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STATE OF THE ART

Exercise and Cardiovascular Risk in Patients With Hypertension

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Evidence for the benefits of regular exercise is irrefutable and increasing physical activity levels should be a major goal at all levels of health care. People with hypertension are less physically active than those without hypertension and there is strong evidence supporting the blood pressure–lowering ability of regular exercise, especially in hypertensive individuals. This narrative review discusses evidence relating to exercise and cardiovascular (CV) risk in people with hypertension. Comparisons between aerobic, dynamic resistance, and static resistance exercise have been made along with the merit of different exercise volumes. High-intensity interval training and isometric resistance training appear to have strong CV protective effects, but with limited data in hypertensive people, more work is needed in this area. Screening recommendations, exercise prescriptions, and special considerations are provided as a guide to decrease CV risk among hypertensive people who exercise or wish to begin. It is recommended that hypertensive individuals should aim to perform moderate intensity aerobic exercise activity for at least 30 minutes on most (preferably all) days of the week in addition to resistance exercises on 2–3 days/week. Professionals with expertise in exercise prescription may provide additional benefit to patients with high CV risk or in whom more intense exercise training is planned. Despite lay and media perceptions, CV events associated with exercise are rare and the benefits of regular exercise far outweigh the risks. In summary, current evidence supports the assertion of exercise being a cornerstone therapy in reducing CV risk and in the prevention, treatment, and control of hypertension.

Keywords: arterial; blood pressure; exercises; fitness; human; hypertension; physical conditioning.

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This paper aims to review evidence on the effect of exercise on cardiovascular (CV) risk in people with hypertension. Regular exercise is one of the most important activities for primary prevention of hypertension[1] and improving long-term survival.[2] Benefits of exercise extend to people with hypertension,[3] as well as those with related morbidity (such as diabetes,[4] renal dysfunction[5] or depression[6,7]) or chronic disease relatively separate from hypertension including cancer,[8] airway disease,[9] and osteoarthritis,[10] to name a few. Many chronic diseases share the risk factor of physical inactivity, which is ranked among the top 10 contributors to the global burden of disease.[11] Thus, increasing exercise levels in the general population is a valuable aspiration with major health and economic gains.[12] Beyond exercise alone, a CV risk reduction program for individuals with hypertension should optimally also include smoking cessation, weight reduction, alcohol moderation, and attention to diet such as that recommended with the Dietary Approaches to Stop Hypertension,[13] which has been shown to lower blood pressure (BP)[14,15] and improve all-cause survival.[16] Thorough analysis of treating and preventing hypertension with diet is addressed by Appel *et al.*[17]

RISK FACTOR MODIFICATION WITH EXERCISE

Some data indicate that people with hypertension are less physically active than those without hypertension.[18] High cardiorespiratory fitness (VO_2max) has been shown to be protective against progression from prehypertension to hypertension,[19] as well as future death from coronary heart disease and all causes,[20] even among people with hypertension or a high burden of other CV risk factors.[21,22] A sedentary or low-activity lifestyle associated with low VO_2max is common among first-world communities[23] and associated with a cluster of CV risk factors including higher BP, total cholesterol, body mass index, and levels of obesity, but lower high-density lipoprotein cholesterol.[24] While the cause and effect relationship has not been thoroughly explored, it is possible that hypertension may be both a risk factor associated with sedentary behavior and low fitness, but it may also be that hypertension directly causes low fitness through its effect on myocardial function (hypertensive heart disease and heart failure with preserved ejection fraction). Engaging in regular aerobic exercise enhances structural, functional, and biochemical characteristics of the CV system, and CV risk factors can undergo reversal toward "normalization" among individuals with normal BP, as well as those with prehypertension or hypertension.[25] Positive BP

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effects include significant reductions in clinic systolic BP (SBP) and diastolic BP (DBP) and daytime ambulatory BP.[26] Among older sedentary men with stage 1 or 2 hypertension, the reduction in BP load from an acute exercise bout of just 45 minutes is immediately apparent and can persist for 24 hours.[27] Interestingly, 1 study has shown that 24-hour BP variability (an emergent CV risk factor) may not be amenable to change with exercise training in people with hypertension;[28] although more controlled study data will be needed to confirm this.

Repeated physiological challenge through the stimulus of exercise is hypothesized to produce beneficial adaptive responses after a period of temporary impairment.[29] An example of this delayed response on the vasculature has been demonstrated by an immediate decrease in nitric oxide–mediated endothelial function, then followed by "supra-normal" function in the period ≈1–24 hours after exercise, before returning to baseline levels at ≈24–48 hours.[30] One of the physiological reasons explaining the supra-normal function from regular exercise is thought to be protection against increases in BP.[30] Another major mechanism of BP lowering from exercise is decreased sympathetic drive, as evidenced by lowered plasma norepinephrine and renin activity,[31] as well as decreased renal and muscle sympathetic activity.[32,33] The lack of effect of aerobic exercise on nighttime BP[26] (especially in nondippers)[34] when sympathetic activity is low, tends to support an autonomic-related hypotensive effect.[31] Regular aerobic exercise enhances sleep quality and duration[35] (which in itself protects against hypertension[36]) and also improves a broad range of other CV risk factors, hemodynamic, metabolic, neural, and arterial and cardiac features, with the overall result of reduced clinical events.[25,31] A summary of these effects is presented in Figure 1.

AEROBIC VS. RESISTANCE TRAINING ON CV RISK FACTORS

Moderate intensity resistance training is recommended as a supplement to aerobic exercise training for BP and CVD risk reduction in patients with hypertension,[3,37] as well as healthy individuals and men with low risk CV disease.[38] Resistance training also appears to be safe and effective for increasing strength and improving functional capacity and hemodynamic function, even in higher risk patients with major cardiac disease.[39] Both aerobic and resistance training promote improvements in a variety of general health and CV risk factors; however, the relative improvement in these factors differs between the exercise modalities. For example, aerobic training generates substantially greater increases in VO_2max, together with greater reductions in body fat compared with resistance training. On the other hand, more effective increases in basal metabolism and strength can be achieved with resistance compared with aerobic training.[38] Having said this, readers should be aware that measuring physical activity as well as the response to exercise programs can be complex and that differences in measurement methods, reporting of results, and lack of standardized reference can make comparisons between studies difficult.

Data are incomplete regarding the comparative health effects between exercise modalities exclusively in people with hypertension. In this population, clinic SBP is relatively unaffected by dynamic resistance training but small reductions in clinic DBP (−3.1 (95% CI −5.1 to −1.2) mm Hg) may be achievable.[32,33] Despite reliance on small cohorts, few of which have recruited only hypertensive patients, meta-analyses have provided reassurance in demonstrating that BP does not increase as a result of dynamic resistance training.[32,33] On the other hand, Bertovic *et al.*[40] observed that vascular stiffness was greater among strength-trained athletes as compared with age-matched controls. However, these findings are yet to be consistently replicated and it is difficult to know the extent to which observations in strength athletes can be extrapolated to nonathletes undertaking more moderate strength training regimes. Furthermore, few resistance training intervention studies have been performed specifically in hypertensive cohorts. Remarkably, isometric resistance training, which is a form of weight training involving sustained muscular contraction without a change in muscle length, has been demonstrated to have stronger BP-lowering effects (SBP, −4.3 (95% CI −6.4 to −2.2) mm Hg; $P < 0.001$) than dynamic resistance training in people treated for hypertension, where the drop in DBP was higher than for normotensive individuals (−5.5 (95% CI −7.9 to −3.0) mm Hg vs. −3.1 (95% CI −3.9 to −2.3) mm Hg) and overall effects on heart rate were slight but statistically significant compared with control (−0.8 (95% CI −1.2 to −0.4) bpm; $P = 0.003$).[41]

The profound effects of isometric resistance training is surprising because most of the studies from which these pooled data were derived used isometric hand-grip contraction as the intervention,[41] which only exercises a small muscle group over a short time period (e.g., <15 minutes) and only elicits transient moderate hemodynamic responses (i.e., SBP and heart rate increases of ≈16 ± 10 mm Hg and 3 ± 4 bpm; although hypertension severity is associated with greater responses[42]) that rapidly return to baseline levels (i.e., ≈1 minute).[43] Carlson *et al.*[41] contend that the reduced time commitment, as well as simplicity and lower cost should lead to greater adherence to exercise in comparison with aerobic interventions, which is plausible but yet to be confirmed. Isometric resistance training appears to be safe, with no adverse events reported from >7,000 isometric exercise training sessions in patients with CV risk factors and comorbidities including hypertension.[43] There are few reports on the mechanisms of BP lowering after chronic isometric training in patients with hypertension, although improved brachial flow–mediated dilatation,[44] decreased sympathetic activity, and enhanced parasympathetic modulation of BP and heart rate[45] have been observed. Table 1 presents a summary comparison of the chronic effects of aerobic vs. resistance training in people with hypertension.

