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Original Article

# Evaluating the seasonal variations in the circulatory dynamics of community-dwelling older people while exercising outdoors in the early morning

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**Abstract.** [Purpose] We aimed to evaluate the risk to clarify the seasonal variations in the circulatory dynamics of community-dwelling older people performing early morning outdoor exercises. [Participants and Methods] This study included 76 community-dwelling older adults (42 men, mean age: 76.9 ± 5.0 years; 34 women, mean age: 74.0 ± 4.2 years) who perform early morning exercises. The prevalence of hypertension among these adults was assessed, and their blood pressure and pulse rate were obtained before and after performing a 30-minute exercise using automatic and aneroid type sphygmomanometers while sitting on a chair. Further, we calculated the double product by multiplying systolic blood pressure and pulse rate. We analyzed the changes in the pre- and post-exercise systolic blood pressure, diastolic blood pressure, pulse rate, double product, diagnosis of hypertension, and seasonal factors (moderate-temperature season/low-temperature season). [Results] Thirty-five participants were assigned in the hypertension diagnosis group, while 40 participants were in the non-hypertension group. There was no significant difference in the mean age between the two groups. The main effects and interactions were not confirmed in relation to systolic blood pressure, diastolic blood pressure, pulse rate, and double product. [Conclusion] Essentially, blood pressure should be obtained before exercise, as individuals with hypertension are more likely to have an increase in baseline systolic blood pressure while exercising in the early morning during the low-temperature seasons.
**Key words:** Seasonal variation, Circulatory dynamics, Community-dwelling older people

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## INTRODUCTION

According to the 2017 Annual Report on the Ageing Society, Japan's population is aging at a rate of 27.6% as of October 1, 2016, and this rate is expected to increase to 38.1% by 2060[1)]. The proportion of elderly people who are authorized to receive primary nursing care and require support is only 17.9%, while the so-called healthy elderly people who are not certified for primary nursing care or requiring support constitute 82.1% of the entire elderly population[2)]. The 2016 National Health and Nutrition Survey reported that 46.5% of men and 38.0% of women aged 65 years and older exercise habitually[3)]; these rates are higher than those for other generations.

Radio calisthenics is a form of exercise that is commonly performed by majority of Japanese people. Radio calisthenics was introduced in Japan after the end of World War II, and these exercises were established as a method of promoting health, which anyone could perform anywhere at any time. Approximately 20% of middle-aged to elderly people have continu-

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ously performed radio calisthenics in Japan[4]. Radio calisthenics is implemented in 76.4% of elementary schools throughout Japan[5], indicating quite a high dissemination rate. The recognition rate of radio calisthenics in elderly residential facilities is high, with 99.6% of residents recognizing radio calisthenics No.1 and 87.2% recognizing radio calisthenics No. 2[6]; it was estimated that a large number of older people perform radio calisthenics.

On the contrary, blood pressure fluctuation is listed as a cardiovascular-related risk of early morning exercise. Generally, blood pressure normally follows the circadian rhythm, with peaks at lunchtime, and decreases in the evening[7]. In contrast, the incidence of cerebral infarction, myocardial infarction, etc., is particularly high during the morning, which is said to be affected by the increase in blood pressure in the early morning (morning surge)[8]. Advanced age is said to be a potentiating factor of the morning surge[9]; hence, early morning exercise increases the risk for changes in the circulatory dynamics of older people.

Air temperature was found to be associated with blood pressure. That is, a 1 °C drop in air temperature increases the blood pressure during sleep by 0.44 mmHg, which results in an increase in blood pressure (0.52 mmHg) immediately before getting out of bed[10], and a 1 °C drop in indoor temperature is related to a 0.38 mmHg blood pressure elevation. A meta-analysis has shown that this increase is even greater in people with heart disease[11]. A number of studies have evaluated the relationship between outdoor temperature and blood pressure elevation upon arising from bed[12–14]. However, none of these studies examined the blood pressure fluctuations and seasonal differences when older people exercise early in the morning.

Thus, the present study aimed to evaluate the risk to circulatory dynamics before and after exercise based on a diagnosis of hypertension and seasonal fluctuations, when community-dwelling older people perform outdoor exercises early in the morning.

