Effect of moderate-intensity seated exercise on the management of metabolic outcomes in hypertensive individuals with or without exercise habits

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ABSTRACT

Background: We aimed to evaluate the effect of moderate-intensity seated exercise on metabolic outcomes in hypertensive individuals with or without exercise habits.
Methods: Forty-two hypertensive individuals volunteered for this study and were classified into 3 groups by their habits and place for moderate-intensity exercise prior to this study: NONE (<2 days/week or no exercise; n = 13), HOME (≥30 min/day and ≥2 days/week at home; n = 15), and GYM (≥30 min/day and ≥2 days/week at a hospital gym; n = 14). They performed their daily activities as usual and seated exercise (stepping and stepping with trunk rotation; a range of 11−13 on the Borg rating of perceived exertion scale) for at least 15 min/day and at least 3 days/week for 12 weeks.
Results: Thirty-five participants (age: 67.7 ± 5.9 years) completed the study, and there was no difference among the 3 groups regarding weekly exercise. The homeostasis model assessment of insulin resistance (HOMA-IR) value in the NONE group was significantly higher than that in the GYM group at baseline (p < 0.05), but it decreased significantly after 12 weeks (from 2.2 ± 0.8 to 1.7 ± 0.7, p < 0.05). Changes in HOMA-IR in the NONE group after 12 weeks was greater than that in the HOME and GYM groups (both p < 0.01). The HOME and GYM groups showed no significant changes in any of the variables.
Conclusion: Moderate-intensity seated exercise may be an effective strategy to improve insulin resistance in hypertensive individuals without exercise habits.

Introduction

Regular physical activity (PA) is an important pillar for the management of various health outcomes, and the decrease of PA is associated with the development of cardiovascular disease (CVD) and all-cause mortality.[1−3] However, people's PA decreases by the increasing availability and popularity of civilization instruments including cars, elevators, and remote controls, as well as busy lifestyles, which often cause impracticability to regularly engage in PA.[4,5] Therefore, despite the known benefits of regular PA, 27.5% of adults globally have insufficient PA and its levels were stable between 2001 and 2016.[6]

Chronic high blood pressure (BP) raises the risk of CVD, and the risk increases along with the deterioration of metabolic outcomes (e.g., body weight, blood glucose, serum lipids) in hypertensive individuals.[7,8] Hence, they are recommended to manage their lifestyles, including PA, and improve BP and metabolic outcomes; for example, it is expected that every 1-kg reduction in boy weight induces a 1-mmHg reduction in systolic BP.[7] Past researches have shown that regular PA improved resting and ambulatory BP, weight control, insulin resistance, and cardiorespiratory fitness in hypertensive adults.[9−12] Generally, recommended aerobic exercise for adults with hypertension is as follows: frequency, ≥3 days/week; intensity, moderate to vigorous; time, ≥30 min/day or ≥150 min/week.[7,8,13]

Seated exercise, such as stepping exercise, is an easy method for performing exercise at home, regardless of weather conditions or training clothes, without the need for preparation time, additional

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exercise implements, and sufficient physical fitness, owing to low-load aerobic and resistance exercises.[14] In fact, hypertensive individuals experience difficulty in maintaining exercise habits due to several factors, such as lack of time and exercise skills.[15,16] Some studies have reported the effectiveness of exercise, including seated exercise, for metabolic derangement and cognitive impairments[17,18]; a systematic review has shown that seated exercise had benefits on cognition, strength, activity, depression, and quality of life in older adults.[14]

However, little is known about whether seated exercise is effective for improving metabolic outcomes, including BP. Skeletal muscle contractions during PA induce vasodilation through an increase in nitric oxide production and bioavailability[19,20] reflected by endothelial function, which correlates the CVD risk.[21,22] A recent systematic review showed that moderate-to-vigorous PA of any bout duration was related to improved metabolic outcomes, including body weight, blood lipids, fasting plasma glucose (FPG), resting BP, and cardiovascular risk assessed by the Framingham CVD Risk Score.[23] Additionally, a noteworthy point is that there was no consideration about people's backgrounds of exercise habits in previous studies.[14,17,18] If individuals exercise regularly (e.g., walking, jogging, cycling), the effects of seated exercise may not be achieved because the intensity and volume of seated exercise are often lower than that of regularly performed exercise.[14] Conversely, inactive or untrained individuals may easily change their metabolic outcomes if they increase their PA than usual.[24]