INFLUENCE OF PARTICIPANT CHARACTERISTICS ON RESPONSES TO AEROBIC AND RESISTANCE TRAINING

Analyses of more than 50 randomized controlled trials of aerobic exercise intervention have determined that significant clinic SBP- and DBP-lowering effects can be achieved irrespective of participant age (≥50 or <50 years), frequency of exercise sessions per week (<3, 3 or 4, or >4/week),[51] or

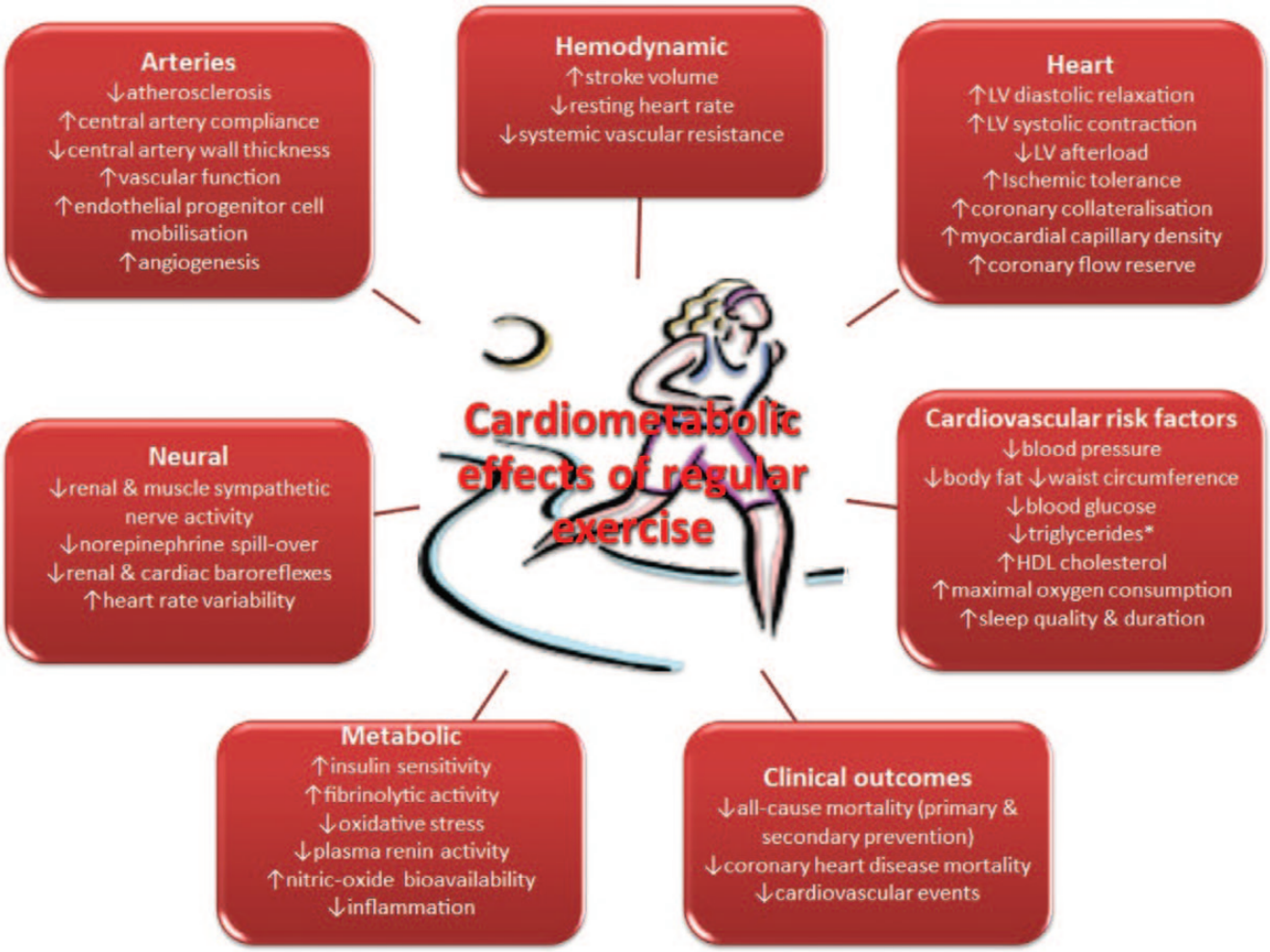

Figure 1. Summary of some of the cardiometabolic beneficial effects of regular exercise. ↑increase or improvement; ↓decrease or improvement; *borderline improvement.

baseline body mass index.[52] Importantly, hypertensive status influences the magnitude of clinic SBP and DBP fall after aerobic training, with largest effects in people with hypertension (SBP, −8.3 (95% CI −10.7 to −6.0) mm Hg) compared to those with prehypertension (SBP, −2.1 (95% CI −3.3 to −0.83) mm Hg), and only a small clinic DBP-lowering effect in normotensive individuals (−1.1 (95% CI −2.2 to −0.07) mm Hg).[51] Male participants appear to have greater responses of both SBP and DBP compared with women,[51] and greater BP reductions are related to greater increases in cardiorespiratory fitness with aerobic training.[25] Pooled data reveal trends toward larger reductions in clinic SBP and DBP associated with greater weight loss after aerobic training. Contrary to aerobic training, the BP-lowering effects of dynamic resistance training do not appear to be impacted by sex or age, but larger reductions may be conferred upon people with prehypertension vs. normotensive and hypertensive individuals.[51] Among patients with hypertension, the overall BP reduction effect is greater after aerobic compared with dynamic resistance exercise training, and as such, aerobic training should be the preferred option where BP lowering is the main goal.[51]

HOW MUCH EXERCISE IS ENOUGH?

The idiom that "something is better than nothing" holds true for exercise volume, where even a small but consistent quantity (i.e., 15 min/day or 90 min/week) performed at moderate intensity can translate to significant health benefits, irrespective of hypertensive status, age, CV disease risk, or lifestyle habits such as smoking or alcohol consumption (Figure 2).[53] In people with hypertension assigned to different exercise durations, but fixed low-to-moderate intensity programs (50% of estimated VO_2max), clinically significant reductions in BP were attained from only 30 to 60 min/week of exercise, with the largest falls in SBP and DBP at 61–90 min/week of exercise.[54] Many other studies are consistent with the message of an inverse relationship between physical activity volume and health outcomes, including incident hypertension,[55] incident diabetes,[49] obesity,[56] and death from coronary artery disease and all causes[57] (including in older men with hypertension).[21] Improvement in inflammatory (high sensitive C-reactive protein) and hemostatic factors (e.g., fibrinogen), as well as conventional CV risk factors (especially BP, lipids, and body mass index)

Table 1. Chronic responses to aerobic and resistance training in people with hypertension

Variable	Aerobic (endurance)	Resistance (dynamic)	Resistance (static)
Blood pressure			
Clinic systolic blood pressure	Large decrease	No change[a]	Large decrease
Clinic diastolic blood pressure	Large decrease	Small decrease	Large decrease
Day time blood pressure	Decrease	—	—
Nighttime blood pressure	No change	—	—
Other cardiovascular risk factors			
Obesity markers			
Body mass index	Decrease	—	—
Body weight	Decrease	No change	—
Waist circumference	Decrease	—	—
Percentage body fat	Decrease	Decrease	—
Blood glucose	Decrease	—	—
Lipid			
Total cholesterol	No change	—	—
Low-density lipoprotein	No change	—	—
High-density lipoprotein	Increase	—	—
Triglycerides	Borderline decrease	—	—
Heart rate	Decrease	No change	Small decrease

Summary data from multiple meta-analyses, review articles,[25,26,31,37,41,46–48] and large well-conducted clinical trials involving people with high blood pressure.[49] Dashed line indicates no, or minimal, available data to draw conclusions regarding training effects.

