Effects of training with hot spring and cognitive movement training machine for middle-aged and elderly persons

Kimiyasu Hayakawa[1] and Kando Kobayashi[2]

[1]Department of Sports and Exercise Nutrition, School of Physical Education, Sendai University, Japan
2-2-18 Funaokaminami, Shibata-machi, Miyagi 989-1693, Japan
[2]Research Center for Total Life Health and Sports Sciences, Graduate School of Frontier Sciences
The University of Tokyo
6-2-1 Kashiwanoha, Kashiwa-city, Chiba, Tokyo 277-0882, Japan

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Abstract

Sixteen men (mean age, 63.7±14.2 y) and 32 women (mean age, 62.2±10.4 y) underwent a 12-wk training program of 2-h training sessions twice a week. The program comprised physical exercises and 8 kinds of machine-based training. Participants were divided into the following 2 groups: Group A, in which water from a hot spring (temperature, 42°C) was applied to various parts of the body 50 times before starting exercises; and Group B, in which it was not. Physical fitness tests and magnetic resonance imaging (MRI) of the psoas major muscle was performed. After training, significant improvements were seen in flexibility, 6-min walk distance, and 10-m obstacle walk time. Cross-sectional area of the psoas major increased by 13.2% in men and 11.5% in women. Group A exhibited significant declines from 150 mmHg to 142 mmHg in systolic blood pressure (BP) and from 83 mmHg to 79 mmHg in diastolic BP. Applying hot spring water prior to exercising appears to have hypotensive effects in individuals who tend to have high BP. Sit-and-reach flexibility test results increased from 29.4 cm to 35.3 cm in men ($p<0.05$) and from 37.1 cm to 41.6 cm in women ($p<0.05$), suggesting that training improved flexibility. Mean number of sit-ups increased from 8.1 to 9.6 in men ($p<0.05$) and 7.0 to 8.7 in women ($p<0.01$). No difference was seen between men and women in mean 10-m walk time, which decreased from 5.0 sec to 4.3 sec in men ($p<0.01$) and from 4.9 sec to 4.4 sec in women ($p<0.01$). Mean 10-m obstacle walk time fell from 7.1 sec to 6.2 sec in men ($p<0.05$) and from 7.4 sec to 6.4 sec in women ($p<0.01$). Six-min walk distance increased from 580.5 m to 654.6 m in men ($p<0.01$) and from 590.3 m to 654.6 m in women ($p<0.01$). Exercising with cognitive motor training machines appears effective for improving quality of life in elderly individuals by strengthening core muscles and improving the quality of motor performance.

1. Purpose

Aerobic exercise and muscular training have been recommended to promote health condition in many people. However, this kind of training is unsuitable for the elderly, particularly in those with poor physical condition and anxiety regarding health[1][2]. Following medical checks carried out before training, individuals with low fitness or health issues have sometimes been turned away from participating in municipal exercise classes because of high risk factors associated with exercising.

Given the increasing aging of society, the greater proportion of older individuals in the population with poor physical condition and anxiety regarding health may represent a serious problem in the near future. New types of physical training thus need to be developed for older individuals in the place of aerobic exercises and conventional weight training.

In the present study, new types of training were implemented in a health promotion class for citizens. The main focus of the new type of training adapted in the present study was to improve “quality of physical motor skills” (QOM) in daily living, such as in walking and some activities of independent daily living[3]. With this training, the workload in terms of cardiovascular function and muscle is small compared with ordinary aerobic training or weight training. The training machines used were called “QOM training machines”, and were designed to be effective in learning motor actions using core muscles of the body.

In the present study, QOM training was undertaken with participants who volunteered to participate in a health promotion class hosted by A City, which is famous throughout Japan for its hot springs (*onsen*). The effects of QOM training and the availability of hot spring water[4] for warming-up prior to exercise were investigated, primarily in terms of locomotive power, blood pressure, and cross-sectional area of core muscles. Usage of hot spring water in physical training was hypothesized to enhance the effect of training from both physiological and psychological perspectives.

2. Methods

This study was conducted with the approval of the ethics committee of the University of Tokyo. Voluntary consent was obtained from all participants prior to enrolment in the study.

2. 1 Participants

Participants in the present study comprised 16 men (mean age, 63.7±14.2 y; range, 59–75 y; mean height, 165.6±7.4 cm; mean body weight (BW), 64.9±9.1 kg) and 32 women (mean age, 62.2±10.4 y; range, 55–73 y; mean height, 155.6±4.8 cm; mean BW, 53.2±7.0 kg). None of the participants were obese.

