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Effects of Dynamic Jumping Exercise on Vascular Function, Physical Performance, and Quality of Life in Middle-aged with Prehypertension

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This study aimed to investigate the effects of home-based dynamic jumping exercise (DJE) in middle-aged with prehypertension. Sedentary individuals were recruited from Banphai district, Khon Kaen, Thailand. Thirty (30) eligible subjects were randomly allocated to the control (CG) and exercise (EX) groups. The CG was instructed about lifestyle modification, and the EX was asked to act like the CG but additionally elongated with DJE program for 8 wk (50 min/day, 3 d/wk at moderate intensity). The primary outcomes were systolic (SBP) and diastolic blood pressure (DBP). There are four secondary outcomes – including carotid-femoral pulse wave velocity (cfPWV), five times sit-to-stand test (FTSST), timed up and go test (TUGT), and quality of life (QOL). After the 8-wk program, the EX significantly improved in all outcomes from baseline ($p < 0.001$) except TUGT ($p = 0.07$) and QOL. On the other hand, the environmental domain of QOL significantly decreased ($p < 0.05$) in the CG from baseline. However, significant differences were found in SBP, DBP, FTSST, and TUGT between the groups except for cfPWV ($p = 0.06$). In conclusion, the DJE program in combination with lifestyle modification was considered a non-pharmacological intervention for controlling blood pressure and improving physical performance in middle-aged adults with prehypertension.

Keywords: exercise, hypertension, blood pressure, physical performance

INTRODUCTION

Aging is gradually developed with the increasing age each day since we were born. However, human growth will deteriorate when they enter not only elderly but also middle age (Dziechciaż and Filip 2014). Advancing medical technology makes life better and longer. On the other hand, facing problems from aging will last longer (Partridge *et al.* 2018). Furthermore, the COVID-19 epidemic situation has been changing our usual habits into a sedentary lifestyle (Schwendinger and Pocecco 2020). For example, we need to self-quarantine and work from home instead of going out from home and traveling to work as usual. This problem has resulted in reducing our outdoor activities such as walking, running, and other natural outdoor sports. Thus, these problems have greatly combined with aging to diminish some biological efficiency in cardiovascular, musculoskeletal, and other systems.

The deterioration of the cardiovascular system caused the arteries to harden and become thicker (atherosclerosis). A higher BP than normal can also decrease blood flow to organs in the body, especially in the heart and brain. Elevated blood pressure in the arterial walls caused damage to the entire blood vessels, resulting in decreased organ function (Costantino *et al.* 2016). Hypertension (HT), one of the major global public health concerns, is

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initiated by these problems (DeGuire *et al.* 2019; Mills *et al.* 2020). It affects millions of people with a prevalence of more than 60% and the greatest incidence among older adults aged more than 60 (Chow *et al.* 2013).

Even though prehypertension is not considered a disease, this condition affects most of all adults worldwide and predicates those who tend to be stage 1 and 2 HT. Prehypertension is defined as office SBP values 120–139 mmHg or DBP values 80–89 mmHg (James *et al.* 2014). However, prehypertension was also recognized to be associated with excessive cardiovascular risk factors – including coronary atherosclerosis, carotid/brachial intima-media thickness, and presence of the other inflammatory markers due to subclinical atherosclerosis (Chia 2008). Tomiyama *et al.* (2011) underlined that the persistence of prehypertension was related to accelerated structural stiffening of the large to middle-sized arteries and increased in a linear manner along with increasing age, likewise HT. The prevalence of prehypertension among middle-aged and elderly subjects is high, and the 5-yr evolutionary incidences of HT were higher in middle-aged (Liu *et al.* 2010). Nevertheless, the interaction between prehypertension and aging that is associated with age-related arterial stiffness is still lacking nowadays.

Although the absolute cardiovascular disease events associated with prehypertension are commonly not serious signs or symptoms at this BP level, the morbidity, mortality, and healthcare costs are substantial around the world (James *et al.* 2014). Preventing these problems and complications since their BP is still in the prehypertension stage may be reasonable, accordingly.

Sarcopenia is well-described as the degenerative loss of skeletal muscle mass in older adults. Especially in lower limbs, fast-twitch fibers show more degeneration, denervation, and atrophy than slow-twitch fibers (Anton *et al.* 2015). Skeletal muscle function was the important factor that affected strength, balance, and QOL, thus losing lower limbs' muscle mass beyond a critical threshold may result in a decline of muscle strength and maximal power output (Janssen *et al.* 2002; Correa *et al.* 2012; Ding *et al.* 2016).

