NIH Public Access
Author Manuscript
Curr Hypertens Rep. Author manuscript; available in PMC 2014 December 01.

Published in final edited form as:
Curr Hypertens Rep. 2013 December ; 15(6): 659–668. doi:10.1007/s11906-013-0386-8.

Physical Activity and the Prevention of Hypertension

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Abstract

As the worldwide prevalence of hypertension continues to increase, the primary prevention of hypertension has become an important global public health initiative. Physical activity is commonly recommended as an important lifestyle modification that may aid in the prevention of hypertension. Recent epidemiologic evidence has demonstrated a consistent, temporal, and dose-dependent relationship between physical activity and the development of hypertension. Experimental evidence from interventional studies have further confirmed a relationship between physical activity and hypertension as the favorable effects of exercise on blood pressure reduction have been well characterized in recent years. Despite the available evidence strongly supporting a role for physical activity in the prevention of hypertension, many unanswered questions regarding the protective benefits of physical activity in high-risk individuals, the factors that may moderate the relationship between physical activity and hypertension, and the optimal prescription for hypertension prevention remain. We review the most recent evidence for the role of physical activity in the prevention of hypertension and discuss recent studies that have sought to address these unanswered questions.

Keywords

Physical activity; Exercise; Hypertension; Prevention; Blood pressure; Resistance training; Endurance training

INTRODUCTION

With one-quarter of the world's adult population estimated to have hypertension, totaling nearly one-billion, and with the worldwide prevalence of hypertension projected to increase 60% by 2025, the primary prevention of hypertension has become a global public health challenge[1]. Current guidelines recommend increasing physical activity as a means to prevent hypertension[2–5]. These guidelines stem from a large body of literature demonstrating the protective effects of physical activity and exercise. The earliest study to demonstrate the potential protective effects of physical activity in hypertension prevention was published in 1968 by Paffenbarger et al. who showed that men who self-reported exercising more than 5 hours/week experienced a lower incidence of hypertension two to three decades later in life[6]. Following this observation, the first interventional study to

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Compliance with Ethics Guidelines

Conflict of Interest

Keith M. Diaz declares that he has no conflict of interest.

Daichi Shimbo has received grants from NIH.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

demonstrate the blood pressure (BP) lowering effect of exercise was published in 1970 by Boyer and Kasch who showed that an aerobic interval training program 2 days/week elicited reductions in BP in both hypertensive and normotensive men[7].

Over the past four to five decades since these publications, accumulating data has generally yielded consistent findings regarding the protective effects of physical activity in the prevention of hypertension. However, many unanswered questions remain regarding the optimal prescription for hypertension prevention. In recent years several important prospective studies and meta-analyses of intervention data have been published which have investigated the many nuanced components of physical activity in relation to hypertension prevention and may help to address some of the previously unanswered questions. The purpose of this report is to review the most recent evidence for the role of physical activity in the prevention of hypertension and discuss the recent studies that have sought to address these unanswered questions.

DEFINING PHYSICAL ACTIVITY

Physical activity, exercise, and physical fitness are related, but distinct umbrella terms commonly used in the present literature. Physical activity is defined as any bodily movement produced by contraction of skeletal muscles that increases energy expenditure above resting levels and comprises routine daily tasks such as commuting, occupational tasks, or household activities, as well as purposeful health-enhancing movements/activities[8]. Exercise is a component of physical activity that is planned, structured, and repetitive with the intent of improving or maintaining health. Physical fitness is defined as a quantifiable attribute an individual has or can achieve that relates to their ability to perform physical activities without undue fatigue and reflects a combination of physical activity behaviors, genetic potential, and health of various organ systems[8]. The components of physical activity, exercise, and physical fitness are defined in table 1.

