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EFFECTS OF DAILY MECHANICAL HORSEBACK RIDING ON INSULIN SENSITIVITY AND RESTING METABOLISM IN MIDDLE-AGED TYPE 2 DIABETES MELLITUS PATIENTS

YOSHIYUKI HOSAKA[1], MASARU NAGASAKI[2], GUSTAVO BAJOTTO[2],
YOUICHI SHINOMIYA[3], TAKAHISA OZAWA[3] and YUZO SATO[2]

[1]Hosaka Medical Clinic, Fujiyoshida, Japan
[2]Department of Health Science, Faculty of Psychological and Physical Science, Aichi Gakuin University, Nisshin, Japan
[3]Advanced Technologies Development Laboratory, Panasonic Electric Works Co., Ltd., Kadoma, Japan

ABSTRACT

The present study was conducted to investigate the effect of daily passive exercise using a horseback riding machine (Joba®) on insulin sensitivity and resting metabolism in middle-aged, diabetic patients. Participants were 24 type 2 diabetes mellitus patients aged 59 ± 8 years (mean ± SD; range from 43 to 75 years of age). Patients were randomly divided into control (normal lifestyle) and Joba® exercise groups. The latter group was instructed to perform one 30-min session of Joba® riding per day, 7 times per week, for 3 months. Compared with baseline values, serum immunoreactive insulin (IRI) concentrations decreased and HOMA-IR was improved by Joba® training. In addition, exercise duration per day significantly correlated (r = –0.65) with changes in serum IRI, and 3-month mechanical horseback riding significantly increased the resting metabolic rate of the patients. These results suggest that daily Joba® passive exercise is potentially useful as a means to improve insulin sensitivity and resting metabolism in diabetic patients. The Joba® fitness equipment can prove especially useful as an alternative exercise therapy for aged individuals incapable of performing independent exercise or for those who suffer from knee-joint disorders.

Key Words: Mechanical horseback riding, Passive exercise, HOMA-IR, Insulin resistance, Type 2 diabetes

INTRODUCTION

Large-scale prospective cohort studies have demonstrated that an increased physical activity level is associated with a substantial reduction in the risk of type 2 diabetes mellitus.[1,2] In addition, combined aerobic and resistance exercise performed on a regular basis has been shown to significantly reduce insulin resistance,[3] which is the central element of the metabolic syndrome. Furthermore, low-intensity physical activities such as walking and light circuit training have reportedly been effective in preventing and improving insulin resistance.[4-6] Although

Corresponding author: Yuzo Sato
Department of Health Science, Faculty of Psychological and Physical Science, Aichi Gakuin University, Nisshin 470-0195, Japan
Phone: +81-561-73-1111 ext. 3431, Fax: +81-561-73-1142, E-mail: satoy@dpc.aichi-gakuin.ac.jp

many participants have shown difficulty in adhering to the diet and exercise recommendations,[7,8] lifestyle improvement or lifestyle intervention has been shown to be more effective than medication in reducing the incidence of diabetes in persons at high risk.[9] Thus, based on the above evidence, numerous studies have been conducted in an attempt to elucidate the detailed molecular mechanisms responsible for mediating the post-exercise increase in insulin sensitivity, especially in skeletal muscle.[10]

The approach to aged individuals incapable of performing traditional forms of exercise by themselves is currently a major medical issue among the Japanese elderly. In fact, although physical exercise training improves the metabolic syndrome and its complications, aged and/or physically debilitated individuals frequently have no capacity to exercise at optimal intensities and, thus, need specially designed fitness equipment and activities that assist them to achieve their goals. In addition, as the incidence of potentially life-threatening heat illnesses markedly increases[11] and the occurrence of falling on snow-covered ground is significantly high[12] among the elderly, the use of indoor fitness equipment during summer and winter months is desirable for safety reasons. Therefore, indoor equipment can be useful for those who need to exercise while reducing the risk of injuries such as sprains and fractures and extreme temperature-related illnesses.

