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The relationship between blood pressure and functional fitness of older adults in Korea

Bogja Jeoung*

Department of Exercise Rehabilitation & Welfare, College of Health Science, Gachon University, Incheon, Korea

Hypertension, also known as high blood pressure (BP), is a critical health issue that can cause cardiovascular disease. It is observed more frequently in older adults. Thus, this study aimed to identify the functional fitness and body composition factors that significantly influence both systolic and diastolic BPs in older adults. Data from 155,266 older adults (51,751 men [33.3%] and 103,505 women [66.7%]) who underwent functional fitness tests between 2013 and 2018 were analyzed. The following seven functional fitness tests were conducted: (a) aerobic endurance (2-min step), (b) upper body muscle strength (hand grip strength), (c) lower body muscle endurance (chair sit-and-stand), (d) flexibility (sit-and-reach), (e) agility (Timed Up and Go), and (f) body composition (body mass index [BMI] and body fat percentage). Systolic and diastolic BPs were used as outcome variables. In examining the proposed relationships, the regression analysis re-vealed that BMI, body fat percentage, sit-and-reach, 2-min step, hand grip, chair sit-and-stand, and Timed Up and Go were significantly associated with reduced systolic and diastolic body pressures.

Keywords: Body composition, Blood pressure, Old people, Functional fitness

INTRODUCTION

Hypertension, a major cause of cardiovascular diseases, including heart disease and stroke, is the most important factor affecting the global disease burden and is a significant public health issue (Wang et al., 2017). Its prevalence is growing worldwide, which may be attributed to population aging, poor diet, alcohol consumption, physical inactivity, being overweight, and persistent ex-posure to stress (World Health Organization, 2013).

High blood pressure (BP) is a major modifiable risk factor for cardiovascular diseases and mortality in older people. It is a risk factor for myocardial infarction, stroke, congestive heart failure, end-stage renal disease, and peripheral vascular disease (Burt et al., 1995; Edwards et al., 2007). In young adults, BP gradually increases with age. By the age of 60 years, the majority of the population develops hypertension, and one in four people aged ≥70 years suffers from hyper-tension (Burt et al., 1995). The Framingham Heart Study has demonstrated that people who maintain a normal BP until the age of 55–65 years have a 90% risk of developing hypertension if they survive until the age of 80–85 years (Guo et al., 2012). The onset and progression of hypertension differ according to sex. The incidence is higher among men until young and middle adulthood, whereas it becomes more prevalent among women in older adulthood. The changes in systolic BP (SBP) and diastolic BP (DBP) also differ according to age. SBP increases throughout an individual's lifetime, whereas DBP increases slowly until approximately 60 years of age, after which it gradually declines or remains unchanged (Burt et al., 1995). Hence, as age increases, SBP increases, whereas DBP decreases with a concomitant increase in pulse pressure (Kim et al., 2023). BP is associated with the risk of cardiovascular disease and all-cause mortality.

From middle to old age, increased BP is strongly correlated with cardiovascular disease and overall mortality without evidence of a lower threshold of at least 115/75 mmHg (Lewington et al., 2002; Noh et al., 2022). Hypertension is the most important global risk factor for disease burden (Kim et al., 2023). In older people, the

*Corresponding author: Bogja Jeoung https://orcid.org/0000-0002-7144-6179
Department of Exercise Rehabilitation & Welfare, College of Health Science, Gachon University, 191 Hambangmoe-ro, Yeonsu-gu, Incheon 21936, Korea
Email: bogja05@gachon.ac.kr
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risk of cardiovascular events and mortality is directly related to SBP and pulse pressure, although it is inversely related to DBP (Franklin et al., 1999; Rigaud and Forette, 2001), reflecting the changing physiological pattern of BP with aging. Lower DBP is a predominant marker of higher pulse pressure, which is a stronger determinant of risk (Franklin et al., 2015).

