Physical Activity and Risk of Hypertension
A Meta-Analysis of Prospective Cohort Studies
Pengcheng Huai, Huanmiao Xun, Kathleen Heather Reilly, Yiguan Wang, Wei Ma, Bo Xi

Abstract—Published literature reports controversial results about the association of physical activity (PA) with risk of hypertension. A meta-analysis of prospective cohort studies was performed to investigate the effect of PA on hypertension risk. PubMed and Embase databases were searched to identify all related prospective cohort studies. The Q test and F statistic were used to examine between-study heterogeneity. Fixed or random effects models were selected based on study heterogeneity. A funnel plot and modified Egger linear regression test were used to estimate publication bias. Thirteen prospective cohort studies were identified, including 136,846 persons who were initially free of hypertension, and 15,607 persons developed hypertension during follow-up. The pooled relative risk (RR) of main results from these studies suggests that both high and moderate levels of recreational PA were associated with decreased risk of hypertension (high versus low: RR, 0.81; 95% confidence interval, 0.76–0.85 and moderate versus low: RR, 0.89; 95% confidence interval, 0.85–0.94). The association of high or moderate occupational PA with decreased hypertension risk was not significant (high versus low: RR, 0.93; 95% confidence interval, 0.81–1.08 and moderate versus low: RR, 0.96; 95% confidence interval, 0.87–1.06). No publication bias was observed. The results of this meta-analysis suggested that there was an inverse dose–response association between levels of recreational PA and risk of hypertension, whereas there was no significant association between occupational PA and hypertension. (Hypertension. 2013;62:1021-1026.)

Key Words: cohort studies ■ hypertension ■ meta-analysis ■ motor activity

Hypertension is the primary and most common risk factor for heart disease, stroke, and renal disease and has been identified as the leading cause of mortality and third cause of disability-adjusted life years worldwide. According to a report from Kearney et al, the total number of adults with hypertension in 2025 was predicted to increase to 1.56 billion worldwide. Identifying and characterizing modifiable risk factors of hypertension remain important for public health and clinical medicine.

Genetic and lifestyle risk factors are thought to be associated with hypertension. The World Health Organization has developed a series of recommendations based on these factors to prevent and control disease. Increasing physical activity (PA) is one of these recommendations because it is considered a widely accessible, inexpensive, and effective intervention. PA can be recreational PA (RPA), performed during free time and to meet personal interests and needs, and occupational PA (OPA), associated with the activity required for one’s job. To our knowledge, the international recommendations for health-promoting PA do not distinguish between RPA and OPA.

Numerous investigations and research have investigated the effect of PA in reducing hypertension risk; however, they have reported conflicting results. Li et al performed a meta-analysis to investigate the relationship between PA and risk of cardiovascular disease; however, there has not yet been a meta-analysis to explore the effect of PA in reducing hypertension risk or the differences in how RPA and OPA can decrease the risk of hypertension. Thus, we performed this meta-analysis to investigate the association between PA and incidence of hypertension.

Methods
The Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines were followed for the current study.

Search Strategy
The PubMed and Embase databases were searched from its inception through November 26, 2012 to identify all relevant literature. The following search strategy was used: (physical activity OR physical activities OR motor activity OR motor activities OR exercise OR exercises OR walking OR energy expenditure) AND (hypertension OR hypertension OR hypertension)
OR high blood pressure OR high blood pressures) AND (cohort study OR prospective study OR longitudinal study OR follow-up study).

The results of all included studies were adjusted for potential confounding factors. In the presence of substantial heterogeneity, the pooled estimate of risk was calculated using the Dersimonian and Laird random effects model (REM) or the fixed effects model (FEM) based on heterogeneity between subgroups. Meta-regression was conducted to explore the possible sources of between-study heterogeneity. Subgroup analysis by duration of follow-up was performed. A sensitivity analysis was performed to validate the stability of outcomes by sequential removal of each individual study.

An individual study is suspected to excessively influence the point estimate if its omitted analysis lies outside the 95% CI of the combined analysis. Publication bias was estimated using a funnel plot and modified Egger linear regression test. All statistical tests were performed with STATA version 11.0 (StataCorp LP, College Station, TX). All tests were 2-sided and a $P$ value <0.05 was considered statistically significant.

