ORIGINAL ARTICLE

The effect of altered physical activity on hypertension: a longitudinal study in Indonesia

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ABSTRACT

A higher level of physical activity is widely recommended for the prevention of several Non-Communicable Diseases (NCDs), such as diabetes and cardiovascular disease, and leads to a reduction of blood pressure in resistant hypertension as well. This study aimed to measure the estimated effect of altered physical activity on hypertension over the course of three years of observation. This longitudinal study was conducted on 3109 adults at baseline using The Cohort Study of NCDs Risk Factors. The investigation was conducted through interviews, self-reports and observations. Data were analyzed using the Generalized Estimating Equation. The results show that the highest proportion of hypertension based on observation time occurred among those with low physical activity and experienced a delta change of less than 100 MET-min/week, which was 24% at the third follow-up. The risk of hypertension was higher among those with low physical activity and unchanged in the second (RR=1,642; 0,922 – 8,224) and third years of follow-up (RR=3,607; 95% CI: 0,923 – 7,993) compared to those who had moderate-vigorous activity. A longer follow-up period led to higher risk estimation. Given the significant impact of inactivity, regular physical activity should therefore be recommended for all individuals at risk of hypertension, including office workers. A firm policy is needed to encourage workplace physical activity breaks, in both government and private sectors.

Key words:
altered physical activity; hypertension; longitudinal study

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INTRODUCTION

The World Health Organization (WHO) has identified NCDs such as hypertension as the leading yearly cause of death worldwide.[1] The WHO estimates that 1.28 billion adults aged 30-79 years suffer from hypertension, two-thirds of whom live in low and middle-income countries.[2] In 2019, hypertension affected 26% of the world's total population. 32% of these cases were in adult women aged 30-79 years and 34% were in adult men aged 32-37 years. By region, it was reported that Southeast Asia saw 33.7% of hypertension cases,[3] meanwhile, Indonesia shows a higher prevalence of hypertension in the female group, at 36.85% compared to 31.34% in men.[4] The data above proves that hypertension remains a public health problem.

Hypertension is known as a multifactor disease, and its underlying causes are unknown. However, the literature has identified modifiable and non-modifiable factors contributing to hypertension incidence.[2] Non-modifiable factors included individual characteristics, such as age, gender, race and genetic factors. Modifiable factors tend to be related to lifestyles, such as obesity, alcohol consumption, smoking, unhealthy eating habits, stress, and physical inactivity.[5].[6] Several studies suggest that high levels of physical activity have a preventive effect on hypertension in youth and adulthood.[7–9] It is well known that lifestyle adjustments, including physical activity, are the first-line treatment for hypertension. For instance, a regular 8-to 12-week treadmill exercise program significantly lowered systolic and diastolic blood pressure.[10] In addition, sex was also found to determine the prevalence of hypertension. The prevalence of hypertension among women has increased over the four years in Indonesia.[11,12] In Iran, it was found that both systolic and diastolic blood pressure were frequently higher in women than in men aged 50-60 years.[12] Furthermore, a prior finding in 2017 found that women in middle-low-income countries had a higher prevalence of hypertension across all age groups compared with high-income countries.[12] The gap will likely increase with continued ageing.[13]

Numerous studies have investigated the association between physical activity and blood pressure among adults in several countries.[14–17] However, only a few studies have focused on the relationship between changes in physical activity and rates of hypertension. No known similar studies calculating the delta change of total physical activity over multiple years have yet been published. In addition, inactivity approximately doubles the risk for coronary heart disease, an adverse effect similar to hypertension.[8,18] Given the high significance of this issue, this study was performed to evaluate the link between changes in total physical activity and the probability of hypertension in adults, followed for three years using The Cohort Study of NCDs Risk Factors.

METHODS

Data management

This study initially used a subset of data from the Cohort Study of NCDs Risk Factor, a large cohort study which involved 3479 adults in Bogor City, Indonesia, from 2014/2015 to 2017/2018. The current study design was a longitudinal study. The inclusion criteria were all subjects with no hypertension at baseline, aged 25 or older, and measured physical activity and blood pressure every year of follow-ups. Outlier data and pregnant subjects were excluded.