Hypertension management guidelines emphasize routine physical activity as an early treatment to prevent, reduce, and halt the progression of hypertension and report that aerobic and resistance exercises contribute to lowering BP. High physical activity enhances physical fitness (Haskell et al., 2007), and high body mass index (BMI), low functional activity, and low functional fitness are modifiable risk factors for hypertension. Functional fitness is a stronger predictor of cardiovascular disease than functional activity (Crump et al., 2016; Nielsen and Andersen, 2003) and a better indicator of habitual functional activity than self-reported activity (Edwards et al., 2007; Williams, 2001).

Since 2013, the Korean government has been working toward increasing functional activity in individuals aged ≥65 years through the National Fitness Award Project, which is a national testing and consultation service to promote functional fitness and health of all citizens. This study aimed to identify the effects of functional fitness on BP in older Korean adults.

MATERIALS AND METHODS

Research data

This cross-sectional study used data from the Korea Institute of Sports Science Fitness Standards as part of the National Fitness Award Project. In Korea, there are 81 test centers (75 fixed centers and 6 mobile measurement teams) across 17 regions. This study tested the functional fitness of older adults. The participants in this study were aged 65–90 years. Raw functional fitness test data from 155,256 individuals (51,751 men [33.3%] and 103,505 women [66.7%]) who voluntarily participated in the centers from 2013 to 2018, along with their demographic information, were used in this study.

Functional fitness measurement

The functional fitness battery developed by the project for older adults comprised seven tests as follows: (a) aerobic endurance (2-min step), (b) upper body muscle strength (hand grip strength), (c) lower body muscle endurance (chair sit-and-stand), (d) flexibility (sit-and-reach), (e) agility (Timed Up and Go), and (f) body composition (BMI and body fat percentage). Their height, weight, and BP were also recorded (Jeoung and Pyun, 2022). All functional fitness parameters were measured at the center. Each functional fitness test revealed high internal consistency with satisfactory relia-bility statistics (r) ranging from 0.70 to 0.93 (Choi et al., 2014). All the items were measured by certified national professional health and fitness instructors working full-time at the centers.

Data analysis

Data were analyzed using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA). De-scriptive statistical analysis was performed to calculate the means, standard deviations, frequencies, and percentages of the measures, and a paired *t*-test was used to determine sex differences. Prior to performing the main analysis, a correlation test was conducted to examine the associations between the variables. Multiple regression analyses were performed to test the relationships between func-tional fitness factors and SBP and DBP. The significance level was set at $P<0.05$.

RESULTS

Table 1 presents the demographic information, sex differences in BP, and functional fitness of participants. Altogether, 155,256 participants were included, comprising 51,751 men and 103,505 women, with the women being older than the men. Although the men were taller and heavier than the women, the women had higher BMI values and body fat percentage than the men. Moreover, the men had higher SBP and DBP than the women. Among the fitness tests, the values for grip strength, chair sit-and-stand, and 2-min step were higher for men who demonstrated better per-formance than for women, although the sit-and-reach values were higher for women than for men. By contrast, the men performed better in the Timed Up and Go test than the women did (Table 1).

According to the BP standard recommended by the Korean Society of Hypertension (2021), 44.9%, 13.75%, 23.7%, and 17.65% of the participants had normal BP, elevated BP, prehyper-tension, and hypertension, respectively. Furthermore, the men had a higher prevalence of hyper-tension than the women (Table 2).

Table 3 demonstrates results confirming the differences in BP according to levels of physical function items. For all the items, a significant difference in BP was observed according to their physical function levels ($P<0.001$). Specifically, in obesity-related BMI, the higher the BMI, the higher the BP (*post hoc*, obesity > over weight > normal > underweight; $P<0.001$). Moreover, it was also confirmed that the weaker the grip, the higher the BP (*post hoc*, 4 > 3 > 2 > 1; $P<0.001$) and the lower the score, the lower the BP

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Table 1. Sex differences in functional fitness and blood pressure