[a]Significant effect for patients with prehypertension,[50] but small to no significant effect for patients with hypertension.[48] Examples of aerobic training include running, cycling, swimming, or rowing. Examples of dynamic resistance training include push-ups, abdominal crunches, or shoulder presses. Examples of static resistance training include holding the position of hand grip using a dynamometer, plank bridges, or wall sit.

could explain most of the variance in the reduction of CV events associated with physical activity level.[58]

IS TOO MUCH EXERCISE HARMFUL?

Since an acute bout of exercise causes temporary physiological stress,[29] there remains the possibility that excessive exercise volume combined with little recovery time could tip the balance toward harmful effects. Indeed, some data suggest an asymptote at which more intense exercise training provides little incremental benefit[59] or even a U-shaped association in which events increase among the most highly trained.[60] Similarly, a higher incidence of myocardial infarction was shown in The British Regional Heart Study among men exercising at the highest levels when compared with moderate levels,[61] and higher rates of CV disease and hypertension were also found among the most active men in the Michigan State University Longevity Study.[62] In patients with manifest coronary heart disease, daily strenuous exercise conferred higher mortality risk (on par with exercising only 1–4 times/month), and this was independent of numerous covariates including hypertension status.[63] However, the premise that "extreme" exercise may portend an increased risk of CV events remains highly controversial[64,65] and there are a number of studies that suggest that longevity may be increased among athletes undertaking the very highest volumes of intense exercise.[66,67]

Little is known regarding the causes underlying associations between chronically higher exercise volume and higher CV risk in some epidemiological studies. However, homeostatic imbalance across multiple organ systems occurs with overtraining and this can result in muscle trauma, inflammation, oxidative stress,[68] adrenal gland dysfunction,[69] and immunosuppression.[70] The heart may be particularly vulnerable to overtraining as chronically high exercise volume is associated with adverse cardiac remodeling (especially atrial enlargement and left ventricular hypertrophy), functional abnormality (favoring damage to the right ventricle),[71] and arrhythmias (especially atrial fibrillation and complex ventricular tachyarrhythmias).[72–74] The role of BP exposure on these adverse heart outcomes is unknown. Overall, these data imply that regular exercise is a potent elixir for CV and general health in which moderate doses may be just as efficacious as more extreme doses.

EXERCISE PRESCRIPTION RECOMMENDATIONS

Resting SBP > 200 mm Hg or DBP > 110 mm Hg is a relative contraindication to exercise stress testing and an excessive BP response to exercise (defined as SBP > 250 mm Hg or DBP > 115 mm Hg) is a relative indication to terminate exercise.[57] In the absence of major comorbidities, patients with hypertension (stage 2 or below)[75] should be encouraged

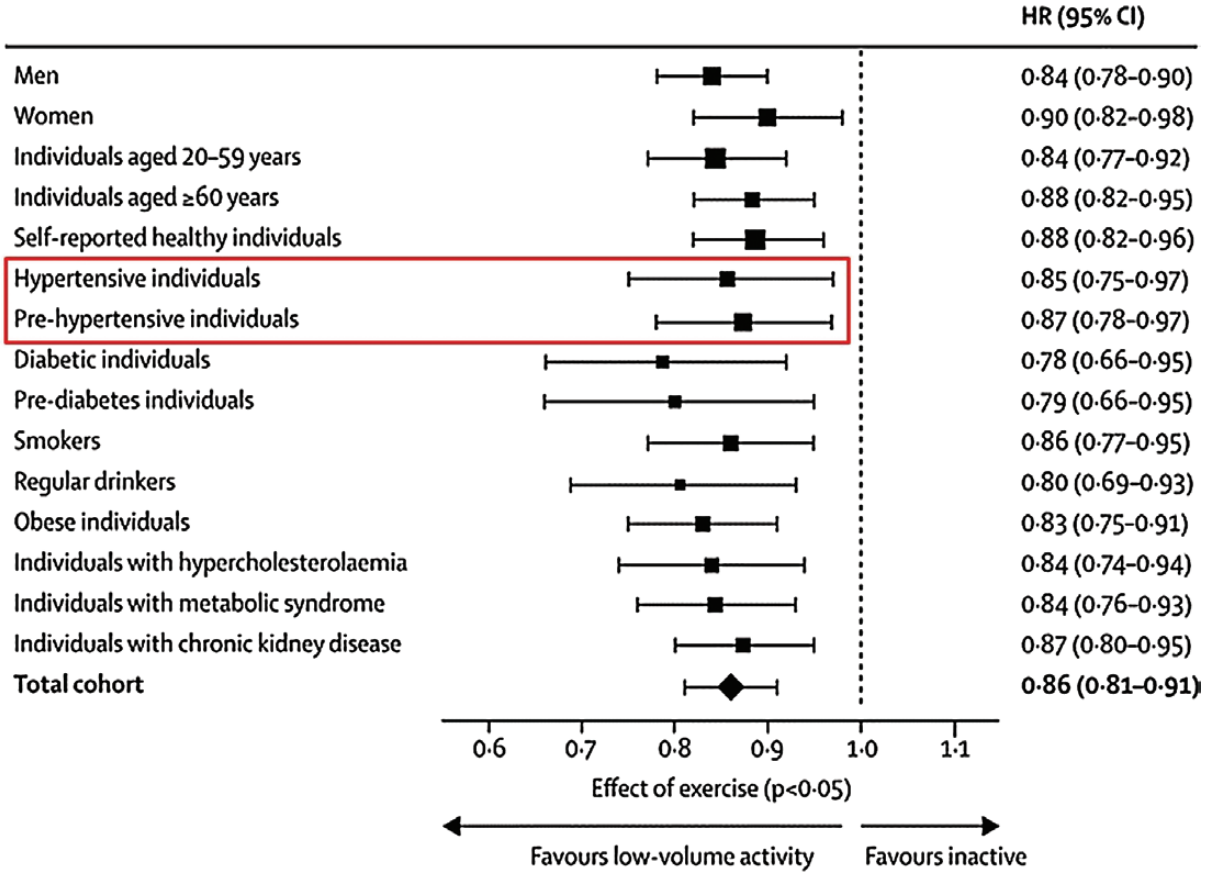

Figure 2. Adjusted all-cause mortality hazard ratio for people engaging in low-volume physical activity compared with inactive people. There was significantly lower risk of all-cause mortality, regardless of sex, age, self-reported health, hypertension, or cardiovascular disease risk. Hazard ratios (HRs) are relative to health outcomes in the inactive group. From Wen *et al.*[53] with permission from Elsevier.

to undertake a light-to-moderate intensity exercise program without needing to consult with their doctor.[76] This intensity approximates that achieved at <3 to <6 metabolic equivalents or <40% to 60% of VO_2 reserve (VO_2max − VO_2rest) and this equates to walking at about 5–7 km/h for a 70-kg person.[77] Other types of activity that can achieve this level of light effort include such things as ballroom or aerobic dancing at low effort, noncompetitive badminton, bicycling (up to 100 W or 15 km/h), bowling, golf (carrying clubs or pulling cart), rowing at ≤4 km/h, small boat sailing, or swimming at ≤2 km/h to name a few examples.[77] Progression of exercise intensity, frequency, and duration should be gradual with a "start low, go slow" approach.