Hypertension ascertainment

Blood pressure was measured yearly on the right arm with calibrated tensimeters after a 5-minute seated rest. Three measurements were taken. Incident hypertension was defined as average systolic and diastolic blood pressure of 140 mm Hg or higher, and 90 mmHg or higher, respectively, or as below 140 mmHg and 90 mmHg, if they had hypertension medicine intake for the last week[19]. Measurement was conducted by a trained interviewer according to the standard protocol.

Changes in the physical activity assessment

Physical activity was assessed using a validated questionnaire, the WHO Step Wise Questionnaire, which was used to collect information on total energy expenditure for physical activity by recalling routine activity of the day before the interview. Energy expenditure in standard metabolic equivalent values (METs) was used to estimate the intensity of each type of physical activity and to identify the alteration. Total physical activity (MET-min/week) was calculated by combining energy expenditure from all types of physical activity. Change in physical activity was categorized into two groups based on the year preceding the follow-up: moderate-to-vigorous activity if the total energy was 600 MET-min/week or higher and low activity if the total energy is below 600 MET-min/week. Categories were defined as unchanged if total energy difference was below 100 MET-min/week between the follow-up measurement and the previous year. Increase and decrease were identified based on a rise or decline at 100 MET-min/week or higher. In this study, the rate of 100 MET-min/week was determined from the value of quartile 2.[20,21]

Other covariates

Demographic characteristics (age, sex, education, and occupation) were determined by self-reporting at every follow-up. Body Mass Index was obtained from body weight and height measurement at every follow-up following standard protocol. Overweight and obese were defined according to the Indonesian standard of BMI 23- 24.9 kg/m^2 and ≥25 kg/m^2 [22]. Abdominal obesity was defined as waist circumference at >90 cm for males and >80 cm for females. Stress data was collected through the Self Reporting Questionnaire (SRQ) with 20 total items to identify if subjects displayed stress tendencies in the last month. Stress was determined for those who answered yes to more than six items.[23] Information regarding smoking was obtained from an interview. Smoking status, identified as individuals' consumption of all tobacco products in the last month, was modelled as a categorical variable with five categories (regular smoker, occasional smoker, ex-regular smoker, ex-occasional smoker, and nonsmoker). All individuals also observed their lipid profiles (total cholesterol, HDL, LDL, and triglyceride) and blood glucose (fasting blood glucose and 2-hour postprandial blood glucose) every two years of follow-ups. The normal range of total cholesterol [24], LDL [25], and triglyceride[24] was less than 200 mg/dL, 100 mg/dL, and 150 mg/dL, respectively. A normal HDL result was less than 40 mg/dL for males and less than 50 mg/dL for females [25]. Blood sugar levels lower than 140 mg/dL were considered normal, 140-199 mg/dL was considered impaired blood sugar tolerance, and 200 mg/dl was considered diabetic[26]. Normal fasting blood sugar was measured at less than 126 mg/dL, impaired blood sugar tolerance at 126-199 mg/dL, and diabetes at 200 mg/dL [26]. Laboratory measurements (HDL, LDL, triglyceride, and blood sugar levels) were conducted only on the first and third follow-ups, therefore these variables were not included in multivariate analysis. A previous diabetes diagnosis was measured based on whether the subjects had ever been diagnosed with diabetes by a health professional before the study.

Sample size determination

According to the calculation of proportions of the two groups for longitudinal study, the minimum number of samples needed to achieve 90% power of the study was 492 subjects.[27] However, this study used all eligible subjects (3109) using the data available from The Cohort Study of NCDs Risk Factor at the first follow-up. The number of subjects was dynamic over study time based on their participation at every follow up. The selection of subjects can be seen in Figure 1.