The updated JNC-8 guideline suggested that prehypertensive adults should adjust their physical inactivity lifestyle first (Aronow 2015). Aerobic exercise can produce positive effects on SBP, DBP, and cardiac autonomic function (Cao *et al.* 2019; da Silva *et al.* 2018). Nevertheless, the controversial results of resistance training alone in the terms of lowering BP and damage to arterial walls are still reported (Eckel *et al.* 2014).

Stretch-shortening cycle (SSC) is an important mechanism of functional everyday tasks such as rising from a chair, using stairs, and stepping ability. This cycle of movement is generated by high-intensity eccentric muscle actions, which result in the accumulation of an elastic energy force producing powerful concentric muscle actions subsequently (Moran *et al.* 2018; Nicol *et al.* 2006; Markovic 2007). Jumping exercise, one of the lower body exercises (plyometric training), which can enhance the efficiency of skeletal muscle exerts SSC movement (Fleck and Kraemer 2014; Ramirez-Campillo *et al.* 2018). Previous studies have found that high and less-impact plyometric training similarly have also increased both muscle strength and muscle power. Nevertheless, postural sway and static balance performance were only slightly enhanced (Allison *et al.* 2018; Sáez de Villarreal *et al.* 2010).

To mitigate high BP and improve functional impairment in middle-aged adults with prehypertension. An appropriate type of exercise for these individuals should be the modified aerobic exercise combined with less impact jumping training, accordingly. To produce greater benefit and to be acceptable as the previous studies mentioned, a bilateral intervention that included less impact hop on both legs and multidirectional skipping should have been created (Allison *et al.* 2018; Sáez de Villarreal *et al.* 2010). Unfortunately, the impact of COVID-19 was more severe than expected; the jumping exercise in this study was designed as a home-based exercise, subsequently.

The present study was designed to confirm the effects of less-impact plyometric training on muscle strength and muscle power. However, the researcher looked at dynamic balance performance instead of postural sway and static balance performance because it was more closely related to daily routine activity than the previous studies.

This is the first study of jumping exercises that we altered from the existing interventions in older adults that should be suitable for middle-aged individuals with prehypertension to be the DJE training. Thus, the objective of this study is to investigate the effects of the DJE on vascular function, physical performance was defined as muscle strength measured by FTSST and dynamic balance performance measured by TUGT, and also the QOL in middle-aged adults with prehypertension.

MATERIAL AND METHODS

Study Design and Participants

This research was a single-blinded randomized controlled trial design. The resting SBP was selected as the primary outcome in this study. The study of Prasertsri *et al*. (2019) investigated the effects of arm swing exercise on cardiac autonomic modulations and other variables in people aged

60–80 yr with prehypertension. The findings of this study show that their intervention can decrease resting SBP by 10.35 mmHg, accordingly. Sample size calculation was followed by the particular formula and when considering a 30% dropout, the number of subjects in this study will be equal to 15 subjects per group. Finally, a total of 30 subjects were enrolled in the study.

Both male (11) and female (19) aged 45–60 yr with prehypertension were recruited from Banphai and Nai Mueang districts of Khon Kaen province, northeastern Thailand from March–July 2021. Their blood pressure levels were proven by taking the same measurement time at home on 2 visits, 1 wk apart. After that, the subjects were asked to undergo routine medical examinations in which medical history by completing a health questionnaire, anthropometric measurements, and vital signs. The inclusion criteria were as follows: [1] a sedentary person who conducted moderate-intensity physical activities < 150 min or vigorous intensity physical activities < 60 min during the 7 days before completing the Thai version of the short-format International Physical Activity Questionnaire, [2] without currently taking antihypertensive medication, [3] no history of physical exercises in the past 3 mo, [4] without abnormal sensation, proprioception, and [5] no smoking and no consuming alcohol. The participants were excluded if they had: [1] diabetes mellitus, thyroid disease, or heart disease; [2] lower extremity reconstructive surgery in the past 2 yr, [3] medical or orthopedic problems that affected their participation and performance, and [4] any vestibular impairments. All subjects were informed verbally and in writing about the experimental protocols and possible risks involved before obtaining their consent to participate in this study. This study was approved by the Khon Kaen University Ethics Committee for Human Research based on the declaration of Helsinki and the Good Clinical Practice Guidelines (HE642001).