Exercise prescription recommendations for people with hypertension broadly follow guidelines that are known to promote and maintain health in the general adult population.[3,78] An overview of preexercise risk evaluation and exercise prescription according to latest guidelines[76] is provided in Figure 3. Only high risk individuals with hypertension (i.e., symptomatic or with known disease) planning to engage in moderate or vigorous intensity exercise are recommended to have a medically supervised exercise stress test prior to beginning an exercise program.[76] Furthermore, people with uncontrolled severe hypertension (e.g., ≥ stage 3)[75] are recommended to have a clinical evaluation prior to regular exercise training.[76] Ideally, this evaluation will involve out-of-office BP measures such as 24-hour ambulatory BP[79] or home BP monitoring[80] to confirm BP status. Finally, recent data suggest that it may be necessary to promote incentives for staff to maintain participant adherence to lifestyle/exercise programs in the primary care setting.[81]

HIGH-INTENSITY INTERVAL TRAINING

The efficacy of HIIT, which is derived from the Swedish Fartlek ("speedplay") method, has been tested among different patient populations including some data in people with hypertension. Lack of time is cited as a barrier for people engaging in regular physical activity[82] and HIIT offers a way to derive exercise benefits in a more time efficient manner.[83] The approach involves alternating several (e.g., 3 or 4) short bursts (e.g., 3–4 minutes) of high-intensity (e.g., 85%–95% of peak heart rate) exercise with a few minutes of rest or light exercise (active recovery at ≈70% of peak heart rate) in the intervening periods. A whole exercise session, including warm-up and cool down, can be completed in ≈40 minutes. HIIT should not be confused with sprint interval training (SIT) that has participants exercising supra-maximally (e.g., all-out 30-second sprints on a cycle ergometer interspersed with recovery slow cycling). SIT has not been investigated

Pre Exercise Risk Evaluation

	Medical examination needed before moderate or vigorous exercise?	
	Moderate exercise (3 to 5 METS; intensity causing noticeable increases in HR and breathing)	**Vigorous exercise*** (≥6 METS; intensity causing substantial increases in HR and breathing)
LOW RISK • Asymptomatic • <2 risk factors	NO	NO
MODERATE RISK • Asymptomatic • ≥2 risk factors	NO	YES
HIGH RISK • Symptomatic or • Known cardiovascular, pulmonary, renal or metabolic disease	YES	YES

Aerobic and Resistance Exercise Prescription for People Cleared to Engage in Moderate or Vigorous Exercise

	Aerobic Exercise	Resistance Exercise
FREQUENCY	On most, preferably all days of the week	2 – 3 days/week
INTENSITY	Moderate (40 – <60% VO_2R or HRR; RPE 11 – 13 on a 6 – 20 scale)	60 – 80% of 1-RM
TIME	30 – 60 mins/d continuous or intermittent; if latter use 10 min minimum bouts accumulated to above total	One set of 8 -12 repetitions for each major muscle group
TYPE	E.g. walking, jogging, cycling, swimming	Machine or free weights; 8 – 10 exercises to target major muscle groups
PROGRESSION	Gradual. Avoiding large increases in any component, especially intensity	

Figure 3. Recommendations regarding exercise prescription for people with hypertension adapted from ref.[76] Before adding exercise to a treatment plan, people with severe uncontrolled hypertension based on clinic blood pressure (systolic ≥ 180 mm Hg and/or diastolic ≥ 110 mm Hg) should firstly be evaluated by their doctor (preferably with addition of out-of-clinic blood pressure measures to confirm blood pressure control). Abbreviations: HR, heart rate; HRR, heart rate reserve; METs, metabolic equivalents; RPE, rating of perceived exertion; 1-RM, one repetition maximal. *includes high-intensity exercise.

in individuals with hypertension and should be avoided by people who do not engage in regular exercise because of the increased (albeit small) CV risk potential.[84]

Compared to conventional moderate intensity continuous training over longer time intervals in patients with hypertension, HIIT has been shown to produce significantly greater improvements in 24-hour ambulatory SBP and DBP, VO_2max, total peripheral resistance, and left ventricular systolic and diastolic function.[85] Young normotensive women with a family history of hypertension engaging in HIIT showed greater improvements in VO_2max, as well as metabolic and hormonal factors related to hypertension compared with moderate intensity exercise.[86] Even small doses of HIIT before meals, touted as "exercise snacks" (6- ×

1-minute walking intervals at 90% maximal heart rate with 1-minute active recovery intervals), were more effective for improving postprandial glucose and 24-hour glycemic control compared with continuous moderate intensity exercise in people with insulin resistance and raised BP.[87]

HIIT appears to be safe and well tolerated in higher risk individuals (e.g., only two nonfatal cardiac arrests in 46,364 exercise hours among 4,846 patients with coronary heart disease).[88] In patients with heart failure and cardiometabolic disease, HIIT can effectively improve cardiac function[89] as well as CV risk factors, including high-density lipoprotein cholesterol, triglycerides, fasting glucose, and insulin sensitivity.[83] Enhanced enjoyment of exercise and quality of life can also be gained,[85] and positive changes in appetite and food choices may also be achieved.[90] HIIT may also be amenable for community-based (nonlaboratory) interventions but may be less effective unless strategies to improve exercise adherence are employed.[91] Continuous exercise may be better than HIIT for improving fat distribution (trunk, abdominal subcutaneous, and visceral adipose tissue), at least in 1 study with 12-week intervention among overweight (body mass index 25–29.9 kg/m^2) inactive, mostly female adults.[92]

Although adverse events from HIIT appear to be rare, protocol details regarding how these data may have been collected are generally lacking. There is also no clear consensus as to the best HIIT methods for general health in clinical populations, and there is a need for more studies in people with hypertension. These studies should provide details regarding adverse events as well as specifics on the methods of event data collection (e.g., the BP cut points used to stop an exercise session and the length of time data are collected after each exercise session). A basic HIIT program recommended on review of current data is provided in Table 2.[83]

EXERCISE TRAINING FOR EXERCISE-INDUCED HYPERTENSION

Even in people with apparently normal resting BP, exercise-induced hypertension (EIH) is probably indicative of underlying hypertension that has failed detection using resting BP screening methods. Evidence to support this (although not yet definitive) comes firstly from the high prevalence of masked hypertension (normal clinic BP but elevated 24-hour ambulatory BP) among people with EIH.[93,94] Secondly, EIH is associated with hypertensive-related end-organ damage[95–97] and thirdly, EIH predicts CV events and mortality independent from resting BP, with the strongest signal for increased risk manifest at light-to-moderate intensity aerobic exercise.[98] Although submaximal exercise BP cut points denoting elevated risk from EIH are yet to be determined, it may be in the region of SBP ≥ 150 mm Hg at the equivalent intensity of stage 2 of the Bruce treadmill protocol (5 metabolic equivalents), as this threshold has been shown as the strongest predictor of left ventricular hypertrophy in a large sample of people with prehypertension.[99] Interpretation of BP during more intense exercise is difficult. In normotensive athletes, BP increases substantially during exercise of high intensity but in a manner proportional to workload such that the P/Q (BP/cardiac output) ratio remains normal and left ventricular wall stress increases are modest.[100] Furthermore, in hypertensive athletes, BP during high-intensity exercise does not correlate well with resting BP.[101]

To our knowledge, there is no evidence that EIH increases risk for adverse events during the exercise bout where the EIH is observed. Indeed, several studies in people with higher BP or resistant hypertension have shown that regular aerobic exercise (over 2- to 6-month intervention) will significantly reduce submaximal intensity exercise BP,[102–104] as well as reduce the propensity toward EIH at maximal intensity (as per conventionally used cut points of ≥210 mm Hg for men and ≥190 mm Hg for women) in people at higher risk for EIH,[105] including treated hypertensives.[106] Thus, it is unfounded for clinicians to discourage regular exercise or suggest that exercise may be dangerous, in people with EIH. On the contrary, regular exercise should be beneficial for these people. A key message from the presentation of EIH is that it should be regarded as an indication to undertake out-of-clinic BP monitoring to confirm true underlying BP[107] and respond with treatment accordingly.

SPECIAL CONSIDERATIONS

Regular exercise can reduce BP beyond that achieved with antihypertensive medications and this could lead to symptomatic excessive BP lowering. A review of medications and BP control in those taking up exercise programs experiencing symptoms is therefore suggested, again, with BP measured preferentially out of the office to avoid white coat effects.[79] There is greater propensity for sudden excessive hypotension in the immediate post exercise period among people

Table 2. General protocol recommended for high-intensity interval training

Training component	Recommendation
Frequency	3 times/week
Duration	40 minutes (includes 10-minute warm-up and 5-minute cool down at 60% peak heart rate)
Exercise intensity	85%–95% peak heart rate[a]
Rest/recovery intensity	70% peak heart rate (RPE 11–13)
Interval times	4 × 4 minutes
Recovery times	3 × 3 minutes

[a]For people using beta blocker medication, this should be a rating of perceived exertion (RPE) 15–17 on the Borg 6–20 scale. Adapted from ref. [83] with permission from BMJ Publishing Group Ltd.