### Results

#### Characteristics of Studies

The literature search identified 3817 potentially relevant articles, of which 13 studies ultimately met the inclusion criteria (Figure S1 in the online-only Data Supplement). The total population of the included studies was 136846 persons who were initially free from hypertension, and 15607 persons developed hypertension during follow-up. The follow-up duration ranged from 2 to 45 years, and the median duration of follow-up was 9.8 years. Twelve studies reported the effect of RPA on hypertension risk, and 6 reported the effect of OPA, and 2 reported the effect of commuting PA. All included studies reported the effect of high-level PA on hypertension risk, and 9 reported the effect of moderate-level PA. Two studies involved men only, and 2 involved women only. 6 studies involved both men and women and reported sex-specific results, and 3 studies involved both men and women but did not report sex-specific results.

Seven studies defined hypertension as systolic blood pressure $\geq 140$ mmHg or diastolic blood pressure $\geq 90$ mmHg or the use of antihypertensive medication, and 2 studies defined hypertension as systolic blood pressure $\geq 160$ mmHg or diastolic blood pressure $\geq 95$ mmHg or the use of antihypertensive medication, and 4 studies ascertained hypertension by self-report or from a reimbursement medication registry. Five studies were conducted in North America, 6 in Europe, and 2 in Asia. Stars in Table S1 indicate the quality of the studies assessed using the Newcastle Ottawa Scale and the maximum score was 9. Five studies were scored 9 stars, 5 studies were scored 8 stars, and 3 studies were scored 7 stars in quality assessment. The results of all included studies were adjusted for potential confounding factors (Table S1). Other characteristics of included articles, such as statistical used to estimate RR, blood pressure measurement, and definition of PA levels, were also extracted in Table S2.

#### RPA and Risk of Hypertension

The association between high-level RPA and risk of hypertension compared with low-level RPA is shown in Figure 1. There was no significant heterogeneity between 12 studies ($P_{Q}=0.171$; $I^2=28.0\%$), and a FEM was used. The overall result showed that high-level RPA was associated with decreased risk of hypertension compared with the reference group with low-level RPA (RR, 0.81; 95% CI, 0.76–0.85).

Figure 2 shows the association between moderate-level RPA and risk of hypertension compared with low-level RPA. There was no significant heterogeneity between 9 studies examining moderate-level RPA and risk of hypertension ($P_{Q}=0.613$; $I^2=0.0\%$), so a FEM was used to pool the RR. The result of the meta-analysis showed that moderate-level RPA decreased the risk of hypertension compared with low-level RPA (RR, 0.89; 95% CI, 0.85–0.94).

In addition, after exclusion of 3 articles (Figure 1), which reported only 2 levels of RPA, the pooled estimate of the RR of high- versus low-level RPA and risk of hypertension, based on 9 studies, was also significant (RR, 0.78; 95%...
CI, 0.72–0.83; Figure S2). The difference of these 2 RRs (RR of high-level RPA and RR of moderate-level RPA based on 9 studies) was significant ($P=0.020$), and the former RR is smaller than the latter one. Thus, we concluded that there was an inverse dose–response association between RPA and incidence of hypertension.

**OPA and Risk of Hypertension**

The association between high-level OPA and risk of hypertension compared with low-level OPA is shown in Figure S3. A REM was used because of the heterogeneity between 6 studies ($P=0.011$; $I^2=66.3\%$). The pooled result showed that the association between high-level OPA and risk of hypertension was not statistically significant (RR, 0.93; 95% CI, 0.81–1.08).

Figure S4 shows the association between moderate-level OPA and risk of hypertension compared with low-level OPA. A FEM was used because there was no significant heterogeneity between 4 studies ($P=0.454$; $I^2=0.0\%$). However, the result showed that the association between moderate-level OPA and risk of hypertension was not significant (RR, 0.96; 95% CI, 0.87–1.06).

**Commuting PA and Risk of Hypertension**

The association between high level of commuting PA and risk of hypertension was not consistent in the 2 included articles. Hayashi et al found that high commuting PA decreased the risk of hypertension (RR, 0.71; 95% CI, 0.52–0.97), whereas the association reported by Barengo et al was not significant (RR, 0.96; 95% CI, 0.82–1.12). The association between moderate level of commuting PA and risk of hypertension was not significant in 2 studies (Table S2).