PROSPECTIVE OBSERVATIONAL STUDIES

Recent data from large prospective studies among U.S. populations including the Nurses' Health Study II, the Aerobics Center Longitudinal Study (ACLS), and the Coronary Artery Risk Development in Young Adults (CARDIA) study have shown that self-reported physical activity is inversely associated with the development of hypertension[11–13]. Similarly, data from the CARDIA and ACLS studies have also shown that cardiorespiratory fitness is inversely associated with the development of hypertension[11, 12]. Inverse associations between physical activity and/or cardiorespiratory fitness and incident hypertension have also been reported amongst various international populations in Britain, China, Denmark, France, Italy, Korea, Saudi Arabi, and Thailand in recent years[14–21]. The relative consistency of findings across different populations meets one of Bradford Hill's criteria of causation (consistency of association)[22]. Recent data from prospective studies suggest that two more of Hill's criteria are met: temporality and a dose-response relationship. We review these criteria below and also review recent prospective data that have provided information on previously unaddressed questions including: Does physical activity provide protective benefits in individuals at high risk for developing hypertension? Does sedentary behavior have a role in the development of hypertension, independent of physical activity levels? Is resistance training beneficial for the prevention of hypertension? Are there factors that moderate the relationship between physical activity and the development of hypertension?

Temporality

Two prospective studies published in 2012 investigated the temporal relationship between changes in cardiorespiratory fitness and incident hypertension[15, 23]. In the ACLS study, improvements in cardiorespiratory fitness were associated with a lower risk of incident hypertension. When individuals were stratified according to how their fitness levels changed, those who maintained or improved fitness had a 26% and 28% lower risk of incident hypertension, respectively, compared with those who lost fitness[23]. Similarly, in a population of South Korean men, individuals whose cardiorespiratory fitness decreased over follow-up had an increased risk of incident hypertension compared to individuals whose cardiorespiratory fitness increased[15].

Dose-Response Relationship

The *2008 Physical Activity Guidelines for Americans* state that ‘For most health outcomes, additional benefits occur as the amount of physical activity increases through higher intensity, greater frequency, and/or longer duration’[24]. A 2010 systematic review critically examined whether this dose-response relationship exists for the primary prevention of hypertension[25]. A total of 12 articles were identified, with all studies demonstrating a positive effect of physical activity on the risk for hypertension. Of the 12 studies, seven (58%) reported a graded relationship between incident hypertension and physical activity. Five (42%) of the studies showed variable results as the dose-response relationship differed by gender and/or ethnicity. Investigators concluded that current evidence supports the protective effects of physical activity in the prevention of hypertension, however the dose-response relationship is still unclear.

Two large studies in 2013 have further explored the dose-response relationship between physical activity and incident hypertension. In the Australian Longitudinal Study on Women, Pavey and colleagues showed that the risk for incident hypertension decreased with increasing total volume of physical activity[26]. The decreasing risk of hypertension was similar among women who engaged in only moderate physical activity and women who engaged in both moderate and vigorous physical activity at all volumes of MET equivalent physical activity with the exception of the highest volume of physical activity (>2000 MET minutes/week; 4 times greater than physical activity guidelines). Investigators concluded that a dose-response relationship for total volume of physical activity and incident hypertension exists, but that the addition of vigorous physical activity does not provide additional benefits in the prevention of hypertension above those from moderate intensity activity, except at very high volumes of physical activity.

Similarly, using data from the National Runners’ Health Study II and the National Walkers’ Health Study, Williams and Thompson found that running and walking were associated with comparable risk reductions of incident hypertension when equivalent energy expenditures (MET hours/day) were compared[27]. There were incremental reductions in risk for incident hypertension with greater MET hours/day for both modes of exercise. This dose-response relationship was similar in both the walking and running groups, suggestive that exceeding current guidelines in terms of energy expenditure incurs greater health benefits, regardless of intensity. A caveat to these findings is that substantially fewer walkers than runners exceeded physical activity guidelines for energy expenditure (450–750 MET minutes/week[28]) by 2-fold, (15.4% vs. 61.1%), 3-fold (4.5% vs. 40.1%), and 4-fold (1.1% vs. 17.9%). This finding was attributed to the fact that running expends more calories in a given period of time compared to walking. Thus, it could be argued that more vigorous exercise may indeed confer greater health benefits in that greater caloric expenditure can be achieved in an allotted time.