Therefore, we hypothesized that regular moderate-intensity seated exercise with any duration may improve metabolic outcomes, including BP, in hypertensive individuals, especially in those without exercise habits. Based on this hypothesis, we examined whether moderate-intensity seated exercise for 12 weeks improves metabolic outcomes in hypertensive individuals with or without exercise habits. If this is confirmed, seated exercise may be one of the ideal choices to be made by individuals who cannot perform the recommended exercise modalities.[7,8,13]

Methods

Participants

A total of 42 adults with hypertension (age: 50–75 years) who regularly visited our hospital were recruited. They had no macrovascular complications, motor dysfunction, or cognitive impairment; 9 participants had hyperlipidemia, and none had diabetes. All participants were under nutritional therapy (energy intake: 25–30 kcal/kg body weight/day) and were taking oral antihypertensive agents (calcium antagonists, angiotensin II receptor blockers, angiotensin-converting enzyme inhibitors, diuretics, beta-blockers). All participants provided written informed consent. The protocol for this study was approved by the institutional review board of the Toyooka Hospital Hidaka Medical Center (Toyooka, Japan; approval number: 9) in accordance with the Declaration of Helsinki.

Experimental design

This was a prospective study. The participants were classified into 3 groups by their exercise conditions (habits and place for exercise) prior to this study; NONE (moderate-intensity aerobic exercise less than 2 days/week or no exercise; n = 13), HOME (moderate-intensity aerobic exercise for at least 30 min/day and at least 2 days/week at home; n = 15), and GYM (moderate-intensity aerobic exercise for at least 30 min/day and at least 2 days/week at hospital gym; n = 14).[25] The HOME and GYM groups were divided because different impacts on metabolic outcomes at baseline might

have been observed, whether performing exercise was supervised or not.[26] We asked them to perform activities of daily living and regular exercise (if any) as usual, and seated exercise at home, as prescribed for 12 weeks. During the intervention period, the participants continued to receive nutritional therapy and take oral antihypertensive agents as usual.

Seated exercise protocol

In this study, we adjusted the height of chairs to be comfortable for the participants, which was approximately 40 cm from the chair leg to the top of the seat; it did not matter whether there were armrests and backrests or not. The exercises prescribed were as follows: a) stepping as the arms swing in turn (90–120 steps/min, for at least 3 min/bout) and b) stepping with trunk rotation as the arms swing in turn (40–60 steps/min for at least 3 min/bout). The seated exercise intensity was moderate, within the range of 11–13 on the Borg rating of perceived exertion scale.[27] We asked the participants to perform the seated exercise for at least 15 min/day (net time) except for interval time, whenever they wanted to during the day, at least 3 days/week for 12 weeks. The intervals between each exercise were free, and performing the exercise with or without intervals (e.g., 5-min exercise, 5-min or 5-h interval, and 10-min exercise; 15-min continuous exercise) were not considered to be relevant for outcomes. We also asked the participants to record the net exercise time of the day they exercised, using self-recording papers.

Measurements

All variables were measured when the participants visited the hospital before the intervention and within a week after the intervention. The variables were as follows: body mass index (BMI), waist circumference, FPG, fasting immunoreactive insulin (F-IRI), homeostatic model assessment of insulin resistance (HOMA-IR), BP, and serum lipids. These measurements were carried out in the morning (8:30 a.m.–12:00 p.m.) after an overnight fast, and the body weight was measured with the participants wearing light clothing and without wearing a jacket and shoes. The FPG and F-IRI values were used to calculate the HOMA-IR, an index of insulin resistance (HOMA-IR = FPG (mmol/L) × F-IRI (pmol/L)/135).[28]

Statistical analysis

All values were reported as the mean ± standard deviation. Comparisons of characteristics between the groups were analyzed using one-way analysis of variance (one-way ANOVA) for continuous variables and Fisher's exact test for nominal variables. The time-course changes of variables were analyzed with two-way repeated measures ANOVA, and post hoc analysis was performed using the Tukey-Kramer post-hoc test to assess the differences between each data point. In addition, differences in the HOMA-IR changes during the intervention period between the groups were analyzed using one-way ANOVA and the Tukey-Kramer post-hoc test. All statistical calculations were performed using the IBM SPSS statistics software (version 20.0, IBM, Tokyo, Japan). Significance was set at p < 0.05.