Procedures

The eligible subjects were equally randomized into the CG and EX groups by the computer-generated table of random numbers. The CG was asked to maintain their daily routines such as housework, cooking, and employment without any additional aerobic exercise. Moreover, they were instructed about the other lifestyle modifications that consisted of the DASH (dietary approaches to stop hypertension) diet combined with salt and alcohol reduction, weight loss, and walking 30 min/day (or lasting 10 min minimum for each bout), 3–5 d/wk. In addition, the EX was asked to act like the CG but additionally elongated with the DJE program for 8 wk.

The subjects were trained to perform the exercise properly by adjusting their posture, intensity, and volume prior to returning to their home. All subjects have self-reporting for recording their exercise schedule. After 1 wk of the intervention, the researcher who is a physiotherapist observed them at their home to prevent potential risks and errors. Although the researcher had followed in the first wk, the researcher still needed to follow up on the 2nd, 4th, and 6th wk to verify that they were still exercising properly or having unexpected risks or not. Moreover, the researcher used a mobile application called “LINE” to stay connected with the subjects during the pandemic instead of the researcher being unable to supervise them at home. If any subjects were injured after performing the DJE training, they would be first aided with physical therapy first and compensated for health care costs. The subjects who could not complete the intervention were asked to stop the experiment and recorded any adverse events. All outcomes were evaluated before and after the intervention.

Dynamic Jumping Exercise (DJE)

DJE is the name of hopping training that consisted of two parts. The first was hopping to the specific points, and the second was marching in place after each set of the first part. This intervention was designed as a home-based exercise program at a frequency of 50 min/d, 3 d/wk (every other day). The total 50 min were divided into 10 min for stretching (warm-up and cool-down) and 40 min for the moderate intensity DJE training (65–75% of their maximum heart rate, 3–4 scores of Borg category ratio, or can talk in a full sentence). This jumping training requires a square space (120 x 120 cm^2) that can be divided into a nine-square-table. The jumping points were as follows: tables 2, 4, and 6 as the landing points and table 8 as the initiation point (Figure 1). The jumping processes were divided into four directions in one round as follows: [1] hopping from table 8 to 6 (anterolateral direction), [2]

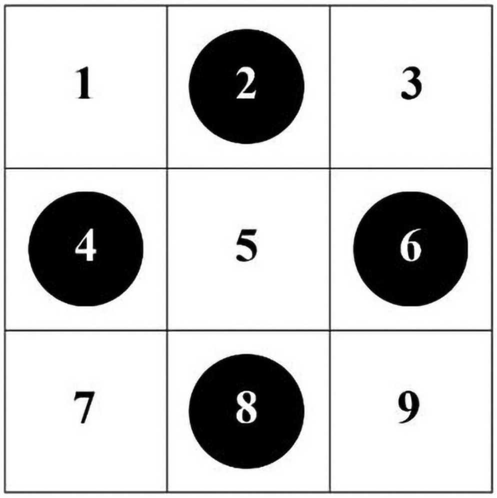

Figure 1. The jumping points.

hopping from table 6 to 2 (anteromedial direction), [3] hopping from table 2 to 4 (posterolateral direction), and [4] hopping back to the initiation point (posteromedial direction) (Figure 2). The DJE program progressively increased in intensity every 2 wk by increasing the number of times and sets until it reached 60 rounds/set, 5 sets/d (Table 5). Then, the subjects were asked to march in place after each set for the relaxation period for 1 min before hopping to the next round.

Measurements

The subjects' characteristics – including gender, height, weight, body mass index (BMI), and % body fat – were measured as anthropometric measurements. An automatic sphygmomanometer (Omron HEM-7120) was used with standard protocol for measuring their BP levels (Williams *et al.* 2018). Arterial stiffness measurement was measured by a non-invasive automatic device (SphygmoCor XCEL) using the oscillometric method. Pulse wave velocity was assessed by a carotid tonometer together with a leg cuff. Using the direct method, measure distances from the carotid and the femoral pulse to the top of the center edge of the leg cuff.

This study has measured two functional performance tests. TUGT was chosen first, then followed by FTSST. The order of the test was sorted according to the fatigue caused by the test. Both TUGT and FTSST were measured using the standard protocol detailed in previously published articles (Kear *et al.* 2017; Melo *et al.* 2019).