High-Risk Populations

In 2003, the Seventh Report of the Joint National Committee (JNC 7) introduced a new BP classification termed 'prehypertension' that was developed to identify individuals at high risk of developing hypertension[3]. Studies have shown that the progression rate from prehypertension to hypertension over a 2- to 4-year period ranges from 30–40%[29, 30]. A 2011 meta-analysis that investigated predictors of prehypertension progression identified 6 studies that provided information on predictors of progression from prehypertension to hypertension, only one of which investigated physical activity as a predictive factor[31]. Investigators concluded that there was insufficient data to make any conclusions regarding predictors of prehypertension progression. Since that time, three recent publications have identified physical activity and its related components as factors associated with progression to hypertension from prehypertension. Kim et al. reported that Korean adults who self-reported engaging in regular exercise had a slower rate of progression from prehypertension to hypertension than non-exercisers[32]. Similarly, among adults with prehypertension living in rural areas of China, individuals with low levels of physical activity had a 40% higher risk of progression from prehypertension to hypertension compared to individuals who engaged in moderate physical activity[33]. Finally, among male US veterans the risk for progressing from prehypertension to hypertension was reported to be progressively higher with decreasing cardiorespiratory fitness[34].

Longitudinal data suggests that individuals with a parental history of hypertension are at high risk of developing hypertension[35]. As such, individuals with a family history of hypertension have also been identified as a high-risk population in whom primary prevention of hypertension should be emphasized[5]. In 2012, Shook and colleagues investigated the association between physical activity and incident hypertension among individuals with a parental history of hypertension and reported that moderately and highly fit individuals with a parental history of hypertension had a 21% and 34% lower risk of developing hypertension, respectively, compared to low fit individuals with a parental history of hypertension. Furthermore, when compared to high fit individuals without a parental history of hypertension, it was found that high fit individuals with a parental history of hypertension had only a 16% higher risk of incident hypertension[36].

Hypertension incidence is disproportionately higher among type 2 diabetes[37], thus type 2 diabetics represents another population at high risk for hypertension. In a prospective study of type 2 diabetics who attended a diabetes center in a Saudi Arabia, it was found that those who regularly exercise had a 62% lower risk of developing hypertension compared to individuals who did not exercise[18].

Sedentary Behavior

In the last decade, literature has accumulated on the role of sedentary behaviors in the development of adverse health outcomes[38]. In 2011, Proper et al. conducted a systematic review to evaluate the literature that has examined the relationship between sedentary behaviors and health outcomes[39]. Only one study was identified that investigated the relationship between sedentary behaviors and incident hypertension. In this study, sedentary behavior was associated with a greater risk of incident hypertension among a cohort of Spanish adults, independent of leisure-time physical activity[40]. Sub-analyses showed that driving and computer use were the sedentary behaviors associated with risk of incident hypertension, while television viewing was not. In a recent study published subsequent to the systematic review, it was found that television-viewing time, but not sitting at work time, was associated with risk of hypertension independent of physical activity levels among British adults[17]. These findings provide some evidence that sedentary behavior may be associated with incident hypertension, independent of physical activity levels. However, the reasons for why sedentary behavior is associated with incident hypertension independent of physical activity are still unclear.

Muscular Strength

Both the American Heart Association and the American College of Sports Medicine have endorsed the inclusion of resistance training as an integral component of an exercise program for preventing cardiovascular disease[4, 41]. These recommendations, in large part, stem from randomized controlled trials on the BP lowering effects of resistance training (reviewed below). Prospective data supporting the role of resistance training or measures of muscular strength/endurance (attributes developed from resistance training), however, are still limited. The earliest prospective study was published in 2010 by Maslow and colleagues who examined the association between muscular strength and incident hypertension among healthy men enrolled in the ACLS study[42]. It was reported that men in the high-strength group had a 28% lower risk for incident hypertension compared to the low-strength group. This association was no longer statistically significant after adjustment for cardiorespiratory fitness, although multicollinearity may have confounded this finding. More recently, in their analysis of the National Runners' Health Study II and the National Walkers' Health Study, Williams and Thompson reported that the amount of MET hours/day spent doing strengthening exercises was not associated with a reduced risk of incident hypertension[27]. Thus, the present literature from prospective studies provides little convincing evidence for a role of resistance training in the prevention of hypertension.

