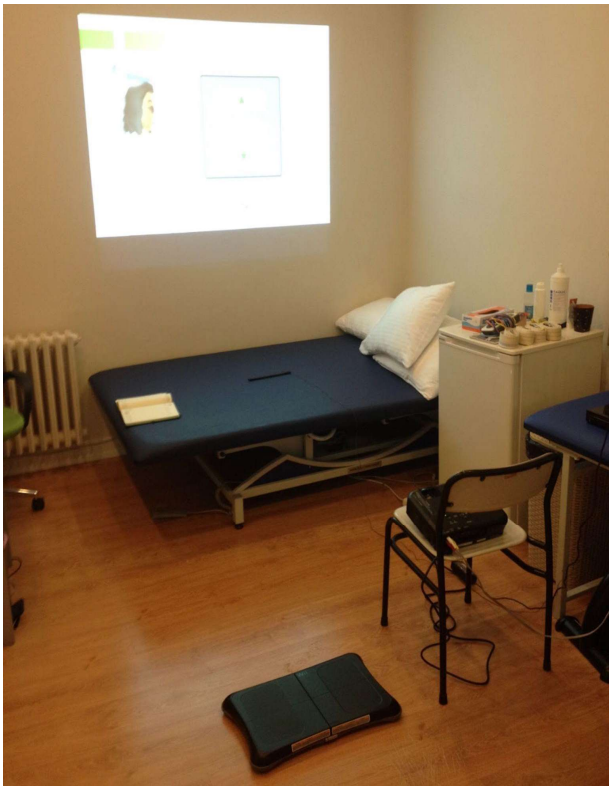

Figure 2. Wii Fit Balance.

difference in terms of QF muscle strength between groups (p>0.05). The differences between groups were shown in Table 2.

Correlations in the Hypertensive Group were shown in Table 3. Significant positive correlations were found between SLB-S time and Right QF (r=0.435), and between SLB-S time and Left QF (r=0.466). Significant negative correlations were found between the Right QF and TUG score (r=-0.555), and between the Left QF and TUG score (r=-0.548) and WFA score (r=-0.372). Correlations in the Normotensive Group were shown in Table 4. Significant positive correlations were found between Right QF and SLB-S time (r=0.459) and SLB-P time (r=0.545), and between Left QF and SLB-S time (r=0.434) and SLB-P time (r=0.516). Significant negative correlations were found between Right QF and TUG score (r=-0.762) and WFA score (r=-0.471), and between Left QF and TUG score (r=-0.676) and WFA score (r=-0.429).

DISCUSSION

In this study, it was aimed to investigate the effects and relationships of HT on muscle strength, balance, and mobility in older adults. Mobility and balance scores were negatively affected in hypertensive than normotensive counterparts. According to our results, it could be observed that HT may more affect mobility and balance than normotensives. There was a negative correlation between muscle strength and mobility, and a positive correlation between muscle strength and balance in both groups. Mobility and balance may be affected by HT in older adults.

Aging is characterized by an accelerated decrease in muscle mass and function, including strength or performance.[24] In particular, the progressive decrease in muscle strength of the lower extremities may affect mobility, causing fragility and functional disability.[25] HT is quite a common disease in older adults and has many consequences.[26] Recent studies reported that high blood pressure is a known risk factor for mobility and disability will increase in older adults with hypertensive compared to normotensives.[27-30] HT has also been strongly associated with rapid decreases in walking speed, an indicator of functional status for the elderly.[31] In our study, there was a significant

Table 1. The demographic data of the groups.

	Hypertensive Group (n=31)	Normotensive Group (n=30)		
	X±SD	X±SD	t	p
Age (year)	76.65±9.24	70.93±9.20	2.418	0.019*
Height (m)	1.62±0.10	1.62±0.11	0.053	0.958
Body weight (kg)	76.72±16.33	77.97±13.99	-0.318	0.751
Body mass index (kg/m^2)	28.93±4.71	29.63±4.25	-0.608	0.546
Blood pressure				
Systolic blood pressure (mmHg)	147.97±19.46	124.17±11.14	5.835	<0.001
Diastolic blood pressure (mmHg)	90.48±14.39	79±16.68	2.881	0.006*
	n (%)	n (%)	x^2	p
Gender				
Female	14 / 45	18 / 60	1.346	0.246
Male	17 / 55	12 / 40		
History of falling				
Yes	13 / 42	7 / 23	2.394	0.122
No	18 / 58	23 / 77		
Balance Problems				
Yes	12 / 39	11 / 37	0.027	0.869
No	19 / 61	19 / 63		

* p<0.05. t: t test. X^2: Chi-Square Test.

Table 2. Muscle strength, mobility balance performance, and physiological age of the groups.