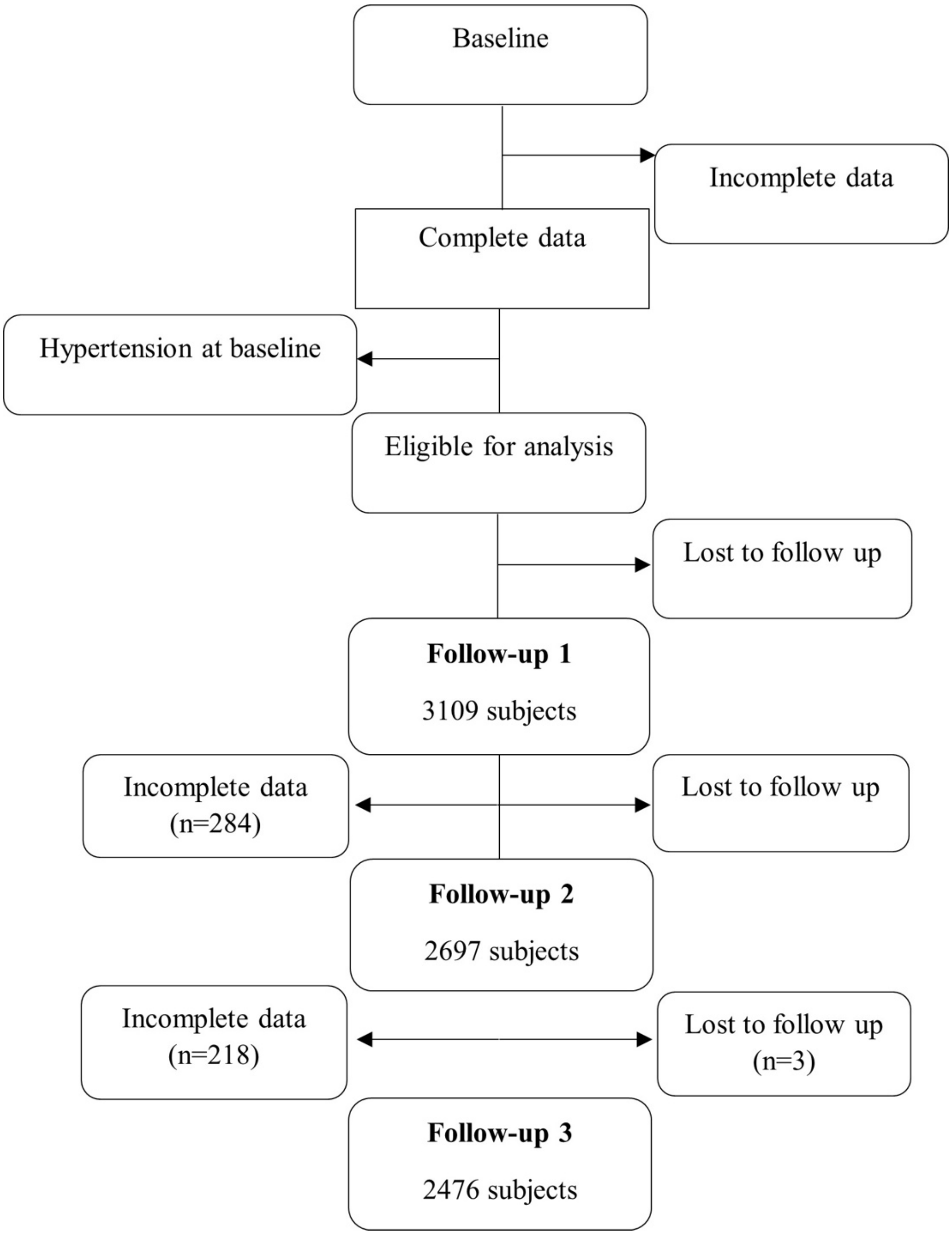

Figure 1. Selection of study subjects

Statistical analysis

A generalized Estimating Equation (GEE) was performed to assess the effect of physical activity on hypertension. All confidence intervals for parameters to be assessed were made with a significance level of alpha 0.05. This analysis used an unstructured working correlation matrix according to statistical consideration, which resulted in the smallest value of Corrected Quasi Likelihood under the Independence Model Criterion in the model.

