What is the magnitude of blood pressure response to a programme of moderate intensity exercise? Randomised controlled trial among sedentary adults with unmedicated hypertension

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SUMMARY

Background. Current guidelines for the management of hypertension recommend regular, moderate intensity aerobic exercise such as brisk walking as a means of blood pressure reduction. However, there is a lack of consistent evidence regarding the magnitude of blood pressure response to such a prescription. In particular, no well designed studies have investigated the efficacy of a programme of exercise meeting current guidelines.

Aim. To investigate the effect of a six-week programme of moderate intensity exercise on daytime ambulatory blood pressure (10.00am to 10.00pm) among unmedicated, sedentary adults aged 25 years to 63 years with office blood pressure of 150 mmHg to 180 mmHg systolic and/or 91 mmHg to 110 mmHg diastolic.

Method. Randomised controlled trial of participants carrying out 30 minutes of moderate intensity exercise (brisk walking or equivalent) five days per week for six weeks compared with controls who maintained existing levels of physical activity.

Results. Compliance with the exercise programme was high. The reduction in mean daytime ambulatory blood pressure between baseline and six-week follow-up was greater in the intervention group than in the control group for both systolic and diastolic blood pressure. However, this net hypotensive effect was not statistically significant (systolic = -3.4 mmHg, 95% CI = -7.4 to 0.6; diastolic = -2.8 mmHg, 95% CI = -5.8 to 0.2). Adjusting for baseline differences in mean ambulatory blood pressure in an analysis of covariance led to a reduction in the estimated magnitude of the effect (systolic = -1.9 mmHg, 95% CI = -5.4 to 1.7, P = 0.31; diastolic = -2.2 mmHg, 95% CI = -4.9 to 0.5, P = 0.11).

Conclusion. Despite high compliance with the exercise programme, the magnitude of the hypotensive effect of moderate intensity exercise was not as great as that found in studies of higher intensity exercise among hypertensives. Expectations of general practitioners and patients that a pro-gramme of moderate intensity exercise will lead to a clinically important reduction in the individual's blood pressure are unlikely to be realised.

Keywords: hypertension; exercise; randomised controlled trials.

Introduction

CURRENT guidelines for the management of hypertension recommend aerobic exercise as a means of blood pressure reduction to be used prior to, and in conjunction with, pharmacological approaches.[1,2] The guidelines typically recommend a programme of moderate intensity aerobic exercise (such as brisk walking) to be carried out for at least 30 minutes on five or more days each week. This prescription is the same as recent recommendations[3-5] for the appropriate amount of exercise required to maintain health and, as such, is likely to be widely utilised in general practice. The guidelines are derived from strong and consistent epidemiological evidence that moderate intensity physical activity carried out over a number of years confers significant protection from the development of cardiovascular disease.[4,6] However, there is relatively little evidence from experimental studies of the short-term improvements in cardiovascular risk factors that might be gained by patients following such an exercise programme.

Many meta-analyses and reviews of intervention studies describing the effects of exercise on blood pressure have been published and consistently show that aerobic exercise training reduces resting systolic and diastolic blood pressure in both normotensives and hypertensives.[7-12] However, there is still a lack of consistent evidence regarding the magnitude of the blood pressure response to exercise training and how this varies according to the intensity of the exercise programme. The majority of studies in hypertensive patients have used vigorous training intensities, frequently within a laboratory setting, to achieve reductions in blood pressure of between 4 mmHg and 10 mmHg. In a review of randomised controlled trials of moderate intensity exercise in unmedicated hypertensives[11] we were able to identify only six studies that met standard methodological criteria, of which only one utilised walking as the intervention. Net reductions in blood pressure ranged from 4 mmHg to 16 mmHg, although these effects were not always statistically significant. A few studies have addressed the issue of exercise intensity by directly comparing low and high intensity training programmes. These studies found lower intensity programmes to be as effective[13,14] or more effective[15-17] than higher intensity programmes, although methodological limitations such as low sample size and high dropout rates require that these findings should be viewed with caution.