Horses have been used as a therapeutic agent since the time of the ancient Greeks[13] and, from the second half of the last century, horse riding (or “equitation”) has gained special popularity in Europe and North America as an alternative outdoor activity that yields physical, psychological, social, and educational benefits for individuals with chronic illnesses and physical disabilities.[13-15] The physical benefits of therapeutic horse riding, or “hippotherapy”, include, among others, enhanced balance, muscle strength, and coordination, increased endurance and low-level cardiovascular conditioning, decreased spasticity, and improved gross motor function.[13,16] Of particular interest are the reported significant riding-induced increases in muscle strength[17] and energy expenditure,[18,19] which support the potential usefulness of horseback riding as a pleasant aerobic exercise for the aged who may also suffer from insulin resistance and diabetes. However, participation in horse riding-related activities is also associated with a high risk of serious injuries (predominantly those due to falling and kicks) that can lead to long-term disabilities or death[20-23] and, for this reason, horse riding has been contra-indicated for people with fragile bones.[13,14] Furthermore, specialized personnel availability, costs for maintaining large animals, environmental arrangement for horseback riding, and available time for this practice represent important limiting factors for its worldwide popularization.

For the purpose of preventing accidents and straightforwardly obtaining the physical benefits of horseback riding, innovative exercise equipment called Joba® (Panasonic Electric Works Co., Ltd., Osaka, Japan) has been developed in an attempt to precisely reproduce the movement of the saddle during horseback riding.[24-26] By repeating a synchronized, three-dimensional movement pattern, the riding simulator continuously and rhythmically imposes unconscious muscular reactions on the user[24-29] to maintain both balance and upright posture. This feature makes it possible to safely and passively stimulate muscles in the dorsal and abdominal regions of the trunk, which may be particularly helpful to frail seniors.[30] Joba® riding has been reported to enhance strength in muscles of the abdomen, back, and thighs[24,25,29,31] and to transiently enhance the whole-body glucose metabolism.[32,33] However, the long-term effects of daily mechanical horseback riding on insulin sensitivity and resting metabolism in type 2 diabetes mellitus patients of both genders remain unclear. Therefore, the present study was conducted to examine whether daily Joba® riding over a 3-month period was effective in improving these two variables in middle-aged, diabetic patients. We hypothesize that regular use of the Joba® machine will lead to improvements in insulin sensitivity and resting metabolism.

EXPERIMENTAL PROCEDURES

Participants

Participants were 24 type 2 diabetes patients who attended an outpatient clinic (Hosaka Medical Clinic) located in Fujiyoshida, Japan. Screening exclusion criteria for this clinical population included habitual exercise, excessive thinness, and insulin treatment. Patients who were physically able to exercise were selected and randomly assigned to control and Joba® exercise groups. The exercise intervention group was composed of 12 patients (8 females and 4 males aged 57 ± 8 years (ranging in age from 43 to 69 years); body mass index = 27 ± 2 kg/m^2; values are means ± SD) who were instructed to perform passive physical exercise (group J), while the control group comprised the remaining 12 patients (6 females and 6 males aged 61 ± 9 years (ranging in age from 47 to 75 years); body mass index = 28 ± 4 kg/m^2; values are means ± SD) who received no exercise guidance and were instructed to continue with their usual daily activities and not commence any exercise programs during the study (group C).

This study was performed in accordance with the precepts established by the Declaration of Helsinki. The study protocol was approved by the ethical committee of the Research Center of Health, Physical Fitness, and Sports, Nagoya University, and all participants provided written informed consent after an explanation of the study design and purpose.

Joba® exercise program

Joba® exercise was performed using a mechanical horseback riding apparatus model EU6402 (Panasonic Electric Works Co., Ltd., Hikone, Japan) borrowed from the Panasonic Company and installed in the residence of each participant. One movement cycle of the Joba® fitness apparatus consists of a set of back and forth swing/slide of the saddle, swaying left and right and returning to the initial position (Fig. 1). Movement speed of the Joba® equipment ranges from level 1 (0.62 Hz) to level 7 (1.21 Hz) with incremental increases in speed resulting in quasilinear augments in energy expenditure.[31)] Thus, since the riding exercise is an "activity that uses large muscle groups, can be maintained continuously, and is rhythmic in nature" (American College of Sports Medicine definition of aerobic exercise), it can be considered aerobic. In the

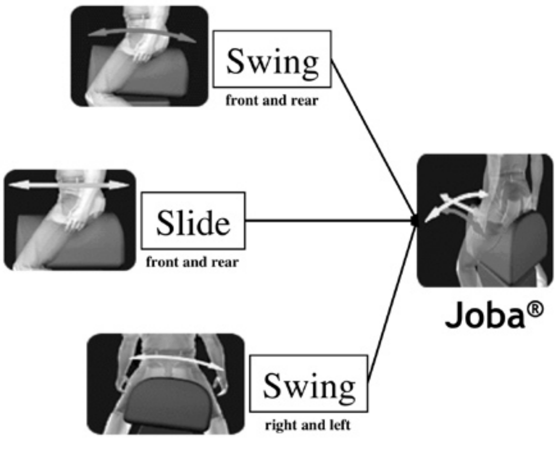

Fig. 1 Overview of the movement pattern of the horseback riding equipment (Joba®).
Combined slide and swings mimic the movement of a saddle on the back of a walking or trotting horse.

present study, the exercise intensity of the Joba® equipment was set at level 7, which is a speed equivalent to a trot,[34] the most common gait of a horse. Group J was instructed to perform one 30-min exercise session per day, 7 times per week, for 3 months.