## PARTICIPANTS AND METHODS

The participants were 76 community-dwelling older people (42 men, mean age: 76.9 ± 5.0 years; 34 women, mean age: 74.0 ± 4.2 years) who belonged to a Radio Calisthenics Group in City A of Kanagawa Prefecture and exercised early in the morning. The participants were asked to perform a 30-minute exercise, incorporating radio calisthenics and light exercise.

The participants were interviewed using a questionnaire and verbal interview, to obtain their baseline information (gender, age, height, weight, etc.) as well as data on current medical conditions, medical history, diagnosis of hypertension, treatment for hypertension (medication), medication status on the day in question, existence of pain, and the location and severity of the pain, which was evaluated using a visual analog scale.

The participants' blood pressure and pulse rate were measured before and after exercise, with the participant in a sitting position, using an automatic sphygmomanometer (OMRON) and a manual aneroid sphygmomanometer. The participants' blood pressure was measured with an automatic sphygmomanometer when the environmental temperature was 10–40 °C, whereas their blood pressure was measured with a manual sphygmomanometer when the temperature fell below the operating range of the automatic sphygmomanometer. Low-temperature season measurements were obtained from early to mid-March 2018 (average temperature; 6.1 ± 1.5 °C), while moderate-temperature season measurements were obtained from mid-September to early October 2018 (average temperature; 20.8 ± 2.9 °C).

Blood pressure measurements were taken twice before exercise and twice after exercise for each participant, and data on systolic blood pressure (SBP), diastolic blood pressure DBP, and pulse were collected. Double product (DP) was adopted as an indicator of cardiac load, calculated by multiplying the systolic blood pressure by the pulse rate. The data for the lower SBP value of each of the two measurements taken before and after exercise were used in the analysis.

The participants were divided into two groups: those who reported that they had been diagnosed with hypertension were included in the hypertension diagnosis group, while those who reported that they have not been diagnosed with hypertension were included in the non-hypertension diagnosis group.

The SBP, DBP, pulse, and DP values obtained before exercise were compared between the two groups (hypertension diagnosis group and non-hypertension diagnosis group) for each measurement season, using paired t-test. Changes in the measurement values before and after exercise in each group were analyzed using paired t-test. And analysis was conducted using repeat measurement of the general linear model, with the SBP, DBP, pulse, and DP values, before and after exercise, as the dependent variables; hypertension diagnosis and seasonal factors (moderate-temperature season, low-temperature season) as the independent variables, and the measurement value of each item at baseline as the moderator variable.

This research was implemented with the approval from the J.F. Oberlin University research ethics committee (approval number: 15013). The participants received a full explanation of the content of the research, both verbally and in writing, and a written consent was obtained.

## RESULTS

The before exercise results for the measurement season and hypertension diagnosis are shown in Table 1. About 35 participants were assigned in the hypertension diagnosis group (75.9 ± 5.0 years) and 40 in the non-hypertension diagnosis group (75.4 ± 4.9 years); there was no significant difference in the mean age between the two groups. There was no significant difference in the SBP, DBP, pulse, and DP between the two groups, irrespective of the season.

**Table 1.** Results of unpaired t-test of the baseline values in the HT diagnosis group and non-HT diagnosis group in each season

| | Low-temperature season | | | Moderate-temperature season | | |
|---|---|---|---|---|---|---|
| | HT diagnosis group (n=35) Mean ± SD | Non-HT diagnosis group (n=40) Mean ± SD | p-value | HT diagnosis group (n=25) Mean ± SD | Non-HT diagnosis group(n=33) Mean ± SD | p-value |
| Mean age (years) | 75.9 ± 4.9 | 75.4 ± 5.0 | 0.67 | 75.9 ± 4.9 | 75.4 ± 5.0 | 0.66 |
| SBP (mmHg) | 141.4 ± 14.8 | 135.1 ± 18.0 | 0.10 | 136.1 ± 11.9 | 137.7 ± 15.6 | 0.67 |
| DBP (mmHg) | 80.9 ± 10.0 | 79.5 ± 10.7 | 0.56 | 81.0 ± 11.8 | 80.8 ± 9.1 | 0.93 |
| Pulse (beats/min) | 67.7 ± 9.9 | 70.5 ± 9.9 | 0.24 | 68.2 ± 10.6 | 67.6 ± 8.3 | 0.56 |
| DP | 9,568.4 ± 1,663.2 | 9,424.3 ± 1,427.7 | 0.69 | 9,319.6 ± 1,871.1 | 9,323.8 ± 1,632.1 | 0.93 |

HT: hypertension; Non-HT: non-hypertension; SBP: systolic blood pressure; DBP: diastolic blood pressure; DP: double product.

