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Original Article

Quantification of carbohydrate and fat oxidation during low-impact aerobic dance

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Abstract

The promotion of health care in Japan includes projects to improve physical activity levels, such as increasing step count, as a means of increasing energy expenditure in daily life. In particular, the importance of lipid metabolism during exercise is a high priority. The present study investigated energy expenditure and the oxidation of carbohydrate and fat during low-impact aerobic dance. Six healthy female volunteers, aged 20 to 23 years, participated in this study. The exercise comprised a 10-minute warm-up and 50 minutes of aerobic dance. The mean exercise intensity was approximately 30% HRmax･reserve, and the total energy expenditure was 245 kcal over the 50-minute exercise. The amount of carbohydrate oxidation was generally constant, while the amount of fat oxidation showed an uptrend. The total amount of carbohydrate oxidized was 42.7 ± 11.2 g, and that of fat was 5.5 ± 1.7 g. It was thought that low-impact aerobic dance in this study was suitable for beginners because the exercise intensity was light. However, increasing the amount of fat oxidation during exercise remained a problem. Further study of aerobic dance as a new method of stimulating fat metabolism is necessary.

Key words : low-impact aerobic dance, carbohydrate oxidation, fat oxidation

Ⅰ. Objectives

Japan has been implementing proactive health promotion campaigns in order to address health issues among the Japanese people. The third set of measures for improving fitness among the Japanese people, the 21st Century National Fitness Campaign (Healthy Japan 21), stresses primary prevention and puts forward specific objectives that should be addressed with regard to improving the environment for supporting fitness, as well as addressing lifestyles and lifestyle diseases. Particularly in the area of "physical activity and exercise," a proactive approach has been taken, including measures such as the formulation of the Exercise 2006 campaign. However, Healthy Japan 21, which was published in 2012 by the Ministry of Health, Labour and Welfare, notes that, with regard to the achievement of objectives in the area of physical activity and exercise, people have not increased their step count within their everyday lives, and it is clear that, although the importance of exercise is understood, this is not linked to behavior.[1] The background to this appears to be that no robust system for recommending exercise to society in general has been created for educational, workplace, or other settings.

Current exercise regimes often comprise muscle strength training and aerobic exercise[2-6]. Anaerobic threshold (AT) intensities for aerobic exercise have been recommended[7, 8], and the American College of Sports Medicine (ACSM) recommends a general exercise prescription for healthy adults[2]. Furthermore, the maximum amounts of fat combustion when using a treadmill or cycle ergometer have been calculated, thus clarifying the exercise intensities that are effective for fat combustion[9]. Furthermore, increased strength and reduction in body fat have been reported through suitable use of muscle training and other exercises together with aerobic dance, a type of aerobic exercise in which combinations of enjoyable movements are carried out in time to music[10-16]. Aerobic dance is popular at fitness clubs and has been introduced into school education.

Aerobic dance has been the subject of numerous studies, which have included investigations of the intensity and amount of exercise[11, 17-20], muscle activity based on motion analysis,[21] and energetic efficiency[22]. There has also been research into injuries caused by aerobic dance.[23, 24] The strength of the exercise in aerobic dance can be controlled to suit the particular characteristics of the persons exercising, and there is a wide range of applications, from relatively intense exercise aimed at young people that incorporates body combat-type martial arts moves to low impact exercise, which is used as the introductory stage in lessons for exercise beginners.[12, 15, 25] Aerobic dance comprising low-impact exercise in particular is considered reasonably undemanding exercise for those unaccustomed to exercise, elderly people, or obese people needing to lose weight. If carried out over a long period, it can be expected to be effective in increasing strength and reducing body fat[12, 15, 25]. Sakamoto et al[9]. carried out a laboratory investigation of the exercise intensity that is effective for fat combustion, but there are few studies with a dynamic focus on exercise intensity and the amount of carbohydrate and fat oxidation during actual exercise lessons such as aerobic dance.

This study investigated the amounts of carbohydrate and fat oxidation during low-impact aerobic dance in order to clarify future coaching challenges from a perspective of weight-loss measures.

