1-1-2022

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Recommended Citation

Son, J.-W., Lee, S., Kang, M., Shin, Y.-A., & Kim, J.-H. (2022). Optimal frequency intensity of physical activity to reduce the risk of hypertension in the korean population. Exercise Science, 31(1), 129–140. https://doi.org/10.15857/ksep.2021.00626

EXERCISE SCIENCE 운동과학
Vol.31, No. 1, February 2022: 129-140
https://doi.org/10.15857/ksep.2021.00626
ISSN(Print) : 1226-1726
ISSN(Online) : 2384-0544

ORIGINAL ARTICLE

Optimal Frequency Intensity of Physical Activity to Reduce the Risk of Hypertension in the Korean Population

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PURPOSE: Regular physical activity (PA) is an effective lifestyle modification for preventing hypertension. This study aimed to analyze the optimal frequency of PA required to reduce the incidence of hypertension in the Korean population. Most Korean studies have included only small samples and limited age ranges.

METHODS: The present study analyzed 16,299,865 participants aged ≥20 years (44.25±12.74 years) from the 2009 to 2012 Korean National Health Insurance Corporation Survey database. The International Physical Activity Questionnaire was used to assess the frequency and intensity of physical activity. Hazard ratios for incident hypertension were analyzed by physical activity participation, age, and sex using multivariable Cox proportional hazard models, with a non-regular physical activity group as reference.

RESULTS: A total of 1,322,674 cases of incident hypertension were identified during the mean follow-up period of over 3 years. Hazard ratios for incident hypertension increased with age, with values of 50.4 and 56.1 for men and women in the older age group, respectively. Hazard ratios for incident hypertension were significantly lower in the regular PA group of middle-aged (4%) and older (7%) adults than in the non-regular PA group. The study revealed that moderate-to-vigorous-intensity PA 3-5 times/week was most effective in reducing the risk of incident hypertension in middle-aged and older adults but not in young adults. We observed no additional lowering of incident hypertension risk in the group undergoing moderate-to-vigorous PA at a frequency of 6-7 days/week compared to the 35 days/week group.

CONCLUSIONS: We suggest PA at a frequency of 3-5 times/week for the prevention of incident hypertension in Korean adults.

Key words: Physical activity, Hypertension, intensity of physical activity, Frequency of physical activity, Korean

INTRODUCTION

Hypertension is a major risk factor for cardiovascular diseases and is a cause of premature death worldwide [1]. One-quarter of the world's adult population is estimated to have hypertension and the prevalence of hypertension has been predicted to increase up to 60% by 2025 [2]. The incidence of hypertension among Koreans aged >30 years has gradually increased from 24.6% in 2007 to 31.2% in 2017 [3].

Among the various important causative factors such as obesity, increased daily sodium intake, fat, alcohol intake, and the lack of physical activity for hypertension, physical activity as a single risk factor, is believed to be responsible for 5% to 13% of the prevalence of hypertension [4]. Physical activity (PA) has been recommended as a non-pharmacological intervention to reduce the incidence of hypertension [5]. Recent studies on normotensive and prehypertensive participants showed an inverse association between self-reported PA and incident hypertension, supporting the role of maintained or improved cardiorespiratory fitness in the prevention of hypertension [6-8]. In line with this, current PA

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*This study was performed using the database from National Health Insurance System (NHIS-2018-4-044) (https://nhiss.nhis.or.kr/bd/ay/bdaya001iv.do).
Received 12 Nov 2021 **Revised** 21 Feb 2022 **Accepted** 24 Feb 2022

guidelines recommend moderate-or high-intensity PA for a minimum of 30 min/day on most days of the week to achieve the blood pressure (BP)-lowering effect of PA [9]. Moreover, there is evidence suggesting additional benefits of an increase in the amount of PA (higher intensity, greater frequency, and longer duration) on most health outcomes [10]. However, the appropriate mode, frequency, and intensity of PA for the prevention of hypertension in non-hypertensive individuals remain elusive. Pescatello et al. [11] reported that PA has a dose-response association with incident hypertension, and that an increase in PA level shows additional benefits for preventing hypertension. However, they used a metabolic equivalent of tasks/week as a quantitative measurement of PA level and specified no intensity or frequency of PA [11]. Therefore, it remains unclear whether a dose-response relationship exists between the frequency of PA and incident hypertension, or if vigorous-intensity PA provides greater benefits for the prevention of hypertension. Furthermore, a recent meta-analysis raised the possibility that the dose-response relationship could differ according to sex and ethnicity [12]. Additionally, there is a lack of data evaluating the dose-response relationship between PA and the incidence of hypertension, including the effects of age and sex on this relationship, among the Korean population [13,14]. Studies examining this relationship have included small samples including one study with women over the age of 40 (N = 4,241) [13], while another utilized population data (N = 13,873) from the Korean National Health and Nutrition Examination Survey [14]. These studies found that only 1,681 women were a group that continued aerobic PA [13] and the subjects with hypertension tended to participate in PA less [14], which was too small to represent the all-Korean population. In addition, another study of hypertension patients (N = 1,721) reported that PA has no or little association with hypertension statues [15], but the other 1,464,377 adults Korean women (aged 50-79 years) study reported inconsistent results because PA may be prevent primary hypertension [16]. Therefore, it is unclear whether the association between PA and the incidence of hypertension. This study considered the National Health Insurance Corporation Survey (NHIS) of Korean adults aged ≥20 years, which included medical information on approximately 50 million Koreans.