**Table 2.** Results of paired t-test of measurement values before and after exercise in the HT diagnosis group and non-HT diagnosis group in each season

| | | Low-temperature season | | | | Moderate-temperature season | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | HT diagnosis group (n=35) Mean ± SD | p-value | Non-HT diagnosis group (n=40) Mean ± SD | p-value | HT diagnosis group (n=25) Mean ± SD | p-value | Non-HT diagnosis group (n=33) Mean ± SD | p-value |
| SBP (mmHg) | Pre | 141.4 ± 14.8 | 0.58 | 135.1 ± 18.0 | 0.28 | 136.1 ± 11.9 | 0.63 | 137.7 ± 15.6 | 0.83 |
| | Post | 142.6 ± 14.8 | | 137.1 ± 20.8 | | 137.0 ± 12.4 | | 137.4 ± 18.0 | |
| DBP (mmHg) | Pre | 80.9 ± 10.0 | 0.30 | 79.5 ± 10.7 | 0.95 | 81.0 ± 11.8 | 0.75 | 80.8 ± 9.1 | 0.79 |
| | Post | 79.5 ± 9.6 | | 79.6 ± 12.1 | | 80.3 ± 8.7 | | 80.3 ± 12.4 | |
| Pulse (beats/ min) | Pre | 67.7 ± 9.9 | 0.67 | 70.5 ± 9.9 | 0.84 | 68.2 ± 10.6 | 0.40 | 67.6 ± 8.3 | 0.10 |
| | Post | 68.2 ± 10.7 | | 70.7 ± 9.7 | | 69.4 ± 12.3 | | 69.6 ± 7.6 | |
| DP | Pre | 9,568.4 ± 1,663.2 | 0.67 | 9,424.3 ± 1,427.7 | 0.25 | 9,319.6 ± 1,871.1 | 0.37 | 9,323.8 ± 1,632.1 | 0.20 |
| | Post | 9,649.5 ± 1,614.3 | | 9,658.3 ± 2,015.3 | | 9,649.5 ± 1,614.3 | | 9,577.7 ± 1,755.2 | |

HT: hypertension; Non-HT: non-hypertension; SBP: systolic blood pressure; DBP: diastolic blood pressure; DP: double product; Pre: before exercise; Post: after exercise.

The before and after exercise results for the measurement season and hypertension diagnosis are shown in Table 2. There was also no significant difference in the SBP, DBP, pulse, and DP values after exercise between the two groups, regardless of the season. The results of the within-subject comparison test using the general linear model (repeat measurements) are shown in Table 3. After adjusting for before exercise values, no significant main effect and interaction were observed in the pre- and post-exercise SBP, DBP, pulse, and DP values; moreover, hypertension diagnosis and measurement season were identified as independent variables.

The percentage of participants with SBP ≥160 mmHg before exercise is shown in Table 4. In low-temperature season, 11.4% (n=4) of the participants were assigned in the hypertension diagnosis group, while 10.0% (n=4) in the non-hypertension diagnosis group; in moderate-temperature season, none (n=0) of the participants were assigned in the hypertension diagnosis group, while 11.8% (n=4) were assigned in the non-hypertension diagnosis group. This finding revealed that a certain number of participants in the non-hypertension diagnosis group had a SBP of ≥160 mmHg before exercise.

## DISCUSSION

The present study aimed to clarify the changes in circulatory dynamics before and after exercise when community-dwelling older people exercise outdoors early in the morning as well as its relationship with hypertension and seasonal changes.

We performed a cross-sectional analysis of pre- and post-exercise measurements obtained in low-temperature season and moderate-temperature season, and results showed no significant difference between the two groups. The participants in the hypertension diagnosis group had been diagnosed with hypertension. They were administered with medications and received other forms of therapy, which was thought to be the reason for the lack of difference in the measurements between the hypertension diagnosis group and non-hypertension diagnosis group. While no statistically significant difference was found in the pre-exercise SBP in low-temperature season, the hypertension diagnosis group had a SBP of 141.4 ± 14.8 mmHg, while the non-hypertension diagnosis group had a SBP of 135.1 ± 18.0 mmHg. This finding demonstrates that the SBP of the hypertension diagnosis group was 5 mmHg higher than that of the non-hypertension diagnosis group. We also confirmed that the pre-exercise SBP in the hypertension diagnosis group was 141.4 ± 14.8 mmHg in low-temperature season, but was 136.1