	Hypertensive Group (n=31)	Normotensive Group (n=30)		
	X±SD	X±SD	t	p
Muscle strength				
Right Quadriceps femoris	11.69±3.34	13.29±3.18	-1.919	0.060
Left Quadriceps femoris	11.96±3.26	13.19±3.13	-1.499	0.139
Mobility				
Timed Up and Go Test	17.37±10.06	12.62±6.11	2.220	0.030*
Balance Performance				
Single Leg Balance-Seconds	14.13±9.89	22.62±9.93	-3.344	0.001*
Single Leg Balance-Performance	18.30±20.31	42.87±24.60	-4.259	<0.05
Physiological Age				
Wii Fit Age	72.97±18.19	58.87±15.98	3.211	0.002*

* p<0.05. t: t test.

Table 3. Correlation in the Hypertensive Group and the Normotensive Group.

	Timed Up and Go r (p)	Single Leg Balance-Seconds r (p)	Single Leg Balance-Performance r (p)	Wii Fit Age r (p)
Hypertensive Group				
Right Quadriceps femoris	-0.555 (0.001)*	0.435 (0.014)*	0.300 (0.101)	-0.319 (0.080)
Left Quadriceps femoris	-0.548 (0.001)*	0.466 (0.008)*	0.343 (0.059)	-0.372 (0.039)*
Normotensive Group				
Right Quadriceps femoris	-0.762 (<0.001)	0.459 (0.011)*	0.545 (0.002)*	-0.471 (0.009)*
Left Quadriceps femoris	-0.676 (<0.001)	0.434 (0.017)*	0.516 (0.004)*	-0.429 (0.018)*

* p<0.05. r: Pearson's Correlation Test.

difference in lower extremity major muscle strength in hypertensive older adults compared to normotensives. When the fall history of elderly individuals with HT was examined, it can be declared that the decrease in muscle strength is due to the negative effects on balance and normal walking patterns. The significant age difference between the hypertensive and normotensive groups should also be considered as a factor affecting muscle strength and thus other parameters related to muscle strength.

The balance control is a multifactorial system and is very complex.[32] As a result of HT drug treatment, alterations in blood flow may occur in conjunction with rapid changes in blood pressure, possibly compromising the body's balance control mechanism. Standing balance problems are common in older people, and they're linked to falls, hospitalization, poor quality of life, and high rates of morbidity and mortality.[33] Maintaining postural balance is another important ability to prevent falls in the elderly population.[8] HT can adversely affect balance by damaging large arteries and reducing microcirculation in specific functional areas.[32] Furthermore, in HT, rapid fluctuations in blood pressure followed by rapid decreases in blood flow may interfere with the mechanisms that control postural balance. In a study of Chang et al.[19] the validity and reliability of the NWBB have been investigated whether it can be used in the assessment of balance in older

adults. They suggested that while clinical testing of balance with balance master systems is relatively expensive, spacious and probably not affordable for every clinician and researcher, a somatosensory gaming console named Nintendo Wii which has gained its popularity in recent years could be used to assess balance. To our knowledge, this is the first study to investigate the relationship between balance performance and HT with NWBB. In our study, the evaluation of the NWBB showed that there was a difference in parameters of SLB-S and SLB-P in hypertensives compared to normotensives. This result may indicate that the negative physiological change caused by HT affects balance and mobility. In addition, as a result of this deterioration in balance, it may be said that there may be a higher history of falls especially in older adults with HT.

In the NWBB system, a physiological age calculation is made based on the functional capacities of individuals. Each body test calculates and updates the player's WFA, a rough estimate of the player's physical strength in relation to his/her actual age. Although there was no significant difference between the hypertensive and normotensive groups for body mass index, the significant difference for WFA in favor of individuals in the normotensive group can be considered as an objective result of the negative effects of HT. This finding shows that the interaction of these factors in older adults with HT can cause problems with everyday functioning.

Poor physical function and physical disability are associated with high blood pressure in older adults.[7] The capacity to walk at a moderate pace, which is critical to older adults' community independence, is essential for social and functional activities.[34] Mobility is a critical feature of working independently. Walking speed is regarded as a reliable indicator of physical fitness for predicting negative health effects and mortality.[35] The decrease in gait speed can be an early precursor to the decline in physical function, the development of disability and the loss of independence.[36] Observational evidence suggests a faster decline in walking speed in adults with high blood pressure. In the Cardiovascular Health Study, participants with a blood pressure of >140/90 mmHg had a faster rate of decline in gait speed than those without HT.[7] Similarly, in the LIFE-Pilot study, researchers found that wider pulse pressure was associated with slower gait.[37] Interestingly, in a study of older adults with HT, parameters of walking function were found to be worse, although not slower gait speed.[11] Hausdorff et al.[11] studied 24 community-dwelling 65 to 90 years old healthy subjects with no report of a disturbance in their walking. The results of the TUG test were better in the normotensive group rather than the hypertensive group. In our study, it was concluded that mobility deteriorated in hypertensive group when compared with normotensives. Furthermore, it may be said that the negative correlation between TUG and balance supports these results. It can be hypothesized that this is due to the physiological changes caused by HT in muscle mass and volume and body systems. This condition highlights the importance of muscular strengthening and stretching in hypertensive older adults to prevent loss of balance and falls.