Therefore, this study aimed to further investigate the adequate intensity and frequency of PA for the prevention of hypertension by analyzing data obtained from the NHIS among Korean adults aged 20 years or older.

METHODS

1. The NHIS database and NHIS health checkup program

The data used were derived from the NHIS health checkup database from 2009 to 2012. The NHIS was constructed by repeatedly surveying approximately 50 million Koreans for the same content every two years, including age, sex, region, medical information, insurers' payment coverage, and data on claims and deductions. The Health Insurance Review and Assessment (HIRA) service provides medical services under health insurance policies. Therefore, the HIRA database includes data on approximately 97.0% of the Korean population's health insurance claims. Details about the NHIS database have been described in a previous study [17].

We used the NHIS database that recorded body composition parameters, such as weight (kg), height (cm), waist circumference (cm), and blood pressure (mmHg), and general health behaviors, such as smoking, alcohol consumption, regular PA, and past medical and family histories, such as hypertension, diabetes mellitus, dyslipidemia, cancer, and surgical histories [18].

2. Participants

Participants aged >20 years were selected from the 2009-2012 NHIS health checkup database. Health checkups and follow up were consecutively performed until December 31, 2015 (N = 23,366,277). We excluded participants who had missing data (n = 50,399), a history of other disease (diabetes, dyslipidemia, cancer, etc.), a history of hypertension, were under antihypertensive medication, or had systolic BP >140 mmHg and diastolic BP >90 mmHg at baseline examination.

Finally, 16,299,865 participants (male = 8,072,292) were included in this study. This study was approved by the Institutional Review Board of the Korea National Institute for Bioethics Policy (No. P01-201603-21-005). Permission was granted for the use of health checkup data from the NHIS (NHIS-2016-4-003). De-identified and anonymized data were used for the analysis. The NHIS database, which is an open public database, guaranteeing anonymity. Trained investigators obtained informed consent from individuals who voluntarily participated in the study.

3. Assessment of physical activity

PA at baseline examination was analyzed using a survey that assesses three domains of PA: the mode of activity, frequency, and intensity [15]. The International Physical Activity Questionnaire (IPAQ), that surveys weekly PA, was used in this study. The questionnaire included the number of days in a week in which participants engaged in both moderate and vigorous PA during the past six months. PA, defined as physical activity for at least 30 min/day, was categorized into quantiles by frequency (0: Q1, 1-2: Q2, 3-5: Q3, 6-7 times/week: Q4). Additionally, PA was classified based on intensity (walking, moderate, or vigorous activity). Moderate PA was defined as a slight increase in breathing or heart rate or in the rate of fairly hard perceived exertion, such as carrying light loads, slow cycling, and fast walking. Vigorous PA was categorized as a substantial increase in breathing or heart rate or in the rate of moderately hard perceived exertion, such as carrying heavy loads, fast cycling, running, mountain climbing, playing soccer, or any other activity [19,20].

According to the World Health Organization (WHO) PA guidelines (10), the regular PA group is defined as those engaging in mild- to moderate-intensity PA for a minimum of five times/week or vigorous-intensity PA for a minimum of three times/week. Participants who did not meet the guidelines were grouped in the "no-PA" or "non-regular PA" group.

4. Definition of hypertension

At each visit, participants rested for at least 5 minutes in a comfortable sitting position in a quiet room without talking, prior to having their BP measured. BP measurements were performed on the right arm using a random-zero sphygmomanometer and the average of two measurements was used. The appropriate cuff size was determined using arm circumference measurements (width: 13 cm, length: 2-24 cm). Incident hypertension was defined as SBP/DBP $\geq$140/90 mmHg [21] or a prior diagnosis of hypertension and taking antihypertensive medication for at least one year under the prescription of International Classification of Diseases (ICD-10) codes I10-I15.