The WHOQOL-BRIEF-THAI (World Health Organization Quality of Life Brief Thai version) questionnaire was used in this study. This questionnaire consisted of 26 questions (23 positive questions and 3 negative questions) that were divided into four domains: physical domain, psychological domain, social relationships, and environment. Each item was scored from 1–5 in order of their satisfaction.

Statistical Analysis

The statistical analysis was operated by STATA/IC Statistics 10.1 for Windows. All data were expressed as mean ± standard deviation. The Shapiro-Wilk test was applied to verify the normal distribution of the received data. The paired t-test was applied to compare the differences in each parameter within the group before and after receiving interventions. The independent t-test

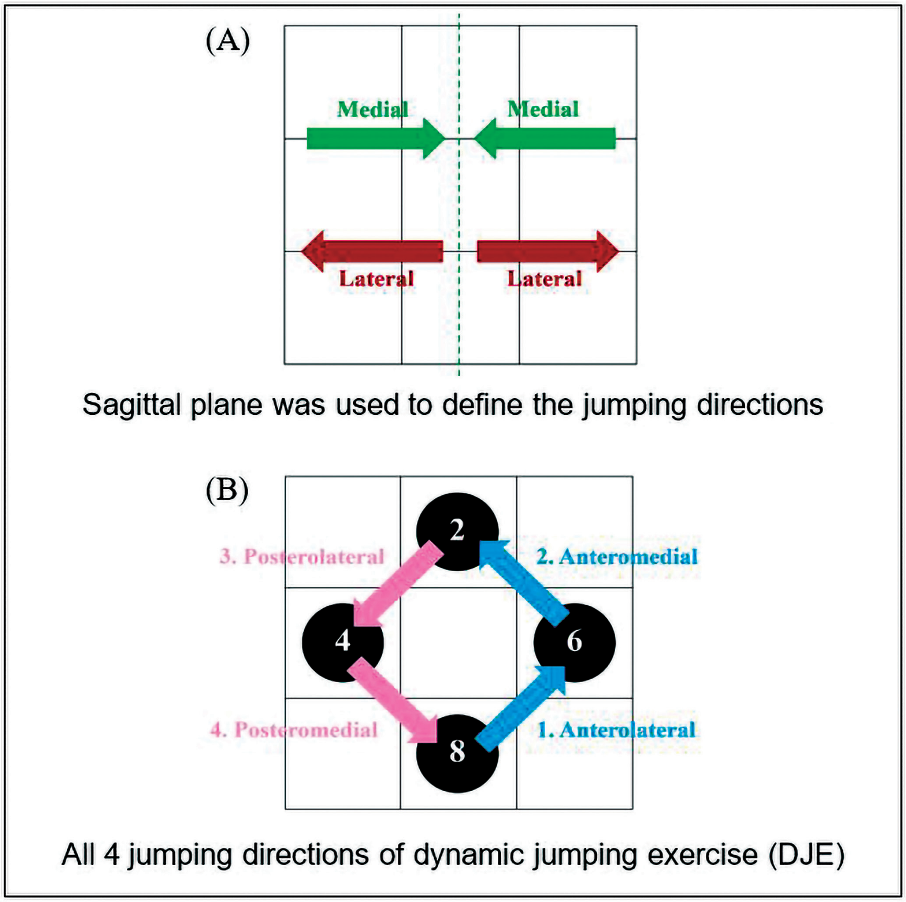

Figure 2. The jumping directions.

Table 5. Guideline for increasing the intensity of dynamic jumping exercise.

Week	Times	Sets	Total (times/d)
1st–2nd	30	5	150
3rd–4th	40	5	200
5th–6th	50	5	250
7th–8th	60	5	300

was applied to compare the differences in each outcome between groups. The value of p-value < 0.05 was considered a significant level.

RESULTS

Subjects

A total of 30 subjects have enrolled in this study. They were equally randomized into the EX (5 males and 10 females) and the CG (6 men and 9 females). After the 8-wk follow-up period, none of the subjects left the study (Figure 3). The mean age values of EX and CG were 53.00 ± 4.54 and 52.60 ± 4.66 yr. The BMIs of the subjects were 24.28 ± 2.95 kg/m^2 for the EX and 25.07 ± 3.78 for the CG. The % body fat were 30.41 ± 8.97 and 30.65 ± 8.71 for the EX and CG, respectively.