Results

A total of 35 participants (11 men and 24 women, aged 67.7 ± 5.9 years) completed the study; 7 participants were excluded due to hospitalization, stopping performing seated exercise at his/her own will, or motor dysfunction (lumbar disk herniation) which interrupted their participation in exercise (Fig. 1 and Table 1). The
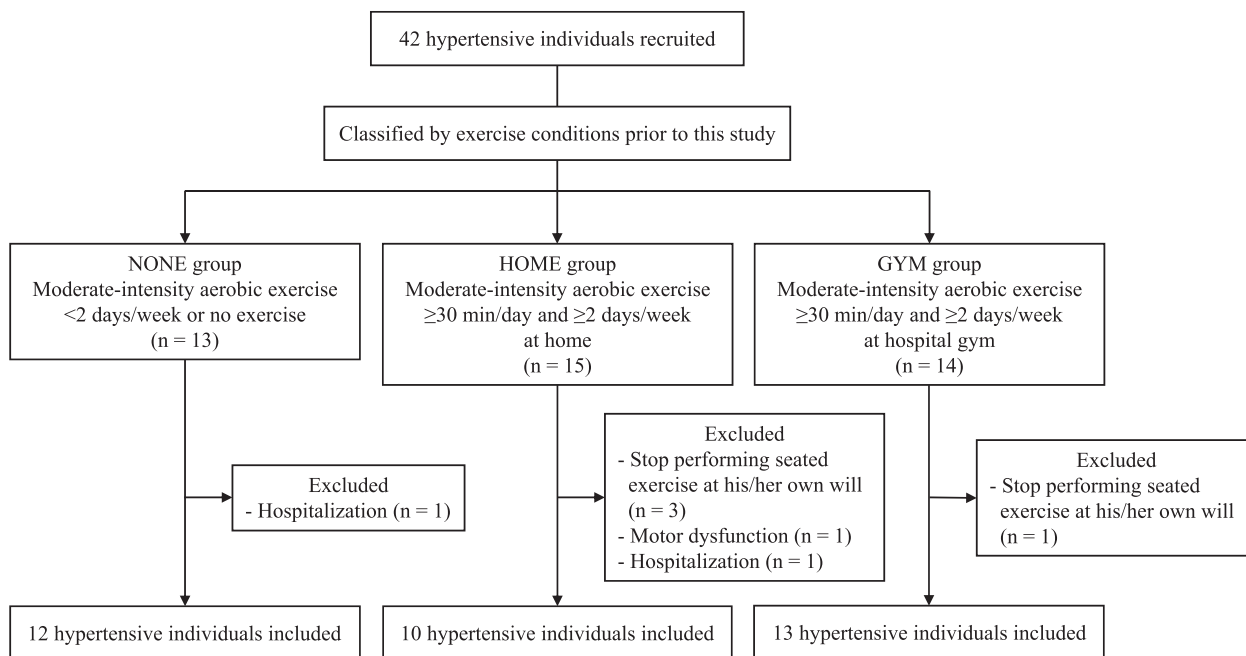
Fig. 1. Flow chart of the study population selection, including participant recruitment.

Table 1
Characteristics of the study participants at baseline.

Variable	
Gender (male/female)	11/24
Age (years)	67.7 ± 5.9
Duration of hypertension (years)	11.4 ± 5.5
BMI (kg/m^2)	25.1 ± 2.7
Waist circumference (cm)	89.2 ± 8.1
FPG (mmol/L)	5.9 ± 0.7
F-IRI (pmol/L)	42.3 ± 12.7
HOMA-IR	1.9 ± 0.9
Systolic BP (mmHg)	131.6 ± 15.9
Diastolic BP (mmHg)	70.6 ± 9.8
Triglycerides (mmol/L)	1.4 ± 0.3
LDL-cholesterol (mmol/L)	3.1 ± 0.6
HDL-cholesterol (mmol/L)	1.6 ± 0.4

Values are presented as mean ± standard deviation. BMI, body mass index; FPG, fasting plasma glucose; F-IRI, fasting immunoreactive insulin; HOMA-IR, homeostasis model assessment of insulin resistance; BP, blood pressure; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

profiles of variables at baseline and end of intervention are shown in Table 2. No significant differences in exercise time per day (NONE: 16.0 ± 5.0 min/day, HOME: 16.4 ± 4.5 min/day, GYM, 16.4 ± 2.5 min/day), exercise time per week (NONE: 77.6 ± 25.8 min/week, HOME: 86.7 ± 28.8 min/week, GYM: 77.2 ± 20.9 min/week), exercise frequency (NONE: 4.8 ± 1.2 days/week, HOME: 5.2 ± 0.8 days/week, GYM: 4.7 ± 1.0 days/week), and proportion of participants fully adherent (completed program: at least 15 min/day and 3 days/week for 12 weeks) (NONE: 92.3%, HOME: 100%, GYM: 92.9%) were shown between the groups. Additionally, nutritional therapy and medication conditions in the participants were stable with no major change (e.g., from a single agent to multiple agents) throughout the study period, although we did not record the detailed amount of oral antihypertensive agents.