5. Main covariates

Covariables that affect hypertension, such as age, sex, BMI, smoking habits, alcohol consumption, income, and the presence of diabetes or dyslipidemia, were included. Age groups were divided into three categories: young adults (aged 20-39 years), middle-aged adults (aged 40-64 years), and older adults (aged $\geq$65 years). Smoking history was divided into three categories: non-smokers, ex-smokers, or current smokers. Alcohol consumption was divided into three categories: non-drinker, mild-to-moderate drinker, and heavy drinker (0, 1-2, or $\geq$3 times/week).

Diabetes was defined as a fasting plasma glucose level of $\geq$126 mg/dL (from the NHIS health checkup) or as currently taking antidiabetic medication prescription under ICD-10 codes E11-14 [22]. Dyslipidemia was defined as a total cholesterol level of $\geq$240 mg/dL or as currently taking antihyperlipidemic medication prescription under ICD-10 code E78 [23].

6. Statistical analysis

Descriptive statistics using mean and standard deviation (SD) for continuous variables, and percentage for categorical variables, were calculated for the entire cohort and subgroups. Incidence rates (IR) of hypertension were obtained by dividing the number of cases by person-years, by age and sex. Hazard ratios (HRs) and 95% confidence intervals (CIs) for incident hypertension by PA participation, age, and sex, were analyzed using multivariable Cox's proportional hazard models with the non-regular PA group as a reference. In addition, participants were further stratified based on the intensity and frequency of PA by age and sex, and the unadjusted and adjusted HRs and 95% CIs for incident hypertension were obtained. The following variables were adjusted for potential confounders: age, body mass index (BMI), current smoking, heavy alcohol consumption, low-income status, and the presence of diabetes and dyslipidemia. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC, USA) and all two-tailed $p<.05$ were considered statistically significant.

RESULTS

1. Baseline characteristics

Among 16,299,865 participants, 2,697,699 (16.5%) were classified into the regular PA group. Baseline characteristics of participants stratified by PA groups are shown in Table 1. Participants with regular PA were mostly male and older, were unlikely current smokers, and had a higher BMI and waist circumference. Fasting plasma glucose level, lipid profiles, SBP and DBP, and the proportion of type 2 diabetes and dyslipidemia, were higher in the regular PA group than in the non-regular PA group. However, these measurements were all fairly comparable and within acceptable healthy ranges. As shown in Fig. 1, the ratio of moderate- and vigorous-intensity PA among participants with regular PA tended to be greater in middle-aged and older adults than in young adults.

2. PA and risk of incident hypertension

A total of 1,322,674 cases of incident hypertension were identified

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Table 1. Baseline characteristics of participants by PA groups

	Regular PA	
	No	Yes
N	13,602,166 (83.50)	2,697,699 (16.50)
Age	42.96±12.74	45.54±12.73
20-39	5,384,734 (39.59)	810,633 (30.05)
40-64	7,402,214 (54.42)	1,686,946 (62.53)
≥65	815,218 (5.99)	200,120 (7.42)
Sex		
Males	6,597,341 (48.5)	1,474,951 (54.67)
Females	7,004,825 (51.5)	122,748 (45.33)
Smoking		
Non-smokers	8,490,038 (62.42)	1,600,455 (59.33)
Ex-smokers	1,515,225 (11.14)	441,204 (16.35)
Current smokers	3,596,903 (26.44)	656,040 (24.32)
Drinking		
Non-drinker	7,066,093 (51.95)	1,326,783 (49.18)
Mild-to-moderate drinker	5,594,126 (41.13)	1155336 (42.83)
Heavy drinker	941,947 (6.92)	215,580 (7.99)
Body composition		
Height (cm)	164.13±8.93	164.8±8.89
Weight (kg)	62.46±11.5	64.16±11.21
BMI (kg/m^2)	23.08±3.15	23.52±2.93
WC (cm)	78.08±9.01	79.01±8.42
CVD risk factors		
FBS (mg/dL)	94.08±19.41	95.01±19.68
SBP (mmHg)	116.83±11.43	117.79±11.24
DBP (mmHg)	72.97±8.04	73.39±7.94
Total cholesterol (mg/dL)	192.81±35.92	194.2±35.71
HDL cholesterol (mg/dL)	56.5±19.17	56.91±18.17
LDL cholesterol (mg/dL)	113.22±44.04	114.61±42.69
Other disease		
Type 2 diabetes (n)	602,929 (4.43)	153,343 (5.68)
Dyslipidemia (n)	1,725,747 (12.69)	381,809 (14.15)

Values are expressed as the number of participants (percentages) or mean (±standard deviation).
PA, physical activity; BMI, body mass index; WC, waist circumference; CVD, cardiovascular disease; FBS, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

during a mean follow-up period of over 3 years. IRs of hypertension, individual PA intensity, and PA frequency varied with age. IRs of hypertension by age and sex are presented in Fig. 2. IRs of hypertension per 1,000 person-years increased with age, equaling to 50.4 and 56.1 for men and women in the older age groups, respectively.