Table 3. Selected considerations regarding exercise in people with hypertension

Factor	Consideration	Response
Antihypertensive medications	• Regular exercise can lower BP in addition to drug effects and this may lead to hypotensive episodes (potential overmedication)	Undertake a review of medications and BP control with preference to using out of office BP to avoid white coat effects.
	• Alpha blockers, calcium channel blockers or vasodilating drugs may lead to sudden excessive hypotension post exercise (also more common in elderly people)	Avoid suddenly stopping exercise and undertake an extended cool down period of light activity.
	• Beta blockers and diuretics may impair thermoregulation	Limit exercise intensity in hot or humid weather. Ensure adequate hydration and wear clothing that encourages cooling.
Exposure to particulate matter from automotive pollution	• Causal relationship with cardiovascular events and mortality • Increases BP	Exercise away from busy roads with preference toward parks, recreation areas and quiet roads with less exposure to particulate matter.
Sudden unaccustomed vigorous exercise	• Associated with increased, albeit rare, risk of sudden death	Regularly undertake vigorous exercise as this protects against the risk of sudden death from vigorous exercise.
Lack of knowledge about exercise	• May lead to inappropriate exercise	Consult a qualified clinical exercise specialist.

Abbreviation: BP, blood pressure.

taking alpha blockers, calcium channel blockers, or vasodilating drugs, as well as in elderly people.[57,76] The potential for hypotensive-related adverse effects may be mitigated with an extended cool down period of light activity and avoidance of suddenly stopping exercise. Beta blockers and diuretics can alter thermoregulation during exercise,[37,76,108] which has led to a precautionary call to those taking these medications to limit exercise intensity in hot or humid weather, as well as ensuring adequate hydration and use of clothing to encourage cooling.[37]

Exposure to fine particulate matter (<2.5 μm in diameter) from automotive and other sources of air pollution is recognized as a trigger of CV-related events and mortality. Populations at increased risk include the elderly and those with preexisting coronary artery disease; however, people with diabetes, women, and also those who are obese (for which there is higher prevalence of hypertension) may also be vulnerable.[109] Since the magnitude of CV risk is related to the duration, intensity and frequency of particulate matter exposure, activities that increase exposure, such as exercising alongside busy roadways, should be avoided. Instead people should exercise in areas with lower ambient pollutant concentration, which may include parks, recreation areas, and quiet roads.[110]

Acute CV events induced by exercise occur more commonly in older people with atherosclerotic disease or younger people with congenital or hereditary heart disease.[84] There is a slight risk of sudden cardiac death occurring during, or within 30 minutes of, unaccustomed vigorous exercise such as racquet sports or heavy yard work, although the absolute risk only approximates 1 death per 1.51 million episodes of exertion.[111] Serious events occur rarely in healthy individuals[112] and may be more frequent in people of older age, or with diabetes or hypertension.[111] Then again, vigorous exercise itself, when performed habitually, is protective against sudden death and CV events,[111,112] which reinforces the notion that the health benefits of regular physical activity far outweigh the risks.[113] People with hypertension starting an exercise program may wish to consult an expert in exercise prescription for chronic and complex diseases such as a qualified Exercise Physiologist. This is especially relevant to higher risk patients or those wishing to partake in high-intensity physical activity. A summary of special exercise considerations is presented in Table 3.

SUMMARY AND CONCLUSION

There is incontrovertible evidence that "exercise is a cornerstone therapy for the prevention, treatment, and control of hypertension."[31] In people with hypertension, aerobic and resistance exercise promote general health and improvement in CV risk factors, including major BP-lowering effects and reduced future incident CV events and mortality. The comparative health effects of aerobic vs. resistance training have not been fully elucidated in people with hypertension, but where BP lowering is a major goal of exercise, then aerobic activity appears to be the preferred method to achieve this. There are promising data on the CV protective effects of HIIT and isometric resistance training, but with only limited data available in people with hypertension, more work is needed in this area. Exercise volume thresholds at which maximum benefits are derived are difficult to determine, although only a small but consistent weekly quantity of moderate exercise can have significant health benefits owing to the graded inverse relationship between exercise volume and adverse clinical outcomes. The benefits of regular physical activity outweigh the risks and should be recommended for the majority of people with hypertension.

