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ORIGINAL ARTICLE

Effect of the use of passive body trunk exercise equipment on oxygen consumption and self-efficacy for carrying out exercise in patients with type 2 diabetes

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ABSTRACT

Aims/Introduction: Considering the difficulty in inculcating the habit of exercise among patients with type 2 diabetes, devising an easily maintained means of exercise is preferable. Passive body trunk exercise equipment (PBTE) developed for home use might solve several problems related to exercise therapy, both for patients and clinical staff involved in diabetes treatment; however, its efficacy as a therapeutic exercise device for patients with diabetes has not been ascertained. The purpose of this study was to measure the exercise intensity and self-efficacy of PBTE, and to determine whether PBTE is a useful tool for exercise therapy.

Materials and Methods: The participants were 20 patients with type 2 diabetes, and the duration of exercise using the PBTE was set to 10 min. Oxygen consumption during exercise was measured, and self-efficacy for continuing to exercise using the PBTE and for walking was evaluated after completion of the study.

Results: The average exercise intensity using the PBTE was 1.7 metabolic equivalents, whereas the maximum exercise intensity was an average of 2.0 metabolic equivalents; the reported self-efficacy for continuing to exercise using the PBTE was significantly higher than for walking.

Conclusions: Exercise intensity using the PBTE is similar to low-intensity walking, and thus, it might be a useful therapeutic exercise device for patients with type 2 diabetes. Furthermore, it could be an effective exercise device for diabetes patients who do not have regular exercise habits, especially with reduced motor function or lower leg muscle strength.

INTRODUCTION

According to the results of the 2016 National Health and Nutrition Survey in Japan, an estimated 10 million people have diabetes[1]; thus, the adoption of a proactive approach to preventing the onset of diabetes and decreasing the disease severity in known diabetes patients is an urgent focus in Japan. Drug, dietary and exercise therapies are recommended for diabetes treatment[2]; however, various concerns have been raised regarding the use of exercise therapy in clinical practice. It has been reported that, while 9.9% of 5,100 surveyed outpatients with diabetes had not received dietary therapy, 30.0% of the patients received almost no exercise therapy, showing that instruction on exercise had not been not sufficiently implemented in Japan[3]. Another issue is that approximately 40% of patients state that they have insufficient time to exercise, and approximately 22% report that exercise causes pain[3]. Furthermore, a

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survey on exercise therapy involving 600 diabetologists and general internists reported that these medical personnel do not have sufficient time to provide instruction on exercise and that there are no suitable exercise instructors[4].

In contrast, self-efficacy has been raised as an important factor for the continuation of exercise therapy. Self-efficacy refers to the belief in one's ability to organize and carry out the actions required to achieve a particular goal[5]. In diabetes treatment, self-efficacy is related to the management of treatment by the patients themselves[6], and the extent of self-efficacy related to exercise is reported to correlate with the amount of physical activity[7,8]. Therefore, to resolve the issues associated with exercise therapy for diabetes patients, we need to provide exercise therapy that can be easily carried out by the patients by themselves.

With the recent increased awareness of public health in Japan, passive exercise equipment that can easily be installed at home might be a tool for exercise therapy. In this context, passive body trunk exercise equipment (PBTE) – a sitting-position exercise device – enables effective training of the core muscles (i.e., thigh adductors, rectus abdominis, external and internal obliques, gluteus maximus, pelvic floor muscle, erector spinae, and latissimus dorsi) using low-intensity activation, as the chair moves to reflexively balance the body[9]. A PBTE can be installed at home, is easy to operate and issues verbal exercise instructions. Exercise therapy has beneficial effects in patients with type 2 diabetes, particularly on skeletal muscles, insulin sensitivity (by increases in GLUT4 protein)[10], and glycogen storage in the muscles (by improving glycemic control)[11]. PBTE might serve as a means of exercise therapy for patients with diabetes. Furthermore, PBTE might solve several problems related to exercise therapy, such as exercise-induced pain, patient's restrictions for allocating time and trainers' unavailability. However, its efficacy as a therapeutic device for diabetes patients has not yet been established. The purpose of the present study was to measure the intensity of PBTE-based exercise carried out by patients with type 2 diabetes using oxygen consumption. The self-efficacy in carrying out PBTE-based exercise was also evaluated to determine its therapeutic effectiveness.