Limitations

The limitation of this study was that balance was not evaluated with a gold standard scale.

Conclusion

In conclusion, it was observed that HT might have a negative effect on balance and mobility, two crucial indicators and mediators of physical function and independence in older adults. Further studies are required to better understand the biological mechanism that associates HT with physical disability and to develop appropriate intervention strategies for hypertensive older adults.

Acknowledgement: *None*

Authors' Contributions: FH: The conception and design of the study, and acquisition of data, and analysis and interpretation of data, revising the article critically for important intellectual content, final approval of the version to be submitted; **DT:** The conception and design of the study, analysis and interpretation of data, drafting the article, final approval of the version to be submitted; **HÖ:** Revising the article critically for important intellectual content, final approval of the version to be submitted; **MB:** Analysis and interpretation of data, Revising the article critically for important intellectual content, final approval of the version to be submitted; **CA:** The conception and design of the study, revising the article critically for important intellectual content,

final approval of the version to be submitted

Funding: *None*

Conflicts of Interest: *None*

Ethical Approval: The protocol of the present study was approved by Istanbul Medipol University Non-Invasive Clinical Research Ethics Committee (issue: 108400987-297 date: 02.06.2015).

REFERENCES

1. Del Pinto R, Ferri C. Hypertension management at older age: an update. High Blood Press Cardiovasc Prev. 2019;26:27-36.
2. Franklin SS, Jacobs MJ, Wong ND, et al. Predominance of Isolated Systolic Hypertension Among Middle-Aged and Elderly US Hypertensives: Analysis Based on National Health and Nutrition Examination Survey (NHANES) III. Hypertension. 2001;37:869-874.
3. Weber MA, Schiffrin EL, White WB, et al. Clinical Practice Guidelines for the management of hypertension in the community: A Statement by the American Society of Hypertension and the International Society of Hypertension. J Clin Hypertens. 2014;16:14-26.
4. Yong V, Saito Y, Chan A. Changes in the Prevalence of Mobility Limitations and Mobile Life Expectancy of Older Adults in Singapore, 1995-2005. J Aging Health. 2010;22:120-140.
5. Hajjar I, Lackland DT, Cupples LA, et al. Association Between Concurrent and Remote Blood Pressure and Disability in Older Adults. Hypertension. 2007;50:1026-1032.
6. Nascimento C de M, Mambrini JV de M, de Oliveira CM, et al. Diabetes, hypertension and mobility among Brazilian older adults: findings from the Brazilian National Household Sample Survey (1998, 2003 and 2008). BMC Public Health. 2015;15:591.
7. Hajjar I, Quach L, Yang F, et al. Hypertension, White Matter Hyperintensities, and Concurrent Impairments in Mobility, Cognition, and Mood: The Cardiovascular Health Study. Circulation. 2011;123:858-865.
8. Acar S, Demırbüken İ, Algun C, et al. Is hypertension a risk factor for poor balance control in elderly adults? J Phys Ther Sci. 2015;27:901-904.
9. Sturnieks DL, St George R, Lord SR. Balance disorders in the elderly. Neurophysiol Clin Neurophysiol. 2008;38:467-478.
10. Spencer RJ, Wendell CR, Giggey PP, et al. Judgment of Line Orientation: an examination of eight short forms. J Clin Exp Neuropsychol. 2013;35:160-166.
11. Hausdorff JM, Herman T, Baltadjieva R, et al. Balance and Gait in Older Adults With Systemic Hypertension. Am J Cardiol. 2003;91:643-645.
12. Huurnink A, Fransz DP, Kingma I, et al. Comparison of a laboratory grade force platform with a Nintendo Wii Balance Board on measurement of postural control in single-leg stance balance tasks. J Biomech. 2013;46:1392-1395.
13. Liuzzo DM, Peters DM, Middleton A, et al. Measurements of weight bearing asymmetry using the Nintendo Wii Fit Balance Board are not reliable for older adults and ındividuals with stroke. J Geriatr Phys Ther. 2017;40:37-41.
14. Clark RA, Bryant AL, Pua Y, et al. Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait Posture. 2010;31:307-310.
15. Fuentes-García A. Katz Activities of Daily Living Scale. In: Michalos AC, editor. Encyclopedia of Quality of Life and Well-Being Research [Internet]. Dordrecht: Springer Netherlands; 2014 [cited 2022 Sep 9]. p. 3465-3468. Available from: http://link.springer.com/10.1007/978-94-007-0753-5_1572.
16. Education OM. Mini-mental state examination (MMSE) [Internet]. Oxford Medical Education. 2015 [cited 2022 Sep 9]. Available from: https://oxfordmedicaleducation.com/geriatrics/mini-mental-state-examination-mmse/.
17. Yelnik A, Bonan I. Clinical tools for assessing balance disorders. Neurophysiol Clin Neurophysiol. 2008;38:439-445.
18. Jorgensen MG, Laessoe U, Hendriksen C, et al. Intrarater Reproducibility and Validity of Nintendo Wii Balance Testing in Community-Dwelling Older Adults. J Aging Phys Act. 2014;22:269-275.
19. Chang WD, Chang WY, Lee CL, et al. Validity and reliability of Wii Fit Balance Board for the assessment of balance of healthy young adults and the elderly. J Phys Ther Sci. 2013;25:1251-1253.
20. Buford TW. Hypertension and aging. Ageing Res Rev. 2016;26:96-111.
21. Faul F, Erdfelder E, Lang AG, et al. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39:175-191.
22. Ozcan Kahraman B, Ozsoy I, Akdeniz B, et al. Test-retest reliability and validity of the timed up and go test and 30-second sit to stand test in patients with pulmonary hypertension. Int J Cardiol. 2020;304:159-163.
23. How to cite IBM SPSS Statistics or earlier versions of SPSS [Internet]. 2022 [cited 2022 Sep