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DISCLOSURE

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REFERENCES

1. Whelton PK, He J, Appel LJ, Cutler JA, Havas S, Kotchen TA, Roccella EJ, Stout R, Vallbona C, Winston MC, Karimbakas J. Primary prevention of hypertension: clinical and public health advisory from The National High Blood Pressure Education Program. *JAMA* 2002; 288:1882–1888.
2. Blair SN, Kampert JB, Kohl HW III, Barlow CE, Macera CA, Paffenbarger RS Jr, Gibbons LW. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA* 1996; 276:205–210.
3. Sharman JE, Stowasser M. Australian association for exercise and sports science position statement on exercise and hypertension. *J Sci Med Sport* 2009; 12:252–257.
4. Hordern MD, Dunstan DW, Prins JB, Baker MK, Singh MA, Coombes JS. Exercise prescription for patients with type 2 diabetes and pre-diabetes: a position statement from Exercise and Sport Science Australia. *J Sci Med Sport* 2012; 15:25–31.
5. Smart NA, Williams AD, Levinger I, Selig S, Howden E, Coombes JS, Fassett RG. Exercise & Sports Science Australia (ESSA) position statement on exercise and chronic kidney disease. *J Sci Med Sport* 2013; 16:406–411.
6. Rethorst CD, Wipfli BM, Landers DM. The antidepressive effects of exercise: a meta-analysis of randomized trials. *Sports Med* 2009; 39:491–511.
7. Cooney GM, Dwan K, Greig CA, Lawlor DA, Rimer J, Waugh FR, McMurdo M, Mead GE. Exercise for depression. *Cochrane Database Syst Rev* 2013; 9:CD004366.
8. Hayes SC, Spence RR, Galvao DA, Newton RU. Australian Association for Exercise and Sport Science position stand: optimising cancer outcomes through exercise. *J Sci Med Sport* 2009; 12:428–434.
9. Morton AR, Fitch KD. Australian association for exercise and sports science position statement on exercise and asthma. *J Sci Med Sport* 2011; 14:312–316.
10. Fransen M, McConnell S, Bell M. Exercise for osteoarthritis of the hip or knee. *Cochrane Database Syst Rev* 2003; 3; CD004286.
11. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, Amann M, Anderson HR, Andrews KG, Aryee M, Atkinson C, Bacchus LJ, Bahalim AN, Balakrishnan K, Balmes J, Barker-Collo S, Baxter A, Bell ML, Blore JD, Blyth F, Bonner C, Borges G, Bourne R, Boussinesq M, Brauer M, Brooks P, Bruce NG, Brunekreef B, Bryan-Hancock C, Bucello C, Buchbinder R, Bull F, Burnett RT, Byers TE, Calabria B, Carapetis J, Carnahan E, Chafe Z, Charlson F, Chen H, Chen JS, Cheng AT, Child JC, Cohen A, Colson KE, Cowie BC, Darby S, Darling S, Davis A, Degenhardt L, Dentener F, Des Jarlais DC, Devries K, Dherani M, Ding EL, Dorsey ER, Driscoll T, Edmond K, Ali SE, Engell RE, Erwin PJ, Fahimi S, Falder G, Farzadfar F, Ferrari A, Finucane MM, Flaxman S, Fowkes FG, Freedman G, Freeman MK, Gakidou E, Ghosh S, Giovannucci E, Gmel G, Graham K, Grainger R, Grant B, Gunnell D, Gutierrez HR, Hall W, Hoek HW, Hogan A, Hosgood HD III, Hoy D, Hu H, Hubbell BJ, Hutchings SJ, Ibeanusi SE, Jacklyn GL, Jasrasaria R, Jonas JB, Kan H, Kanis JA, Kassebaum N, Kawakami N, Khang YH, Khatibzadeh S, Khoo JP, Kok C, Laden F, Lalloo R, Lan Q, Lathlean T, Leasher JL, Leigh J, Li Y, Lin JK, Lipshultz SE, London S, Lozano R, Lu Y, Mak J, Malekzadeh R, Mallinger L, Marcenes W, March L, Marks R, Martin R, McGale P, McGrath J, Mehta S, Mensah GA, Merriman TR, Micha R, Michaud C, Mishra V, Mohd Hanafiah K, Mokdad AA, Morawska L, Mozaffarian D, Murphy T, Naghavi M, Neal B, Nelson PK, Nolla JM, Norman R, Olives C, Omer SB, Orchard J, Osborne R, Ostro B, Page A, Pandey KD, Parry CD, Passmore E, Patra J, Pearce N, Pelizzari PM, Petzold M, Phillips MR, Pope D, Pope CA III, Powles J, Rao M, Razavi H, Rehfuess EA, Rehm JT, Ritz B, Rivara FP, Roberts T, Robinson C, Rodriguez-Portales JA, Romieu I, Room R, Rosenfeld LC, Roy A, Rushton L, Salomon JA, Sampson U, Sanchez-Riera L, Sanman E, Sapkota A, Seedat S, Shi P, Shield K, Shivakoti R, Singh GM, Sleet DA, Smith E, Smith KR, Stapelberg NJ, Steenland K, Stockl H, Stovner LJ, Straif K, Straney L, Thurston GD, Tran JH, Van Dingenen R, van Donkelaar A, Veerman JL, Vijayakumar L, Weintraub R, Weissman MM, White RA, Whiteford H, Wiersma ST, Wilkinson JD, Williams HC, Williams W, Wilson N, Woolf AD, Yip P, Zielinski JM, Lopez AD, Murray CJ, Ezzati M, AlMazroa MA, Memish ZA. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; 380:2224–2260.
12. Annemans L, Lamotte M, Clarys P, Van den Abeele E. Health economic evaluation of controlled and maintained physical exercise in the prevention of cardiovascular and other prosperity diseases. *Eur J Cardiovasc Prev Rehabil* 2007; 14:815–824.
13. Blumenthal JA, Babyak MA, Hinderliter A, Watkins LL, Craighead L, Lin PH, Caccia C, Johnson J, Waugh R, Sherwood A. Effects of the DASH diet alone and in combination with exercise and weight loss on blood pressure and cardiovascular biomarkers in men and women with high blood pressure: the ENCORE study. *Arch Intern Med* 2010; 170:126–135.
14. Conlin PR, Chow D, Miller ER III, Svetkey LP, Lin PH, Harsha DW, Moore TJ, Sacks FM, Appel LJ. The effect of dietary patterns on blood pressure control in hypertensive patients: results from the Dietary Approaches to Stop Hypertension (DASH) trial. *Am J Hypertens* 2000; 13:949–955.
15. Harrington JM, Fitzgerald AP, Kearney PM, McCarthy VJ, Madden J, Browne G, Dolan E, Perry IJ. DASH diet score and distribution of blood pressure in middle-aged men and women. *Am J Hypertens* 2013; 6:6.
16. Parikh A, Lipsitz SR, Natarajan S. Association between a DASH-like diet and mortality in adults with hypertension: findings from a population-based follow-up study. *Am J Hypertens* 2009; 22:409–416.
17. Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM. Dietary approaches to prevent and treat hypertension. A scientific statement from the American Heart Association. *Hypertension* 2006; 47:296–308.
18. Churilla JR, Ford ES. Comparing physical activity patterns of hypertensive and nonhypertensive US adults. *Am J Hypertens* 2010; 23:987–993.
19. Faselis C, Doumas M, Kokkinos JP, Panagiotakos D, Kheirbek R, Sheriff HM, Hare K, Papademetriou V, Fletcher R, Kokkinos P. Exercise capacity and progression from prehypertension to hypertension. *Hypertension* 2012; 60:333–338.
20. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, Sugawara A, Totsuka K, Shimano H, Ohashi Y, Yamada N, Sone H. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA* 2009; 301:2024–2035.
21. Faselis C, Doumas M, Pittaras A, Narayan P, Myers J, Tsimploulis A, Kokkinos P. Exercise capacity and all-cause mortality in male veterans with hypertension aged ≥70 years. *Hypertension* 2014; 64:30–35.
22. Berry JD, Willis B, Gupta S, Barlow CE, Lakoski SG, Khera A, Rohatgi A, de Lemos JA, Haskell W, Lloyd-Jones DM. Lifetime risks for cardiovascular disease mortality by cardiorespiratory fitness levels measured at ages 45, 55, and 65 years in men: the Cooper Center Longitudinal Study. *J Am Coll Cardiol* 2011; 57:1604–1610.
23. Gordon-Larsen P, Nelson MC, Popkin BM. Longitudinal physical activity and sedentary behavior trends: adolescence to adulthood. *Am J Prev Med* 2004; 27:277–283.
24. Carnethon MR, Gulati M, Greenland P. Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. *JAMA* 2005; 294:2981–2988.
25. Cornelissen VA, Fagard RH. Effects of endurance training on blood pressure, blood pressure-regulating mechanisms, and cardiovascular risk factors. *Hypertension* 2005; 46:667–675.
26. Cornelissen VA, Buys R, Smart NA. Endurance exercise beneficially affects ambulatory blood pressure: a systematic review and meta-analysis. *J Hypertens* 2013; 31:639–648.