METHODS

Participants

The participants were 20 patients with type 2 diabetes hospitalized in Hiroshima University Hospital, Hiroshima, Japan, from June 2018 to July 2019. Patients were excluded if they had lower back pain and/or diabetic complications that would contraindicate exercise therapy (Table 1).

Ethics

This study was approved by the Hiroshima University Epidemiological Ethics Review Board (Approval Number: E-1338). All participants received an explanation of the study protocol and provided their informed consent.

Table 1 | Characteristics of participants

Sex (male/female)	7/13
Age (years)	64.2 ± 13.1
BMI (kg/m^2)	24.1 ± 5.1
Heart rate (b.p.m.)	80.1 ± 18.5
Systolic blood pressure (mmHg)	128.7 ± 21.9
Diastolic blood pressure (mmHg)	76.7 ± 13.6
Duration of diabetes (years)	10.7 ± 8.5
HbA1c (%)	10.2 ± 2.2

BMI, body mass index; HbA1c, hemoglobin A1c.

Measurement protocol

In this study, PBTE (Core Training Chair [EU-JC70]; Panasonic, Osaka, Japan) was used for trunk and lower limb exercises. After sitting at rest on the PBTE for 3 min, the participants carried out exercises for 10 min. After completing the exercises, the participants were allowed to rest on the PBTE for 3 min. To assess the exercise intensity, the oxygen consumption was dynamically evaluated using an expiration gas analyzer (AE-100i; Minato Medical Science, Osaka, Japan) from the period of sitting at rest until the end of the recovery period, and a rating of perceived exertion (Borg scale) was obtained for dyspnea and lower limb fatigue before and after the exercises. In the present study, we also measured knee extension force and the 25-question locomotive function scale as indices for motor function before exercise and, after the measurements were completed, the patients were asked about self-efficacy for continuing exercise.

Exercise protocol for the PBTE

Exercise duration on the PBTE was set to 10 min, with the exercise mode set to the whole-body Core Training; the exercise intensity was set to high, and the chair speed was set to 5 out of 10. The exercises on the PBTE aimed to strengthen muscles in both the trunk and lower limbs. Six types of exercises, comprising nine different movements – each involving different muscles – were implemented in this study. The exercises on the PBTE comprised abdominal breathing (Figure 1a) and exercises focused on the trunk (Figure 1b), on the trunk and a single lower limb (Figure 1c), and on the trunk and both lower limbs (Figure 1d–f). Abdominal breathing times were included as rests between exercises. The participants were instructed as far as possible to avoid leaning back and to avoid holding their breath during the exercises.

Dynamic evaluation of oxygen consumption during exercise

The oxygen consumption during exercise was calculated as the average oxygen consumption every 60 s from rest to recovery, including PBTE-based exercises according to the method described in previous studies[12,13]. The breath-by-breath method was used, and the value was divided by the weight of each participant. The intensity of exercise carried out on the PBTE was calculated as metabolic equivalents (METs). In the present