**Exploration of the Heterogeneity Source**

Exploratory univariate meta-regression was performed with the introduction of follow-up duration, study area (North America, Europe, and Asia), publication year, sample size, and number of cases during follow-up. The results of meta-regression indicated that follow-up duration was the main source of heterogeneity both in high-level RPA (meta-regression coefficient, 0.005; 95% CI, 0.001–0.009; $P=0.020$) and in high-level OPA (meta-regression coefficient, 0.007; 95% CI, −0.001 to 0.014; $P=0.065$). Thus, the subgroup analyses of the association between RPA/OPA and risk of hypertension by follow-up duration (≥10 years versus <10 years) were

![Figure 1. Fixed effects meta-analysis of the association between high-level recreational physical activity (RPA) and risk of hypertension (12 studies included). CI indicates confidence interval; and RR, relative risk.](image)

![Figure 2. Fixed effects meta-analysis of the association between moderate-level recreational physical activity (RPA) and risk of hypertension (9 studies included). CI indicates confidence interval; and RR, relative risk.](image)
conducted. However, the differences between short and long follow-up durations were not significant for either high-level RPA or high-level OPA (Table S3).

**Sensitivity Analysis and Publication Bias Evaluation**

In the sensitivity analysis, no individual study substantially influenced the pooled RRs for both high- and moderate-level RPA (Figures S5–S8). The shape of the funnel plot to assess publication bias was roughly symmetrical for high- and moderate-level RPA. No publication bias was detected by Egger test for high-level RPA ($P=0.052$), moderate-level RPA ($P=0.301$), high-level OPA ($P=0.329$), or moderate-level OPA ($P=0.430$).

**Discussion**

To our knowledge, this meta-analysis represents the first one investigating the association between PA and incidence of hypertension. The current meta-analysis included 13 prospective studies with a total population of 136,846 and 15,607 hypertensive cases found at follow-up. The results of this study suggested that there was an inverse dose–response association between levels of RPA and risk of hypertension.

The results also showed that there was no evidence of an association between high- or moderate-level OPA and developing hypertension. Holtermann et al\(^\text{31}\) hypothesized that OPA increased the risk for long-term sickness absence, which is an acknowledged measure of global health and economic burden in Western societies, whereas RPA is thought to decrease the risk for long-term sickness absence.\(^\text{32,33}\) A study conducted among female Filipino workers found that excessive work was associated with poorer health, dissatisfaction with life, poor recuperation from fatigue, and hypertension.\(^\text{34}\) Generally, high-level OPA consists of heavy lifting, prolonged standing, and highly repetitive work, whereas RPA is often characterized by dynamic contractions of large muscle groups increasing whole-body metabolism and cardiac output with the ability to rest when fatigued.\(^\text{35}\) The international recommendations for health-promoting PA should distinguish between OPA and RPA.

In addition, a meta-analysis of randomized controlled trials supports the blood pressure–lowering potential of dynamic resistance training.\(^\text{36}\) The mechanism between RPA and hypertension is complex. Generally, exercise reduces blood pressure, systemic vascular resistance, sympathetic activity, plasma renin activity, the homeostasis model assessment insulin resistance index, weight, and abdominal circumference, and that it improves blood lipids.\(^\text{37}\) First, RPA is helpful in maintaining body weight. A randomized clinical trial conducted among overweight adults suggested that weight loss was effective in lowering systolic and diastolic blood pressures.\(^\text{38}\) Second, exercise decreased total peripheral resistance. Because mean arterial pressure is determined by cardiac output and total peripheral resistance, reductions in resting cardiac output do not typically occur after chronic exercise, whereas total peripheral resistance will decrease followed by decreased blood pressure.\(^\text{39}\) A meta-analysis that involved 72 trials also found that aerobic endurance training decreased blood pressure through a reduction of vascular resistance.\(^\text{37}\) Third, hyperinsulinemia and insulin resistance may contribute to hypertension through the effects of insulin on the retention of sodium, increasing sympathetic nervous system activity, and vascular smooth muscle proliferation.\(^\text{40}\) RPA has been shown to improve insulin sensitivity by Henriksen et al,\(^\text{41}\) which is another possible mechanism of antihypertension effect of RPA. The proposed mechanisms include neurohumoral and structural adaptations, but no definitive conclusion has been made on the exact mechanism.\(^\text{39}\) Furthermore, the indirect association between RPA and decreased risk of hypertension might also be because of the characteristics of physically active subjects, who usually have a healthier lifestyle in general. In other words, they may be younger, smoke less, drink less, have more healthy eating habits, be less stressed, which are protective factors of hypertension.