27. Taylor-Tolbert NS, Dengel DR, Brown MD, McCole SD, Pratley RE, Ferrell RE, Hagberg JM. Ambulatory blood pressure after acute exercise in older men with essential hypertension. *Am J Hypertens* 2000; 13:44–51.
28. Pagonas N, Dimeo F, Bauer F, Seibert F, Kiziler F, Zidek W, Westhoff TH. The impact of aerobic exercise on blood pressure variability. *J Hum Hypertens* 2014; 28:367–371.
29. Radak Z, Chung HY, Koltai E, Taylor AW, Goto S. Exercise, oxidative stress and hormesis. *Ageing Res Rev* 2008; 7:34–42.
30. Dawson EA, Green DJ, Cable NT, Thijssen DH. Effects of acute exercise on flow-mediated dilatation in healthy humans. *J Appl Physiol* 2013; 115:1589–1598.
31. Fagard RH, Cornelissen VA. Effect of exercise on blood pressure control in hypertensive patients. *Eur J Cardiovasc Prev Rehabil* 2007; 14:12–17.
32. Meredith IT, Friberg P, Jennings GL, Dewar EM, Fazio VA, Lambert GW, Esler MD. Exercise training lowers resting renal but not cardiac sympathetic activity in humans. *Hypertension* 1991; 18:575–582.
33. Grassi G, Seravalle G, Calhoun DA, Mancia G. Physical training and baroreceptor control of sympathetic nerve activity in humans. *Hypertension* 1994; 23:294–301.
34. Nami R, Mondillo S, Agricola E, Lenti S, Ferro G, Nami N, Tarantino M, Glauco G, Spanò E, Gennari C. Aerobic exercise training fails to reduce blood pressure in nondipper-type hypertension. *Am J Hypertens* 2000; 13:593–600.
35. King AC, Oman RF, Brassington GS, Bliwise DL, Haskell WL. Moderate-intensity exercise and self-rated quality of sleep in older adults. A randomized controlled trial. *JAMA* 1997; 277:32–37.
36. Gangwisch JE. A review of evidence for the link between sleep duration and hypertension. *Am J Hypertens* 2014; 27:1235–1242.
37. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc* 2004; 36:533–553.
38. Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, Limacher M, Pina IL, Stein RA, Williams M, Bazzarre T. AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: an advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. *Circulation* 2000; 101:828–833.
39. Benton MJ. Safety and efficacy of resistance training in patients with chronic heart failure: research-based evidence. *Prog Cardiovasc Nurs* 2005; 20:17–23.
40. Bertovic DA, Waddell TK, Gatzka CD, Cameron JD, Dart AM, Kingwell BA. Muscular strength training is associated with low arterial compliance and high pulse pressure. *Hypertension* 1999; 33:1385–1391.
41. Carlson DJ, Dieberg G, Hess NC, Millar PJ, Smart NA. Isometric exercise training for blood pressure management: a systematic review and meta-analysis. *Mayo Clin Proc* 2014; 89:327–334.
42. Sumimoto T, Hamada M, Muneta S, Shigematsu Y, Fujiwara Y, Sekiya M, Kazatani Y, Hiwada K. Influence of age and severity of hypertension on blood pressure response to isometric handgrip exercise. *J Hum Hypertens* 1991; 5:399–403.
43. Araujo CG, Duarte CV, Goncalves Fde A, Medeiros HB, Lemos FA, Gouvea AL. Hemodynamic responses to an isometric handgrip training protocol. *Arq Bras Cardiol* 2011; 97:413–419.
44. McGowan CL, Levy AS, Millar PJ, Guzman JC, Morillo CA, McCartney N, Macdonald MJ. Acute vascular responses to isometric handgrip exercise and effects of training in persons medicated for hypertension. *Am J Physiol Heart Circ Physiol* 2006; 291:28.
45. Taylor AC, McCartney N, Kamath MV, Wiley RL. Isometric training lowers resting blood pressure and modulates autonomic control. *Med Sci Sports Exerc* 2003; 35:251–256.
46. Pattyn N, Cornelissen VA, Eshghi SR, Vanhees L. The effect of exercise on the cardiovascular risk factors constituting the metabolic syndrome: a meta-analysis of controlled trials. *Sports Med* 2013; 43:121–133.
47. Hagberg JM, Park JJ, Brown MD. The role of exercise training in the treatment of hypertension: an update. *Sports Med* 2000; 30:193–206.
48. Cornelissen VA, Fagard RH. Effect of resistance training on resting blood pressure: a meta-analysis of randomized controlled trials. *J Hypertens* 2005; 23:251–259.
49. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002; 346:393–403.
50. Cornelissen VA, Fagard RH, Coeckelberghs E, Vanhees L. Impact of resistance training on blood pressure and other cardiovascular risk factors: a meta-analysis of randomized, controlled trials. *Hypertension* 2011; 58:950–958.
51. Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta-analysis. *J Am Heart Assoc* 2013; 2:004473.
52. Whelton SP, Chin A, Xin X, He J. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. *Ann Intern Med* 2002; 136:493–503.
53. Wen CP, Wai JP, Tsai MK, Yang YC, Cheng TY, Lee MC, Chan HT, Tsao CK, Tsai SP, Wu X. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *Lancet* 2011; 378:1244–1253.
54. Ishikawa-Takata K, Ohta T, Tanaka H. How much exercise is required to reduce blood pressure in essential hypertensives: a dose–response study*. *Am J Hypertens* 2003; 16:629–633.
55. Hu G, Barengo NC, Tuomilehto J, Lakka TA, Nissinen A, Jousilahti P. Relationship of physical activity and body mass index to the risk of hypertension: a prospective study in Finland. *Hypertension* 2004; 43:25–30.
56. Church TS, Thomas DM, Tudor-Locke C, Katzmarzyk PT, Earnest CP, Rodarte RQ, Martin CK, Blair SN, Bouchard C. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One* 2011; 6:25.
57. Fletcher GF, Ades PA, Kligfield P, Arena R, Balady GJ, Bittner VA, Coke LA, Fleg JL, Forman DE, Gerber TC, Gulati M, Madan K, Rhodes J, Thompson PD, Williams MA. Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation* 2013; 128:873–934.
58. Mora S, Cook N, Buring JE, Ridker PM, Lee IM. Physical activity and reduced risk of cardiovascular events: potential mediating mechanisms. *Circulation* 2007; 116:2110–2118.
59. Blair SN, Kohl HW III, Paffenbarger RS Jr, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989; 262:2395–2401.
60. Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med* 1986; 314:605–613.
61. Shaper AG, Wannamethee G, Weatherall R. Physical activity and ischaemic heart disease in middle-aged British men. *Br Heart J* 1991; 66:384–394.
62. Quinn TJ, Sprague HA, Van Huss WD, Olson HW. Caloric expenditure, life status, and disease in former male athletes and non-athletes. *Med Sci Sports Exerc* 1990; 22:742–750.
63. Mons U, Hahmann H, Brenner H. A reverse J-shaped association of leisure time physical activity with prognosis in patients with stable coronary heart disease: evidence from a large cohort with repeated measurements. *Heart* 2014.
64. La Gerche A HH. Intensive exercise can harm the heart: you can get too much of a good thing. *Circulation*, in press.
65. Levine BD. The athlete's heart: friend or foe? The benefits of competitive endurance training for cardiovascular structure and function. *Circulation*, in press.
66. Sarna S, Sahi T, Koskenvuo M, Kaprio J. Increased life expectancy of world class male athletes. *Med Sci Sports Exerc* 1993; 25:237–244.
67. Marijon E, Tafflet M, Antero-Jacquemin J, El Helou N, Berthelot G, Celermajer DS, Bougouin W, Combes N, Hermine O, Empana JP, Rey G, Toussaint JF, Jouven X. Mortality of French participants in the Tour de France (1947-2012). *Eur Heart J* 2013; 34:3145–3150.
68. Peake JM, Suzuki K, Wilson G, Hordern M, Nosaka K, Mackinnon L, Coombes JS. Exercise-induced muscle damage, plasma cytokines, and markers of neutrophil activation. *Med Sci Sports Exerc* 2005; 37:737–745.
69. Brooks K, Carter J. Overtraining, Exercise, and Adrenal Insufficiency. *J Nov Physiother* 2013; 3:11717.
70. Lakier Smith L. Overtraining, excessive exercise, and altered immunity: is this a T helper-1 versus T helper-2 lymphocyte response? *Sports Med* 2003; 33:347–364.
71. La Gerche A, Burns AT, Mooney DJ, Inder WJ, Taylor AJ, Bogaert J, Macisaac AI, Heidbuchel H, Prior DL. Exercise-induced right