The risk estimation of every period was calculated by using the formula:

$RR\ n\ year = e^{(\beta\ altered\ PA + \beta\ EM\ PA * time)}$

PA= physical activity

EM= effect modification of change in physical activity and follow-up period

Ethics Statement

The present study proceeded following an ethical assessment procedure and has been approved by The Research and Community Engagement Ethical Committee, Faculty of Public Health, Universitas Indonesia (Ethical Approval No: Ket-88/UN2.F10.D11/PPM.00.02/2022).

RESULTS

A total of 3479 subjects were identified, 3191 of whom were eligible for the current analysis. After excluding people with hypertension at baseline, a total of 3109 subjects were monitored in the first follow-up. Most subjects were females (73.1%), aged ≥45 (61.2%) with moderate education background (54.0%), and were blue-collar workers (44.9%). Subjects' demographic characteristics are shown in Table 1.

Table 1. Demographic Characteristics of Study Subjects at Baseline

Characteristic	Frequency (N = 3109)	Percent
Sex		
Female	2273	73.1
Male	836	26.9
Age		
29-45	1206	38.8
45-71	1903	61.2
Education		
High	170	5.5
Moderate	1680	54.0
Low	1035	33.3
N/A	224	7.8
Occupation		
No	168	1.8
Blue collar	1396	44.9
Civil servant/private employee	238	7.7
Self-employment	692	22.3
Others	615	19.8

Most subjects in the first and second follow-ups were characterized by low activity and experienced an increase in total activity. At the third follow-up, most subjects had moderate-to-vigorous activity and experienced a decrease in total activity compared to the previous period. The proportion of hypertension found tends to fluctuate, ranging from 6.3-9.9%. Most subjects in this study had no history of diabetes, had never smoked, and had no stress. Based on laboratory tests, as well as from the measurement of triglycerides and HDL, it was determined that the subjects' blood sugar, both 2-hour postprandial blood glucose and fasting blood glucose, was more than 50% at normal levels. Exceptions from the results of total cholesterol and LDL measurement were mostly included in the high category. More than 50% of subjects were found to be obese based on measurements of abdominal circumference and BMI during three periods of follow-up. (Table 2).

Table 2. Characteristics of Subjects Based on Covariates in The Study of Effects of Changes in Physical Activity on Hypertension: Three-Year Follow Up of The Cohort Study of Non-communicable Disease Risk Factor

Variable	Follow up 1 (n=3109)		Follow up 2 (n=2697)		Follow up 3 (n=2476)	
	n	%	n	%	n	%
Physical activity change						
Moderate-to-vigorous						
Unchanged	69	2,2	204	7,6	249	10,1
Increase	282	9,1	604	22,4	497	20,1
Decrease	181	5,8	724	26,8	1032	41,7
Low						
Unchanged	455	14,6	200	7,4	150	6,1
Increase	1958	63,0	873	32,4	462	18,7
Decrease	164	5,3	92	3,4	86	3,5
Hypertension						
Normal	2913	93,7	2431	90,1	2257	91,2
Hypertension	196	6,3	266	9,9	219	8,8
History of diabetes						
No	2630	84,6	2382	8,9	2138	86,3
Yes	278	8,9	231	8,6	338	13,7
N/A	201	6,5	84	13,7	-	-
Smoking status						
Never smoking	1344	43,2	1284	47,6	1167	47,1
Daily smoker	598	19,2	569	21,1	469	18,9
Occasional smoker	138	4,4	72	2,7	85	3,4
Ex daily smoker	499	16,1	324	12,0	351	14,2
Ex occasional smoker	247	7,9	187	6,9	194	7,8
N/A	283	9,1	261	9,7	210	8,5