Ⅱ. Methods

1. Subjects

The subjects were 6 healthy female students, aged 20–23 years, with no prior aerobic dance experience (Table 1).

2. Study methods

a) Measurement of heart rate during exercise

Heart rate at rest and during exercise was measured at 1-minute intervals using a transmitter (BR-913P, Nihon Kohden, Tokyo, Japan) and receiver (Life Scope 6, Nihon Kohden).

Table 1 Age and physical characteristics of the subjects

	Mean ± SD	Range
Age, yr	21.3 ± 1.0	20-22
Height, cm	159.6 ± 5.0	152.0-166.1
Weight, kg	54.7 ± 5.1	46.0-60.9
BMI, kg/m^2	21.4 ± 0.8	19.9-22.1

n=6

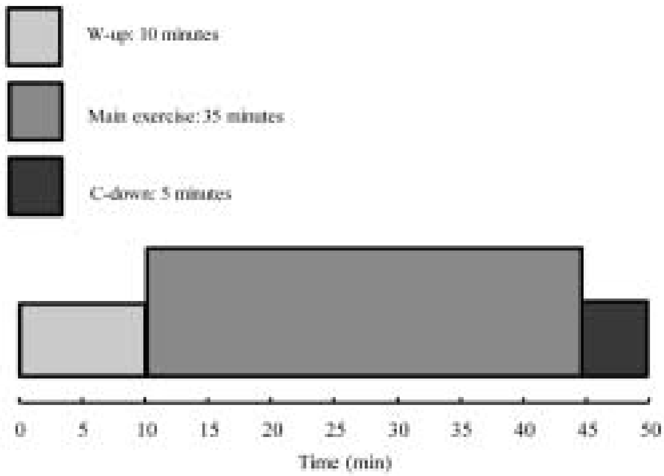

Fig.1 Content of lesson on low-impact aerobic dance during a 50-minute

b) Analysis of gas expired during exercise

$\dot{V}O_2$ and $\dot{V}CO_2$ at rest and during exercise were measured at 1-minute intervals using an Aeromonitor AE300S (Minato Medical Science, Tokyo, Japan).

c) Calculation of amounts of carbohydrate and fat oxidation

The amounts of carbohydrate and fat oxidation during exercise were calculated as follows, based on the indirect calorimetry (IC) method,[26]

Amount of carbohydrate oxidation (g) = $(4.114 \times \dot{V}CO_2 - 2.908 \times \dot{V}O_2) - 2.543 \times Nu$

Amount of fat oxidation (g) = $1.689(\dot{V}O_2 - \dot{V}CO_2) - 1.943 \times Nu$

where Nu is assumed to be 8 mg.

d) Carbohydrate and fat utilization rates based on the nonprotein respiratory quotient

The carbohydrate and fat utilization rates based on the nonprotein respiratory quotient were determined from the ratio of $\dot{V}O_2$ to $\dot{V}CO_2$ in expired gas.

e) Rating of perceived exertion during exercise

The degree of fatigue during aerobic dance was examined after the end of the exercise using the rating of perceived exertion.[27]

f) Details and exercise intensity of low-impact aerobic dance

The subjects were required to carry out aerobic dance in time with the movements of an aerobic dance instructor. The aerobic dance comprised low-impact exercise that beginners or elderly people would be able to perform comfortably. The aerobic dance session was a total of 50 min, comprising a 10-min warm-up, 35 min of main exercise, and a 5-min cool-down (Fig. 1). The content of the main exercise was as follows:

A（1–10 min）: Start with steps with no bodily displacement,

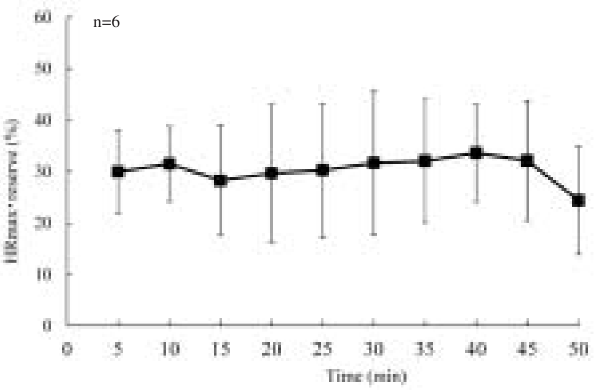

Fig.2 Change of exercise intensity during a 50-minute low-impact aerobic dance

such as marching on the spot and step-touches, and then a combination of forwards and backwards walking and side steps.