Baseline Characteristics

There were no significant differences between the EX and the CG in terms of age, gender, height, weight, BMI, and % body fat ($p > 0.05$; Table 1).

After the intervention, the values of weight, BMI, and % body fat recorded no changes in both EX and CG. Moreover, there were no significant differences in the EX as compared with the CG (Table 2).

Blood Pressure and Heart Rate

SBP and DBP were significantly reduced ($p < 0.001$) in the EX following the 8-wk intervention. However, DBP reduced modestly ($p = 0.07$) in the CG. The results showed significantly lower SBP and DBP ($p < 0.001$ and $p < 0.05$) in the EX as compared with the CG (Table 3).

On the other hand, HR showed a modest reduction ($p = 0.06$) in the EX after the intervention. However, the results showed significantly lower HR ($p < 0.05$) in the EX as compared with the CG (Table 3).

Arterial Stiffness

The cfPWV values were significantly reduced ($p < 0.001$) in the EX following 8 wk. However, the results showed only modestly lower cfPWV ($p = 0.06$) in comparison to the CG (Table 3).

Physical Performances

TUGT showed modestly improved ($p = 0.07$) in the EX following the 8-wk intervention period. On the other hand, the CG showed a modest decrease ($p = 0.09$). The results showed significant differences ($p < 0.05$) in the EX as compared with the CG (Table 3).

Table 1. Baseline data of the participant characteristics.

Data/group	EX (n = 15)	CG (n = 15)	*p*-value
Age, y	53.00 ± 4.54	52.60 ± 4.66	0.49
Gender, M/F	5/10	6/9	0.79
Height, m	1.59 ± 0.08	1.57 ± 0.07	0.32
Weight, kg	61.05 ± 7.00	61.94 ± 10.74	0.98
BMI, kg/m^2	24.28 ± 2.95	25.07 ± 3.78	0.27
Body fat, %	30.41 ± 8.97	30.65 ± 8.71	0.42
HR, bpm	73.47 ± 6.41	76.87 ± 8.71	0.16
SBP, mmHg	128.27 ± 5.80	128.87 ± 6.21	0.06
DBP, mmHg	75.93 ± 5.23	76.73 ± 7.13	0.77
cfPWV, m/s	7.54 ± 0.55	7.78 ± 1.29	0.12

Data are expressed as mean ± standard deviation
[EX] exercise group; [CG] control group; [BMI] body mass index; [HR] heart rate; [SBP] systolic blood pressure; [DBP] diastolic blood pressure; [cfPWV] carotid-femoral pulse wave velocity; [m] meter; [kg] kilogram; [bpm] beats per minute; [mmHg] millimeter mercury; [s] second

Table 2. Changes in weight, BMI, and % body fat before and after the 8-wk intervention period.

Data/group	EX (n = 15)		CG (n = 15)	
	Before	After	Before	After
Weight, kg	61.05 ± 7.00	60.57 ± 6.65	61.94 ± 10.74	62.08 ± 10.22
BMI, kg/m^2	24.28 ± 2.95	24.09 ± 2.85	25.07 ± 3.78	25.15 ± 3.65
Body fat, %	30.41 ± 8.97	30.21 ± 9.30	30.65 ± 8.71	30.67 ± 8.83

Data are expressed as mean ± standard deviation
[EX] exercise group; [CG] control group; [BMI] body mass index; [kg] kilogram; [m] meter

Table 3. Changes in vascular function and physical performance before and after the 8-wk intervention period**.**

Data/group	**EX (n = 15)**		**CG (n = 15)**	
	Before	After	Before	After
HR, bpm	73.47 ± 6.41	70.93 ± 7.27[d]	76.87 ± 8.71	77.13 ± 8.68
SBP, mmHg	128.27 ± 5.80	118.33 ± 6.52[c,f]	128.87 ± 6.21	128.07 ± 6.94
DBP, mmHg	75.93 ± 5.23	70.33 ± 4.30[c,d]	76.73 ± 7.13	75.27 ± 6.13
cfPWV, m/s	7.54 ± 0.55	7.07 ± 0.63[c]	7.78 ± 1.29	7.79 ± 1.28
TUGT, s	7.57 ± 0.73	7.27 ± 0.98[d]	7.73 ± 0.75	7.99 ± 0.96
FTSST, s	8.99 ± 0.80	7.76 ± 0.85[c,f]	9.93 ± 1.78	9.80 ± 1.73