Variable	Male		Female		*t*	*P*-value
	No.	Mean ± SD	No.	Mean ± SD		
Age (yr)	51,751	72.27 ± 5.4	103,505	72.96 ± 5.2	24.0	< 0.001***
Height (cm)	51,751	165.5 ± 5.9	103,505	152.4 ± 5.5	-415.5	< 0.001***
Weight (kg)	51,751	66.09 ± 8.8	103,505	57.5 ± 7.9	-185.6	< 0.001***
Body mass index (kg/m^2)	51,751	24.2 ± 2.7	103,505	24.7 ± 3.0	32.2	< 0.001***
Body fat (%)	51,751	25.5 ± 7.2	103,505	34.7 ± 7.2	236.5	< 0.001***
Systole (mmHg)	51,751	131.9 ± 14.9	103,505	129.4 ± 14.6	-31.1	< 0.001***
Diastole (mmHg)	51,751	75.7 ± 10.2	103,505	75.5 ± 9.8	-3.3	< 0.001***
Grip strength (kg)	51,699	30.6 ± 6.7	103,288	19.3 ± 4.8	-340.5	< 0.001***
Sit-and-reach (cm)	51,654	3.9 ± 9.7	103,259	13.2 ± 7.9	187.3	< 0.001***
Chair sit-and-stand (reps)	51,578	20.2 ± 6.7	102,962	18.0 ± 6.2	-62.4	< 0.001***
2-Min step (reps)	48,675	107.0 ± 24.9	97,078	99.7 ± 27.7	-50.6	< 0.001***
Timed Up and Go (sec)	51,507	6.3 ± 2.2	103,018	6.9 ± 2.5	44.1	< 0.001***

SD, standard deviation.
****P* < 0.001.

Table 2. Prevalence of blood pressure category according to the Korean Society of Hypertension 2020 guidelines

Classification	No.	Normal < 120/≤ 79 mmHg (SBP%/DBP%)	Elevated 120–129/80 mmHg (SBP%/DBP%)	Prehypertension 130–139/81–89 mmHg (SBP%/DBP%)	Hypertension ≥ 140/≥ 90 mmHg (SBP%/DBP%)
Overall	155,071	44.9 (26.8/63.0)	13.75 (21.1/6.4)	23.7 (24.7/22.7)	17.65 (27.4/7.9)
Male	51,696	43.8 (23.5/62.2)	12.8 (19.6/6.1)	24.15 (25.4/22.9)	20.15 (31.5/8.8)
Female	103,375	45.8 (28.4/63.3)	14.15 (21.8/6.5)	23.6 (24.4/22.9)	17.1 (25.4/8.8)
65–69 (overall)	54,277	45.5 (31.1/59.9)	14.5 (22.5/6.5)	24.5 (23.9/25.1)	15.7 (22.5/8.9)
Male	15,571	40.8 (25.9/55.7)	13.8 (21.1/6.5)	26.2 (25.5/26.8)	19.3 (27.5/11.2)
Female	38,706	47.1(33.2/61.0)	14.8 (23.1/6.5)	23.8 (23.2/24.5)	14.3 (20.5/8.1)
70–74 (overall)	49,170	44.6 (26.1/63.2)	13.8 (21.3/6.4)	23.9 (25.0/22.8)	17.5 (27.5/7.6)
Male	17,046	42.3 (23.0/61.7)	13.8 (20.0/6.2)	24.4 (25.3/23.6)	20.1 (31.6/8.6)
Female	32,124	44.4 (27.7/64.1)	14.2 (22.0/6.4)	23.6 (24.9/22.4)	16.2 (25.3/7.1)
75–79 (overall)	33,376	44.6 (23.3/65.9)	13.0 (19.8/6.2)	22.9 (25.4/20.5)	19.4 (31.5/7.3)
Male	12,857	44.5 (21.8/67.2)	11.9 (18.2/5.6)	22.7 (25.6/19.8)	20.3 (34.4/7.3)
Female	20,519	44.6 (24.2/65.1)	13.7 (20.8/6.6)	23.1 (25.3/20.9)	18.5 (29.7/7.3)
80–84 (overall)	14,271	44.7 (22.1/67.3)	12.8 (19.0/6.6)	22.4 (25.4/19.4)	20.1 (33.5/6.7)
Male	4,954	45.8 (22.4/69.2)	12.1 (17.8/6.3)	21.4 (24.5/18.3)	20.8 (35.3/6.3)
Female	9,317	45.5 (21.9/66.3)	13.1 (19.6/6.7)	23.0 (25.9/20.1)	19.7 (32.6/6.9)
85–90 (overall)	3,977	43.9 (21.3/66.6)	11.8 (17.4/6.2)	22.2 (24.6/19.9)	22.0 (36.7/7.3)
Male	1,268	47.1 (22.4/71.9)	11.8 (17.6/4.6)	20.9 (24.4/17.4)	20.8 (35.6/6.1)
Female	2,709	47.1 (20.8/64.1)	12.1 (17.3/6.9)	22.9 (24.7/21.1)	22.5 (37.2/7.8)