Analysis using a one-way ANOVA revealed a significant interaction between time and exercise conditions on F-IRI and HOMA-IR ($p < 0.05$ and $p < 0.01$, respectively). There was no significant difference in the F-IRI values between exercise conditions at any

sampling time, whereas the HOMA-IR value in the NONE group was higher than that in the GYM group at baseline ($p < 0.05$) and significantly decreased after 12 weeks ($p < 0.05$). In addition, the HOMA-IR change in the NONE group for 12 weeks decreased by 21%, which was greater than that in the HOME and GYM groups (both increased by 2%, both $p < 0.01$) (Fig. 2). As a result, there was no difference between the groups at the end of the intervention.

Analysis using a one-way ANOVA revealed no significant interaction between time and exercise conditions on other variables. With respect to systolic BP, the main effect of exercise conditions was noted ($p < 0.05$), and the NONE group had higher systolic BP than the GYM group ($p < 0.01$).

Discussion

To the best of our knowledge, this was the first study to examine the effect of seated exercise in hypertensive individuals, focusing on their exercise habits. In this study, performing moderate-intensity seated exercise for at least 15 min/day and 3 days/week for 12 weeks improved the HOMA-IR value in the NONE group. Finally, the HOMA-IR value in the NONE group, which was higher than that in the GYM group at baseline, was close to that in other groups after the intervention (Table 2).

Generally, aerobic exercise of at least moderate-intensity for at least 10 min/bout and 30 min/day is recommended for hypertensive patients.[29] In this study, the participants performed moderate-intensity seated exercise continuously or intermittently for 15–17 min/day. Past studies have shown that a high volume of exercise might be required to improve insulin resistance when exercise intensity was low or moderate.[30,31] Conversely, as aforementioned, recent evidence from cross-sectional studies concluded that moderate-to-vigorous PA of short duration, even <10 min, was associated with improved FPG and fasting insulin,[23] which affected the HOMA-IR value. Thus, although the FPG and F-IRI values showed decreasing trends without significance, the short-duration moderate-intensity exercise program performed in this study may have a benefit for the improvement in insulin resistance. Furthermore, we consider that it is an advantage for individuals, who

Table 2
Characteristics of the groups and profiles at baseline and the end of the intervention.

Variable	NONE (n = 12)		HOME (n = 10)		GYM (n = 13)	
Gender (male/female)	3/9		4/6		4/9	
Age (years)	67.5 ± 6.8		66.8 ± 5.0		68.5 ± 5.4	
Duration of hypertension (years)	10.5 ± 4.5		12.1 ± 5.8		11.7 ± 5.9	
	Baseline	At 12 weeks	Baseline	At 12 weeks	Baseline	At 12 weeks
BMI (kg/m^2)	25.7 ± 2.6	25.5 ± 2.4	24.8 ± 2.5	24.5 ± 2.6	24.9 ± 2.9	25.0 ± 2.9
Waist circumference (cm)	90.9 ± 7.1	90.2 ± 7.0	87.7 ± 7.5	88.0 ± 6.7	88.7 ± 9.1	88.2 ± 8.6
FPG (mmol/L)	6.0 ± 0.4	5.8 ± 0.4	5.9 ± 0.7	5.9 ± 0.6	5.8 ± 0.8	5.8 ± 0.7
F-IRI (pmol/L)	47.9 ± 18.7	39.6 ± 15.4	40.0 ± 17.7	42.1 ± 23.8	38.9 ± 12.0	39.8 ± 15.6
HOMA-IR	2.2 ± 0.8	1.7 ± 0.7*	1.8 ± 0.8	1.8 ± 0.9	1.7 ± 0.7*	1.7 ± 0.8
Systolic BP (mmHg)	139.2 ± 17.0	137.8 ± 21.6	133.9 ± 12.9	136.2 ± 14.5	126.9 ± 11.3	127.1 ± 11.6
Diastolic BP (mmHg)	73.5 ± 8.9	73.0 ± 9.9	69.1 ± 8.9	69.0 ± 8.2	69.1 ± 10.7	69.0 ± 6.9
Triglycerides (mmol/L)	1.4 ± 0.5	1.4 ± 0.5	1.3 ± 0.6	1.4 ± 0.3	1.4 ± 0.6	1.3 ± 0.3
LDL-cholesterol (mmol/L)	3.3 ± 0.5	3.3 ± 0.4	3.1 ± 0.7	3.0 ± 0.4	2.9 ± 0.5	2.9 ± 0.7
HDL-cholesterol (mmol/L)	1.5 ± 0.4	1.4 ± 0.3	1.7 ± 0.5	1.6 ± 0.5	1.6 ± 0.4	1.6 ± 0.4