9]. Available from: https://www.ibm.com/support/pages/how-cite-ibm-spss-statistics-or-earlier-versions-spss.
24. Buch A, Kis O, Carmeli E, Keinan-Boker L, Berner Y, Barer Y, et al. Circuit resistance training is an effective means to enhance muscle strength in older and middle aged adults. Ageing Res Rev. 2017;37:16-27.
25. Damas Nogueira FR, Libardi CA, Vechin FC, et al. Comparison of maximal muscle strength of elbow flexors and knee extensors between younger and older men with the same level of daily activity. Clin Interv Aging. 2013:8:401-407.
26. Abdelhafiz AH, Marshall R, Kavanagh J, et al. Management of hypertension in older people. Expert Rev Endocrinol Metab. 2018;13:181-191.
27. Rosano C, Longstreth WT, Boudreau R, et al. High blood pressure accelerates gait slowing in well-functioning older adults over 18-years of follow-up. J Am Geriatr Soc. 2011;59:390-307.
28. Mahinrad S, Kurian S, Garner CR, et al. Cumulative blood pressure exposure during young adulthood and mobility and cognitive function in midlife. Circulation. 2020;141:712-724.
29. Okamura M, Konishi M, Saigusa Y, et al. Impact of grip strength and gait speed on exercise tolerance in patients with pulmonary hypertension without left heart disease. Heart Vessels. 2022;37:1928-1936.
30. Zhang Z, Fan Z, Zhang J. Correlation between frail status and lower extremity function in elderly inpatients with hypertension. Nutr Hosp. 2022;39:39-45.
31. Abellan Van Kan G, Rolland Y, Andrieu S, et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. J Nutr Health Aging. 2009;13:881-889.
32. Abate M, Di Iorio A, Pini B, et al. Effects of hypertension on balance assessed by computerized posturography in the elderly. Arch Gerontol Geriatr. 2009;49:113-117.
33. Timmermans ST, Reijnierse EM, Pasma JH, et al. Blood pressure change does not associate with Center of Pressure movement after postural transition in geriatric outpatients. BMC Geriatr. 2018;18:10.
34. Perera S, Studenski S, Chandler JM, et al. Magnitude and patterns of decline in health and function in 1 year affect subsequent 5-year survival. J Gerontol A Biol Sci Med Sci. 2005;60:894-900.
35. Odden MC, Peralta CA, Berlowitz DR, et al. Effect of intensive blood pressure control on gait speed and mobility limitation in adults 75 years or older: a randomized clinical trial. JAMA Intern Med. 2017;177:500-507.
36. Vermeulen J, Neyens JC, van Rossum E, Set al. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr. 2011;11:33.
37. Heffernan KS, Manini TM, Hsu FC, et al. Relation of Pulse Pressure to Long-Distance Gait Speed in Community-Dwelling Older Adults: Findings from the LIFE-P Study. Scuteri A, editor. PLoS ONE. 2012;7:e49544.