A similar trend was observed in men and women with respect to the risk of incident hypertension. Table 2 presents the unadjusted and multivariate-adjusted HRs (95% CI) for incident hypertension by PA group and age. After adjusting for age, BMI, smoking, alcohol consumption, income, and the presence of diabetes and dyslipidemia, the HRs for incident hypertension were significantly lower in the regular PA group of middle-aged (4%) and older adults (7%) than in the non-regular PA group. We observed a slight increase in hypertension risk among young adults, with an approximately 3% higher risk of incident hypertension in the regular PA group than in the non-regular PA group (1.031 [1.016, 1.046]).

3. Risk of incident hypertension by PA intensity and frequency in male participants

As shown in Table 3, the frequency of walking was associated with hypertension risk in young male adults. Compared with the zero-frequency group, the frequency groups with 1-2, 3-5, and 6-7 days/week of walking had 3%, 3%, and 6% lower risks of incident hypertension, respectively. We found a similar dose-response association between walking frequency and hypertension risk in middle-aged (5-7% lower risk of incident hypertension within all frequency groups) and older (6% and 5% lower risks of incident hypertension in the frequency groups of 3-5 and 6-7 days, respectively) male adults. However, no additional benefit was observed in the high-frequency group with 6-7 days/week of walking, compared to the frequency group of middle-aged and older adults with

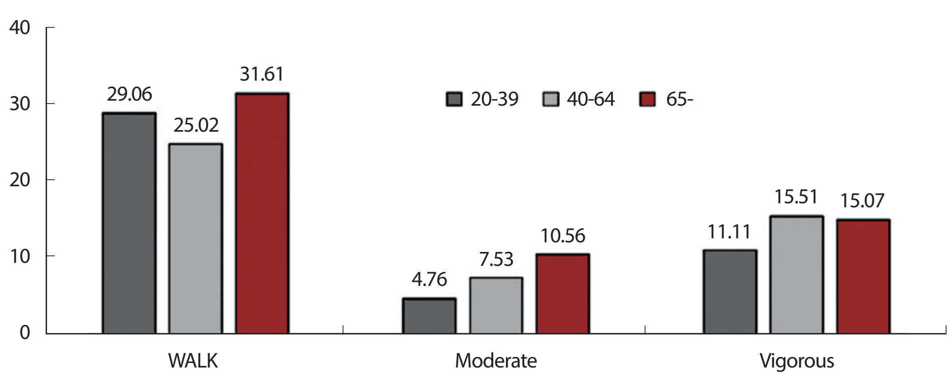

Fig. 1. Percentage of participants with regular PA by intensity and age. Values are expressed as the percentage of participants.

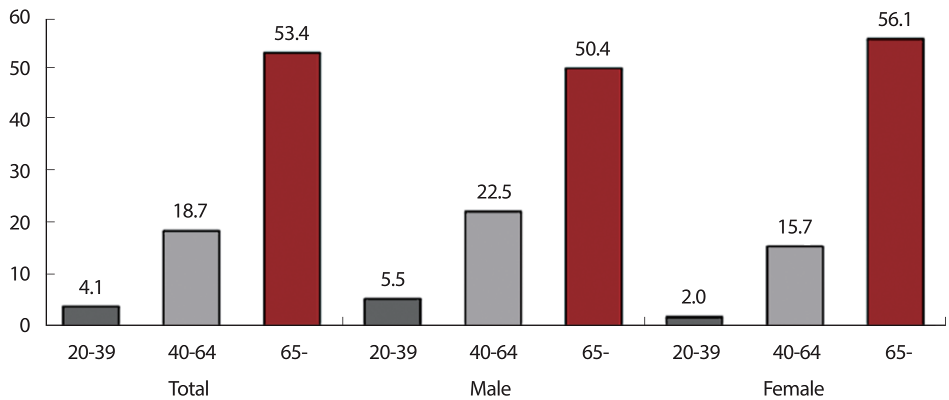

Fig. 2. Incident rates of hypertension by age and sex. Values are expressed as the percentage of participants.