Values are presented as mean ± standard deviation. NONE, group with no exercise habits prior to this study; HOME, group with exercise habits at home prior to this study; GYM, group with exercise habits at the hospital prior to this study; BMI, body mass index; FPG, fasting plasma glucose; F-IRI, fasting immunoreactive insulin; HOMA-IR, homeostasis model assessment of insulin resistance; BP, blood pressure; LDL, low-density lipoprotein; HDL, high-density lipoprotein. *$p < 0.05$ vs. corresponding NONE group at baseline.
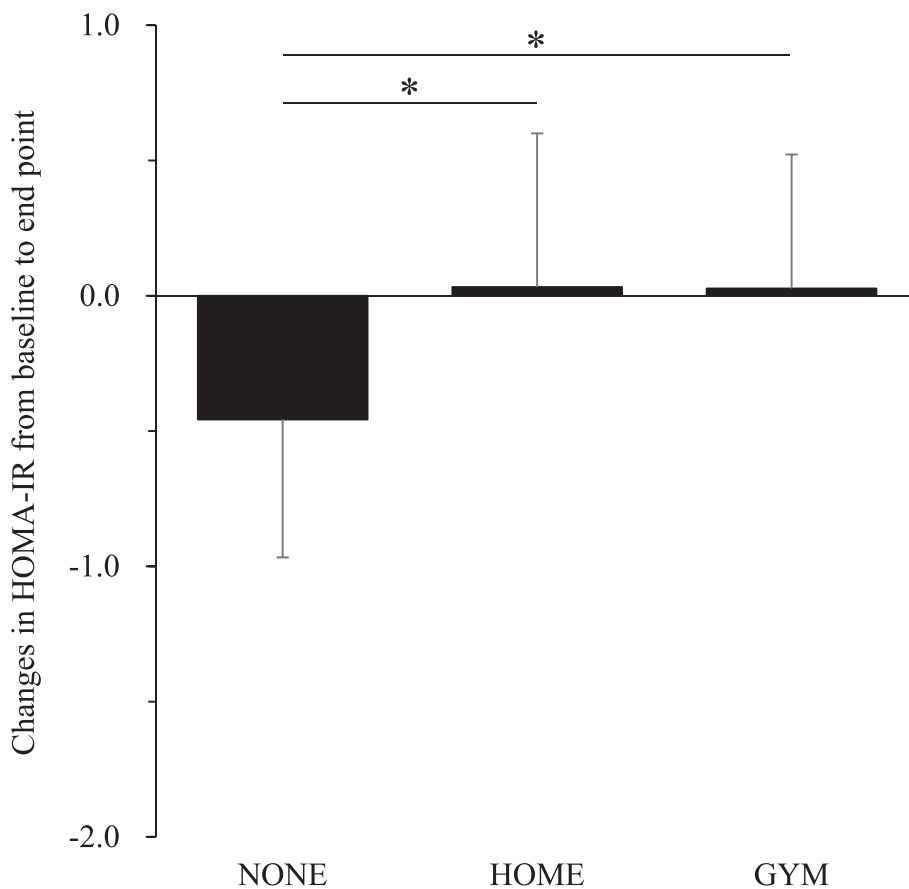

Fig. 2. Changes in homeostasis model assessment of insulin resistance (HOMA-IR) from baseline to end point.
Values are presented as mean ± standard deviation. NONE, group with no exercise habits prior to this study; HOME, group with exercise habits at home prior to this study; GYM, group with exercise habits at the hospital prior to this study. *$p < 0.01$ vs. NONE group.

experience difficulty in performing exercise regularly due to lack of continuous exercise time (e.g., the busyness of a job), the preparation of exercise implements (e.g., purchase of a bicycle), severe climate conditions (e.g., heavy snowfall in winter), or insufficient physical fitness (e.g., frailty in the elderly), to obtain improvement in metabolic outcomes by using seated exercise which is an easy and simple method for performing at home.