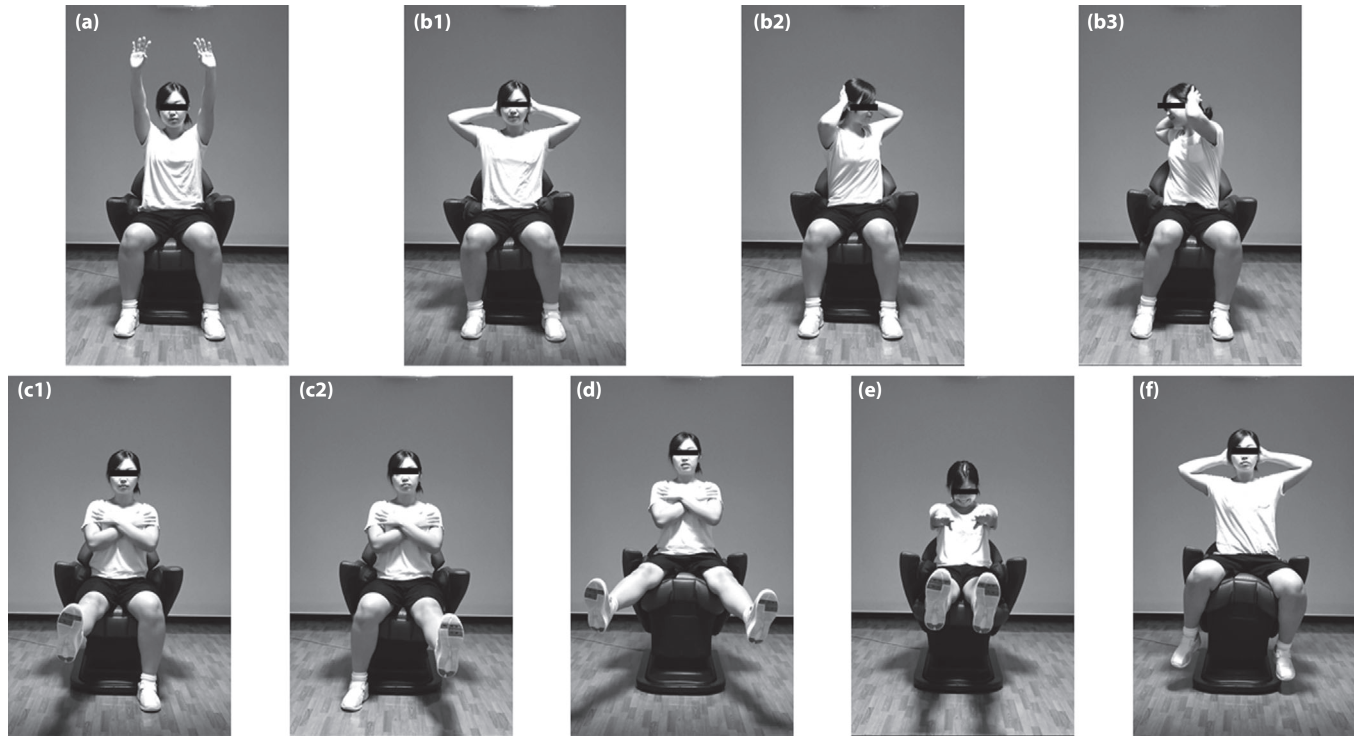

Figure 1 | Exercise on the passive body trunk exercise equipment. (a) Abdominal breathing. (b1) Clasp both hands behind the head, push chest out and hold for 30 s. (b2,3) Clasp both hands behind the head, push the chest out, and rotate the torso twice to the left and right. (c1,2) Knee extension (twice on left and right). (d) Extend both the knees at the same time, hold for 30 s and repeat twice. (e) Shoulder joint flexion of both shoulders at 90°, extend both the knees at the same time, hold for 30 s and repeat twice. (f) Hold the torso in the extended position (clasp both hands behind the head, push chest out, pull heels back and hold for 40 s), repeat twice.

study, the average METs for 10 min and the maximum METs were calculated from oxygen consumption during exercise divided by oxygen consumption at rest, as shown in the previous studies[14–16], because several studies suggested that the standard 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ does not represent oxygen consumption at rest for the general population[17–19].

Evaluation of exercise-induced dyspnea and lower limb fatigue

The subjective rating of perceived exertion caused as a result of exercise carried out using the PBTE was evaluated using the Borg scale before and after exercise[20]. Dyspnea was shown as Borg-B and lower limb fatigue was shown as Borg-L.

Self-efficacy for continuing exercise

The participants were asked about their self-efficacy for continuing to exercise after discharge from the hospital. The patients were questioned with respect to their performance of 10 min of exercise three times per week on the PBTE at home and walking for 10 min three times per week at home. The responses were evaluated on a 5-point scale with "Very easy (5 points)," "Easy (4 points)," "Neutral (3 points)," "Difficult (2 points)" and "Very difficult (1 point)."

25-Question locomotive function scale

In 2008, the Japanese Orthopedic Association proposed that "conditions at high risk of requiring nursing care due to motor disorders" be classified as locomotive syndrome. The 25-question locomotive function scale (LS-25) is a questionnaire capable of evaluating motor function[21]. The questions are scored as 0–4 each, with 100 points a full score and ≥16 points being diagnosed as locomotive syndrome.

Knee extension force

The lower extremity muscle strength measured maximal isometric knee extension force in keeping with previous studies[22]. The extension strength of both knees was measured using a handheld dynamometer (μTas F-1; Anima Inc., Tokyo, Japan). In the present study, the KEF was defined as the absolute value of both legs and a value expressed as a percentage of body weight (%KEF).

Regular exercise habits

We used questionnaires based on previous studies to evaluate those who carried out 20 min per day of physical activity and carried out physical activity three times per week or more[23].