Table 2. HRs (95% CI) for incident hypertension by PA groups and age

Age group	PA	N	HP	RATE	Unadjusted	Adjusted	*p* for interaction
Total							
20-39	No	5,384,734	113,319	3.96	1 (Ref.)	1 (Ref.)	<.001
	Yes	810,633	20,800	4.79	1.201 (1.183,1.218)	1.031 (1.016,1.046)	
40-64	No	7,402,214	701,938	18.58	1 (Ref.)	1 (Ref.)	
	Yes	1,686,946	169,864	19.48	1.048 (1.042,1.053)	0.961 (0.956,0.966)	
≥65	No	815,218	207,735	54.50	1 (Ref.)	1 (Ref.)	
	Yes	200,120	47,218	49.18	0.903 (0.894,0.912)	0.929 (0.919,0.938)	

Note. The values were expressed as the number of participants. Adjusted for age, BMI, smoking, drinking, type 2 diabetes, and dyslipidemia; HRs, hazard ratios; CI, confidence interval; PA, physical activity; HP, hypertension.

3-5 days.

With respect to moderate PA, the adjusted HR for incident hypertension was significantly lower in the low-frequency group with 1-2 days/week (0.972 [0.959-0.985]) than in the zero frequency group among young adults. The high-frequency groups with 3-5 and 6-7 days/week had 3% and 6% higher risks of incident hypertension, respectively, compared to the low-frequency group with 1-2 days/week. Among middle-aged adults, the frequency of moderate PA was associated with hypertension risk (3-6% lower risk of incident hypertension within all frequency groups); similar associations were found in older adults (2-7% lower risk of incident hypertension within all frequency groups).

With respect to vigorous PA, the adjusted HRs for incident hypertension were significantly lower in the frequency groups with 1-2, 3-5, and 6-7 days/week of vigorous PA than in the zero frequency group among middle-aged (2-5% lower risk of incident hypertension) and older adults (5-7% lower risk of incident hypertension). Among young adults, the HR for incident hypertension was lower in the frequency group with 1-2 days/week (0.972 [0.959-0.985]) than in the zero frequency group. Nonetheless, paradoxically, the frequency group with 3-5 days/week of vigorous PA had an increased risk of incident hypertension by 2%.

4. Risk of incident hypertension by PA intensity and frequency in female participants

Table 4 shows that the overall frequency of walking was associated with hypertension risk. Compared with the zero frequency group, the frequency groups with 1-2 and 3-5 days/week of walking had 5% and 6% lower risks of incident hypertension among young adults, respectively. No additional benefit was observed in the frequency group with 6-7 days/week, compared with the zero frequency group (0.969 [0.933-1.006]). Among middle-aged adults, the frequency groups with 1-2, 3-5, and 6-7 days/week of walking had 6%, 8%, and 5% lower risks of incident hypertension, respectively. We observed a similarly significant relationship between the frequency of walking and hypertension risk in older adults, except in the frequency group with 1-2 days/week (0.990 [0.975-1.006]).

In young female adults engaged in moderate PA, the frequency did not reduce hypertension risk. Instead, the frequency group with 6-7 days/week of moderate PA showed an increased hypertension risk by 14%, compared with the zero frequency group. Among middle-aged female adults, compared with the zero frequency group, the groups with 1-2, 3-5, and 6-7 days/week of moderate PA had 5%, 7%, and 3% lower

Table 3. Adjusted HRs (95% CI) for incident hypertension by PA intensity and frequency in male participants

Age group	Frequency	N	HP	RATE	No
Vigorous					
20-39	No	1,914,656	54,972	5.39	1 (Ref.)
	1-2	1,162,193	35,415	5.62	0.972 (0.959,0.985)
	3-5	421,825	13,797	6.01	1.021 (1.002,1.04)
	6-7	69,407	2,103	5.65	1.038 (0.993,1.084)
40-64	No	2,17,277	252,717	23.04	1 (Ref.)
	1-2	1,152,251	126,089	20.97	0.945 (0.938,0.951)
	3-5	554,071	66,063	22.86	0.955 (0.947,0.963)
	6-7	140,468	19,080	26.67	0.983 (0.969,0.998)
≥65	No	317,772	76,235	51.73	1 (Ref.)
	1-2	70,010	16,073	47.99	0.948 (0.932,0.965)
	3-5	56,435	12,860	47.43	0.93 (0.912,0.947)
	6-7	36,927	8,581	48.68	0.932 (0.911,0.953)
Moderate					
20-39	No	1,781,436	51,411	5.41	1 (Ref.)
	1-2	1,201,804	36,897	5.66	0.972 (0.959,0.985)
	3-5	491,183	15,332	5.78	1.003 (0.985,1.022)
	6-7	93,658	2,647	5.33	1.028 (0.988,1.069)
40-64	No	2,119,196	248,408	23.18	1 (Ref.)
	1-2	1,109,166	119,518	20.69	0.942 (0.936,0.949)
	3-5	629,821	74,379	22.80	0.951 (0.943,0.959)
	6-7	164,884	21,644	26.00	0.973 (0.959,0.987)
≥65	No	298,011	71,374	51.55	1 (Ref.)
	1-2	69,689	16,347	49.47	0.976 (0.96,0.993)
	3-5	69,677	15,957	47.98	0.947 (0.931,0.963)
	6-7	43,767	10,071	48.33	0.93 (0.91,0.949)
Walk					
20-39	No	882,132	26,759	5.67	1 (Ref.)
	1-2	967,298	31,471	5.96	0.97 (0.954,0.986)
	3-5	1,003,995	30,543	5.66	0.966 (0.95,0.982)
	6-7	714,656	17,514	4.63	0.94 (0.922,0.958)
40-64	No	1,245,826	150,052	23.78	1 (Ref.)
	1-2	1,032,749	112,078	20.85	0.938 (0.931,0.945)
	3-5	1,077,780	122,819	22.14	0.933 (0.926,0.94)
	6-7	666,712	79,000	23.54	0.947 (0.939,0.956)
≥65	No	168,353	40,756	52.13	1 (Ref.)
	1-2	67,908	16,396	51.09	0.986 (0.969,1.004)
	3-5	114,595	26,258	48.50	0.935 (0.92,0.949)
	6-7	130,288	30,339	49.57	0.945 (0.931,0.96)