2. 2 Procedures

Forty-eight individuals residing in A City, Shizuoka Prefecture, underwent 24 physical training sessions, held for 2 h twice a week for 12 wk. Participants were recruited via an advertisement in the municipal newsletter. Interested applicants attended a briefing session and completed a questionnaire on their physical condition, and then received a thorough explanation of the training before providing informed consent.

A health checkup was conducted before each training session of physical exercise and machine-based QOM training.

Participants were randomly assigned to either Group A or Group B. Prior to warming-up exercises, Group A disrobed and applied hot water to various parts of the body a total of 50 times in the *onsen* bathhouse. Group B participants, on the other hand, did not apply hot water. Except for the application of hot water, both groups followed the same training program.

The Japanese custom of repeatedly applying hot water to the body with a pail (known as '*kakeyu*' in Japanese) before entering the bathtub is a way of preparing the body for bathing. The procedure for *kakeyu* is illustrated in Figure. 1. It is recommended to apply hot water to the body with a pail before entering the bathtub to both adapt to the temperature of the hot water and to clean the body. In recent years, the custom of applying hot water has steadily decreased. Other studies have shown effects of showering under hot water before or after training[5], but the present investigation used *kakeyu* to achieve warming-up and other physiological effects. This includes not only heat and pressure stimulation to the skin, but also elements of movement. We therefore guess there are different effects from entering the bathtub. Participants used a pail to apply hot water to the body 25 times with the left hand and 25 times with the right hand while assuming the poses shown in Figure 1. This procedure was set to be similar to hot water showering in terms of effects of warming-up and stimulating the skin.

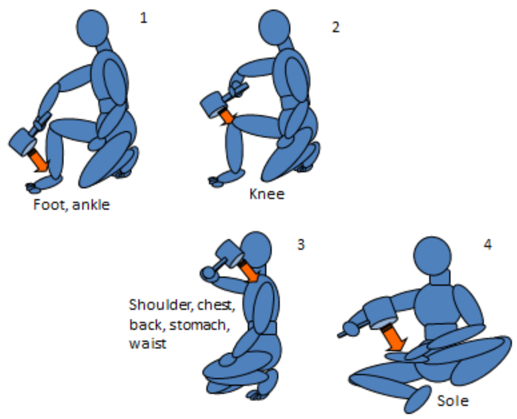

Figure 1: Method of applying hot spring water

After performing *kakeyu*, Group A joined Group B to perform warming-up exercises before entering the machine training room.

Training sessions were conducted in the training room located on the second floor and the *onsen* hot spring located on the third floor of a building managed by the A City Municipal Government.

Training machines newly developed for QOM training were set in the training room, with a total of 10 machines providing 8 kinds of exercise. The kinds of training machine were as follows: 2 sprint training machines; 2 sprint power bikes; 2 standing rowing machines (Fig. 2); 1 treadmill; 1 moving bed machine for body inner muscle training; 1 shoulder stretch machine; and 1 machine for ipsilateral motions of the legs and arms.

Figure 2: Standing row exercise

The training machines used in the present study were intended to exercise core muscles such as the psoas major. Unlike conventional weight-loaded training machines, these electronically weighted machines require the trainee to relax while exercising on a mobile trajectory, without tensing the outer muscles[7][8].

On the first and final training sessions, participants underwent body composition and physical fitness tests and completed a questionnaire regarding changes in physical condition.

Physical fitness test variables measured comprised body height, BW, percentage body fat (%BF), chest, waist, and hip circumference, blood pressure (BP), heart rate, grip strength, 'sit-and-reach' flexibility test, number of sit-ups in 30 sec, 10-m walk time, 10-m obstacle walk time and 6-min walk distance. Stress measurements and hemoglobin (Hb) concentration were also taken using a pupillary reflex measurement device and a noninvasive Hb analyzer (Astrim™; Sysmex, Hyogo, Japan), respectively; a questionnaire on the physical condition of participants was also administered.

Changes in cross-sectional area of the psoas major muscle were measured both before and after training using magnetic resonance imaging (MRI). MRI between the 4th and 5th lumbar vertebrae was performed with the participant in a supine position inside the scanner.

2. 3 Statistical analyses

Measurement results for each parameter are presented as mean ± standard deviation (SD). Paired t-tests were applied to comparisons of mean values for the two groups. Statistical significance was set at $p<0.05$. Excel 2007 software (Microsoft, Japan) was used for statistical analyses.