The existing data are thus suggestive that moderate exercise may be effective in reducing blood pressure in hypertensive patients, though the predominance of small, poor quality studies tends to lead to overestimates of the effect size.[7-11] Indeed, it is consistently noted that smaller values are reported in the better

designed studies. Few good quality studies have investigated the efficacy of walking as the preferred mode of exercise and, to date, no studies have utilised the current exercise recommendations in a hypertensive population. Such a prescription is likely to be viewed favourably by the patient, since it requires no specific training, facilities or clothing, is achievable by almost everybody, and carries a negligible risk of injury. Programmes broadly utilising such prescription (home-based, unsupervised, moderate intensity walking) have been demonstrated to be the most effective means of increasing physical activity in free-living adults.[18]

In order to use exercise effectively in the management of hypertension there is a need to identify an exercise prescription that is both acceptable to the patient and likely to achieve a clinically worthwhile reduction in blood pressure. This report describes a randomised trial of a programme of home-based, unsupervised, moderate intensity exercise. This trial was conducted among participants whose office blood pressure at recruitment was above the minimum acceptable level of control (150/90 mmHg) recommended by the British Hypertension Society guidelines for management of hypertension but who were not receiving pharmacological treatment for hypertension.

Method

Recruitment of participants and baseline measures

Ethical approval for the study was granted by the United Bristol Healthcare Trust Research Ethics Committee. Participants were recruited from general practices and the workplaces of two large companies. Eligibility criteria were that participants should: be aged 18 years to 64 years, not be receiving pharmacological blood pressure or lipid lowering treatment, be sedentary, and have a resting office blood pressure of 150 mmHg to 180 mmHg (systolic) and/or 91 mmHg to 110 mmHg (diastolic). Office blood pressure was measured at least three times to confirm sustained elevation using either a sphygmomanometer or manually operated ambulatory monitor with the participant seated.

Following informed consent, height and weight were measured using a beam scale and stadiometer (SECA). To confirm self-reported sedentary behaviour, participants wore an accelerometer (Caltrac™) during waking hours for four days (two weekdays and a weekend) to provide an objective measure of the energy expended in physical activity.[14] The participant recorded daily energy expenditure (in kilocalories) in a diary.

On the day that they returned the accelerometer, daytime ambulatory blood pressure was measured using SpaceLabs 90207 monitors[20,21] programmed to record a reading every 15 minutes between 9.00am and 10.00pm. Participants were asked not to exercise on measurement days or for 24 hours prior to ambulatory blood pressure measurement to standardise for potential acute hypotensive effects of exercise.

Randomisation and sample size

At the completion of baseline ambulatory blood pressure measurement, an opaque envelope with the treatment allocation was opened to reveal the participant's treatment allocation. Randomisation envelopes were prepared by a member of the research team not involved in data collection and researchers collecting data were unaware of the allocation of participants until opening each envelope. The sample size required to detect a 4 mmHg difference in mean blood pressure with standard deviation of 6.5, power of 80%, and two-tailed Type I error of 0.05 was calculated to be 42 participants per group. Potential loss to follow-up was anticipated to be 30% in the intervention group and 15% in the control group, so 60 (42/0.7) and 50 (42/0.85) were planned to be randomised to each group respectively. Block

randomisation within strata defined by sex was used to generate the allocation, with six intervention and five control conditions within each block of 11.

Intervention

Intervention participants were asked to expend a daily 150 kcal to 200 kcal in 30 minutes of physical activity (equivalent to 30 minutes of brisk walking) in addition to their normal levels of activity for at least five days each week for a period of six weeks. Participants wore an accelerometer on each exercising day and recorded total daily energy expenditure, energy expenditure during exercise, and the type and duration of each exercise session in diaries. Participants met with the researchers after two and four weeks to replace diaries and to resolve problems encountered in achieving the exercise target. Control group participants were asked to maintain their usual levels of physical activity over the subsequent six weeks. All participants were requested not to change other aspects of their lifestyle during the intervention period.

Follow-up measures

At the end of the six-week period, participants were interviewed to confirm that no changes to lifestyle (exercise, alcohol consumption, and diet) other than participation in the exercise programme (intervention group) had taken place. Participants' weight and ambulatory blood pressure were re-measured. Baseline and follow-up ambulatory blood pressure measurements for each participant were taken with the same monitor to account for between-monitor variation. The researcher responsible for administering the collection of data at six-week follow-up was not blinded to treatment allocation.