The values were expressed as the number of participants.
HRs, hazard ratios; CI, confidence interval; PA, physical activity; HP, hypertension.

risks of incident hypertension, respectively. In older adults, the HRs for incident hypertension were lower in the frequency groups with 3-5 (0.919 [0.903-0.935]) and 6-7 (0.955 [0.933-0.978]) days/week than in the zero frequency group, and the hypertension risk in the frequency group with 1-2 days/week of moderate PA did not decrease.

With respect to vigorous PA, the pattern of association between the frequency of vigorous PA and hypertension risk was similar to that in moderate PA among young female adults; the frequency of vigorous PA did not reduce hypertension risk. In middle-aged female adults, the HRs for incident hypertension were significantly lower in the frequency groups with 1-2, 3-5, and 6-7 days/week of vigorous PA than in the zero frequency group (4-9% lower risk of incident hypertension). In older adults, the HRs for incident hypertension were lower in the frequency groups with 3-5 (11%) and 6-7 (3%) days/week of vigorous PA than in the zero frequency group. Notably, the HRs for incident hypertension were significantly higher in the frequency group with 6-7 days/week than in

Table 4. Adjusted HRs (95% CI) for incident hypertension by PA intensity and frequency in female participants

Age group	Group	N	HP	RATE	No
Vigorous					
20-39	No	1,905,437	19,664	1.97	1 (Ref.)
	1-2	524,548	5,751	2.08	1.026 (0.996,1.057)
	3-5	176,485	2,135	2.30	1.032 (0.986,1.079)
	6-7	20,816	282	2.60	1.081 (0.959,1.214)
40-64	No	3,478,875	285,803	16.14	1 (Ref.)
	1-2	871,619	65087	14.46	0.959 (0.95,0.967)
	3-5	574,266	43,601	14.70	0.91 (0.901,0.92)
	6-7	141,333	13,362	18.17	0.957 (0.941,0.974)
≥65	No	418,376	111,873	57.10	1 (Ref.)
	1-2	56,215	14,772	54.93	0.987 (0.97,1.004)
	3-5	40,038	9,469	48.94	0.887 (0.868,0.906)
	6-7	19,565	5,090	54.17	0.971 (0.944,0.998)
Moderate					
20-39	No	1,579,037	16,258	1.97	1 (Ref.)
	1-2	723,965	7,572	1.99	1.002 (0.975,1.03)
	3-5	284,526	3,422	2.29	1.034 (0.996,1.073)
	6-7	39,758	580	2.80	1.136 (1.045,1.233)
40-64	No	3,061,125	256,511	16.42	1 (Ref.)
	1-2	1,017,314	72,689	13.95	0.948 (0.94,0.956)
	3-5	782,424	59,685	14.84	0.929 (0.921,0.937)
	6-7	205,230	18,968	17.9	0.965 (0.951,0.979)
≥65	No	375,379	100,674	57.3	1 (Ref.)
	1-2	68,478	18,219	56.14	1.001 (0.985,1.017)
	3-5	60,377	14,700	50.62	0.919 (0.903,0.935)
	6-7	29,960	7,611	53.01	0.955 (0.933,0.978)
Walk					
20-39	No	689,372	7,950	2.20	1 (Ref.)
	1-2	743,691	7,861	2.00	0.953 (0.924,0.984)
	3-5	772,994	7,860	1.95	0.936 (0.907,0.966)
	6-7	421,229	4,161	1.90	0.969 (0.933,1.006)
40-64	No	1,655,986	145,007	17.15	1 (Ref.)
	1-2	1,126,469	81,908	14.17	0.941 (0.933,0.949)
	3-5	1,437,863	108,606	14.78	0.92 (0.913,0.928)
	6-7	845,775	72,332	16.72	0.952 (0.943,0.96)
≥65	No	210,334	57,522	58.54	1 (Ref.)
	1-2	84,967	23,164	57.50	0.99 (0.975,1.006)
	3-5	122,600	30,611	52.69	0.922 (0.91,0.935)
	6-7	116,293	29,907	54.46	0.95 (0.937,0.963)

The values were expressed as the number of participants.
PA, physical activity; HP, hypertension.

those with 3-5 days/week, among middle-aged and older female adults at all levels of PA intensity.