3. Results

The results of the main training measurement variables are summarized in Table 1.

	Male n=16 Female n=32
Age (years)	Male 63.7 ± 14.2 Female 62.2 ± 10.4
Height (cm)	Male 165.6 ± 7.4 Female 155.6 ± 4.8
Weight (kg)	Male 64.9 ± 9.1 Female 53.2 ± 7.0
Body fat (%)	Male 20.1 ± 4.8 Female 28.7 ± 6.1

Table 1-1: Background characteristics

*:p<.05　**:p<.01

		Weight (kg)		%Fat (%)		Internal organ fat level		BMI		Systolic BP (mmHg)		Diastolic BP (mmHg)		Chest (cm)		Waist (cm)	
		Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.
Male	Mean	64.9	65.9	20.1	21.3	12.2	12.7	23.8	24.2	152.6	155.9	86.1	86.7	95.2	94.8	86.5	88.2
	SD	9.1	9.5	4.8	5.5	4.9	5.0	3.6	3.8	19.5	14.6	8.3	8.4	6.4	7.2	9.5	9.6
	Maximum	75.3	78.1	28.3	30.6	18.0	19.0	29.2	30.0	206.0	182.0	98.0	96.0	105.0	103.0	102.5	107.0
	Minimum	52.3	53.2	11.5	9.5	1.0	1.0	17.1	16.9	133.0	129.0	69.0	69.0	84.5	81.0	71.0	77.0
		**		*		**		*		NS		NS		NS		NS	
Female	Mean	53.2	53.6	28.7	29.8	5.8	6.0	22.0	22.2	145.0	136.1	80.8	74.9	87.1	88.5	75.3	76.0
	SD	7.0	7.0	6.1	5.8	2.1	2.3	2.7	2.9	21.6	21.1	12.8	12.6	6.1	6.1	7.9	7.1
	Maximum	68.3	67.6	41.2	41.9	10.0	11.0	28.5	28.9	202.0	179.0	104.0	100.0	98.0	101.0	89.0	87.0
	Minimum	38.9	38.9	13.6	15.9	1.0	1.0	15.7	15.8	107.0	105.0	54.0	55.0	74.0	77.0	56.0	57.0
		NS		NS		NS		NS		**		**		**		NS	

		Hip (cm)		Grip (Right) (kg)		Grip (Left) (kg)		Sit-and-reach (cm)		Sit-ups (times)		10-m Walk (sec)		10-m Obstacle Walk (sec)		6-min walk (m)	
		Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.	Before T.	After T.
Male	Mean	96.0	97.8	36.8	39.2	35.6	36.6	29.4	35.3	8.1	9.6	5.0	4.3	7.1	6.2	580.5	654.6
	SD	4.8	4.6	2.5	5.2	2.8	5.4	8.8	9.6	3.9	3.8	0.8	0.8	1.5	0.9	100.9	78.9
	Maximum	104.5	105.0	42.9	51.4	41.1	45.1	42.0	48.5	13.0	15.0	6.8	5.8	10.6	8.0	662.0	784.0
	Minimum	88.0	92.5	33.3	32.9	32.8	26.9	12.0	16.5	0.0	1.0	4.3	3.1	5.5	5.3	340.0	512.0
		NS		NS		NS		*		*		**		*		**	
Female	Mean	93.2	94.5	25.3	26.1	23.4	24.4	37.1	41.6	7.0	8.7	4.9	4.4	7.4	6.4	590.3	654.6
	SD	5.1	5.7	4.5	4.4	5.4	4.1	9.7	7.8	2.9	3.7	0.6	0.6	1.1	0.9	45.6	56.0
	Maximum	103.0	105.0	38.0	38.0	35.8	36.9	52.0	53.5	11.0	14.0	6.4	5.6	9.6	8.3	663.0	784.0
	Minimum	83.0	81.5	17.3	19.4	10.0	19.3	12.0	22.5	0.0	0.0	3.7	3.5	6.0	4.9	482.0	573.0
		**		*		NS		**		**		**		**		**	

Table 1-2: Measurements before and after training

Over the 12-wk training period, mean BW varied by 1 kg in men (1.5% increase; $p<0.01$), but was unchanged in women. Mean %BF was 21% in men and 29% in women and mean visceral fat levels and body mass index (BMI) (men, 24; women, 22) did not vary significantly between before and after training. Resting systolic BP (SBP) before and after training was virtually unchanged in men at 153 mmHg and 156 mmHg, but declined in women from 144 mmHg to 136 mmHg ($p<0.01$). Moreover, resting diastolic BP (DBP) was unchanged in men at 86 mmHg and decreased in women from 80.5 mmHg to 75 mmHg ($p<0.01$). Chest and waist circumferences were unchanged; however, hip circumference increased significantly by about 1 cm in both men (96.0→97.8 cm) and women (93.3→94.5 cm). Grip strength was more or less unchanged in both men (36.8→39.2 kg) and women (25.3→26.1 kg).