Data are expressed as mean ± standard deviation
[EX] exercise group; [CG] control group; [HR] heart rate; [SBP] systolic blood pressure; [DBP] diastolic blood pressure; [cfPWV] carotid-femoral pulse wave velocity; [TUGT] timed up and go test; [FTSST] five times sit to stand test; [bpm] beats per minute; [mmHg] millimeter mercury; [m] meter; [s] second
[a, b, c] Significantly different from prior to intervention ($p < 0.05$, $p< 0.01$, and $p < 0.001$, respectively)
[d, e, f] Significantly different from control group ($p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively)

Table 4. Changes in quality of life before and after the 8-wk intervention period.

Data/group	**EX (n = 15)**		**CG (n = 15)**	
	Before	After	Before	After
Physical	26.87 ± 3.16	27.93 ± 2.96	26.93 ± 2.84	26.20 ± 3.19
Psychological	24.07 ± 2.58	23.87 ± 2.45	23.93 ± 2.69	22.87 ± 1.51
Social	11.07 ± 2.15	11.07 ± 1.83	11.00 ± 2.24	10.80 ± 1.93
Environment	29.00 ± 3.51	28.67 ± 2.77	28.33 ± 3.52	26.73 ± 2.94[a]
Overall	98.47 ± 10.03	99.07 ± 8.70	97.40 ± 9.58	92.93 ± 8.41

Data are expressed as mean ± standard deviation
[EX] exercise group; [CG] control group
[a] Significantly different from prior to intervention ($p < 0.05$)

With regard to FTSST, there was significantly improved ($p < 0.001$) in the EX following the 8-wk intervention. The results showed significant differences ($p < 0.001$) in the EX as compared with the CG (Table 3).

Quality of Life

After the intervention, the physical, psychosocial, and social relationships domains were no changes in both the EX and CG. There were no significant differences in the EX as compared with the CG (Table 4).

On the other hand, the environment showed a significant decrease ($p < 0.05$) in the CG following the 8-wk intervention. The overall QOL showed a modest decrease ($p = 0.07$) in the CG after the intervention. The results showed only modestly lower scores in the environment and overall QOL ($p = 0.07$ and $p = 0.06$, respectively) in comparison to the EX (Table 4).

DISCUSSION

Importantly, three notable results were found in this study. First, the EX became normotensive after the 8-wk intervention without any change in body mass, BMI, and % body fat. Second, the EX had better cardiovascular function and physical performance than the CG. Third, the CG had lower QOL when compared with the EX.

DJE program reduced resting SBP by 9.93 mmHg. The SBP lowering effect of DJE was significantly different ($p < 0.001$) when compared with the CG by 9.73 mmHg. A decrease in SBP 10 mmHg reduces the risk of developing cardiovascular disease by 20%, coronary artery disease by 17%, heart failure by 28%, stroke by 27%, and overall mortality by 13% (Ettehad *et al.* 2016).

Compared to a recent meta-analysis of moderate-intensity aerobic exercise in healthy East Asians, a short period (8 wk) of the DJE program showed similar results in SBP reduction with 10–24 wk other forms and more effective than the other 8-wk aerobic exercises (Igarashi *et al.* 2018). The reason for these results is based on the previous meta-analysis of Carpio-Rivera *et al.* (2016). First, they said that incremental aerobic exercise had better reduced SBP than constant intensity. This is consistent with the type of DJE program, which gradually increases intensity every 2 wk. Therefore, the systemic adaptation of the arterial walls in these individuals has been greater than the static aerobic exercise of the previous studies. Next, the DJE program was designed as a modified aerobic exercise. Thus, this may improve the functional vasodilation ability by increasing nitric oxide (NO) and decreasing the presence of endothelin-1 (ET-1) (Pedralli *et al.* 2020; Boeno *et al.* 2020). Interestingly, the special characteristic of DJE was rhythmically pumping effects from SSC that occurred every time hopping. The mechanical effect of muscle contraction has evoked both rapid and prolonged increases in blood flow, causing vasodilation and also augmenting perfusion pressure in skeletal muscles (Joyner and Wilkins 2007). Moreover, less impact hopping also contributed to improving endothelial function as a result of avoiding concentric failure and exaggerating BP, which is different from traditional resistance training (Boeno *et al*. 2020).