DISCUSSION

This study aimed to investigate the adequate intensity and frequency of PA for the prevention of hypertension among Korean adults aged 20 years or older. The results indicated that the incidence of hypertension was significantly lower in the regular PA group in both middle-aged and older adults. According to the risk of incident hypertension by PA intensity and frequency in males, the frequency of moderate-vigorous PA decreased the incidence of hypertension among middle-aged and older adults, and found a dose-response association between walking frequency and hypertension risk in all ages. In females, the frequency of overall intensity PA was associated with hypertension risk among middle-aged adults, and a similarly significant relationship was found between the frequency of overall intensity and hypertension risk in older adults, except in the frequency group with 1-2 days/week.

Increased PA has been recommended for the prevention and management of hypertension [24,25]. PA recommendation for the treatment of both prehypertension and hypertension includes 30 minutes or more of moderately-intense PA on most and preferably all days of the week [26]. Regular moderate-to-vigorous PA or sports/exercise-related PA has also been reported to reduce the incidence of hypertension [27]. This suggests that higher-intensity PA produces greater benefits than lower-intensity PA. However, these results were not consistent. Some studies have shown no changes in BP with varying intensities [28,29], whereas others have reported ambiguous results and effects of training on hypertension [30,31].

In this study, walking, irrespective of frequency, was associated with a lower risk of incident hypertension in both men and women of all ages. However, moderate-to-vigorous intensity of PA was associated with a lower risk of incident hypertension only in middle-aged and older adults, but not in young adults. Hagberg et al. [32] reported that BP reduction was greater in the lower-intensity group (walked at 53% VO_{2max}) than in the higher-intensity group (walked/jogged and cycled at 73% VO_{2max}) among hypertensive men and women aged 60-69 years, after 9 months. Similarly, low-intensity cycling (40% VO_{2max}) resulted in more effective BP control than higher-intensity cycling (60% VO_{2max}) after cycle exercise bouts [33]. Our finding of a greater effect of walking and moderate-intensity PA rather than higher-intensity PA in reducing BP, irrespective of sex, is in agreement with the results of previous reports [26,32,34]. However, the mechanism underlying the association between the different intensities of PA and BP is unclear. Several explanations have been proposed, such as high-intensity PA inducing a stress response by sympathetic activation [30] and differences in plasma volume depletion [35,36].

Regarding the frequency of PA, contrary to general recommendations which suggested a certain amount of PA to reduce BP [37], the optimal PA amount remains unclear. More than 2 to 3 days/week of intense PA is associated with increased vascular risk even in middle aged women [38,39] and the incidence of hypertension was found to have a U-shape, signifying the prevalence of hypertension was found to increase with PA below or above the appropriate intensity and frequency [40]. Moreover, Iwaneet et al. [41] investigated the significant correlation between DBP reduction and walking less than 15,000 steps/day, and reported a significantly negative correlation with the number of steps. Their findings indicated that walking more than 15,000 steps/day leads to no additional reduction in BP [41]. Zhu et al. [40] reported an increase in hypertension risk in young and middle-aged individuals who performed excessive PA as well as a lack of PA, and suggested that individuals who participated in high-intensity and long-duration PA may have abnormal BP and are susceptible to increased BP. Long-term and sustained PA may increase hypertension risk in young and middle-aged subjects. Ryu et al. [13], in 2020, reported that 5-7 days/week of walking and 1-4 days/week of muscle strength exercise is associated with hypertension, in a group of 4,241 Korean women aged 40 years or older compared with the zero frequency group. We found a similar association between walking frequency and hypertension risk in middle-aged and older male and female adults among 16,299,865 Korean participants; 3-5 days/week PA was associated with the incidence of hypertension in all ages and intensities. Therefore, we suggest that 3-5 days/week of PA is most effective in reducing the incidence of hypertension in Korean adults.