Previous studies have also found PA and RPA to be associated with other health outcomes besides hypertension. Regular PA and RPA might decrease the risk of lung cancer, prostate cancer, colon cancer, and cardiovascular disease.\(^\text{16,42–45}\) Because RPA may reduce the risk of hypertension through weight loss, moderate- to high-level RPA that is sufficient to maintain a normal weight should be recommended and promoted in populations, which may prevent hypertension and other diseases.

This meta-analysis had several strengths. This study included prospective cohort studies to determine the risk of hypertension over time. This meta-analysis also had a large sample size and included studies were adjusted for potential confounding, which increased the accuracy of the effect estimate.\(^\text{46}\) However, the potential limitations of this meta-analysis should be considered. First, this meta-analysis only included English and Chinese language articles; eligible articles with other languages were not included in this analysis, which may influence the pooled estimated value. Second, because of the inability to obtain raw data, we could perform only a study-level but not a patient-level meta-analysis, which would have enabled us to adjust for multiple factors. Third, the measurements of PA varied among the 13 included studies with regard to frequency, intensity, and duration, leading to different definition of low-, moderate-, and high-level PA, so the optimal energy that should be consumed to reduce risk of hypertension could not be evaluated.

The results of this meta-analysis suggest that there was an association between levels of RPA and decreased risk of hypertension, whereas there is no significant association between OPA and hypertension.

**Perspectives**

It is important to calculate the precise energy that one should consume through RPA. In addition, sex, age, race, and obese status should be stratified when the precise energy is calculated. In addition, the association between RPA and decreased risk of hypertension in this meta-analysis might be confounded by various factors. Thus, large-scale randomized, controlled trials are recommended to assess the impact of PA per se on the incidence rates of hypertension.
Sources of Funding
The study was supported by Independent Innovation Foundation of Shandong University (2010JC008 and 2012JC035), the Research Fund for the Doctoral Program of Higher Education of China (20120131120004), and the Foundation for Outstanding Young Scientist in Shandong Province (BS2011YY026).

Disclosures
None.

References


---

### Novelty and Significance

**What Is New?**

- Published literature reports controversial results about the association of physical activity (PA) with risk of hypertension, but no meta-analysis has been performed to clarify the association.
- Types of PA, that is, recreational PA and occupational PA, were distinguished.

**What Is Relevant?**

- Both high and moderate levels of recreational PA were associated with reduced risk of hypertension.
- The association between occupational PA and hypertension was not significant.

**Summary**

Thirteen prospective cohort studies were identified. There was an inverse dose–response association between levels of recreational PA and risk of hypertension.
Physical Activity and Risk of Hypertension: A Meta-Analysis of Prospective Cohort Studies
Pengcheng Huai, Huanmiao Xun, Kathleen Heather Reilly, Yiguan Wang, Wei Ma and Bo Xi

Hypertension. 2013;62:1021-1026; originally published online September 30, 2013; doi: 10.1161/HYPERTENSIONAHA.113.01965

Hypertension is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2013 American Heart Association, Inc. All rights reserved.
Print ISSN: 0194-911X. Online ISSN: 1524-4563

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/62/6/1021

Data Supplement (unedited) at:
http://hyper.ahajournals.org/content/suppl/2013/09/30/HYPERTENSIONAHA.113.01965.DC1

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Hypertension can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Hypertension is online at:
http://hyper.ahajournals.org//subscriptions/
Online supplements

Physical Activity and Risk of Hypertension: A Meta-Analysis of Prospective Cohort Studies

Short title: Physical activity and hypertension

Pengcheng Huai 1, Huanmiao Xun 1, Kathleen Heather Reilly 2, Yiguan Wang 3, Wei Ma 1, Bo Xi 4

1. Department of Epidemiology and Health Statistics, School of Public Health, Shandong University, Jinan, China
2. Independent consultant, New York, USA
3. National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing, China
4. Department of Maternal and Child Health, School of Public Health, Shandong University, Jinan, China

Correspondence to

Wei Ma, Department of Epidemiology and Health Statistics, School of Public Health, Shandong University, 44 Wenhuaxi Road, Jinan 250012, China (Tel: +86531-88382141; Fax: +86531-88382553; Email weima@sdu.edu.cn).