In the same manner, the DJE program reduced DBP by 5.6 mmHg after the 8-wk intervention and significantly lower ($p < 0.05$) than the CG by 4.93 mmHg. The reduction of DBP in this study was quite different from the previous studies that spent the same amount of time exercising (Miyaki *et al.* 2012; Sugawara *et al.* 2012; Uchikawa *et al.* 2012). Most of the traditional aerobic exercise forms (walking and bicycle ergometer) did not have the rhythmically pumping effects from SSC; likewise, the DJE increased the venous effluent expelled (Joyner and Wilkins 2007). Moreover, the increase in functional vasodilation may directly decrease systemic vascular resistance, thereby making the residual blood in the proximal aorta more easily flow into the heart. In addition, the participants in this study were middle-aged with prehypertension. Thus, vascular adaptation caused by aerobic training was still more effective than in the elderly with hypertension (Collier *et al.* 2008).

Although the DBP-lowering effect of the DJE program significantly differed from the CG at $p < 0.05$, it was lower than the SBP ($p < 0.001$). This may be due to the definition of prehypertension by JNC-8 that "or" was used (James *et al.* 2014), and the researcher found that most of the participants (18 out of 30) had only SBP as high as the reference, whereas DBP was in the normal range.

The previous meta-analysis said that the reduction of HR caused by improving cardiac contractility as a result of increasing stroke volume (SV) without changes in cardiac output was the benefit of aerobic exercise (Saco-Ledo *et al.* 2020). On the other hand, the reduction of HR in the EX did not reach a significant level ($p = 0.06$). This may be because the exercise pattern was incremental or the participants in this study already reached a high level of cardiac performance (ceiling effect). However, the HR-lowering effect of DJE was significantly different ($p < 0.05$) from the CG. The previous study underlined that aerobic exercise had been causing ejection fraction improvement (Pedralli *et al.* 2020). Thus, the DJE program was more effective to improve ejection fraction and SV than operated life modification alone in middle-aged adults with prehypertension.

The cfPWV was a gold standard indicator of arterial stiffness (Mikael *et al.* 2017). The higher PWV showed higher arterial stiffness from lower vessel distensibility and compliance (Pereira *et al.* 2015). A cfPWV > 10 m/s was considered as an estimated reference value of the significant alteration in aortic function in middle-aged with hypertension (Banegas and Townsend 2020). After the 8-wk intervention, the EX had a significantly lower cfPWV by 0.47s or about 6.23%. The reduction of cfPWV was consistent with a previous study that determined the impact of both moderate-intensity exercises on arterial stiffness in prehypertensive and HT (Collier *et al.* 2008). The results showed that aerobic exercise (treadmill training) reduced cfPWV by 9.5%, but resistance training increased cfPWV by 14.5%. The reduction of cfPWV in this study was less than 9.5%; this may be related to the characteristics of DJE training as an aerobic exercise, both as less impact jumping training and resistance training. Although the EX actually had significantly decreased cfPWV ($p < 0.001$), the cfPWV lowering effect of the DJE program did not reach a significant level ($p = 0.06$) when compared to the CG. The researcher extrapolated that the DJE session was insufficient to make a significant difference in lifestyle modification. However, arterial stiffness was still directly related to the inflammatory response (Boeno *et al.* 2020). The DJE program might be contributing to the prevention of end-organ damage, and the results of this study can be used as evidence to support the anti-inflammatory effect of aerobic exercise, consequently.

To the best of our knowledge, the effects on vascular function as mentioned above have shown that the DJE program can be considered a suitable nonpharmacological intervention for middle-aged adults with prehypertension in this study when operating it together with lifestyle modification.

The researcher hypothesized that applying the benefits of the SSC may only maintain muscle mass, especially in the legs. However, the results showed that the time taken by the EX to complete FTSST was significantly reduced by 1.24 s and significantly different ($p < 0.001$) when compared with the CG by 2.04 s. This result differed from the previous study that used the same amount of time to perform aerobic exercise. They found that there was no significant improvement in FTSST after an 8-wk modified stepping exercise (Janyacharoen *et al.* 2017). The different results were probably due to the additive effect of SSC. First, SSC is the cycle of movement that generated powerful concentric contraction by an accumulating of elastic energy from eccentric contraction. Second, SSC occurred by the extensors group of the main leg (hip, knee, and ankle extensors), which bounce up against the body weight. Therefore, in each round having a total of four directions, SSC occurred two times in each leg while bouncing up. Third, there was no need to rely on the deceleration phase during concentric contraction likewise the previous intervention. And another reason was the participants in the previous study were elderly with an average age of 69 yr. Fast-twitch fibers in the elderly show more degeneration, denervation, and atrophy than in middle-aged due to sarcopenia (Anton *et al.* 2015). Therefore, these were the reason why changes in FTSST were more pronounced than in the previous study.