Untrained individuals have a lower physiological response to the same intensity of exercise, such as energy expenditure and fat oxidation, than trained individuals.[32–34] Conversely, those untrained also have a higher exercise hormone response, such as leptin which is a hormone associated with lipid oxidation, energy expenditure, and energy homeostasis,[35] compared to those trained, due to the difference in body fat mass and/or body weight.[36,37]

Thus, in this study, although the total energy expenditure of seated exercise may be lower in the NONE group than in the HOME and GYM groups, the stimulation of seated exercise may induce a higher hormone response than usual PA in the NONE group, where the BMI at baseline trended to be higher (not significant) than other groups. Additionally, a previous study showed that it may be easy for sedentary or inactive people to change their metabolic outcomes by slightly increasing their PA than usual.[24] A recent report showed that 90 min/week of moderate-intensity exercise for 8 weeks improved FPG, which affected the HOMA-IR value, in sedentary individuals with type 2 diabetes, including people with hypertension[38]; thus, the amount of seated exercise performed by the NONE group [mean value: 77.6 min/week, 52% of the generally recommended amount (150 min/week)[7,8,13]] may be enough to improve HOMA-IR, although the amount of seated exercise in our study was a little lower than in the previous study (60% of the generally recommended amount). Therefore, this study protocol may cause no additional improvement when the participants already have established exercise habits, whereas it may be effective for improving insulin resistance when the participants have no exercise habits.

There were no significant changes in other variables in this study (Table 2). The main aim of management in hypertensive individuals is to improve or maintain their BP. In this study, BP levels at baseline in all groups were within the normal range of office BP (<140 mmHg)[39]; thus, the significant change in BP after the intervention might not be observed. In addition, lowering of BP occurs after improvement in insulin resistance that induces high BP.[40] Furthermore, improvement in both systolic and diastolic BP is affected by the exercise intensity.[41] Therefore, BP levels may be improved after the long-term intervention and/or by higher exercise intensity. Regarding other variables, weight control is affected by activity volume and energy expenditure.[42] We consider that a significant reduction in weight did not occur because activity volume and energy expenditure in this study were low (moderate intensity, 15–17 min/day), although we did not evaluate them. The lipid profiles at baseline in all groups were also within the normal range (triglycerides, <1.7 mmol/L; low-density lipoprotein cholesterol, <3.6 mmol/L; high-density lipoprotein cholesterol, ≥1.0 mmol/L)[43] and there were no significant changes after the intervention. Hence, moderate-intensity seated exercise induced no change in all variables, excluding HOMA-IR in this study population.

In this study, 4 participants with exercise habits stopped performing seated exercise at their own will (Fig. 1). That might indicate that seated exercise was a monotonous or boring modality for those who already had performed moderate-intensity exercise for at least 30 min/day and 2 days/week. Conversely, sedentary or inactive individuals should start an exercise program at a lower intensity and shorter duration than recommended levels[44]; hence, we consider that seated exercise is suitable for individuals without exercise habits, but not those with these habits.

This study has some limitations. First, the sample size was small due to a single facility. Second, the results were not compared with other exercise modalities or no exercise group, since the main purpose of this study was to compare the effect of seated exercise in hypertensive individuals with and without exercise habits. Third, we recruited individuals who had no complications, such as a motor or cardiopulmonary dysfunction; PA of individuals with complications of metabolic diseases is of lower frequency and intensity compared with those without complications.[45] Thus, our results may not apply to complicated hypertensive individuals. Finally, the net exercise time of the day was recorded using self-recording papers, but not evaluated objectively, and details of type, intensity, duration, and timing of other PA during the intervention period were unclear because they were not evaluated. Thus, further studies are needed to confirm the clinical relevance of seated exercise by comparing other types of exercises, recruiting complicated individuals, or evaluating total PA during the intervention period.

Conclusion

We believe that moderate-intensity seated exercise comprising mainly stepping for 12 weeks reduced insulin resistance in hypertensive individuals without exercise habits. Additionally, we suggest that untrained individuals, who have difficulty in performing a general exercise,[7,8,13] would benefit from adopting some kind of moderate-intensity exercise like seated exercise, which is easy to perform at home, regardless of weather conditions, training clothes, exercise implements, and/or sufficient physical fitness and may induce physiological responses more than regular PA, even if the increase of PA is slight. This study protocol may be a useful method for first-step treatment for improving insulin resistance in hypertensive individuals without exercise habits.

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Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

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