Bo Xi, Department of Maternal and Child Health, School of Public Health, Shandong University, 44 Wenhuaxi Road, Jinan 250012, China (Tel: +8653188382134; Fax: +8653188382134; Email xibo2010@sdu.edu.cn).
<table>
<thead>
<tr>
<th>First author, year</th>
<th>Country</th>
<th>Follow-up duration</th>
<th>Population</th>
<th>No. of cases</th>
<th>PA (type, measurement mode)</th>
<th>Adjustments</th>
<th>Stars*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pouliou, 2012²⁴</td>
<td>UK</td>
<td>45 years</td>
<td>9297 men and women, birth cohort</td>
<td>2363</td>
<td>RPA and OPA indices based on duration and intensity of activities, and expressed as MET</td>
<td>age, BMI, birth weight, smoking, alcohol, dietary factors and others</td>
<td>9</td>
</tr>
<tr>
<td>Asferg, 2011¹⁰</td>
<td>Denmark</td>
<td>mean 9.8 years</td>
<td>744 women and 367 men, age 30-60 years</td>
<td>304</td>
<td>RPA index based on time, frequency and intensity of activities</td>
<td>age and sex</td>
<td>8</td>
</tr>
<tr>
<td>Carnethon, 2010¹⁴</td>
<td>USA</td>
<td>20 years</td>
<td>4618 men and women, age 18-30 years</td>
<td>1022</td>
<td>RPA scores based on frequency and exercise units of activities, and expressed as EU</td>
<td>age, sex, BMI, race, smoking, alcohol, blood pressure and others</td>
<td>8</td>
</tr>
<tr>
<td>Camoes, 2010¹¹</td>
<td>Portugal</td>
<td>median interval of 3.8 years</td>
<td>549 men and women, age ≥40 years</td>
<td>160</td>
<td>RPA and OPA index based on self-reported time and metabolic equivalent of activities, and expressed as energy expenditure</td>
<td>age, sex, BMI, education, and total energy intake</td>
<td>8</td>
</tr>
<tr>
<td>Chase, 2009¹⁵</td>
<td>USA</td>
<td>mean 18 years</td>
<td>16601 men, age 20-82 years</td>
<td>2346</td>
<td>RPA index based on average intensity of activities</td>
<td>age, BMI, smoking, alcohol, family history of hypertension and cardiovascular disease, blood pressure and others</td>
<td>7</td>
</tr>
<tr>
<td>Ford, 2008¹²</td>
<td>USA</td>
<td>6 years</td>
<td>14309 men and women, age 18-26 years</td>
<td>768</td>
<td>RPA index based on average time and frequency of activities</td>
<td>age, sex, race, and use of healthcare</td>
<td>8</td>
</tr>
<tr>
<td>Gu, 2007²⁵</td>
<td>China</td>
<td>8.2 years</td>
<td>10525 men and women, age ≥40 years</td>
<td>2936</td>
<td>OPA index based on average intensity of activities</td>
<td>age</td>
<td>8</td>
</tr>
<tr>
<td>Author, Year</td>
<td>Country</td>
<td>Years</td>
<td>Participants</td>
<td>Measurements</td>
<td>Variables</td>
<td>Score</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>---------</td>
<td>-------</td>
<td>--------------</td>
<td>--------------</td>
<td>-----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Barengo, 2005&lt;sup&gt;36&lt;/sup&gt;</td>
<td>Finland</td>
<td>11.3</td>
<td>5935 men and 6227 women, age 25-64 years</td>
<td>RPA, OPA and commuting PA indices based on average intensity of activities</td>
<td>age, sex, BMI, area, education, smoking, alcohol, blood pressure and others</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Juntunen, 2003&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Finland</td>
<td>5</td>
<td>9485 women, age 47-56 years</td>
<td>RPA and OPA indices based on average time and intensity of activities</td>
<td>age, smoking, menopausal status, weight, height, retirement and others</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Pereira, 1999&lt;sup&gt;26&lt;/sup&gt;</td>
<td>USA</td>
<td>6</td>
<td>7459 men and women, age 45-65 years</td>
<td>RPA and OPA scores based on average frequency, duration and intensity of activities, and expressed as Baecke sport index</td>
<td>age, BMI, smoking, alcohol, education, blood pressure, parental history of hypertension, energy intake, menopausal status and others</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Hayashi, 1999&lt;sup&gt;27&lt;/sup&gt;</td>
<td>Japan</td>
<td>10</td>
<td>6017 men, age 35-60 years</td>
<td>RPA and commuting PA indices based on average frequency and duration of activities</td>
<td>age, BMI, smoking, alcohol, blood pressure and others</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Haapanen, 1997&lt;sup&gt;28&lt;/sup&gt;</td>
<td>Finland</td>
<td>10</td>
<td>1340 men and 1500 women, age 35-63 years</td>
<td>RPA index based on average frequency, duration and intensity of activities, and expressed as energy expenditure</td>
<td>age</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Folsom, 1990&lt;sup&gt;29&lt;/sup&gt;</td>
<td>USA</td>
<td>2</td>
<td>41873 women, age 55-69 years</td>
<td>RPA index based on average intensity of activities</td>
<td>age</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

RPA indicates recreational physical activity; OPA, occupational physical activity; MET, metabolic equivalent; BMI, body mass index; EU, exercise units.