Statistical analysis

JMP® version 14 (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis. Dunnett's test was used for comparison of the dynamic changes in oxygen consumption during rest with each stage of exercise, and the paired *t*-test was used for exercise intensity, self-efficacy, LS-25, KEF and %KEF. The χ^2-test was used for the categorical variables. *P*-values of <0.05 were considered statistically significant.

RESULTS

In the present study, there was no lower back pain during and after exercise, no changes in vital signs that reached the criteria for stopping exercise and no participants experienced exercise-related adverse events.

The oxygen consumption dynamics while using the PBTE had significantly higher levels at each stage from 4 to 10 min after starting exercise (4 min, 6.6 ± 2.4; 5 min, 6.8 ± 2.5; 6 min, 7.2 ± 2.2; 7 min, 7.2 ± 3.6; 8 min, 7.2 ± 4.0; 9 min, 7.1 ± 4.3; 10 min, 7.4 ± 4.3; and rest, 4.0 ± 0.7 mL·kg^{-1}·min^{-1}, respectively, all $P < 0.05$) compared with the consumption at rest. Conversely, no significant difference was seen between the recovery period and resting (Figure 2).

In the present study, exercise intensity during PBTE was 1.7 ± 0.6 for average METs and 2.0 ± 0.9 for maximum METs.

Both Borg-B and Borg-L were significantly higher after exercise than before in evaluation of subjective exercise intensity (Figure 3).

Self-efficacy was significantly higher for the PBTE compared with walking (Figure 4).

We investigated the differences in LS-25, KEF and exercise habits from self-efficacy questionnaire results. The high self-efficacy (HSE) group comprised eight patients, whose self-efficacy for carrying out exercise using the PBTE was better than that for walking. In contrast, the low self-efficacy (LSE) group comprised 12 patients, whose self-efficacy for carrying out exercise using the PBTE was worse than or unchanged with respect to the self-efficacy for walking. In Table 2, the HSE group had significantly higher LS-25 scores ($P = 0.001$), and significantly lower KEF ($P = 0.001$) and %KEF ($P = 0.001$) than the LSE group. Furthermore, there was a significantly lower proportion of individuals carrying out exercise regularly in the HSE group ($P = 0.03$).

DISCUSSION

This study investigated whether the use of PBTE for patients with type 2 diabetes could serve as a means of exercise therapy. The results showed that oxygen consumption was higher during exercise compared with at rest, and self-efficacy for continuing exercise was higher for the PBTE than for walking. Exercise using the PBTE in the present study had significantly higher subjective lower limb and breathing fatigue after exercise compared with before exercise. These results suggest that the exercise using the PBTE in the present study might be effective for a certain level of physical activity.

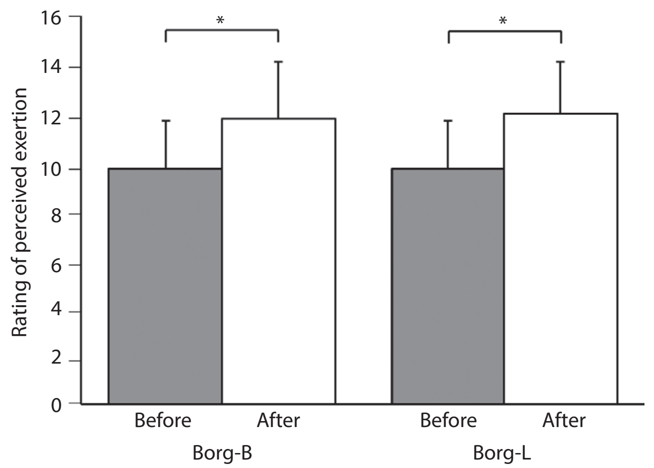

Figure 3 | Rate of perceived exertion (Borg scale) based on the difference in breathing (Borg-B) and lower limb fatigue (Borg-L) before and after exercise. The paired *t*-test was used for comparison between the before and after exercise values. Mean ± standard deviation. *Statistically significant ($P < 0.05$). Borg-B, breathing fatigue; Borg-L, limb fatigue.