Sit-and-reach flexibility test results increased from 29.4 cm to 35.3 cm in men ($p<0.05$) and from 37.1 cm to 41.6 cm in women ($p<0.05$), suggesting that training improved flexibility. Mean number of sit-ups increased from 8.1 to 9.6 in men ($p<0.05$) and 7.0 to 8.7 in women ($p<0.01$). The mean 10-m walk time decreased from 5.0 sec to 4.3 sec in men ($p<0.01$) and from 4.9 sec to 4.4 sec in women ($p<0.01$). Mean 10-m obstacle walk time fell from 7.1 sec to 6.2 sec in men ($p<0.05$) and from 7.4 sec to 6.4 sec in women ($p<0.01$). The 6-min walk distance increased from 580.5 m to 654.6 m in men ($p<0.01$) and from 590.3 m to 654.6 m in men ($p<0.01$). Exercising with cognitive motor training machines appears effective for improving quality of life in elderly individuals by strengthening the core muscles and improving the quality of motor performance. Hb concentration was virtually unchanged in both men (14.8→14.2 g/dl) and women (13.8→13.9 g/dl). Cross-sectional area of the psoas major in left increased by 13.2% in men (1,245→1,409 cm^2) and 11.5% in women (802→894 cm^2) (Figs. 3). An example of the assessment sheet given to subjects is shown in Figure 4.

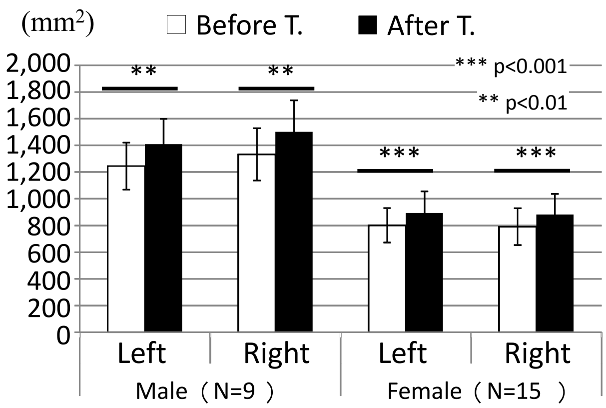

Figure 3: Comparison of cross-sectional area of psoas major muscle (left) before and after training

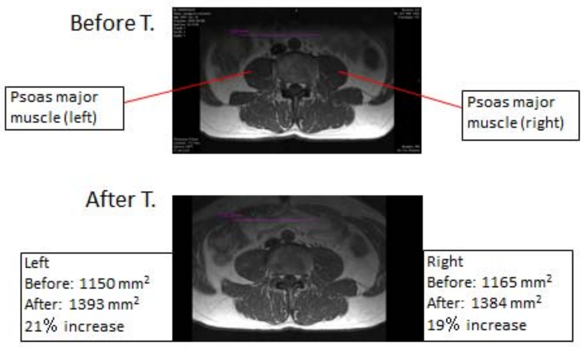

Figure 4: Changes in cross-sectional area of psoas major muscle in a 65-year-old man

The majority of Group A participants who applied hot water prior to exercise reported perceived health benefits, with 39% indicating that the hot water was '*very comfortable*' and 61% stating that it was '*comfortable*', while 32% stated that it was '*very good for health*' and 36% claimed that it was '*good for health*'.

Some differences in BP were observed between groups before and after training. SBP decreased from 150 mmHg to 142 mmHg, and DBP decreased from 83 mmHg to 79 mmHg after training in Group A. In Group B, no changes were observed between before and after training in SBP (143 to 141 mmHg) or DBP (81 to 78 mmHg) (Figs. 5 and 6).