* The quality of the studies assessed using the Newcastle-Ottawa Scale<sup>19</sup>.
<table>
<thead>
<tr>
<th>First author, year</th>
<th>RR(95%CI) or HR(95%CI) *</th>
<th>Statistic used to estimate RR</th>
<th>BP measurement (method, device used)</th>
<th>Definition of PA levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pouliou, 2012^{24}</td>
<td>High RPA: 0.92(0.83-1.02) High OPA: 1.13(1.01-1.26)</td>
<td>Multiple logistic regression</td>
<td>An automated digital oscillometric sphygmomanometer was used to measure BP for 3 times. The 3 readings were averaged.</td>
<td>Low RPA (h/day): &lt;0.7 for men and &lt;0.5 for women. High RPA (h/day): ≥0.7 for men and ≥0.5 for women. Low OPA (h/day): &lt;0.04 for men and &lt;0.01 for women. High OPA (h/day): ≥0.04 for men and ≥0.01 for women.</td>
</tr>
<tr>
<td>Asferg, 2011^{10}</td>
<td>High RPA: 0.64(0.47-0.85)</td>
<td>Multiple logistic regression</td>
<td>An sphygmomanometer was used to measure BP. Times of measuring BP was NR.</td>
<td>Low RPA: almost entirely sedentary; light physical activity for 2-4 hours per week. High RPA: light physical activity for more than 4 hours per week or more vigorous activity for 2-4 h per week; highly vigorous physical activity for more than 4 hours per week or regular heavy exercise or competitive sports several times per week.</td>
</tr>
<tr>
<td>Carnethon, 2010^{14}</td>
<td>High RPA: 0.79(0.60-1.04) Moderate RPA: 0.89(0.77-1.02)</td>
<td>Cox proportional hazards regression</td>
<td>A random-0 sphygmomanometer or an automated BP device was used to measure BP for 3 times. The last 2 readings were averaged.</td>
<td>Low RPA (EU): 0-195 for women; 0-345 for men. Moderate RPA (EU): 196-401 for women; 346-608 for men. High RPA (EU): 402-2126 for women; 609-1962 for men.</td>
</tr>
<tr>
<td>Camoes, 2010^{11}</td>
<td>High RPA: 0.74(0.48-1.11) High OPA: 1.00(0.65-1.53) Moderate RPA: 0.77(0.51-1.16) Moderate OPA: 0.85(0.54-1.35)</td>
<td>Poisson regression</td>
<td>A mercury sphygmomanometer was used to measure BP for 2 times. The 2 readings were averaged.</td>
<td>Low RPA(MET-h/day): &lt;3.0 for women; &lt;4.5 for men. Moderate RPA (MET-h/day): 3.0-6.5 for women; 4.5-8.5 for men. High RPA(MET-h/day): &gt;6.5 for women; &gt;8.5 for men. Low OPA (MET-h/day): &lt;11.9 for women; &lt;9.5 for men. Moderate OPA (MET-h/day): 11.9-17.6 for women; 9.5-15.7 for men. High OPA (MET-h/day): &gt;17.6 for women; &gt;15.7 for men.</td>
</tr>
<tr>
<td>First author, year</td>
<td>RR(95%CI) or HR(95%CI)</td>
<td>Statistic used to estimate RR</td>
<td>BP measurement (method, device used)</td>
<td>Definition of PA levels</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------</td>
<td>------------------------------</td>
<td>--------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Chase, 2009&lt;sup&gt;13&lt;/sup&gt;</td>
<td>High RPA: 0.76(0.66-0.86) Moderate RPA: 0.87(0.79-0.95)</td>
<td>Cox proportional hazards regression</td>
<td>Auscultation method was used to measure BP for 2 times. The 2 readings were averaged.</td>
<td>Low RPA: sedentary or did not participated in any activity. Moderate RPA: participated in a run/walk/jog program in the last three months. High RPA: participated in racquet sports, other strenuous sports, cycling, stair climbing, cross-country skiing, aerobic dancing, or swimming.</td>
</tr>
<tr>
<td>Ford, 2008&lt;sup&gt;12&lt;/sup&gt;</td>
<td>High RPA: 0.81(0.64-1.04) Moderate RPA: 0.90(0.80-1.02)</td>
<td>Multiple logistic regression</td>
<td>Self-reported hypertension</td>
<td>Low RPA: participated in 0-2 times activities per week. Moderate RPA: participated in 3-4 times activities per week. High RPA: participated in 5 or more times activities per week.</td>
</tr>
<tr>
<td>Gu, 2007&lt;sup&gt;25&lt;/sup&gt;</td>
<td>High OPA: 0.84(0.63-1.12)</td>
<td>A modified Poisson model</td>
<td>A standardized mercury sphygmomanometer was used to measure BP for 3 times. The 3 readings were averaged.</td>
<td>NR</td>
</tr>
<tr>
<td>Barengo, 2005&lt;sup&gt;36&lt;/sup&gt;</td>
<td>High RPA: 0.77(0.64-0.93) High OPA: 0.86(0.74-0.99) High commuting PA: 0.96(0.82-1.12) Moderate RPA: 0.94(0.83-1.07) Moderate OPA: 0.86(0.74-0.99) Moderate commuting PA: 0.98(0.84-1.16)</td>
<td>Cox proportional hazards regression</td>