Variable	Follow up 1 (n=3109)		Follow up 2 (n=2697)		Follow up 3 (n=2476)	
	n	%	n	%	n	%
Stress						
No	2692	86,6	2485	92,1	2325	93,9
Yes	193	6,2	209	7,7	151	6,1
N/A	224	7,2	3	0,1	-	-
2-hour postprandial blood glucose						
Normal	1945	62,6	-	-	1463	59,1
Impaired blood glucose tolerance	674	21,7	-	-	674	27,2
Diabetes	239	7,7	-	-	306	12,4
N/A	251	8,1	-	-	33	1,3
Fasting blood glucose			-	-		
Normal	2362	76,0	-	-	1372	55,4
Impaired blood glucose tolerance	318	10,2	-	-	802	32,4
Diabetes	179	5,8	-	-	275	11,1
N/A	250	8,0	-	-	27	1,1
Total cholesterol						
Normal	1419	45,6	-	-	933	37,7
High	1440	46,3	-	-	1512	61,1
N/A	250	8,0	-	-	31	1,3
Triglyceride						
Normal	2287	73,6	-	-	1818	73,4
High	572	18,4	-	-	637	25,7
N/A	250	8,0	-	-	21	0,8
HDL						
Normal	1884	60,6	-	-	1401	56,6
High	974	31,3	-	-	1054	42,6
N/A	251	8,1	-	-	21	0,8
LDL						
Normal	531	17,1	-	-	386	15,6
High	2328	74,9	-	-	2057	83,1
N/A	250	8,0	-	-	33	1,3
Waist circumference						
Normal	1126	36,2	1059	39,3	864	34,9
Obese	1733	55,7	1627	60,3	1593	64,3
N/A	250	8,0	11	0,4	19	0,8
Body Mass Index						
Normal	727	23,4	665	24,7	563	22,7
Underweight	141	4,5	115	4,3	97	3,9
Overweight	478	15,4	451	16,7	420	17,0
Obese	1507	48,5	1448	53,7	1374	55,5
N/A	256	8,2	18	0,7	22	0,9

Table 3 shows a higher tendency towards hypertension in those with low activity that remains unchanged over years. Research data showed that during the three observation periods the incidence of hypertension in this group continued to increase based on the follow-up time, from 8.6 to 24.0%, with the lowest proportion of cases in the initial follow-up period.

Table 3. Proportion of Hypertension According to Change in Physical Activity: Three-Year Follow Up of The Cohort Study of NCDs Risk Factor

Change in Physical Activity	Hypertension					
	Follow up 1 (n=3109)		Follow up 2 (n=2697)		Follow up 3 (n=2476)	
	Yes	No	Yes	No	Yes	No
Moderate-to-vigorous						
Unchanged	5 (7,2)	64 (92,8)	25 (12,3)	179 (87,7)	20 (8,0)	229 (92,0)
Increase	16 (5,7)	266 (94,3)	48 (7,9)	556 (92,1)	42 (8,5)	455 (91,5)
Decrease	13 (7,2)	168 (92,8)	72 (9,9)	652 (90,1)	79 (7,7)	953 (92,3)
Low						
Unchanged	39 (8,6)	416 (91,4)	37 (18,5)	163 (81,5)	36 (24,0)	114 (76,0)
Increase	119 (6,1)	1839 (93,9)	72 (8,2)	801 (91,8)	36 (7,8)	426 (92,2)
Decrease	4 (2,4)	160 (97,6)	12 (13,0)	80 (87,0)	6 (7,0)	80 (93,0)

The final model results show the highest risk of hypertension was in subjects with low activity and experienced changes of 100 MET-min/week or activity levels that remained unchanged throughout the period, with a risk of 1.223 times (95% CI: 0.466-3.211). Meanwhile, in other categories, there is no precise risk estimation value due to overlapping confidence intervals (Table 4).