Moderating Factors

Although individuals who are physically active or physically fit have a lower risk of developing hypertension, some of these individuals nonetheless will still become hypertensive. The vice versa, sedentary or unfit individuals not developing hypertension, may also occur. Underlying factors contributing to inter-individual variation in the effects of physical activity for preventing hypertension are still poorly understood. In recent years, some studies have sought to identify potential factors which may moderate this relationship.

Sarzynski and colleagues investigated the interaction between cardiorespiratory fitness and single nucleotide polymorphisms (SNPs) from seven hypertension candidate genes and their association with incident hypertension in the CARDIA study[43]. It was reported that cardiorespiratory fitness was associated with incident hypertension, however the SNPs tested did not modify this relationship. Thus, present data do not suggest a role for genetic factors in moderating the relationship between physical activity and the development of hypertension. Further research is still needed.

Using data from the Nurses' Health Study I cohort, Cohen and colleagues investigated whether the relationship between physical activity and incident hypertension varied with age[44]. It was reported that the association between high levels of physical activity and the prevention of hypertension was weaker among older women when compared to younger women. However, because the incidence of hypertension is higher in older than in younger persons, increased physical activity would theoretically prevent a similar number of cases of hypertension in younger and older populations. Thus, investigators speculated that the overall public health benefit of lifestyle modification for the prevention of hypertension is similar for all ages.

INTERVENTION STUDIES

The strongest support for a cause-effect relationship between physical activity and hypertension prevention comes from randomized controlled trials. Dozens of trials have confirmed the favorable effects of exercise on BP reduction. This effect is more pronounced in hypertensives than in normotensives or prehypertensives, however it has been reported that even a 2-mmHg reduction in the population average diastolic BP would result in a 17% decrease in the prevalence of hypertension[5]. Thus, even modest reductions in BP amongst normotensives and prehypertensives could have important public health implications. In recent years, several systematic reviews and meta-analyses have summarized the effects of different exercise modalities on BP. We review these publications and several important subsequent publications below, with a focus on normotensive and prehypertensive populations.

Aerobic Exercise

In 2013, Corenlissen and Smart conducted an updated meta-analysis examining the effects aerobic, resistance, and combined aerobic and resistance training on BP in randomized controlled trials[45]. Among prehypertensives, the effect of aerobic exercise training on BP was significant for systolic and diastolic BP, with net reductions of 4.3 mmHg and 1.7 mmHg reported, respectively. Among normotensives, the effect of aerobic exercise training on BP was significant only for diastolic BP as a net reduction of 1.1 mmHg was reported. In a separate meta-analysis, Cornelissen and colleagues investigated the effect of aerobic exercise on daytime and nighttime BP derived from ambulatory BP monitoring[46]. Significant reductions in daytime BP were observed in normotensives (daytime ambulatory BP <135/85 mmHg) when data from 11 randomized controlled trials were pooled, with net reductions of 2.2 mmHg for systolic BP and 3.3 mmHg for diastolic BP reported. No effect was observed for nighttime BP.

Also in 2013, Huang et al. conducted a meta-analysis investigating the effects of aerobic exercise training among elderly adults[47]. Pooling 23 studies, the net changes in systolic and diastolic BP were statistically significant and represented a net decrease of 5.3 mmHg and 3.7 mmHg, respectively. Four of the 23 studies included participants with hypertension, however investigators reported that results were similar when data were stratified according to hypertension status.