<td>BP was measured for 2 times. The 2 readings were averaged.</td>
<td>Low RPA: reading, watching TV or working in the household without much physical activity. Moderate RPA: walking, cycling or practicing some other form of light exercise for at least 4 hours per week. High RPA: participation in recreational sports or in intense training or sports competitions for at least 3 hours a week. Low OPA: mostly sedentary work without much walking. Moderate OPA: walking quite a lot at work without lifting or carrying heavy objects. High OPA: a lot of walking and lifting at work, taking the stairs or walking uphill. Low commuting PA: exercising less than 15 minutes daily on the way to work and back home.</td>
</tr>
<tr>
<td>First author, year</td>
<td>RR(95%CI) or HR(95%CI) *</td>
<td>Statistic used to estimate RR</td>
<td>BP measurement</td>
<td>Definition of PA levels</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>---------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Juntunen, 2003&lt;sup&gt;13&lt;/sup&gt;</td>
<td>High RPA: 0.86(0.68-1.07)  High OPA: 0.80(0.61-1.04)  Moderate RPA: 0.87(0.72-1.06)  Moderate OPA: 0.85(0.70-1.04)</td>
<td>Multiple logistic regression</td>
<td>Hypertension was defined according to reimbursement medication registry</td>
<td>Moderate commuting PA: exercising between 15 and 30 minutes daily on the way to work and back home.  High commuting PA: more than 30 minutes exercising daily on the way to work and back home.  Low RPA: no activity.  Moderate RPA: 1-4 hours PA per week.  High RPA: 5 or more hours per week.  Definition of OPA levels: NR.</td>
</tr>
<tr>
<td>Pereira, 1999&lt;sup&gt;26&lt;/sup&gt;</td>
<td>High RPA: 0.90 (0.73-1.11)  High OPA: 0.99(0.81-1.19)  Moderate RPA: 0.98(0.81-1.19)  Moderate OPA: 0.98(0.81-1.20)</td>
<td>Multiple logistic regression</td>
<td>A random-zero sphygmomanometer was used to measure BP for 3 times. The last 2 readings were averaged.</td>
<td>Low RPA (leisure index): &lt;1.75 for black women and men; &lt;2.00 for white women; &lt;2.25 for white men.  Moderate RPA (leisure index): 1.75-2.50 for black women; 1.75-2.75 for black men; 2.00-3.00 for white women; 2.25-3.25 for white men.  High RPA (leisure index): &gt;2.50 for black women; &gt;2.75 for black men; &gt;3.00 for white women; &gt;3.25 for white men.  Low OPA (sport index): &lt;1.75 for black women and men; &lt;2.00 for white women; &lt;2.25 for white men.  Moderate OPA (sport index): 1.75-2.50 for black women; 1.75-2.75 for black men; 2.00-3.00 for white women; 2.25-3.25 for white men.  High OPA (sport index): &gt;2.50 for black women; &gt;2.75 for black men; &gt;3.00 for white women; &gt;3.25 for white men.</td>
</tr>
<tr>
<td>First author, year</td>
<td>RR(95%CI) or HR(95%CI)</td>
<td>Statistic used to estimate RR</td>
<td>BP measurement (method, device used)</td>
<td>Definition of PA levels</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Hayashi, 1999&lt;sup&gt;27&lt;/sup&gt;</td>
<td>High RPA: 0.72(0.59-0.88) &lt;br&gt;High commuting PA: 0.71(0.52-0.97) &lt;br&gt;Moderate RPA: 0.65(0.47-0.90) &lt;br&gt;Moderate commuting PA: 0.88(0.75-1.04)</td>
<td>Cox proportional hazards regression</td>
<td>A standard mercury sphygmomanometer was used to measure BP for 2 times. Readings of calculating BP was NR.</td>
<td>Low RPA: participated in regular PA less than once per week. Moderate PA: participated in regular PA once per week. High PA: participated in regular PA two or more times per week. Low commuting PA: walking to work lasted 10 minutes or less. Moderate commuting PA: walking to work lasted 11-20 minutes. High commuting PA: walking to work lasted 21 minutes or more.</td>
</tr>
<tr>
<td>Haapanen, 1997&lt;sup&gt;28&lt;/sup&gt;</td>
<td>High RPA: 0.70(0.52-0.95)</td>
<td>Cox proportional hazards regression</td>
<td>Self-reported hypertension</td>
<td>Low RPA: 0-1100 Kcal/week for men and 0-900 Kcal/week for women. Moderate RPA: 1101-1900 Kcal/week for men and 901-1500 Kcal/week for women. High RPA: &gt;1900Kcal/week for men and &gt;1500Kcal/week for women. NR</td>
</tr>
<tr>
<td>Folsom, 1990&lt;sup&gt;29&lt;/sup&gt;</td>
<td>High RPA: 0.70(0.60-0.90) &lt;br&gt;Moderate RPA: 0.90(0.70-1.10)</td>
<td>Multiple logistic regression</td>
<td>Self-reported hypertension</td>
<td></td>
</tr>
</tbody>
</table>