Blood collection and biochemical analyses

Participants had their last meal at around 09:00 p.m. of the day prior to blood collection and were instructed to report fasting to the clinic by 08:00 a.m. They were further instructed not to perform any kind of physical activity after their last meal. Blood samples (6 to 10 ml) were taken after at least 30 min of rest and, after clotting, serum was obtained by centrifugation at 3000 rpm for 10 min. Fasting blood glucose (FBG) and immunoreactive insulin (IRI) were measured by an enzymatic method and double antibody immunoassay, respectively. Serum concentrations of triglycerides (TG), total cholesterol (TC), and high-density lipoprotein (HDL) cholesterol were measured by enzymatic methods. Serum biochemical analyses were carried out by the Clinical Examination Center of the Fujiyoshida Medical Association (Fujiyoshida, Japan). In addition, one drop of blood was taken from the earlobe and used for determining hemoglobin $A1_c$ ($HbA1_c$) by a latex agglutination method (Bayer DCA 2000, Bayer Corporation, Elkhart, IN). Fresh samples were used for all assays, which were carried out in the morning of the blood collection day. Blood sampling and biochemical analyses were performed the very same way both before and after the 3-month experimental period. Insulin resistance was estimated using the validated homeostasis model assessment of insulin resistance (HOMA-IR) based on fasting insulin and glucose concentrations: HOMA-IR = [fasting insulin (mU/l) × fasting glucose (mmol/L)] / 22.5.[35]

Resting metabolic rate determination

Pre- and post-training steady-state resting metabolic rates (RMR) of overnight-fasted participants were measured in the morning. For the post 3-month measurement, no riding exercise was allowed on the RMR assessment day. After bed rest for 15–60 min, participants were instructed to sit upright in a chair with their knees bent at 90°, hands on their thighs, and eyes closed during gas measurements. The respiratory exchange ratio was monitored for at least 10 min until the value was stabilized. Average values measured between 7 and 10 min were recorded as expired gas data. Gas analysis was performed using a portable CO_2/O_2 analyzer (Model VO2000, MedGraphics Co., St. Paul, MN). Since no RMR changes were, a priori, expected to occur in individuals who performed no regular exercise, RMR was not determined in control patients.

Data analysis

Data are expressed as means ± SD. Differences between pre- and post-training measurements and between groups C and J were analyzed using Student's paired and unpaired t-tests, respectively. The correlation between exercise duration per day (which varied among patients) and delta IRI (difference between pre- and post-training serum IRI concentration) was analyzed by the Pearson's product-moment coefficient, and its value was tested using the Fisher transformation. StatView 5.0 software (SAS Institute, Cary, NC) was used for data analysis. For all analyses, a *P* value of less than 0.05 was considered significant.

RESULTS

As shown in Table 1, participants were typical middle-aged patients with type 2 diabetes. There were no significant differences in FBG, $HbA1_c$, TG, TC, and HDL cholesterol between groups C

Table 1 Effect of Joba® training on glucose and lipid metabolism in middle-aged type 2 diabetes patients

Blood biochemistry	Control group		Joba® group	
	Pre	Post	Pre	Post
FBG (mmol/L)	7.19 ± 1.64	7.93 ± 2.16	6.79 ± 1.40	6.93 ± 1.52
IRI (pmol/L)	73.1 ± 47.0	61.5 ± 25.2	81.6 ± 26.9	57.1 ± 17.0*
$HbA1_c$ (%)	6.44 ± 0.97	6.91 ± 1.20	6.65 ± 0.93	6.51 ± 1.07
TG (mmol/L)	1.54 ± 0.98	1.54 ± 0.68	1.37 ± 0.58	1.36 ± 0.56
TC (mmol/L)	4.70 ± 0.70	4.75 ± 0.84	4.67 ± 0.37	4.86 ± 0.43
HDL (mmol/L)	1.18 ± 0.20	1.20 ± 0.18	1.20 ± 0.30	1.21 ± 0.27