B（10–20 min）: Steps were gradually introduced into the movements in A, and arm movements were added to increase the intensity of the exercise.

C（20–30 min）: When subjects had become comfortable with the movements in B, they were instructed to make bigger movements, and the intensity of the exercise was maintained.

D（30–35 min）: The intensity of the exercise was reduced by lessening the movements in C to the level of stage B and finally only doing exercise with no bodily displacement, such as marching on the spot or step-touches as in A.

The exercise intensity of aerobic dance was investigated using%HRmax・reserve. This was calculated by (HRexercise－HRrest/HRmax － HRrest) × 100, where HRexercise is the heart rate during exercise, HRrest is the heart rate at rest, and HRmax is a value estimated by "220−age".

3. Food intake

Given the effects of food intake on carbohydrate and fat metabolism during exercise in this study, subjects were required to eat a mixed meal for dinner on the night prior to the experiment. They were also required not to eat for 3 h prior to the starting time on the day of the experiment.

4. Statistical analysis

Data are presented as means ± SD. Changes over time during aerobic dance were examined using a Friedman test, with the significance level set at <5%.

This study was approved by the research ethics committee of the Graduate School of Mukogawa Women's University.

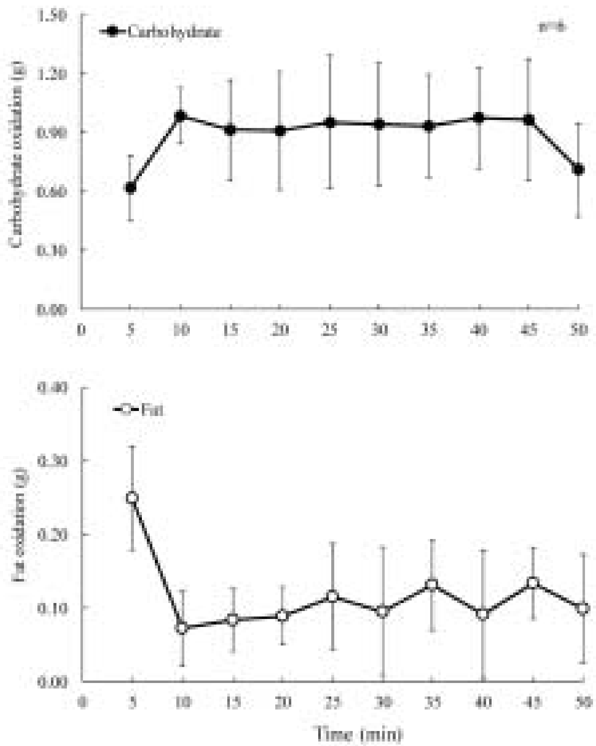

Fig. 3 Changes of carbohydrate and fat oxidation during a 50-minute low-impact aerobic dance

Ⅲ. Results

1. Changes over time in %HRmax・reserve during low-impact aerobic dance

Fig. 2 shows the changes over time in %HRmax・reserve (exercise intensity) during low-impact aerobic dance. The mean exercise intensity of the main exercise was approx. 31% (range, 21.0 － 54.6%). The intensity during the exercise gradually increased in accordance with the exercise program and gradually decreased at the end (cool-down). At the end of the exercise, the subjects were asked for their subjective evaluation of the intensity. The mean value was 12, between "fairly light" and "somewhat hard."