Table 4. Effect of Physical Activity Alteration on Hypertension: Three-Year Follow Up of The Bogor Cohort Study of Non-communicable Disease Risk Factor

Change in Physical Activity	P Value	RR [a]	95% Confidence Interval
Moderate-to-vigorous			
Unchanged	Ref.	1	
Increase	0.653	0.788	0.279 – 2.225
Decrease	0.990	1.007	0.345 – 2.936
Low			
Unchanged	0.683	1.223	0.466 – 3.211
Increase	0.723	0.846	0.335 – 2.136
Decrease	0.102	0.325	0.084 – 1.250

[a] Adjusted by follow-up period; included effect modification physical activity* follow-up period

All of the resulting risk estimates overlap the null value, except in the group with low physical activity and a delta of measured activity change of less than 100 MET-min/week. The risk of hypertension in the low activity and unchanged over time group increased from the first to the third period. In addition, a significant increase in risk occurred in the third period, with an increase of more than 100% compared to the risk of the second period. The risk at the third follow-up was also recorded as the highest estimated risk of hypertension compared to other years, which was 3.607 (95% CI: 0.923-7.993) (Table 5).

Table 5. Estimating Risk of Changes in Physical Activity to Hypertension Based on Follow-up Period

Change in Physical Activity	Risk Estimation		
	Follow-up 1	Follow-up 2	Follow-up 3
Moderate-to-vigorous			
Increase [a]	0.788 (0.279 – 2.225)	0.627 (0.120 – 3.271)	1.053 (0.202 – 5.496)
Decrease [a]	1.007 (0.345 – 2.936)	0.984 (0.185 – 5.238)	0.946 (0.199 – 5.629)
Low			
Unchanged [a]	1.223 (0.466 – 3.211)	1.642 (0.922 – 8.224)	3.607 (0.923 – 7.993)
Increase [a]	0.846 (0.335 – 2.136)	0.647 (0.132 – 3.158)	0.963 (0.197 – 4.702)
Decrease [a]	0.325 (0.084 – 1.250)	1.091 (0.169 – 7.036)	0.853 (0.132 – 5.501)

[a] All reference category is those with moderate-to-vigorous and unchanged

DISCUSSION

In the present study, the risk of hypertension due to changes in physical activity over time yields varying estimation results. Several studies have estimated the association between physical activity and hypertension with varying results.[28] Some showed an inverse association between physical activity and hypertension.[29,30] In a study involving a large adult population using data from The Australian Longitudinal Study on Women's Health (ALSWH), the reduction in the risk of hypertension was lower in the group with moderate-to-vigorous activity (MVPI) compared to the low-intensity group. The difference in the results of this study illustrates that hypertension is a multifactorial disease, and the process of interaction between factors and their contribution as a cause of hypertension is complex.[31] Nonetheless, previous literature showed results consistency with the present study, in which low physical activity increases the risk of hypertension in the adult population.[14,32] Another study reported the relationship between higher levels of moderate–vigorous physical activity and lower rates of incident hypertension.[33]

Lifestyle adjustment in the form of increased physical activity is shown to prevent hypertension.[33,34] Sufficient physical activity has been shown to prevent hypertension, through adaptation mechanisms that improve hemodynamics and metabolism. Regular and adequate physical activity strengthens the heart, allowing it to pump blood throughout the body. Ultimately, the decrease in the force required by the arteries causes blood pressure to decrease as well.[6] Physical activity also reduces the risk of obesity, which is one of the predictors of hypertension. Kim et al. reported the results of a study of an adult population in Korea, showing that regular physical activity collected using a self-reported questionnaire was shown to reduce the prognostic rate from prehypertension to hypertension compared to those with less activity [35]. Another study conducted on an adult population aged 35 years who had pre-hypertension in rural China showed that individuals with low activity had a 40% higher risk of developing hypertension than individuals with sufficient physical activity.[36] Sufficient physical activity has been shown to prevent hypertension by reducing body fat and body weight, improving vascular endothelial function and having a positive effect on lipid profiles, inflammatory markers and autonomic nervous balance.[37]