Data are expressed as means ± SD (n = 12). FBG: fasting blood glucose; IRI: immunoreactive insulin; $HbA1_c$: hemoglobin $A1_c$; TG: triglycerides; TC: total cholesterol; HDL: high-density lipoprotein cholesterol. * $P < 0.001$ vs. before Joba® training (within-group comparison)

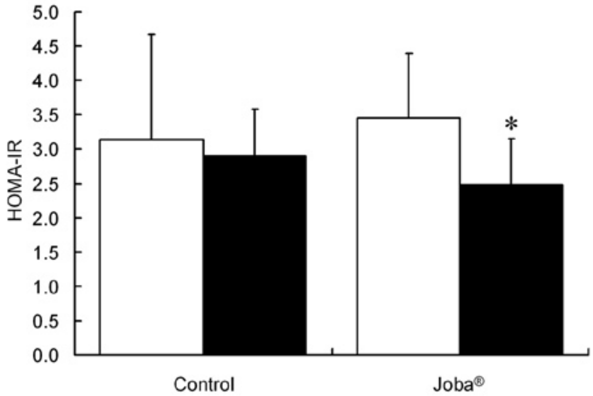

Fig. 2 Effect of Joba® training on HOMA-IR in middle-aged type 2 diabetes patients.
Bar graph shows homeostasis model assessment of insulin resistance (HOMA-IR) values for control and Joba® groups both before (white bars) and after (black bars) the experimental period. Data are expressed as means ± SD (n = 12). * $P < 0.001$ vs. before Joba® training (within-group comparison).

and J either before or after the 3-month intervention period (Table 1). However, serum IRI was significantly diminished in group J by the end of the study (Table 1). In addition, HOMA-IR was markedly improved by the Joba® training (Fig. 2).

A significant negative correlation was detected between exercise duration per day and changes in IRI after training (Fig. 3). Furthermore, steady-state RMR (1552 ± 445 and 1748 ± 432 kcal/day for pre- and post-training, respectively) was significantly ($P < 0.05$) increased by daily Joba® riding (Fig. 4).

DISCUSSION

In the present study, Joba® exercise over 3 months improved within-group HOMA-IR, while the exercise duration per day was demonstrated to be negatively correlated with IRI changes in middle-aged, diabetic patients. These results indicate that long-term Joba® riding performed on a daily basis and prolonged exercise time per day collectively contributed to insulin sensitivity enhancement. In this study, however, no statistically significant changes in FBG or $HbA1_c$ were

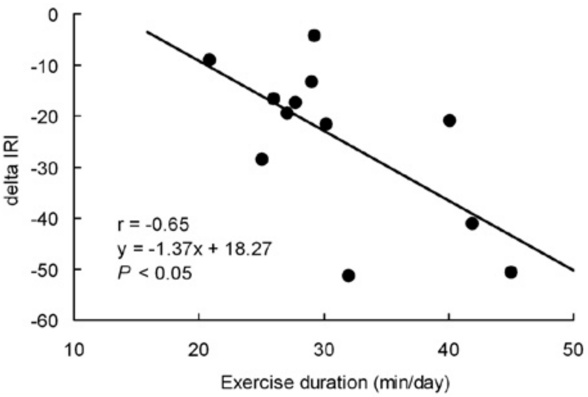

Fig. 3 Relationship between Joba® exercise duration per day and delta IRI in middle-aged type 2 diabetes patients.
Scatterplot illustrates the inverse correlation between Joba® exercise duration per day and immunoreactive insulin (IRI) changes at the end of the experiment. This association remains significant even after omitting apparent outliers.

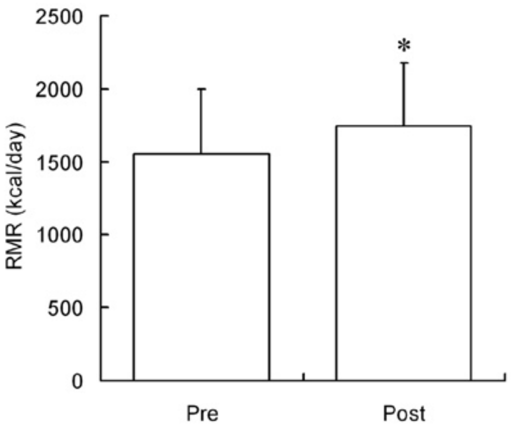

Fig. 4 Effect of Joba® training on RMR in middle-aged type 2 diabetes patients.
Bar graph shows resting metabolic rate (RMR) values for Joba®-trained individuals both before and after the experimental period. Data are expressed as means ± SD (n = 12). * $P < 0.05$ vs. before Joba® training.

observed after Joba® training. Others have demonstrated that combined dietary intervention and low-intensity exercise improves blood biochemical parameters such as FBG in type 2 diabetes mellitus patients.[4)] Therefore, for the reason that no specific dietary recommendations were given to patients in the present study, we believe that probably increased daily caloric intake may be responsible for these outcomes.

