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Two consecutive lapses in participation in a weekend exercise program may lessen the benefit of the intervention for hyperglycemia

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Abstract Recent studies have suggested that the amounts of both moderate to vigorous physical activity and sedentary behavior affect the incidence of type 2 diabetes. Recommendations regarding frequency of aerobic exercise training for persons with type 2 diabetes are to not allow more than 2 consecutive days without aerobic physical activity. This study reanalyzed the data from a Risk Factor Intervention Trial in Japan to examine whether a lack of participation in the exercise program on weekends lessened the benefit of the exercise intervention in hyperglycemia. Thirty-two participants with fasting serum glucose above 126 mg/dl at baseline or with a diagnosis of type 2 diabetes were selected from the original dataset. They had joined an aerobic exercise program at a fitness club for 8 weeks, and serum glucose was measured before and after the intervention. Participants who exercised once or more per week on the weekends (Saturday and/or Sunday) along with their weekday routine showed a significant decrease in serum glucose; and changes in serum glucose were smaller in those who participated less often. Adjustment for baseline serum glucose, undergoing diagnosis, total exercise time and changes in energy intake and body weight did not alter this result. It was shown that in exercise interventions for people with hyperglycemia, recommendations on the maximum sedentary interval, in addition to the minimum duration of exercise, should be considered.

Keywords : exercise interval, serum glucose, aerobic exercise

Introduction

Higher physical activity levels are known to reduce the risk of type 2 diabetes. Aune et al. have suggested that there is a clear dose-response relationship of total exercise time, leisure time, and vigorous, moderate, and light intensity activities, and walking duration with risk of type 2 diabetes¹⁾. Recently, the amount and pattern of sedentary behavior have also been studied. A review by Brocklebank suggested that longer total sedentary time decreased insulin sensitivity, but breaks in sedentary time had no effect on insulin sensitivity²⁾. In addition, cross-sectional analysis of total amount and patterns of sedentary behavior and type 2 diabetes has also suggested that each additional hour of sedentary time increases the prevalence of type 2 diabetes, but the number of sedentary breaks, number of prolonged sedentary bouts and average bout duration did not affect glucose metabolism³⁾.

The American College of Sports Medicine (ACSM), the American Diabetes Association (ADA)⁴⁾, and the Japan Diabetes Society (JDS)⁵⁾ have recommended exercise as one of the essential therapies for type 2 diabetes. They ad-

vocate a minimum of 150 min/week of exercise at moderate or greater intensity. In addition, the recommendations stipulate that there should be no more than two consecutive days without aerobic physical activity. Boule et al. found that exercise-related improvement in fasting insulin disappeared 72 h after the last bout of exercise at the end of a 20-week exercise training program for subjects with normal fasting glucose⁶⁾.

We suggested previously that a period of two consecutive sedentary days on the weekend increases the incidence of hyperglycemia⁷⁾. Therefore, we now hypothesize that, regarding exercise therapy for type 2 diabetes, a lack of exercise on weekends lessens the benefit of an exercise intervention on serum glucose among individuals with hyperglycemia. The purpose of this study is to examine our hypothesis through preliminary reanalysis of previous data.

Materials and methods

Study design. In this study, we reanalyzed the unlinkable anonymized dataset from a previous study of a Risk Factor Intervention Trial in Japan conducted from 1992 to 1997. The present work was approved by the Ethics Com-

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mittee of the National Institutes of Biomedical Innovation, Health and Nutrition (206-2, 16 October, 2016).

Participants. A total of 1,425 participants initially joined the trial. Subjects of this trial were referred and recruited from routine medical examinations at their respective companies or local health care centers. In the present study, 32 of the 82 participants, who either had fasting serum glucose above 126 mg/dl at baseline or were diagnosed with type 2 diabetes before recruitment, had data suitable for analysis. No subjects were taking any medication for diabetes before or during the trial. Exclusion criteria were a training period of < 8 weeks ($n = 28$), actual duration of the exercise program < 60 min/week ($n = 13$), and changes in dietary energy intake of > 300 kcal according to the pre and post intervention dietary survey ($n = 9$). No subjects had a family history of diabetes. Those who participated in the exercise program once or more per week on Saturday and/or Sunday were classified as Weekend-Active (WA), while those who took part less frequently were classified as Weekend-Inactive (WI). WA was then subdivided into WA-low and WA-high according to the median duration of the exercise program.