Resistance Training

In 2011, Cornelissen and colleagues conducted a meta-analysis on the BP lowering effects of resistance training[48]. Pooling data from 28 randomized controlled trials, resistance training resulted in a net decrease of 3.9 mmHg and 3.9 mmHg for systolic and diastolic BP, respectively, in normotensive/prehypertensive participants. In their updated meta-analysis, Cornelissen and colleagues stratified the effects of resistance training on BP according to BP subgroup (e.g. normotensive or prehypertensive) and reported that the net effect of resistance training on BP was significant for systolic and diastolic BP among prehypertensives, but was only significant for diastolic BP among normotensives[45]. Recently, it has been argued by Rossi and colleagues that the results from Cornelissen et al. may have overestimated the effect sizes of resistance training on BP due to inclusion of studies in which BP was not the primary end point[49]. Conducting their own meta-analysis, Rossi et al. identified 11 randomized control trials wherein BP was the primary outcome. Among normotensives and prehypertensives they reported that the net effect of resistance training was significant for diastolic BP (net effect: −2.4 mmHg), but not systolic BP (net effect: −1.5 mmHg)[50]. Although these findings diverge in the net BP lowering effects of resistance training from the findings of Corenelissen and colleagues, they nonetheless are consistent in showing that, one, there is no detrimental effect of resistance training on BP as once previously proposed[51], and two, resistance training may be beneficial in eliciting reductions in diastolic BP amongst normotensives and prehypertensives. Contrary to the limited evidence from prospective studies, the data from randomized controlled trials do support a role for resistance training in the prevention of hypertension. Reasons for the discrepant evidence from prospective studies and randomized controlled trials are still unclear, but may, in part, be attributed to the limitations of current prospective studies including the use of self-report data[27] and multicollinearity among exposure variables[42].

Combined Aerobic and Resistance Training

In a 2004 position stand, the American College of Sports Medicine recommended aerobic exercise supplemented with resistance training as a means to prevent hypertension[4]. In their 2013 meta-analysis, Cornelissen and colleagues reviewed evidence for these recommendations that combining aerobic and resistance training lowers BP to a greater extent than aerobic or resistance training alone[45]. In total 4, 8, and 2 randomized controlled trials were identified that investigated the BP lowering effects of combined aerobic and resistance training among normotensives, prehypertensives, and hypertensives, respectively. Pooling all studies, a significant net effect was found only for diastolic BP (−2.2 mmHg), but not systolic BP (−1.4 mmHg). There were, however, no statistically significant differences between the net effects of aerobic training, resistance training, and combined training on BP. When analyses were stratified for normotensives and prehypertensives, the net effects of combined aerobic and resistance training were not significant in either group. Thus, there is limited evidence to suggest that combined aerobic and resistance training confers greater protective effects against the development of hypertension than aerobic or resistance training alone. However, it’s likely the small number of studies among normotensives and prehypertensives, and the fact that these studies were stratified and not combined, may have limited the statistical power of this meta-analysis. Recent studies in 2013 have yielded more promising results[52, 53], with one study reporting that combined aerobic and resistance training for as little as one day/week for each mode of exercise was sufficient to reduce BP among healthy elderly women[52].

High Intensity Interval Training

High-intensity interval training (HIT), which consists of several brief bouts (typically 15 seconds to 4 minutes) of high-intensity exercise (typically >85% of maximum heart rate or aerobic capacity) separated by recovery periods of lower intensity aerobic exercise or rest, has received considerable attention as a potentially superior exercise prescription for improving cardiovascular health that may also be a time-efficient alternative to continuous moderate exercise (CME)[54–56]. In 2012, a quasi-systematic review identified 12 studies that have investigated the effects of HIT on BP, with three of these studies conducted exclusively among populations without hypertension[57]. In a study of 44 normotensives with a parental history of hypertension who were randomized to either a HIT or CME group with equivalent training loads, both groups showed similar reductions in BP[58]. Likewise, in a study of 36 healthy men divided into four groups (HIT, CME, resistance training, and control groups), systolic BP was similarly reduced in the HIT and CME groups[59]. Notably, in this study similar BP reductions were achieved in the HIT group with considerably less time (HIT: 20 minutes/session vs. CME: 60 minutes/session). Finally, in a group of 62 overweight/obese adolescents HIT significantly decreased BP, however no CME arm was included for comparison[60].