As for the short-term effect of Joba® exercise, it has been reported that the exogenous glucose infusion rate markedly increases during riding,[32,33)] reaching values comparable to those obtained during bicycle ergometer exercise performed at a work load of 40–50% of the maximum oxygen consumption of the subjects.[36)] In actual horse riding, the average oxygen uptake in experienced riders reaches at least 60% of their maximal aerobic power during trot and canter.[37] In addition, during a typical dressage session, recreational riders use about 23%, 48% and 62% of their maximal aerobic capacity at walk, trot and canter, respectively.[19] A previous study has shown that the metabolic equivalent during mechanical horse riding at 0.71 Hz ranges from about 1.4 to 1.8 METs,[31] which characterizes light intensity activities.[38] Although the riding speed used in the present study (1.21 Hz) may represent an exercise intensity above 2 METs for elderly patients (an assumption based on existing data published in non-peer-reviewed journals), it remains unclear whether this activity elicits an aerobic component suitable for enhancing or at least maintaining cardiorespiratory fitness.

In accordance with the present findings, Kubota et al.[33] have demonstrated that Joba® training resulted in improved insulin sensitivity—as evaluated by the euglycemic-hyperinsulinemic clamp—in a small group of elderly female type 2 diabetes patients. Given that HOMA-IR constitutes a reliable indicator of insulin resistance during the follow-up of patients with type 2 diabetes,[39] an insulin resistance assessment based on this model can be considered equally valid when compared to the clamp procedure. It should be recognized, however, that this model is a measure of basal insulin sensitivity and β-cell function and, in contrast to clamps, is not intended to provide information about the stimulated state.[35] Thus, in addition to a partial confirmation of earlier results,[33] this is the first study to show that Joba® exercise performed daily at home has the potential to improve basal insulin resistance in diabetic patients of both genders. This effect may be attributed to the increased energy demand in large muscle groups located in the thighs, hips, and abdominal region. Further studies are needed to determine glucose uptake and energy expenditure in specific muscles of the lower body during Joba® riding.

Significantly increased RMR in the patients who exercised with the Joba® fitness apparatus was another promising result of the present study. Improvements in RMR are a well-known outcome of long-term, moderate-intensity exercise training[40,41] and are attributed to increases in lean tissue mass.[40] Regular use (2 to 4 times per week) of the Joba® equipment for short periods of time (15 to 30 min) can produce sufficient stimuli in several skeletal muscles for augmenting strength[24,25,29] and probably tissue mass as well. Therefore, we hypothesize that the RMR of the diabetic patients in this study could be enhanced in proportion to the increased mass/strength in large muscular groups of the lower body. Taking into account the low intensity nature of the Joba® exercise, it is unlikely that the observed RMR improvement was a result of the long-lasting excess post-exercise O_2 consumption.[40]

Given that the continuation of an exercise program is fundamental for realizing health promotion benefits, another issue that should be pointed out is the compliance of the patients with regard to exercise intervention. Common reasons for lack of perseverance or exercise discontinuation include 'shortage of time and facilities' and 'lack of energy for doing anything'.[7] In the present study, a few patients failed to perform Joba® exercise daily due to personal reasons (i.e., travel, etc.). On the other hand, other patients exercised longer than prescribed, and subsequently these variations significantly correlated with changes in insulin levels (Fig. 3). Thus, easy and safe Joba® riding may represent an enjoyable way of performing passive exercise at home, while watching TV, listening to music or reading a book. Needless to say, however, this equipment cannot be recommended for patients who suffer from serious problems in the lumbar spine or vertigo/dizziness.

The present study had 2 main limitations: 1) because RMR was determined only in group J patients, potential time-dependent changes in RMR in non-exercising patients could not be addressed in our discussion and 2) since body mass and muscle strength of the participants were not measured, it was necessary to find support for our discussion in previous reports.

In conclusion, the present data showed that daily Joba® exercise performed for 3 consecutive months improved insulin sensitivity and RMR in middle-aged, diabetic patients. Continued Joba® riding can be expected to produce effects equivalent to those achieved through conventional types of low-intensity exercise, with the added advantage of being a non-weight-bearing physical activity ideal for aged individuals with gonalgia and low back pain.

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