Analysis

Daytime ambulatory blood pressure was defined as including all readings recorded between 10.00am and 10.00pm inclusive, with the first hour's readings (9.00am to 10.00am) discarded to account for accommodation effects. No manual editing of monitor data was carried out.

Data were analysed on an intention to treat basis with participants lost to follow-up excluded from the analysis. Two-sample t-tests were used to test the null hypothesis that the mean change in daytime ambulatory blood pressure between baseline and follow-up was the same among intervention and control groups. Analysis of covariance was used to adjust analysis for any imbalance between groups at baseline in ambulatory blood pressure, energy expenditure, sex, age, and body mass index (BMI). The interaction between baseline ambulatory blood pressure and treatment group was also tested.

Results

Study population

Recruitment was ended once 42 subjects had been randomised to each treatment group. A total of 90 participants were included in the trial (48 intervention, 42 control [Figure 1]). Loss to follow-up was not as great as had been anticipated in sample size calculations, as there were only four participants (3 control, 1 intervention) for whom follow-up data were not obtained. There were five departures from protocol: one commenced drug treatment during the study (thyroxin), three had baseline accelerometer values indicating high levels of activity despite reporting sedentary behaviour, and one in the intervention group did not undertake any additional exercise.
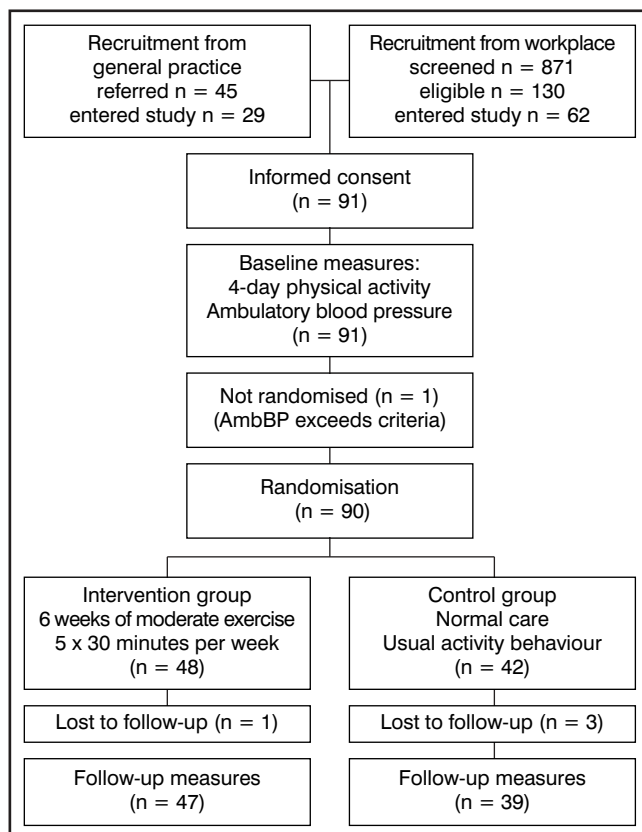
Figure 1. Flow chart describing participants' progress through the study.

Baseline characteristics

Characteristics of the study participants are shown in Table 1. Control group participants were slightly older (3.2 years) and heavier (2.7 kg) than intervention participants, with office blood pressure virtually the same in both groups. However, mean ambulatory blood pressure, both systolic and diastolic, was higher in the intervention group than control. The baseline ambulatory blood pressure is also markedly lower than the office blood pressure, raising the possibility that a number of participants were not truly hypertensive. While the value of ambulatory blood pressure that corresponds to normal values is a matter of debate, commonly used values are daytime ambulatory blood pressure >140/90 (hypertension) and ^135/85 (normal).[32] By these criteria, 47 participants were hypertensive, 23 normotensive, with the remainder (20) borderline. Equal proportions of each group were recruited from general practice and the workplace and there was equal allocation of these categories between intervention and control conditions.