BP, blood pressure; NR, not reported; MET, metabolic equivalent; EU, exercise units.
* Low level of PA is considered as referent.
**Table S3** The subgroup analyses of the association between physical activity and risk of hypertension by follow-up duration

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>No. of studies</th>
<th>RR(95%CI)</th>
<th>I², %</th>
<th>PQ</th>
<th>Pu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High vs. low</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 years</td>
<td>6</td>
<td>0.78 (0.71-0.87)</td>
<td>8.3</td>
<td>0.363</td>
<td></td>
</tr>
<tr>
<td>≥10 years</td>
<td>6</td>
<td>0.82 (0.76-0.87)</td>
<td>46.9</td>
<td>0.094</td>
<td></td>
</tr>
<tr>
<td>Occupational physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High vs. low</td>
<td>0.715</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 years</td>
<td>4</td>
<td>0.91 (0.80-1.04)</td>
<td>0.0</td>
<td>0.548</td>
<td></td>
</tr>
<tr>
<td>≥10 years</td>
<td>2</td>
<td>0.97 (0.72-1.31)</td>
<td>91.0</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

P<sub>Q</sub>, P value of Q test; P<sub>u</sub>, P value of U-test.
Figure S1 Flow chart of study selection.

Figure S2 Fixed effects meta-analysis of the association between high level of RPA and risk of hypertension (9 studies included). RPA indicates recreational physical activity.
**Figure S3** Random effects meta-analysis of the association between high level of OPA and risk of hypertension (6 studies included). OPA indicates occupational physical activity.

**Figure S4** Fixed effects meta-analysis of the association between moderate level of OPA and risk of hypertension (4 studies included). OPA indicates occupational physical activity.
Figure S5 Sensitivity analysis of the association between high level of RPA and risk of hypertension. RPA indicates recreational physical activity.

Figure S6 Sensitivity analysis of the association between moderate level of RPA and risk of hypertension. RPA indicates recreational physical activity.
**Figure S7** Sensitivity analysis of the association between high level of OPA and risk of hypertension. OPA indicates occupational physical activity.

**Figure S8** Sensitivity analysis of the association between moderate level of OPA and risk of hypertension. OPA indicates occupational physical activity.