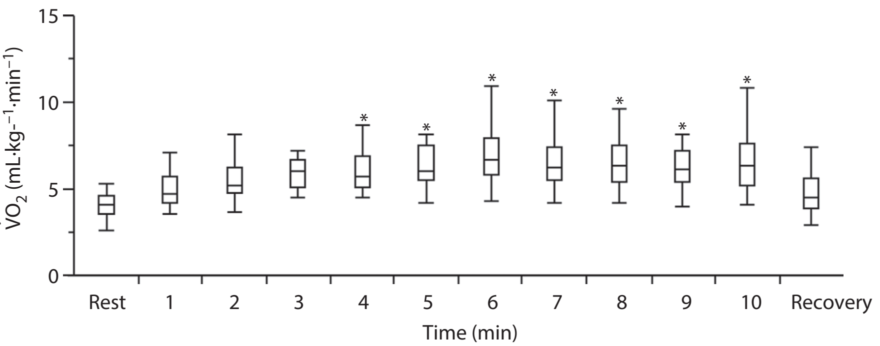

Figure 2 | Changes in the oxygen consumption at each stage. Dunnett's test was used for comparison of the dynamic changes in oxygen consumption with each stage of exercise versus during rest. *Statistically significant ($P < 0.05$).

Figure 4 | Comparison of the self-efficacy between carrying out exercise using the passive body trunk exercise equipment (PBTE) and walking. The paired *t*-test was used for comparison between PBTE and walking. Mean ± standard deviation. *Statistically significant ($P < 0.05$).

Table 2 | Comparison of motor function and exercise habits according to the self-efficacy

	HSE	LSE	*P*-value
LS-25	38.3 ± 21.1	11.8 ± 10.0	0.001
KEF (kgf)	23.7 ± 9.7	27.9 ± 5.1	0.001
%KEF (%)	37.4 ± 6.7	45.6 ± 6.8	0.001
Regular exercise habits (yes/no)	1/7	8/4	0.03

HSE, high self-efficacy; LSE, low self-efficacy; LS-25, 25-question locomotive function scale; KEF, knee extension force; %KEF, knee extension force divided by bodyweight

However, with respect to exercise intensity, which is an important factor for exercise prescription, the National Institute of Health & Nutrition revised version of the METs Table for Physical Activity states that 1.8 METs equates to an exercise intensity equivalent to standing, and 2.0 METs correlates to an intensity of walking <3.2 km/h[24], so the exercise using the PBTE in the present study could be classified as low-intensity exercise. The Japan Diabetes Society guideline stipulates that exercise for patients with type 2 diabetes should be aerobic, as this is the exercise therapy reported to be effective for glycemic control, and is to be implemented at a moderate exercise intensity for 20–60 min[25]. The American Diabetes Association guidelines also recommend implementing exercise therapy with a moderate exercise intensity, and recommend exercising for ≥150 min per week[26]. At present, high-intensity exercise is also recommended for patients with diabetes. Little *et al.*[27] carried out a study in eight patients with type 2 diabetes where the patients carried out 10 sets of 60-s sessions on a bicycle ergometer at an intensity of 90% maximum heart rate for 2 weeks. They reported a decline in the mean blood glucose levels for 24 h after training. Therefore, it was considered that exercise using PBTE would not reach an intensity effective for glycemic control.

However, it has recently become apparent that the length of time spent sitting during daily living is related to the mortality rate as a result of cardiovascular disease and the incidence of fatal myocardial infarction[28]. Sedentary is defined according to the Sedentary Behavior Research Network as "all actions during the time a person is awake that equate to 1.5 METs or less of energy consumption, conducted in a seated, semi-recumbent, or recumbent position"[29]. The exercises using PBTE in the present study had an average of 1.7 METs; therefore, its use might be an effective way to reduce sitting time.

Although it is important to carry out exercise therapy to maintain good glycemic control in diabetes, it is also important to increase non-exercise activity thermogenesis (NEAT) through methods such as reducing the time spent sitting in the activities of daily living. Non-exercise activity thermogenesis shows energy that is consumed through physical activity other than exercise[30], and a study of obese patients with diabetes reported that walking for 2 min every 20 min reduced postprandial blood glucose levels and insulin secretion more than continuous sitting did[31]. Duvivier *et al.*[32] also reported that reducing sitting time and replacing it with low-intensity walking was beneficial for 24-h glycemic control, as well as improving insulin sensitivity. This information suggests that, although the exercise using the PBTE is low-intensity, it might be an effective tool for reducing sitting time during daily activities, as well as for increasing NEAT.