SBP, systolic blood pressure; DBP, diastolic blood pressure.

($P < 0.001$). However, low scores in the sit-and-reach, chair sit-and-stand, Timed Up and Go, and 2-min step tests were associated with higher BP ($P < 0.001$).

As presented in Table 4, to identify the risk factors for hypertension, models 1, 2, and 3 were corrected for the following parameters: fitness level, BMI, age, sex and disability level. Compared to normal BP, an increase in BP owing to borderline hypertension and hypertension is a factor that shows a significant risk depending on a person's physical fitness level, obesity, age and sex. Specifically, age and sex differed by 1.025 times (odds ratio [OR], 1.025; 95% confidence interval [CI], 1.016–1.035; $P < 0.001$), hypertension by 1.033 times (OR, 1.033; 95% CI, 1.023–1.044;

Table 3. Differences in blood pressure by functional fitness level

Variable	Functional fitness grade	Blood pressure (systolic)		*F*	*P*-value	*Post hoc*
		No.	Mean ± SD			
Grip strength	1	39,342	129.2 ± 15.1	818.23	< 0.001***	4 > 3 > 2 > 1
	2	38,396	129.5 ± 14.7			
	3	38,584	130.3 ± 14.5			
	4	38,419	132.2 ± 14.5			
Sit-and-reach	1	38,484	129.5 ± 14.5	240.41	< 0.001***	4 > 3 > 2 > 1
	2	38,656	130.1 ± 14.6			
	3	38,721	130.5 ± 14.8			
	4	38,800	131.1 ± 15.1			
Chair sit-and-stand	1	33,424	129.9 ± 14.5	69.14	< 0.001***	4 > 3, 2, 1
	2	40,426	130.1 ± 14.6			
	3	30,977	130.4 ± 14.7			
	4	49,456	130.7 ± 15.0			
2-Min step	1	35,801	130.1 ± 14.7	26.41	< 0.001***	4 > 3, 2, 1
	2	35,436	130.4 ± 14.7			
	3	35,532	130.5 ± 14.8			
	4	38,759	130.6 ± 14.8			
Timed Up and Go	1	38,803	129.3 ± 14.7	460.37	< 0.001***	4 > 3 > 1
	2	38,458	129.9 ± 14.6			
	3	38,732	130.6 ± 14.6			
	4	38,298	131.4 ± 15.1			
BMI (kg/m^2)	Underweight	2,494	124.6 ± 16.1	2,392.61	< 0.001***	4 > 3 > 2 > 1
	Normal	42,980	128.0 ± 15.2			
	Overweight	43,241	130.1 ± 14.5			
	Obesity	66,290	132.1 ± 14.3			

SD, standard deviation; BMI, body mass index.
****P*< 0.001 tested by performing a one-way analysis of variance. Scheffe was done for *post hoc*.

Table 4. Odds ration with 95% confidence intervals for the National Fitness Award Project data on hypertension risk

Hypertension	(a) Model 1		(b) Model 2		(c) Model 3	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
≤ 120 (ref.)						
121–139	1.025 (1.016–1.035)	< 0.001***	1.206 (1.179–1.234)	< 0.001***	1.082 (1.063–1.102)	< 0.001***
≥ 140	1.033 (1.023–1.044)	< 0.001***	1.338 (1.304–1.373)	< 0.001***	1.189 (1.166–1.213)	< 0.001***

(a) Model 1: further adjusted for age, sex. (b) Model 2: further adjusted for obesity factor (body mass index). (c) Model 3: further adjusted for grip strength (upper strength).
OR, odds ratio; CI, confidence interval.
****P*< 0.001 tested by performing multiple logistic regression analysis.