Another outcome that showed the ability of dynamic balance performance was the time the participants had spent on the TUGT. The researcher supposed that if their leg muscle strength improves, the time taken to complete TUGT should be reduced. Nevertheless, the EX has only modestly improved ($p = 0.07$). The result was inconsistent with the researcher's hypothesis, consequently. First, the DJE training pattern may challenge their ability only in the beginning. Second, each square was 40 x 40 cm^2, resulting in a distance of 56 cm for each time hopping may not be enough to challenge their performance. On the other hand, it might be necessary to reduce the size of each square to a smaller size. Because the smaller base of support, the more challenged (Nam *et al.* 2017). Third, more than 8 wk of DJE training was required for improving the TUGT to reach a significant level. Lastly, dynamic balance performance was the skill-related fitness component that required more complex motor skills than improving muscle strength (Deborah *et al.* 2018). The researcher suggested that further studies interested in DJE training and dynamic balance performance should increase the exercise duration, record a result every week to see the changing trends, and try to increase or decrease the square size to see how the result changes. On the contrary, the time taken by the CG to complete TUGT was longer and closer to the significant level ($p = 0.09$). The reduction in TUGT time in the EX was significantly different ($p < 0.05$) when compared with the CG by 0.72 s. In other words, the CG has a lower dynamic balance performance just after 8 wk. Importantly, this was a rather dangerous signal because the CG had been instructed about lifestyle modification already. Although one of these recommendations was walking for 30 min/d, this may not be sufficient to maintain their dynamic balance performance in this COVID-19 epidemic situation.

Continually, the CG – which received only lifestyle modification – showed a significantly decreased in the environmental domain by 1.60 scores after the 8-wk program. The decrease in this domain and overall QOL scores were close to the significant level ($p = 0.07$ and $p = 0.06$, respectively) when compared with the EX. The results of this study were inconsistent with the previous studies at all (Janyacharoen *et al.* 2017, 2018). The researcher has supposed that this may be due to external factors, as the questions about this domain were related to their safety, finances, environment, and transportation – which were greatly affected by the COVID-19 epidemic situation. Or it could be inferred that the DJE program may help to maintain quality of life in this situation, consequently.

There were some limitations to this study. First, the regulation of sedentary controls may be unethical because individuals with prehypertension associated with excessive cardiovascular risk factors would not be treated. Second, using 24-hr ambulatory blood pressure (ABP) was correlated with cardiovascular risk factors more closely than the office BP (Dolan *et al.* 2005). However, clinically significant improvements in the main outcomes were demonstrated. Third, another limitation was the lack of maximal exercise measuring to elucidate how long the training effect lasts. Finally, the researcher collected the data amid the COVID-19 epidemic situation. Therefore, if this epidemic diminishes, the results of further studies may be varied from now on.

CONCLUSION

The DJE program was designed to fulfill the missing requirements of middle-aged with prehypertension, whether the degenerative loss in skeletal muscle mass in lower limbs or high BP. Pleasurable, the DJE program can improve their vascular function by reducing BP and arterial stiffness. In addition, it also improves physical performance by increasing lower limbs muscle strength and dynamic balance performance. Importantly, these changes have been different from the traditional aerobic exercise due to the rhythmical SSC that occurred every time hopping. However, the reduction in both FTSST and TUGT did not reach the minimal clinically important differences (Meretta *et al.* 2006; Gautschi *et al.* 2017). Lastly, the researcher has not focused on assessing how gender differences and has not conducted about direct anti-inflammatory effects. Using the DJE program in the other groups such as the middle-aged with hypertension and different genders in conjunction with dietary control required further studies to investigate how the results change.

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STATEMENT ON CONFLICT OF INTEREST

The researchers certify that there is no conflict of interest with any financial organization regarding the material discussed in this manuscript.

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