The present study found that self-efficacy was higher for continuing the PBTE exercises than for continuing to walk. In a questionnaire to patients with diabetes in Japan, the reasons cited for not exercising included lack of time and exercise causing pain[3]. As a countermeasure for lack of time, the PBTE can be used easily while watching television at home, which might make it a means of exercise that can be recommended to people who profess insufficient time for exercise. A report has shown that the aging of the Japanese population is associated with an increased prevalence of motor disorders, such as osteoarthritis of the knee[33]. Type 2 diabetes is considered to be a risk factor for severe osteoarthritis, even when adjusted for body mass index, showing the need for countermeasures for pain-causing exercise[34]. It is believed that many of the participants in the present study would have had pain during exercise as a result of osteoarthritis or other such disorders. It has also been clarified that locomotor pain is related to general self-efficacy[35], suggesting that the PBTE used in the present study might serve as a means of exercise that, by carrying out the exercises in a seated position, does not intensify the pain experienced with loading for diabetes patients with osteoarthritis of the knee.

The HSE group, whose self-efficacy was better for exercise using the PBTE, had an LS-25 score of 38 points, indicating they were already showing locomotive syndrome (diagnostic cut-off: ≥16 points). They also had reduced knee extension force and a greater percentage of people who did not exercise habitually. A decline in mobility was already apparent at this stage: many patients had difficulty receiving training with walking and related movements, and when knee extension strength started to decrease in parallel, individuals needed to be wary of exercise-related falls. Given the low risk of falling when exercising in the seated position with the PBTE, this approach could serve as a safe training exercise for patients with diabetes with musculoskeletal disabilities who do not exercise regularly.

The limitations of the present study include that the exercise intensity on the PBTE was set to “high,” but the chair speed was set to 5 out of 10. However, it is possible to set the chair speed to higher settings; hence, it is essential to elucidate the change in exercise intensity caused as a result of a change in speed. Additionally, this study was a cross-sectional study and was carried out at a single facility; therefore, it will be necessary to verify whether continuous exercise can actually be performed; an interventional study should be conducted to verify the effect of exercise on glycemic control.

In conclusion, the present study suggests that, although exercise using the PBTE for patients with type 2 diabetes is low intensity, it might be used as a safe form of exercise by increasing the amount of physical activity.

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DISCLOSURE

The authors declare no conflict of interest.

REFERENCES

1. Ministry of Health Law. Outline of the National Health and Nutrition Survey Japan 2016. Available from: https://www.mhlw.go.jp/stf/houdou/0000177189.html. Accessed August 26, 2019.
2. Haneda M, Noda M, Origasa H, *et al*. Japanese clinical practice guideline for diabetes 2016. *J Diabetes Investig* 2018; 9: 657–697.
3. Arakawa S, Watanabe T, Sone H, *et al*. Current situation of diet and exercise therapy in terms of medical consultations in patients with diabetes mellitus in Japan: a nationwide survey. *J Jpn Diabetes Soc* 2015; 58: 265–278 (Japanese).
4. Sato Y, Sone H, Kobayashi M, *et al*. Current situation of exercise therapy in patients with diabetes mellitus in Japan (Report No. 1): Nationwide survey to physicians using the questionnaires. *J Jpn Diabetes Soc* 2015; 58: 568–575 (Japanese).
5. Chiaki M. Practical Guide on the Health Behavior Theories for the Medical and Health Care Staff – Focusing on the Lifestyle-Related Disease, 1st edn. Tokyo: Ishiyaku Publishers, Inc, 2002 (Japanese).
6. Sarkar U, Fisher L, Schillinger D. Is self-efficacy associated with diabetes self-management across race/ethnicity and health literacy? *Diabetes Care* 2006; 29: 823–829.
7. Dishman RK, Vandenberg RJ, Motl RW, *et al*. Using constructs of the transtheoretical model to predict classes of change in regular physical activity: a multi-ethnic longitudinal cohort study. *Ann Behav Med* 2010; 40: 150–163.
8. Dutton GR, Tan F, Provost BC, *et al*. Relationship between self-efficacy and physical activity among patients with type 2 diabetes. *J Behav Med* 2009; 32: 270–277.
9. Panasonic. Core Training Chair EU-JC70 2018. Available from: https://panasonic.jp/fitness/coretra/products/eu-jc70.html. Accessed August 26, 2019 (Japanese).
10. Dela F, Ploug T, Handberg A, *et al*. Physical training increases muscle GLUT4 protein and mRNA in patients with NIDDM. *Diabetes* 1994; 43: 862–865.
11. Hickner RC, Fisher JS, Hansen PA, *et al*. Muscle glycogen accumulation after endurance exercise in trained and untrained individuals. *J Appl Physiol* 1997; 83: 897–903.
12. Kim CH, Wheatley CM, Behnia M, *et al*. Effect of aging on relationships between lean body mass and VO2max in rowers. *PLoS ONE* 2016; 11: e0160275.
13. Jang DG, Ko BH, Sunoo S, *et al*. A modified D-max method to estimate heart rate at a ventilatory threshold during an incremental exercise test. *Conf Proc IEEE Eng Med Biol Soc* 2017; 2017: 4503–4506.
14. Kozey SL, Lyden K, Howe CA. Accelerometer output and MET values of common physical activities. *Med Sci Sports Exerc* 2010; 42: 1776–1784.
15. Ázara HM, Farinatti PTV, Midgley AW. Standardized MET value underestimates the energy cost of treadmill running in men. *Int J Sports Med* 2017; 38: 890–896.
16. Fujika Y, Hamada H, Sekikawa K. Effect of body weight support on predicted locomotive physical activity. *J Phys Ther Sci* 2018; 30: 759–763.
17. Byrne NM, Hills AP, Hunter GR. Metabolic equivalent: one size does not fit all. *J Appl Physiol* 1985; 2005: 1112–1119.
18. Savage PD, Toth MJ, Ades PA. A re-examination of the metabolic equivalent concept in individuals with coronary heart disease. *J Cardiopulm Rehabil Prev* 2007; 27: 143–148.
19. Cunha FA, Midgley AW, Montenegro R. Metabolic equivalent concept in apparently healthy men: a re-examination of the standard oxygen uptake value of 3.5 mL·kg(-1) min(-1). *Appl Physiol Nutr Metab* 2013; 38: 1115–1119.
20. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14: 377–381.
21. Seichi A, Hoshino Y, Doi T, *et al*. Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. *J Orthop Sci* 2012; 17: 163–172.
22. Nomura T, Ishiguro T, Ohira M, *et al*. Regular exercise behavior is related to lower extremity muscle strength in patients with type 2 diabetes: data from the multicenter survey of the isometric lower extremity strength in type 2 diabetes study. *J Diabetes Investig* 2018; 9: 426–429.