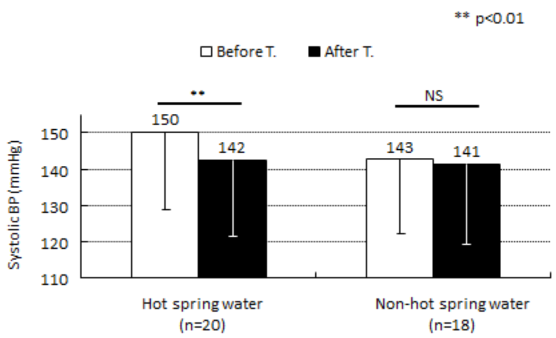

Figure 5: Comparison of changes in SBP before and after training

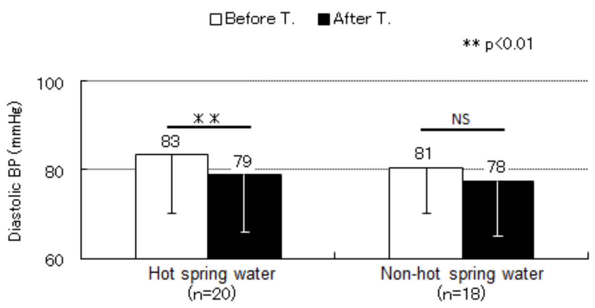

Figure 6: Comparison of changes in DBP before and after training

Most responses to the questionnaire indicated favorable impressions of the exercise training, such as "*It was enjoyable*", "*I could feel the effects*", "*It was difficult at first, but I eventually managed to do it*", and "*I would like to continue in the future*".

4. Discussion

Resistance training, aerobic training, and balance training programs targeting elderly individuals employ a variety of methods. Balance training is often designed to prevent falls among the elderly. Previous reports have described the effects of each of these training modalities[6][7][8].

The efficacy of aerobic exercises and muscle training has also been described in past studies; however, from the perspective of safety, these exercises may not always be suitable for elderly individuals with a low level of physical fitness. Keysor et al.[9] questioned the effects of training programs prescribed for the treatment and prevention of diseases and disabilities, particularly among infirm elderly individuals.

Walking is often promoted as the most suitable form of exercise for the elderly, and is also an exercise that has an aerobic component. Exercise including walking has also been reported to reduce the risk of dementia and inhibit cognitive decline[10].

The resistance training methods used in those studies included rubber tubes, BW, and weight-loaded training machines. The muscle group targeted by this form of training is the outer muscles close to the surface of the body.

Conversely, the training machines used in the present study were intended to exercise core muscles such as the psoas major. Unlike conventional weight-loaded training machines, these electronically weighted machines require the trainee to relax while exercising on a mobile trajectory, without tensing the outer muscles[11][12].

The recent attention focused on the psoas major muscle is based on biomechanical research finding that top international sprinters use their core muscles effectively, and the psoas major is now understood to be closely linked to sports performance[13] (Fig. 9).

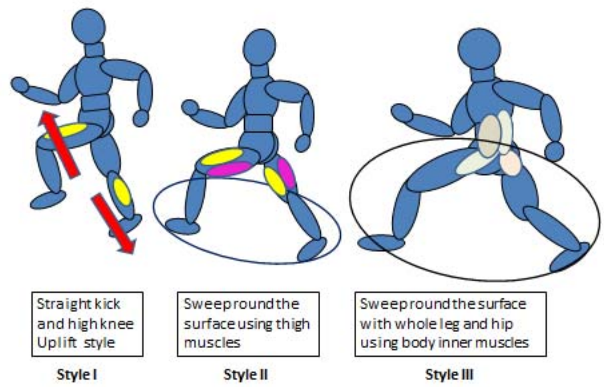

Figure 9: Changes in running technique for top athletes

Measurement of the psoas major in all Japanese Olympians has also shown that this muscle is large in superior athletes. Core training is now a highly regarded sports training technique capable of strengthening the core muscles of the body. This approach is also thought to be effective in preventing bedridden conditions, maintaining posture and improving walking ability in elderly individuals.

While QOM training reportedly strengthens core muscles such as the psoas major, the present results showed that the cross-sectional area of the psoas major increased by 13% in male participants and 12% in female participants. This outcome may have been associated with the improvements in walking ability.

The 8 different types of QOM training machines used in the study mainly involved exercises to stretch the shoulders, back, and knees, as well as moving the pelvis. In the upright rowing exercise (Fig. 3), the participant holds a horizontal handlebar with both hands and transmits force generated by forward and rearward momentum of the trunk to push and pull the handlebar. Shoulder joint stretches were performed to exercise the shoulder muscles, and an “arm/leg ipsilateral machine” was used to stretch the arms, legs, and lower back in the same direction while in a sitting position. On the “bed mobility machine”, participants performed a stretching exercise designed to enhance hip joint flexibility.