Intervention characteristics

Mean compliance with the intervention for all participants (n = 47) was 89% (100% compliance was defined as recording that exercise was undertaken on 30 of 42 days) and 95% of participants exceeded the minimum requirement of 150 kcal per exercise bout. The majority of participants (92%) allocated to the intervention group chose walking as their mode of exercise. Thirty-five participants recorded accelerometer readings for the full day on each day that they planned an exercise session: mean energy expenditure in physical activity on exercise days increased by 34.3% (162 kcal) compared with baseline (633.6 ± 196.5 kcal versus 471.5 ± 167.2 kcal).

Blood pressure outcomes

Intervention participants showed significant reductions in both systolic and diastolic daytime ambulatory blood pressure between baseline and follow-up (systolic = -2.8 mmHg, 95% CI = -5.4 to -0.2; diastolic = -1.9 mmHg, 95% CI = -3.7 to -0.04), while control participants showed a small, non-significant increase (Table 2). However, the net differences between intervention and control groups did not achieve statistical significance (systolic = -3.4 mmHg, 95% CI = -7.4 to 0.6; diastolic = -2.8 mmHg, 95% CI = -5.8 to 0.2). When adjusted for baseline ambulatory blood pressure, the net difference was -1.9 mmHg (95% CI = -5.4 to 1.7, P = 0.31) for systolic and -2.2 mmHg (95% CI = -4.9 to 0.5, P = 0.11) for diastolic. Further adjusting for other baseline covariates (BMI, sex, age, physical activity) did not influence this result. Analyses excluding the five participants who deviated from the study protocol produced similar results to the intention to treat analyses and are not reported. No significant change in weight occurred in either group between baseline and follow-up. There was no statistically significant interaction between baseline ambulatory blood pressure and treatment group for either systolic blood pressure (P = 0.059) or diastolic blood pressure (P = 0.095).

Discussion

In primary care, advice to increase physical activity may be a central component of therapy for those with uncontrolled blood pressure below the recommended threshold for pharmacological treatment. The magnitude of the blood pressure response to a programme of moderate exercise among this patient group has previously not been clearly identified in well conducted randomised trials and we sought to provide an estimate of this response.

The study found that a six-week programme of moderate exercise was associated with an approximate 2 mmHg reduction in both systolic and diastolic blood pressure, although this difference was not statistically significant. The magnitude of blood pressure response found was less than that reported in meta-analyses of other well conducted studies[8] (4/3 mmHg systolic/diastolic), which included programmes of higher intensity exercise, although the 95% confidence interval (systolic = -5.4 to 1.7; diastolic = -4.9 to 0.5) included these values. Thus, although potentially of benefit when undertaken as an adjunct to drug treatment[22] or other lifestyle modification,[23] a programme of moderate intensity exercise on its own is unlikely to achieve a clinically important reduction in blood pressure in an individual patient. However, the small reduction in resting blood pressure identified in this study would be important in terms of protection against cardiovascular disease if it could be achieved at a population level. It has been estimated that a reduction of 2 mmHg in the average blood pressure of the population would reduce deaths from coronary heart disease by 4% and from strokes by 6%.[24]

The methodological limitations of many studies in this field are well documented and it is consistently noted that smaller effect sizes are reported in the better controlled trials and in those utilising ambulatory blood pressure measurement.[9,10] The present study was designed to address many of these shortcomings and the magnitude of the results are in agreement with those from other well designed studies.[23,25] One potential shortcoming was that the assessor was not blind to treatment allocation at follow-up. However, ambulatory blood pressure measurement is unlikely to be sensitive to observer bias and no manual editing of readings was undertaken prior to analysis. A further concern is that a relatively short intervention period was used to maximise com-

Table 1. Baseline characteristics of participants included in the study. Values are means (standard deviation) except where indicated otherwise.