Inconsistent risk estimation across levels of change in physical activity may be caused by bias. In this study, physical activity data were obtained with questions regarding the routine, intensity, and duration of physical activity during the past day. Due to a tendency for subjects to have difficulty remembering physical activities that are carried out routinely, this may cause bias and a high likelihood of positive responses. The detailed nature of the questions asked, creates a dependence on subjects's recall abilities.[38] In addition, the questionnaire's language is less suited to measuring light and moderate activity.[39].[40] Therefore, there is a possibility that the distribution of the subject's answers may be random, causing a non-differential misclassification that would underestimate the risk.

The possibility of bias in subjects; responses should be considered. The increasing proportion of people with moderate-to-vigorous activity and with a longer follow-up is possibly due to incorrect subjects' reports. In addition, external factors such as age, awareness and attention to the study's urgency affect responses.[41] Furthermore, results of blood pressure measurements are also prone to bias. In this case, non-differential bias may occur due to measurement errors. However, bias was minimized by using a calibrated digital tensimeter and trained observers.

It is noteworthy that the causality of the findings is valid considering the time relationship between exposure and outcome. All exposure and outcome variables were measured repeatedly in each follow-up period. Exposure was measured using a routine recall that subjects completed before being interviewed. In contrast, outcomes were obtained at the time of the interview by measuring blood pressure on-site. Based on these measures, this study can identify events and exposures in chronological time. This indicates that the study's results are valid in describing the association of exposure and outcome in the study subjects. The association estimates obtained describe a causal relationship between changes in physical activity and hypertension, although information bias may impact results. However, the chance variation that occurs in most categories of physical activity poses a barrier to the precise estimation of the magnitude of the risk posed by physical activity.

The results of this study are considered to be generalizable to the source population because of a minimal loss of subjects (less than 5%). The characteristic of concern is gender, given that more than 70% of subjects were women, producing a tendency to overestimate the results of the association in female subjects to be applied to other populations. In addition, studies have shown gender differences exist in physical activity levels; women were shown to have greater levels of inactivity and participated in less moderate-to-vigorous physical activity compared to men.[42,43] However, when other domains of activities (housework, transportation and occupational) are considered, no gender differences are observed. This is possibly explained by a higher level of physical activity in the form of housework among females.[43] Therefore, the term gender bias to evaluate the differences in physical activity levels across the sexes may distort the results.

Although gender issues appear, the results of this study are consistent when compared with similar studies with RR = 1.37 (95% CI: 1.07 – 1.75) and RR = 1.33 (95 % CI: 1.1–1.7).[44] Despite overlapping and potentially misleading estimates, in the delta category, the change of less than 100 MET-min/week among those with low activity, showed the role of low activity as a risk factor, especially in the second and third periods. Based on this explanation, this study's use of delta of changes in the total activity of 100 MET-min/week suggests that the group with changes of 100 MET-min/week among subjects with total activity less than 600 MET-min/week has a potentially increased risk of hypertension.

The authors acknowledge some limitations in the present study. Firstly, the present model did not include important confounding variables such as the results of laboratory tests and family history of hypertension due to the lack of an appropriate data set. In addition, a specific type of physical activity will be more informative in describing the causal relationship to outcomes, however, this study lack specificity.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the present study suggests that unchanged physical activity in those with insufficient physical activity accounts for increasing hypertension cases in the second and third follow-ups. In addition, a longer follow-up period may lead to a higher risk of hypertension. The government needs to encourage and raise awareness about the importance of increasing physical activity through the development of worksite policies and practices that build physical activity into routines. These may include exercise breaks at a certain time of day and in meetings or walking meetings. The activities should not be too physically demanding so most employees can feel like the activity is still practical and fun. The most important point is that the activities can reduce their sitting duration and improve their physical and mental health. Furthermore, taking regular active breaks must be implemented firmly so that it is not only practised in government offices, but also in the private sector.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare for this study.

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