**Table 3.** Within-subject comparison test using the general linear model (repeat measurements)

1) Systolic blood pressure

| | | Type III sum of squares | Degree of freedom | Mean square | F-value | p-value |
|---|---|---|---|---|---|---|
| HT diagnosis group | Before and after exercise | 371.919 | 1 | 371.919 | 6.703 | 0.012* |
| | Before and after exercise × initial value | 371.402 | 1 | 371.402 | 6.694 | 0.012* |
| | Before and after exercise × measurement season | 20.533 | 1 | 20.533 | 0.37 | 0.545 |
| | Error (before and after exercise) | 3,051.666 | 55 | 55.485 | | |
| Non-HT diagnosis group | Before and after exercise | 9.140 | 1 | 9.140 | 0.17 | 0.682 |
| | Before and after exercise × initial value | 3.881 | 1 | 3.881 | 0.072 | 0.789 |
| | Before and after exercise × measurement season | 36.369 | 1 | 36.369 | 0.675 | 0.414 |
| | Error (before and after exercise) | 3,662.748 | 68 | 53.864 | | |

2) Diastolic blood pressure

| | | Type III sum of squares | Degree of freedom | Mean square | F-value | p-value |
|---|---|---|---|---|---|---|
| HT diagnosis group | Before and after exercise | 617.499 | 1 | 617.499 | 22.197 | <0.001* |
| | Before and after exercise × initial value | 684.767 | 1 | 684.767 | 24.615 | <0.001* |
| | Before and after exercise × measurement season | 4.767 | 1 | 4.767 | 0.171 | 0.681 |
| | Error (before and after exercise) | 1,530.051 | 55 | 27.819 | | |
| Non-HT diagnosis group | Before and after exercise | 23.304 | 1 | 23.304 | 0.689 | 0.410 |
| | Before and after exercise × initial value | 25.182 | 1 | 25.182 | 0.744 | 0.391 |
| | Before and after exercise × measurement season | 17.493 | 1 | 17.493 | 0.517 | 0.475 |
| | Error (before and after exercise) | 2,301.276 | 68 | 33.842 | | |

3) Pulse

| | | Type III sum of squares | Degree of freedom | Mean square | F-value | p-value |
|---|---|---|---|---|---|---|
| HT diagnosis group | Before and after exercise | 53.257 | 1 | 53.257 | 2.286 | 0.136 |
| | Before and after exercise × initial value | 51.726 | 1 | 51.726 | 2.220 | 0.142 |
| | Before and after exercise × measurement season | 5.066 | 1 | 5.066 | 0.217 | 0.643 |
| | Error (before and after exercise) | 1,258.081 | 54 | 23.298 | | |
| Non-HT diagnosis group | Before and after exercise | 272.049 | 1 | 272.049 | 14.037 | <0.001* |
| | Before and after exercise × initial value | 262.015 | 1 | 262.015 | 13.519 | <0.001* |
| | Before and after exercise × measurement season | 7.293 | 1 | 7.293 | 0.376 | 0.542 |
| | Error (before and after exercise) | 1,298.523 | 67 | 19.381 | | |

4) Double product

| | | Type III sum of squares | Degree of freedom | Mean square | F-value | p-value |
|---|---|---|---|---|---|---|
| HT diagnosis group | Before and after exercise | 2,770,617.101 | 1 | 2,770,617.101 | 4.812 | 0.033* |
| | Before and after exercise × initial value | 2,838,348.204 | 1 | 2,838,348.204 | 4.930 | 0.031* |
| | Before and after exercise × measurement season | 229,486.046 | 1 | 229,486.046 | 0.399 | 0.530 |
| | Error (before and after exercise) | 31,092,407.511 | 54 | 575,785.324 | | |
| Non-HT diagnosis group | Before and after exercise | 188,465.681 | 1 | 188,465.681 | 0.253 | 0.617 |
| | Before and after exercise × initial value | 52,615.915 | 1 | 52,615.915 | 0.071 | 0.791 |
| | Before and after exercise × measurement season | 360.338 | 1 | 360.338 | 0.000 | 0.983 |
| | Error (before and after exercise) | 49,966,621.876 | 67 | 745,770.476 | | |

HT: hypertension; Non-HT: non-hypertension; SBP: systolic blood pressure; DBP: diastolic blood pressure; DP: double product.