	Intervention (n = 48)	Control (n = 42)
Sex	39 male, 9 female	33 male, 9 female
Age (years)	46.2 (9.4)	49.4 (8.9)
Height (cm)	174.5 (9.7)	172.8 (8.8)
Weight (kg)	81.1 (15.4)	83.8 (15.4)
BMI (kg m^{-2})	26.6 (4.3)	28.1 (5.1)
Office BP (systolic, mmHg)	155.5 (13.1)	155.4 (13)
Office BP (diastolic, mmHg)	97.1 (6.2)	98.2 (7.1)
AmbBP[a] (systolic, mmHg)	139.8 (12.5)	137 (10.9)
AmbBP[a] (diastolic, mmHg)	89.5 (9.6)	88.4 (9)
Number[a] (%) AmbBP ^135/85	12 (25)	11 (26.2)
Number[a] (%) AmbBP >135/85, ×140/90	12 (25)	8 (19.1)
Number[a] (%) AmbBP >140/90	24 (50)	23 (54.7)

[a]Daytime blood pressure 10.00am to 10.00pm.

Table 2. Changes in daytime ambulatory blood pressure (10.00am to 10.00pm) and weight in intervention and control groups after six weeks.

	Intervention (n = 47)	Control (n = 39)
Systolic (mmHg)		
Baseline	139.8 (12.7)	135.7 (9.3)
Follow-up	137.0 (12.2)	136.3 (8.6)
Change (95% CI)	-2.82	0.57
	(-5.42 to -0.23)[a]	(-2.52 to 3.67)
Net difference (95% CI)	-3.40 (-7.35 to 0.55)	
Net difference adjusted for baseline ambulatory blood pressure (95% CI)	-1.85 (-5.44 to 1.73)	
Diastolic (mmHg)		
Baseline	89.5 (9.6)	87.6 (8.5)
Follow-up	87.7 (9.4)	88.5 (7.6)
Change (95% CI)	-1.85	0.91
	(-3.63 to -0.04)[a]	(-1.51 to 3.33)
Net difference (95% CI)	-2.80 (-5.75 to 0.16)	
Net difference adjusted for ambulatory blood pressure (95% CI)	-2.19 (-4.87 to 0.49)	
Weight (kg)		
Baseline	81.1	83.8
Follow-up	81.2	82.4

[a]Significant difference from baseline at P<0.05.

pliance and provide a realistic estimate of the potential acute effect of such a programme and this may have been insufficient to elicit a more marked reduction in blood pressure. However, significant reductions in blood pressure have been reported in trials of four weeks' duration or less[26-30] and a meta-analysis[10] has concluded that most of the reduction in blood pressure is obtained within the first ten weeks of training, or even more rapidly. Conversely, in a well controlled trial of moderate exercise in unmedicated hypertensives, a one-year programme produced results similar to the present study.[23]

In addition, it is possible that the effect of the intervention was reduced by control group participants increasing their physical activity as a result of taking part in the study. No information was collected regarding physical activity levels among the control group, since accelerometers or diaries might have acted as motivational prompts to increase activity. However, it is unlikely that these participants would spontaneously adopt and maintain regular activity and self-reports indicated that none had increased their level of physical activity during the study period.

The study population was chosen to represent the 'typical' individual who might present with elevated blood pressure below thresholds for pharmacological treatment and for whom lifestyle approaches to control would be appropriate. Since ambulatory blood pressure is frequently lower than office values, it is not surprising that a quarter of participants were normotensive by ambulatory blood pressure criteria, raising the possibility that the hypotensive effect of exercise might be diluted. While the magnitude of blood pressure reduction reported in meta-analyses[8,12] for normotensives is approximately 2 mmHg less than for hypertensives, this is unlikely to have had a significant impact on our results. Testing for interaction confirmed that there was no statistically significant intervention effect modification dependent on baseline ambulatory blood pressure.

The most effective ways to promote physical activity in primary care have yet to be identified, although it appears that a focus on home-based, moderate intensity activity, particularly walking, is most promising.[18,31] This was supported in the current study, where such an intervention, supported by three face-to-face contacts over six weeks, secured high levels of compliance and resulted in a mean increase in energy expenditure of 34.3%. The majority of participants chose walking as their preferred mode of exercise, giving support to the promotion of this form of exercise for health benefits. Larger studies are required to provide more precise estimates of the magnitude of blood pressure response to moderate physical activity and should also seek to identify the impact of such activity on other cardiovascular risk factors and over a longer period than six weeks.[25] Such studies will be able to estimate the likely public health benefit of increasing popula-

tion levels of physical activity, both on blood pressure and on other risk factors.

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