However, this study's comparison with previous studies has been difficult because of variations in frequency, duration, intensity and mode of PA. Moreover, it is unclear why moderate-to-vigorous intensity of PA was not associated with a lower risk of incident hypertension in young adults in this study. The incidence of hypertension increased with age, and hypertension prevalence was very low in young adults: 4.1%, 18.7%, and 53.4% in young adults, middle-aged adults, and older adults, respectively. Therefore, we speculated that the low prevalence of hypertension may have affected the statistics of young adults.

We assessed PA using a self-report questionnaire. Intensity of PA was measured by the individuals' perceived exertion. Excessive PA has been shown to increase cardiac and left ventricular diastolic function abnormalities [42,43]. These results may reflect the effects of phenomena such as remodeling of an athlete's heart due to extreme or intense exercise, including cycling, triathlons, and ultra-marathon running [44]. This study did not analyze the incidence of hypertension by occupation, but the athletes participating in this study are all under the age of 40 years. The athletes have been reported to have a larger left ventricular mass and left atrium size [45] and increased cardiac stroke volume [46]. Therefore, this condition may have a potential abnormal effect on blood vessels [47,48], and it may increase the chances of developing hypertension among athletes [49,50].

Another Chinese study reported a higher rate of PA among urban compared to rural residents. Urban residents experienced a higher incidence of hypertension than did rural residents despite the former participating in more than 300 minutes/week of moderate PA, and one-fifth of these individuals participating more than 150 minutes/week in vigorous PA [51]. It was suggested that risk factors other than PA, such as higher stress, irregular diet, smoking, obesity, and pollution, are more prevalent in urban than in rural areas. This study included smoking habits and obesity but could not include psychological stress, dietary habits, and pollution, which is a limitation.

Another limitation should be considered while interpreting these findings. First, our study was a cross-sectional analysis; therefore, diachronic causal relationships between trends in this study cannot be guaranteed. Additionally, the study has the potential for bias inherent to the study design and registry studies in general. Second, estimative errors may have occurred due to the nature of the self-report PA intensity and frequency in this study. The accuracy of self-reporting may be influenced by health status, personal expectations, and eating and exercising behaviors [50]. As high-intensity PA is difficult to maintain for a longer period, it is unlikely that the majority of the population would volitionally perform these activities due to the initial discomfort and increased potential for injury [52] and would therefore be demotivated. Furthermore, the study did not record PA duration. The results of this study indicated that lower-intensity PA could be carried out longer than high-intensity PA, such that the PA level is equivalent irrespective of PA intensity. The differential effect of PA intensity on BP was associated with a high frequency of walking, and moderate intensity of PA and mild high-intensity PA, approximately 3-5 times/week, was similarly effective in reducing the incidence of hypertension. Finally, in this study, incident hypertension was defined as SBP/DBP ≥140/90 mmHg or a minimum of 1 claim/year for antihypertensive medication prescription under ICD-10 codes I10-I15. The results would have been different if we had used the new 2017 classification (SBP/DBP ≥130/80 mmHg) by the American Heart Association [53]. Furthermore, this study used relatively simple definitions for hypertension (based on measurements on one occasion), dyslipidemia, and diabetes (based on pathological measurement or national registry claims data), and these definitions can lead to over- or underestimation of the prevalence of these diseases.

CONCLUSION

This study is the first to examine the association between PA and the incidence of hypertension considering the intensity and frequency of PA in the Korean population aged over 20 years. Additionally, the study revealed that moderate-to-vigorous-intensity PA 3-5 times/week was the most favorable in reducing the risk of incident hypertension in middle-aged and older adults, but not in young adults. No additional benefit for lowering the risk of incident hypertension was observed in the frequency group with 6-7 days/week of moderate-to-vigorous PA compared to the frequency group with 3-5 days of PA. Previous studies reported that the blood pressure-lowering effect of exercise was not lasting and requires continually maintained regular activity in order to remain [54]. These results suggest the criteria for PA in the Korean population that can reduce the risk of incident hypertension to be 1-2 times or 3-5 times/week of PA regardless of its intensity. This suggests meaningful results that can improve participation and maintenance of PA.

In this study, there is a regret that the time and duration of PA could not be analyzed, further research is needed to identify the influence of time and duration of PA on the incidence of hypertension.

ACKNOWLEDGEMENTS

We thank all participants in the Korean Health Insurance Cohort study, as well as the National Health Insurance Service who developed the NHIS-NSC (2009-2012) database (NHIS-2018-4-044).

CONFLICT OF INTEREST

No potential competing interest was reported by the authors.

AUTHOR CONTRIBUTIONS

Conceptualization: YA Shin; Data curation: JH Kim; Formal analysis: JW Son; Funding acquisition: JW Son, YA Shin; Methodology: JW Son; Project administration: YA Shin; Visualization: GD Hong, SS Lee; Writing-original draft: JW Son, YA Shin; Writing-review & editing: SH Lee, MS Kang.

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