2. Changes over time in the amounts of carbohydrate and fat oxidation during low-impact aerobic dance and the overall amount of oxidation

Fig. 3 shows the changes over time in the amounts of carbohydrate and fat oxidation during low-impact aerobic dance. The amount of carbohydrate oxidation increased during the warm-up at the start of exercise, showed stable values during the subsequent main exercise, and decreased from the start of cooling down. The amount of fat oxidation changed somewhat at the start of the main exercise, showing an upward tendency, and decreased during cool-down. When

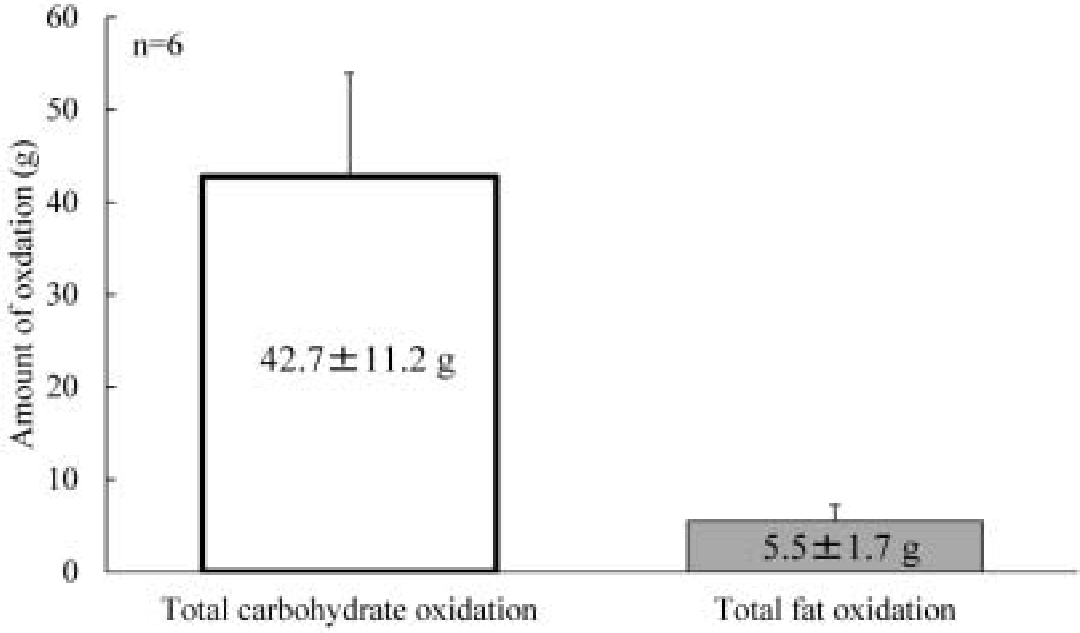

Fig. 4 Comparison between total carbohydrate and total fat oxidation during a 50-minute low-impact aerobic dance

the carbohydrate and fat utilization rates during the main exercise were examined, it was found that the carbohydrate utilization rate showed a slight decreasing trend, and the fat utilization rate showed a slight upward trend. The mean carbohydrate utilization rate was 75.0% ± 3.5%, and the mean fat utilization rate was 25.6% ± 3.5%.

Fig. 4 shows the overall amount of carbohydrate oxidation and the overall amount of fat oxidation during the main exercise. The overall amount of carbohydrate oxidation was 42.7 ± 11.2 g, while that of overall fat oxidation was 5.5 ± 1.7 g.

IV. Discussion

This study investigated energy metabolism during low-impact aerobic dance through non-invasive analysis of expired gas. The main items for analysis were the amounts of oxidation of carbohydrate and fat during exercise, and these two variables were determined by substituting the measured values of $\dot{V}O_2$ and $\dot{V}CO_2$ obtained from expired gas into the formula of the indirect calorimetry (IC) approach[26]. In this study, carbohydrate and fat utilization rates based on the nonprotein respiratory quotient were also determined in order to permit comparisons to prior studies.

The low-impact aerobic dance used in the present study comprised the main exercise (35 min) preceded by warming up (10 min) and cooling down (5 min), a total of 50 min. The amount of carbohydrate oxidation showed no significant change due to exercise intensity in the main exercise (Fig. 3, mean 0.94 ± 0.02 g). The amount of fat oxidation showed no significant change, but there was a rising trend with as the exercise progressed (mean 0.11 ± 0.02 g). Mean heart rate during the main exercise was 102 beats/min, and %HRmax・reserve was 31%, indicating that this was relatively light exercise. Adachi et al[28]. investigated the relationship between different walking speeds (economical speed, 40% $\dot{V}O_2$max; comfortable speed, 49% $\dot{V}O_2$max; and fast speed, 66% $\dot{V}O_2$max) and energy metabolism in middle-aged women; under these three speed conditions they found greater fat combustion at higher speed. Average exercise intensity during the main exercise of the present study was 31%, and the amount of fat combustion was lower than that found by Adachi et al[28]. at their "economical speed" (Fig. 3).