In the present study, flexibility as measured by the sit-and-reach test improved. Fatouros et al.[13] pointed out the importance of flexibility for maintaining or improving joint range of motion in the aged. Trunk flexibility is a predictor of back pain, which is strongly associated with aging. The “sprint training machine” used in the present study was developed with the intention of improving motion of the pelvis, which is related to walking and running, using the inner muscles.

Flexibility and balance of pelvis movement are important for creating smooth action on sprint training machines[10]. The machine features elevated foot pedals that move elliptically to raise the knees and lower back above the height of a normal gait position. The power-assisted pedals of the machine allow the trainee to make large stepping motions in time with the back-and-forth motions of the pedals.

The “rotating-axis power bike machine” used in the present study is pedaled in an elliptical direction with the trainee in a standing position, so that the force applied to the pedals allows the trainee to maintain a posture that effectively utilizes BW. The torque generated by pedaling is therefore determined by the assumed posture, and the machine is designed so that no force is required when raising the pedal[12][14].

The main purpose of the treadmill-walking exercise was to learn the “core-stretch walking technique”, which effectively utilizes the psoas major by positioning the hip vertical to the front foot striking the ground in what is referred to as an “ipsilateral knee/hip movement”. In other words, the knee and hip of the stepping leg are swung forward when the foot touches the ground and the BW is supported by this front leg. Core-stretch walking therefore requires ipsilateral motor control. These movements comprise motions that are anatomically intended to use the psoas major effectively.

The fact that the cross-sectional area of the psoas major muscle increased in participants within a short period of time represents a key feature of the present study. This increase over a relatively brief period as seen on MRI is probably due to the participants having exercised a muscle that they had not typically used in activities of daily living. This finding reflects the effects of tissue changes (such as increased water content) accompanying increased circulation and tissue activation in response to psoas major activity. The most obvious benefit of learning exercises that use the psoas major is improved walking ability.

The appearance of marked increases in 6-min walking distance, 10-m walk time, and 10-m obstacle walk time is largely due to the effects of learning how to walk with synchronized leg movements and hip rotation, as practiced in core-stretch walking. Improved gait is mainly due to increased step width and better balance, and rotating the pelvis contributes to larger steps.

Hot water bathing prior to exercise was considered to have a dilating effect on cutaneous blood vessels, a relaxing effect as a result of the accompanying pleasant sensation, and a calming effect on the autonomic nervous system.

Hot water bathing is also a way to stay healthy. In the present study, participants applied hot spring water with a temperature of 42°C to various parts of the body as a way of warming-up before exercise. In addition to incorporating the principle of a warming-up, this approach also stimulated acupoints used in traditional Chinese medicine, thermally stimulated the skin, improved circulation, enhanced cutaneous stimulation and respiration, rejuvenated the senses and stimulated the autonomic nerves (sympathetic nerves). The present findings suggest that participants prone to high BP who applied hot water to the body before exercising experienced improved vascular response as well as enhanced hypotensive effects following exercise.

Numerous studies have described the effects of exercise in improving BP. The current evidence indicates that in order to improve or maintain arterial function, endurance exercise or low-intensity circuit training at least 2 days a week for several weeks is recommended for middle-aged to elderly individuals[15].

In a study by Jakobsson et al.[16] on pain management in 294 elderly individuals aged 76–100 y, the most frequently used methods of pain management were prescribed medicine (20%), rest (20%), and distraction (15%). The methods rated most effective were using cold, exercise, hot bath/shower and consuming alcohol. A study by Hamlin[5] described the use of hot showers to relieve post-exercise fatigue; however, the effects were not clear. The hot spring water used in the present study was effective both for relieving the various aches and pains typically experienced by the elderly and for providing mental diversion.

While health training programs designed for the elderly tend to limit the benefits of training to the duration of the training session, the most important point is to actively integrate the effects of physical exercise in activities of daily living. Strengthening the psoas major and other core muscles is an effective way to stay active.

Exercising with cognitive motor training machines appears effective for improving quality of life in elderly individuals by strengthening the core muscles and improving the quality of motor performance.

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Kimiyasu Hayakawa
Present post: Associate Professor, Department of Sports and Exercise Nutrition, School of Physical Education, Sendai University, Japan

Latest academic background: Doctoral Course, Graduate School, the University of Tokyo (Got credits)
Specialism: QOM(Quality of Motion), Sports Nutrition, Health and Sports Science