± 11.9 mmHg in moderate-temperature season. This finding indicates that the hypertension diagnosis group's SBP was 5 mmHg higher in low-temperature season than in moderate-temperature season. The relationship between air temperature and blood pressure fluctuation was described as follows: a 1 °C drop in air temperature increases the blood pressure during sleep by 0.44 mmHg, resulting in a 0.52 mmHg increase in blood pressure immediately before arising from bed[10]. The present study did not find a significant difference, but the results showed a tendency similar to findings of previous studies. It was

**Table 4.** Percentage of participants with pre-exercise systolic blood pressure of ≥160 mmHg

| | Low-temperature season | | Moderate-temperature season | |
|---|---|---|---|---|
| | HT diagnosis group (n=35) | Non-HT diagnosis group (n=40) | HT diagnosis group (n=25) | Non-HT diagnosis group (n=33) |
| 160 mmHg >, Number (%) | 31 (88.6) | 36 (90.0) | 25 (100) | 30 (91.0) |
| 166 mmHg >, Number (%) | 4 (11.4) | 4 (10.0) | 0 (0) | 3 (9.0) |

HT: hypertension; Non-HT: non-hypertension.

presumed that the no significant difference in values may have been attributed to the study's small sample size.

Meanwhile, result of paired t-test showed that there was no significant difference in the changes in SBP, DBP, pulse, and DP before and after exercise in low- and in moderate-temperature season between the hypertension diagnosis group and non-hypertension diagnosis group. And result of repeat measurement of the general linear model was no significant main effect and interaction were observed in the values; moreover, hypertension diagnosis and measurement season were identified as independent variables. This finding is thought to be related to the level of physical activity exerted by the participants while performing the exercise. The exercise performed by the participants consisted of radio calisthenics, the most well-known exercise in Japan, and other light exercises. The level of physical activity exerted during radio calisthenics ranges from 4.0 Mets to 4.5 Mets; it was presumed that the level of physical activity has little effect on circulatory dynamics. While advanced age is a potentiating factor for morning surge[9], blood pressure values are reported to change depending on the level of physical activity, such as lower extremity resistance training with a 1 RM load of 40% and 60% increasing both SBP and DBP[15], while aerobic exercise has been shown to reduce both SBP and DBP[16]. The DP before and after exercise is more affected by physical activity than by air temperature. These findings suggest that even in the early morning, where there is an increased risk of morning surge, exercise with a comparatively low level of physical activity can be safely implemented irrespective of the season or whether the participant is diagnosed with hypertension.

Approximately 11.4% (n=4) of the participants in the hypertension diagnosis group had a pre-exercise SBP of ≥160 mmHg in low-temperature season and none (n=0) in moderate-temperature season. In the non-hypertension diagnosis group, 10.0% (n=4) of the participants had a SBP of ≥160 mmHg in low-temperature season and 11.8% (n=4) in moderate-temperature season. These findings suggest that elevation in SBP is easier to detect as the air temperature falls. Conversely, we confirmed that around 10% of the participants in the non-hypertension diagnosis group had high SBP throughout the year. According to the 2017 National Health and Nutrition Survey, 49% of older people aged 65 years and older had high blood pressure (SBP ≥140 mmHg or DBP ≥90 mmHg, or currently taking antihypertensive agents)[17]. Moreover, reports indicate that 52.6% of people with essential hypertension experience a morning surge[18], and some patients with latent hypertension remained undiagnosed and not managed with medications. Approximately 10% of the population who are not diagnosed with hypertension exhibit symptoms of high blood pressure[19], and the results of the present study support the findings of previous research.

The aforementioned results suggest that exercise with a comparatively low level of physical activity can be safely performed in the early morning, irrespective of the season or whether the participant is diagnosed with hypertension. On the other hand, the results demonstrated that SBP tends to increase in low-temperature season mornings, in community-dwelling older people diagnosed with high blood pressure; therefore, it is preferable if these people performed such exercise after confirming their physical condition, using several approaches, such as measuring their blood pressure before exercise. Furthermore, given that approximately 10% of community-dwelling older people undiagnosed with hypertension presented with high blood pressure symptoms, it is important to check blood pressure regularly before exercise in this population.

## *Conflict of interest*

The authors declare that they have no conflict of interest.

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