23. Choi JH, Lee B, Han KD, *et al*. The impact of parity and age at first and last childbirth on the prevalence of delayed-onset asthma in women: the Korean National Health and Nutrition Examination Survey. *Maturitas* 2017; 97: 22–27.
24. National Institute of Health and Nutrition. METS table of physical activity Revised edition 2012. Available from: http://www.nibiohn.go.jp/files/2011mets.pdf. Accessed August 26, 2019.
25. Japan Diabetes Society. Diabetes Clinical Practice Guidelines 2016. Exercise Therapy. Available from: http://www.fa.kyorin.co.jp/jds/uploads/GL2016-04.pdf. Accessed August 26, 2019 (Japanese).
26. Colberg SR, Sigal RJ, Yardley JE, *et al*. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. *Diabetes Care* 2016; 39: 2065–2079.
27. Little JP, Gillen JB, Percival ME, *et al*. Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. *J Appl Physiol* 2011; 111: 1554–1560.
28. Weller I, Corey P. The impact of excluding non-leisure energy expenditure on the relation between physical activity and mortality in women. *Epidemiology* 1998; 9: 632–635.
29. Tremblay MS, Aubert S, Barnes JD, *et al*. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017; 14: 75.
30. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science* 1999; 283: 212–214.
31. Dunstan DW, Kingwell BA, Larsen R, *et al*. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care* 2012; 35: 976–983.
32. Duvivier BMFM, Schaper NC, Hesselink MKC, *et al*. Breaking sitting with light activities vs structured exercise: a randomised crossover study demonstrating benefits for glycaemic control and insulin sensitivity in type 2 diabetes. *Diabetologia* 2017; 60: 490–498.
33. Yoshimura N, Muraki S, Oka H, *et al*. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. *J Bone Miner Metab* 2009; 27: 620–628.
34. Schett G, Kleyer A, Perricone C, *et al*. Diabetes is an independent predictor for severe osteoarthritis: results from a longitudinal cohort study. *Diabetes Care* 2013; 36: 403–409.
35. Taylor WJ, Dean SG, Siegert RJ. Differential association of general and health self-efficacy with disability, health-related quality of life and psychological distress from musculoskeletal pain in a cross-sectional general adult population survey. *Pain* 2006; 125: 225–232.