Assessment and intervention of the original trial. The details of the clinical assessment and exercise intervention were described previously^{8,9}. Briefly, prior to participation, each participant underwent a physical examination and a graded exercise test, and received his/her doctor's permission to participate in the trial. The post-intervention physical examination was done 2 to 3 days after the last exercise program. On the day before the examination, the subjects were asked not to exercise. The subjects were also asked to finish their dinner before 8 PM the day before the physical examination. Venous blood was drawn for measurements after an overnight fast, and fasting serum glucose was analyzed at SRL Inc. (Tokyo, Japan). Walking steps were counted using a DIGI WALKER L (Yamasa Tokei Corporation, Tokyo, Japan) from 3 days before the examination until the end of the intervention. To calculate the walking steps for weekdays and the weekend separately, the average walking steps from 3 days before the physical examination until the day before the first exercise program (a total of 2 to 4 days for weekdays and 1 to 2 days for weekends) were used as the pre-intervention measure of walking steps. Participants were asked to wear the pedometer all day except when participating in the exercise program. The average number of walking steps during the intervention (excluding steps taken during the exercise program) was used as the post-intervention measure.

The 8-week exercise program was performed at the fitness club nearest to each participant, under the supervision of a personal trainer. Each exercise session consisted of a brief warm-up period, 30 to 40 minutes of aerobic exercise (e.g., walking, jogging, cycle ergometer, and swim-

ming) at an intensity of 50% of maximal oxygen intake, followed by 10 to 20 minutes of conditioning exercises. Participants were not in the habit of exercising before the study and did not participate in any other exercise during the study.

Statistical analysis. Data were analyzed using SPSS for Windows (ver. 22, IBM Japan, Tokyo, Japan) and presented as proportions or means $\pm$ SDs. Differences among groups were compared by one-way analysis of variance (ANOVA). Where there was a significant difference between groups, the Bonferroni procedure was used as a post hoc test. Change in serum glucose level was adjusted for baseline serum glucose, diagnosis of diabetes before the recruitment, total exercise time and changes in energy intake, body weight, and daily steps walked, and compared by analysis of covariance (ANCOVA).

Results

Baseline values were not different among groups or subgroups (Table 1). WI and WA-low significantly decreased body weight ($p = 0.049$ for WI and $p = 0.027$ for WA-low). Walking steps on weekdays and weekends did not change significantly in any subgroup. In addition, walking steps on weekdays and weekends did not differ significantly among the subgroups before or after the intervention. Both WA-low and WA-high decreased their serum glucose levels significantly ($p < 0.001$); these changes were notably smaller in WI compared with WA-low and WA-high subgroups. After adjustment for possible confounding factors, the difference was only significant between the WI group and the WA-low subgroup.

Discussion

The main finding of this study is that lapses in participation in an exercise program may lessen the benefit of an exercise intervention on serum glucose levels in people with hyperglycemia.

The exercise-associated decrease in serum glucose was significantly greater in WA-low compared to WI. Increased insulin sensitivity from a single period of exercise is known to persist from 12 h to 24 h after the last bout of exercise, with any major effects on insulin action being lost within a few days^{6,10,11}. The benefit of an isolated period of physical activity is short-lived. In this study, WI subjects did not engage in the exercise program on weekends. The beneficial effects of weekday exercise on insulin sensitivity would therefore be lessened during weekends before the next training session. The subjects participated in the exercise program more than once during the weekdays; however, we were unable to check the interval between exercise sessions.

WA-low showed similar adjusted changes in serum glucose to WA-high in spite of significant differences

Table 1. Subject characteristics, details of the exercise intervention and serum glucose before and after.