Recently, several studies have further explored the effects of HIT on BP amongst non-hypertensive populations. In two studies amongst adolescents, HIT elicited greater reductions in BP when compared to CME despite much lower total training times (~70–85% less)[61, 62]. Among adult populations, a study of 16 healthy men showed similar reductions in diastolic BP among HIT and CME groups, with total training time approximately 70% less in the HIT group[63]. Recently, Tjønna and colleagues explored an important, fundamental question of how abbreviated can HIT be to still elicit improvements in cardiovascular risk factors. In a 10-week study, 26 overweight men were randomized to either a single 4-minute bout of high-intensity exercise group (totaling 19 minutes/session with warm-up and cool-down) or a 4×4 minute bouts of high-intensity exercise group (totaling 40minutes/session with warm-up and cool-down). It was reported that both interventions elicited similar reductions in BP, suggestive that only brief duration bouts of high-intensity exercise are needed to reduce BP[64].

In summary, available data suggest that HIT can elicit similar reductions in BP when compared to CME among non-hypertensives, but with much less time demands. Evidence that HIT is superior to CME for reducing BP, however, is limited as few studies have compared these training modalities using comparable workloads. The literature for HIT in reducing BP is also limited in that there have been only a few randomized controlled trials conducted and these studies were largely limited by small sample sizes. Large randomized controlled trials are still needed.

Accumulated Exercise

Physical activity guidelines endorse the accumulation of exercise in short bouts over the course of the day to make it easier for individuals to meet daily recommendations[28]. In a quasi-systematic review, Murphy and colleagues reviewed the studies that have compared the effects of a single continuous bout of exercise versus the effects of short accumulated bouts of the same total duration and identified six studies that have reported BP measures pre- and post-intervention[65]. Two of the six studies showed significant decreases in BP following training, with similar reductions reported among continuous and accumulated exercise bouts. Authors concluded that there is insufficient data in the present literature to allow comparison of the effects of accumulated and continuous bouts of exercise on BP. Furthermore, none of the identified studies excluded hypertensives, thus data supporting physical activity guidelines that endorse the accumulation of exercise in 10-minute bouts or greater for the prevention of hypertension are scarce and still needed.

Walking

Walking-based interventions that encompass the accumulation of daily step count goals (e.g. 10,000 steps/day) are analogous to interventions designed to increase daily physical activity levels. Evidence regarding whether the accumulation of steps over the course of a day may be beneficial for reducing BP is still limited. A meta-analysis of pedometer-based interventions pooled data from 12 studies totaling 468 participants who were mostly normotensive showed significant net reductions in systolic and diastolic BP of 3.8 mmHg and 0.3 mmHg, respectively[66]. More recently, findings from the ASUKI Step study, a pedometer-based workplace intervention with an overall goal to increase physical activity by walking 10,000 steps/day, found that BP was significantly reduced with BP changes shown to be linearly associated with steps taken[67]. These findings were consistent among the entire sample (n=355) and when the sample was restricted to non-hypertensives (n=251) and suggest the goal of walking 10,000 steps/day could be effective in reducing BP.

Additive benefits of physical activity and exercise

Epidemiologic evidence suggests that individuals who meet daily physical activity guidelines but who accumulate high volumes of sitting time throughout the remainder of their day outside their bouts of physical activity have greater mortality risk than individuals who meet physical activity guidelines and have low volumes of daily sitting time[68]. These findings suggest that being physical active throughout the course of a day coupled with structured daily exercise has potentially additive effects. In 2012, investigators from the Dose Response to Exercise in Women (DREW) trial evaluated the effects of habitual physical activity level in combination with aerobic exercise training on BP among 325 post-menopausal women[69]. It was reported that changes in BP with aerobic exercise training were not significantly different across tertiles of habitual physical activity. These findings were consistent with a previous study of 34 postmenopausal women in whom no differences in BP were observed between women who decreased spontaneous activity during exercise training and women who maintained or increased their physical activity outside of training[70]. Thus, there is no present evidence to suggest that habitual physical activity provides any additive benefits to a structured exercise training program for lowering BP.