P < 0.001), obesity-related indicators by 1.206 times (OR, 1.206; 95% CI, 1.179–1.234; *P* < 0.001), and hypertension by 1.338 times (OR, 1.338; 95% CI, 1.304–1.373; *P* < 0.001). Finally, it was confirmed that the risk of differences in physical fitness level in Model 3 increased 1.082 times in borderline hypertension (OR, 1.082; 95% CI, 1.063–1.102; *P* < 0.001) compared to 1.189 times in high BP (OR, 1.189; 95% CI, 1.166–1.213; *P* < 0.001).

DISCUSSION

This study aimed to determine the prevalence of hypertension and the effects of functional fitness factors on BP among older adults (≥ 65 years) in South Korea. This study compared the functional fitness and BP according to sex. Obesity was more prevalent among women than among men, and the female participants performed better in grip strength, chair sit-and-stand, 2-min step,

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and Timed Up and Go tests, except for the sit-and-reach test, than the men did. The prevalence of hypertension tends to increase with age, and it is higher in men than women in all age groups. The prevalence of systolic hypertension increases with age, whereas that of diastolic hypertension tends to decline. The prevalence of systolic hypertension was higher among men than women in the 60–74 year group, whereas that of diastolic hypertension was higher among women than men in the 80–90 year group. Lee and Lee (2012) have reported that the incidence of hypertension tended to increase with advancing age and was higher among men than among women.

The Korean Society of Hypertension (2021) has reported similar results. Furthermore, the rates of increase of both SBP and DBP were higher in men than in women. However, Burt et al. (1995) observed that SBP increased with age, with a higher rate of increase observed in men than in women. DBP generally increased until the age of 50–59 years but declined with advancing age. These results are inconsistent with those of this study. Further research is needed to examine the relationship between the increasing prevalence of hypertension and environmental factors and race, in addition to previously known factors that contribute to the increasing prevalence of hypertension such as diet, alcohol consumption, physical activity, being overweight, and stress. Burt et al. (1995) have reported that the prevalence of hypertension differs according to race, and our findings revealed consistent trends in an elderly Korean population. Our study demonstrated that functional fitness factors were significantly associated with both SBP and DBP, suggesting that they affect SBP and DBP elevation. Many previous studies have highlighted the importance of regular physical activity and nutritional management in hypertension management; in particular, high physical activity contributes to enhanced physical fitness. Regarding the relative risk of cardiovascular disease in relation to physical activity and physical fitness, the prevalence of cardiovascular disease declined by approximately 25% with increased physical activity and by 60% with increased physical fitness. Interestingly, although physical activity gradually decreased the relative risk of cardiovascular disease, even a slight improvement in physical fitness to the bottom 25% drastically diminished the relative risk of cardiovascular disease. Hence, physical fitness has more health benefits than physical activity alone (Williams, 2001).

In this study, hypertension was linked to health-related fitness parameters, and poor fitness parameters contributed to elevated BP. Crump et al. (2016) has reported that physical fitness factors help reduce hypertension. Choi et al. (2014) has also demonstrated that the hypertensive population had poor cardiopulmonary endurance, muscle strength, and balance, based on which they recommended exercises that improved cardiopulmonary endurance and muscle strength. Regarding chronic levels of inflammation, Edwards et al. (2007) have reported evidence on the relationship between inflammatory response to acute exercise and physical fitness, and that the change in circulating lymphocyte populations with acute exercise is differentiated by physical fitness. Many studies have emphasized the importance of increasing physical activity and func-tional fitness with age (Bakker et al., 2018; Chen et al., 2009; Edwards et al., 2007; Haskell et al., 2007; Jeoung and Pyun, 2022). Hence, various measures to promote physical activity and functional fitness are required to treat and prevent chronic diseases, including hypertension, in the aging population.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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