Romijn et al[29]. compared the amount of fat oxidation in subjects who performed continuous exercise on a cycle ergometer with three kinds of fixed loads of 25%, 65%, and 85% $\dot{V}O_2$max. The oxidation rate of free fatty acids (FFA), which are closely involved in fat metabolism, was higher (25% $\dot{V}O_2$max) than at the other conditions. However, the overall amount of fat oxidation showed the highest value at 65% $\dot{V}O_2$max. This is probably due to the effects of the difference in oxygen consumption (25%<65%) during exercise of different intensities for the same length of time. The results of Adachi et al.[28] also show that, at lighter exercise conditions, the rate of fat combustion is higher, although the overall amount of energy consumption from fat is ultimately greater at higher exercise intensity. Increases in fat metabolism can generally be seen by observing dynamic changes in FFA and other markers in the blood. Romijn et al.[29] reported that the increases of FFA and glycerol were higher during exercise at 65% $\dot{V}O_2max$ than at other intensities. This is probably largely due to the secretory action of catecholamine, since lipolysis in adipose tissue is increased in response to the stimulus of catecholamine secretion. At the same time, while the amount of catecholamine secretion was highest at 85% $\dot{V}O_2max$, the overall amount of fat oxidation was no different from that at exercise at 25% $\dot{V}O_2max$. This is probably because, at high exercise intensity, the energy supply to the skeletal muscles relies on carbohydrates, so that increased blood glucose and accelerated glyconeogenesis caused by hormonal action during exercise cause carbohydrate metabolism to take preference. From the foregoing, no obvious increase in fat metabolism was observed in the present study, because, while the main exercise was aerobic, the intensity of the exercise was low. Therefore, if fat metabolism is to be preferentially promoted, the intensity needs to be raised to a somewhat higher level.

Yoshikawa et al[30]. investigated the intensity of aerobic dance performed by beginners by looking at exercise intensity with arm and leg movements and high-impact and low-impact exercise. They found that exercise intensity during arm exercise and low-impact exercise was less than 50–85% $\dot{V}O_2max$, and thus not equivalent to the ACSM guidelines. The authors therefore note that such exercise cannot be expected to improve cardiopulmonary function. In addition, Yoshioka et al[17]. compared relative exercise intensity between aerobic dance instructors, people with aerobic dance experience, and beginners, and reported low intensity in both beginners and instructors. The authors note that relative intensity was low particularly in beginners because they were unable to perform the exercise adequately since they lacked the necessary skills. As the subjects in the present study did not have sufficient experience in aerobic dance, the reason noted by Yoshioka et al.[17] probably applies also to them.

The physiological and subjective intensity of the low-impact aerobic dance in the present study was "relatively comfortable," so that this level of exercise is desirable for people who should avoid strenuous exercise, such as "those unused to exercise," "obese people" who need to lose weight, or chronically ill "patients requiring therapeutic exercise." However, issues still remain with regard to increasing cardiopulmonary function and fat metabolism, which are the benefits of aerobic exercise. Specifically, in the aerobic dance of the present study, the mean rating of perceived exertion (RPE) was 12 (between "comfortable" and "slightly hard"), so that raising the exercise intensity by a further 10–20% or so would probably result in aerobic exercise that could be expected to increase cardiopulmonary function and the amount of fat oxidation. Goto et al[31]. carried out muscle strength training (intensity of 50–70% of 1 RM) prior to aerobic exercise on a cycle ergometer and reported increased FFA and glycerol levels during the aerobic exercise, so that this exercise regime increased fat metabolism. Adjusting the aerobic dance load to around 50% and carrying out moderate muscle strength training before the aerobic dance may therefore be expected to facilitate fat metabolism. Future work will be needed to examine what effects these will have on carbohydrate and fat metabolism during aerobic dance.

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