ventricular dysfunction and structural remodelling in endurance athletes. *Eur Heart J* 2012; 33:998–1006.
72. La Gerche A, Schmied CM. Atrial fibrillation in athletes and the interplay between exercise and health. *Eur Heart J* 2013; 34:3599–3602.
73. Andersen K, Farahmand B, Ahlbom A, Held C, Ljunghall S, Michaëlsson K, Sundström J. Risk of arrhythmias in 52 755 long-distance cross-country skiers: a cohort study. *Eur Heart J* 2013; 34:3624–3631.
74. Biffi A, Pelliccia A, Verdile L, Fernando F, Spataro A, Caselli S, Santini M, Maron BJ. Long-term clinical significance of frequent and complex ventricular tachyarrhythmias in trained athletes. *J Am Coll Cardiol* 2002; 40:446–452.
75. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT, Roccella EJ. Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* 2003; 42:1206–1252.
76. Pescatello LS (ed). *American College of Sports Medicine's Guidelines for Exercise Testing and Prescription*, 9th edn. Wolters Kluwer: Philadelphia, PA, 2014.
77. Jette M, Sidney K, Blumchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin Cardiol* 1990; 13:555–565.
78. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation* 2007; 116:1081–1093.
79. Head GA, McGrath BP, Mihailidou AS, Nelson MR, Schlaich MP, Stowasser M, Mangoni AA, Cowley D, Brown MA, Ruta LA, Wilson A. Ambulatory blood pressure monitoring in Australia: 2011 consensus position statement. *J Hypertens* 2012; 30:253–266.
80. Parati G, Stergiou GS, Asmar R, Bilo G, de Leeuw P, Imai Y, Kario K, Lurbe E, Manolis A, Mengden T, O'Brien E, Ohkubo T, Padfield P, Palatini P, Pickering T, Redon J, Revera M, Ruilope LM, Shennan A, Staessen JA, Tisler A, Waeber B, Zanchetti A, Mancia G. European Society of Hypertension guidelines for blood pressure monitoring at home: a summary report of the Second International Consensus Conference on Home Blood Pressure Monitoring. *J Hypertens* 2008; 26:1505–1526.
81. Niiranen TJ, Leino K, Puukka P, Kantola I, Karanko H, Jula AM. Lack of Impact of a Comprehensive Intervention on Hypertension in the Primary Care Setting. *Am J Hypertens* 2014; 27:489–496.
82. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc* 2002; 34:1996–2001.
83. Weston KS, Wisloff U, Coombes JS. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. *Br J Sports Med* 2014; 48:1227–1234.
84. Thompson PD, Franklin BA, Balady GJ, Blair SN, Corrado D, Estes NA III, Fulton JE, Gordon NF, Haskell WL, Link MS, Maron BJ, Mittleman MA, Pelliccia A, Wenger NK, Willich SN, Costa F. Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology. *Circulation* 2007; 115:2358–2368.
85. Molmen-Hansen HE, Stolen T, Tjonna AE, Aamot IL, Ekeberg IS, Tyldum GA, Wisloff U, Ingul CB, Stoylen A. Aerobic interval training reduces blood pressure and improves myocardial function in hypertensive patients. *Eur J Prev Cardiol* 2012; 19:151–160.
86. Ciolac EG, Bocchi EA, Bortolotto LA, Carvalho VO, Greve JM, Guimaraes GV. Effects of high-intensity aerobic interval training vs. moderate exercise on hemodynamic, metabolic and neuro-humoral abnormalities of young normotensive women at high familial risk for hypertension. *Hypertens Res* 2010; 33:836–843.
87. Francois ME, Baldi JC, Manning PJ, Lucas SJE, Hawley JA, Williams MJA, Cotter JD. 'Exercise snacks' before meals: a novel strategy to improve glycaemic control in individuals with insulin resistance. *Diabetologia* 2014; 57:1437–1445.
88. Rognmo O, Moholdt T, Bakken H, Hole T, Molstad P, Myhr NE, Grimsmo J, Wisloff U. Cardiovascular risk of high- versus moderate-intensity aerobic exercise in coronary heart disease patients. *Circulation* 2012; 126:1436–1440.
89. Kemi OJ, Wisloff U. High-intensity aerobic exercise training improves the heart in health and disease. *J Cardiopulm Rehabil Prev* 2010; 30:2–11.
90. Alkahtani SA, Byrne NM, Hills AP, King NA. Interval Training Intensity Affects Energy Intake Compensation in Obese Men. *Int J Sport Nutr Exerc Metab*, published online 25 March 2014.
91. Lunt H, Draper N, Marshall HC, Logan FJ, Hamlin MJ, Shearman JP, Cotter JD, Kimber NE, Blackwell G, Frampton CM. High intensity interval training in a real world setting: a randomized controlled feasibility study in overweight inactive adults, measuring change in maximal oxygen uptake. *PLoS One* 2014; 9.
92. Keating SE, Machan EA, O'Connor HT, Gerofi JA, Sainsbury A, Caterson ID, Johnson NA. Continuous exercise but not high intensity interval training improves fat distribution in overweight adults. *J Obes* 2014; e-pub ahead of print 19 January 2014.
93. Schultz MG, Hare JL, Marwick TH, Stowasser M, Sharman JE. Masked hypertension is "unmasked" by low-intensity exercise blood pressure. *Blood Pressure* 2011; 20:284–289.
94. Kramer CK, Leitao CB, Canani LH, Ricardo ED, Pinto LC, Gross JL. Blood pressure responses to exercise in type II diabetes mellitus patients with masked hypertension. *J Hum Hypertens* 2009; 1–3.
95. Scott JA, Coombes JS, Prins JB, Leano RL, Marwick TH, Sharman JE. Patients with type 2 diabetes have exaggerated brachial and central exercise blood pressure: relation to left ventricular relative wall thickness. *Am J Hypertens* 2008; 21:715–721.
96. Sharman JE, Hare JL, Thomas S, Davies JE, Leano R, Jenkins C, Marwick TH. Association of masked hypertension and left ventricular remodeling with the hypertensive response to exercise. *Am J Hypertens* 2011; 24:898–903.
97. Stewart KJ, Sung J, Silber HA, Fleg JL, Kelemen MD, Turner KL, Bacher AC, Dobrosielski DA, DeRegis JR, Shapiro EP, Ouyang P. Exaggerated exercise blood pressure is related to impaired endothelial vasodilator function. *Am J Hypertens* 2004; 17:314–320.
98. Schultz MG, Otahal P, Cleland VJ, Blizzard L, Marwick TH, Sharman JE. Exercise-induced hypertension, cardiovascular events, and mortality in patients undergoing exercise stress testing: a systematic review and meta-analysis. *Am J Hypertens* 2013; 26:357–366.
99. Kokkinos P, Pittaras A, Narayan P, Faselis C, Singh S, Manolis A. Exercise capacity and blood pressure associations with left ventricular mass in prehypertensive individuals. *Hypertension* 2007; 49:55–61.
100. La Gerche A, Heidbuchel H, Burns AT, Mooney DJ, Taylor AJ, Pfluger HB, Inder WJ, Macisaac AI, Prior DL. Disproportionate Exercise Load and Remodeling of the Athlete's Right Ventricle. *Med Sci Sports Exerc* 2011; 43:974–981.
101. Palatini P, Mos L, Mormino P, Munari L, Del Torre M, Valle F, Scaldalai E, Pessina AC. Intra-arterial blood pressure monitoring in the evaluation of the hypertensive athlete. *Eur Heart J* 1990; 11:348–354.
102. Van Hoof R, Hespel P, Fagard R, Lijnen P, Staessen J, Amery A. Effect of endurance training on blood pressure at rest, during exercise and during 24 hours in sedentary men. *Am J Cardiol* 1989; 63:945–949.
103. Dimeo F, Pagonas N, Seibert F, Arndt R, Zidek W, Westhoff TH. Aerobic exercise reduces blood pressure in resistant hypertension. *Hypertension* 2012; 60:653–658.
104. Barone BB, Wang NY, Bacher AC, Stewart KJ. Decreased exercise blood pressure in older adults after exercise training: contributions of increased fitness and decreased fatness. *Br J Sports Med* 2009; 43:52–56.
105. Schultz MG, Hordern MD, Leano R, Coombes JS, Marwick TH, Sharman JE. Lifestyle change diminishes a hypertensive response to exercise in type 2 diabetes. *Med Sci Sports Exerc*, in press.
106. Kokkinos PF, Narayan P, Fletcher RD, Tsagadopoulos D, Papademetriou V. Effects of aerobic training on exaggerated blood pressure response to exercise in African-Americans with severe systemic hypertension treated with indapamide +/- verapamil +/- enalapril. *Am J Cardiol* 1997; 79:1424–1426.
107. Mancia G, Fagard R, Narkiewicz K, Redón J, Zanchetti A, Böhm M, Christiaens T, Cifkova R, De Backer G, Dominiczak A, Galderisi M, Grobbee DE, Jaarsma T, Kirchhof P, Kjeldsen SE, Laurent S, Manolis AJ, Nilsson PM, Ruilope LM, Schmieder RE, Sirnes PA, Sleight P, Viigimaa M, Waeber B, Zannad F; Task Force Members. 2013 ESH/ESC Guidelines for the management of arterial hypertension: the task force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *J Hypertens* 2013; 31:1281–1357.

108. Pescatello LS, Mack GW, Leach CN Jr, Nadel ER. Thermoregulation in mildly hypertensive men during beta-adrenergic blockade. *Med Sci Sports Exerc* 1990; 22:222–228.
109. Brook RD, Rajagopalan S, Pope CA III, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD. Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association. *Circulation* 2010; 121:2331–2378.
110. Sharman JE. Clinicians prescribing exercise: is air pollution a hazard? *Med J Aust* 2005; 182:606–607.
111. Albert CM, Mittleman MA, Chae CU, Lee I-M, Hennekens CH, Manson JE. Triggering of sudden death from cardiac causes by vigorous exertion. *N Eng J Med* 2000; 343:1355–1361.
112. Goodman JM, Thomas SG, Burr J. Evidence-based risk assessment and recommendations for exercise testing and physical activity clearance in apparently healthy individuals. *Appl Physiol Nutr Metab* 2011; 36:S14–S32.
113. Goodman J, Thomas S, Burr JF. Physical activity series: cardiovascular risks of physical activity in apparently healthy individuals: risk evaluation for exercise clearance and prescription. *Can Fam Physician* 2013; 59:46–49.