MECHANISMS

The mechanisms by which physical activity may reduce BP and prevent the development of hypertension are unclear. This is in large part due to the fact that the etiology of hypertension is multifactorial in nature and it is as of yet unclear how these factors interact to contribute to the development of hypertension. Recent findings from animal studies suggest aerobic exercise may prevent increases in BP through beneficial alterations in insulin sensitivity and autonomic nervous system function[71], while resistance training may prevent increases in BP through beneficial alterations in vasoconstriction regulation[72]. Proposed mechanisms through which physical activity may prevent the development of hypertension are summarized in table 2. Although precise mechanisms have yet to be fully elucidated, available data have provided enough information to establish biologically plausible mechanisms for the relationship between physical activity and hypertension. Interestingly, findings among recent cell studies suggest race-dependent responses to exercise stimuli, thus the proposed mechanisms may have differential effects across populations [73, 74].

CONCLUSIONS

Recent evidence from prospective studies continues to suggest a relationship between physical activity and incident hypertension. These data are supported by a large body of literature on the effects of physical activity/exercise interventions on BP among normotensives and prehypertensives. Together, the available evidence strongly supports a role for physical activity in the prevention of hypertension. The optimal prescription for the prevention of hypertension, however, still remains elusive. More conclusive evidence regarding the appropriate mode (aerobic, resistance, or combined), intensity (HIT, CME, or combined), and duration (accumulated bouts or continuous bouts) of physical activity for non-hypertensive individuals is still needed.

Acknowledgments

This work was supported by a National Institutes of Health (NIH)/National Heart, Lung, and Blood Institute (NHLBI) Diversity Supplement awarded to Keith M. Diaz (P01-HL047540-19S1).

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Table 1

Definitions of physical activity, exercise, and physical fitness terms/components.

Term/Component	Definition
Physical Activity	
Leisure-Time Physical Activity	Activities that one participates in during their free time that results in substantial energy expenditure. These activities include structured exercise as well as walking, hiking, gardening, sport, and dance[9].
Occupational Physical Activity	Activities that are associated with the performance of a job which might include might include walking, hauling, lifting, pushing, carpentry, shoveling, and packing boxes[9].
Sedentary Behavior	Lack of physical activity. Refers to activities that do not increase energy expenditure above the resting level and has been operationally defined as activities with energy expenditures ≤ 1.5 METs while in a sitting or reclined posture (e.g. sleeping, watching television, video gaming, computer use)[10].
Exercise	
Aerobic Exercise	A form of exercise that involves the use of large muscle groups to perform repetitive activities that result in increases in heart rate and energy expenditure (e.g. walking; cycling).
Resistance Training	A form of exercise designed to improve muscular strength and/or endurance wherein physical effort is performed against an opposing force that elicits resistance to induce muscular contraction, typically at a high intensity of effort for a short duration of time (e.g. weight lifting).
Physical Fitness	
Cardiorespiratory Fitness	The ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity.
Muscular Strength	The amount of external force that a skeletal muscle can exert[8].
Muscular Endurance	The ability of muscle groups to exert external force for many repetitions or successive exertions[8].

Table 2

Proposed mechanisms through which physical activity may prevent the development of hypertension.

↓ Vascular Resistance	↑ Endothelial Function
↓ Arterial Stiffness	↑ Insulin Sensitivity/Glucose Handling
↓ Oxidative Stress	↑ Renal Function
↓ Inflammation	↑ Sodium Handling
↓ Body Weight/Body Mass	↑ Baroreflex Sensitivity
↓ Sympathetic Activity	↑ Parasympathetic Activity
↓ Renin-angiotensin System Activity	↑ Angiogenesis
↓ Vascular responsiveness to adrenergic- and endothelin-receptor stimulation	↑ Arteriogenesis
↓ Intima-media thickness	↑ Arterial Compliance
↓ Psychosocial Stress	↑ Arterial lumen diameter