	Weekend-Inactive (WI)			Weekend-Active (WA-low)			Weekend-Active (WA-high)			Sig.
	Tol (n=12)	Male (n=8)	Female (n=4)	Tol (n=10)	Male (n=7)	Female (n=3)	Tol (n=10)	Male (n=6)	Female (n=4)	
Age (yr.)	49.4±8.9	47.4±6.5	53.5±10.6	50.6±6.2	49.1±6.5	54.0±4.4	54.2±10.7	47.3±6.6	64.5±5.7	0.415
Height (cm)	161.4±8.5	165.4±7.5	153.6±3.2	161.9±8.4	166.4±5.2	151.5±0.9	160.5±8.6	166.8±3.3	151.1±2.5	0.928
Weight (kg)										
Before	68.4±12.6	72.0±14.0	61.1±4.4	66.3±10.1	70.8±8.6	56.0±2.8	65.3±12.6	72.6±6.7	54.2±11.3	0.825
After	67.8±12.4	71.4±13.6	60.5±4.8	65.8±10.1	70.2±8.6	55.5±3.1	65.2±12.6	72.8±7.6	53.9±11.5	0.870
Change	-0.6±0.9	-0.6±1.1	-0.6±0.5	-0.6±0.7	-0.6±0.8	-0.5±0.5	-0.0±1.1	-0.2±1.2	-0.4±1.0	0.315
Exercise time (min/wk)										
weekday	76±54	69±57	89±51	70±27	70±33	68±3	159±46**##	157±58	163±25	<0.001
weekend	9±8	7±8	11±9	37±10*	39±11	31±7	76±38**##	93±37	52±28	<0.001
total	84±51	75±53	100±49	107±25	109±30	100±5	236±74**##	250±90	215±47	<0.001
Frequency of weekday exercise (times/wk)										
1.5±0.9	1.3±0.9	2.0±0.7		1.9±2.1	2.1±2.5	1.5±0.5	2.9±1.6	2.9±2.0	3.1±1.2	0.104
Walk step (steps/day)										
Before										
weekday	8,396±3,191	8,839±3,071	7,510±3,707	6,866±2,585	6,622±2,935	7,434±1,880	7,946±3,208	8,237±4,083	7,509±1,633	0.495
weekend	7,308±2,423	6,880±2,059	8,165±3,187	6,155±2,712	6,398±2,504	5,590±3,689	6,857±2,256	6,932±2,898	6,743±1,113	0.556
After										
weekday	9,307±2,372	8,793±2,087	10,336±2,888	7,181±2,830	7,522±2,838	6,387±3,244	7,539±2,859	8,486±3,062	6,121±2,103	0.150
weekend	6,567±1,498	6,138±1,637	7,423±714	5,899±1,633	6,107±1,177	5,415±2,710	6,736±1,965	7,198±1,991	6,046±1,980	0.510
Serum glucose (mg/dl)										
Before	151.8±24.3	155.5±28.2	144.3±14.3	140.7±12.2	140.6±15.0	141.0±1.7	148.1±15.8	149.2±13.2	146.5±21.5	0.390
After	145.3±49.6	151.4±59.3	133.0±22.3	107.1±17.6	101.3±12.3	120.7±23.6	102.0±14.5	98.2±10.2	107.8±19.6	0.008
Change	-6.5±34.3	-4.1±40.6	-11.3±20.9	-33.6±19.8*	-39.3±16.4	-20.3±24.2	-46.1±20.1**	-51.0±20.6	-38.8±19.7	0.004
Adjusted change ^a	-5.4±9.9			-35.7±9.3*			-45.2±13.7			0.043

All values are expressed as mean±SD.

Sig. = p values of differences among groups (males and females grouped together).

a: adjusted for baseline serum glucose, diagnosis of diabetes, total exercise time, and changes in energy intake, body weight and walking steps.

* p < 0.05, ** p < 0.01 compared with Weekend-Inactive.

p < 0.05, ## p < 0.01 compared with Weekend-Active (low).

in their respective exercise times. In addition, in spite of the greater exercise time, no substantial changes in body weight were observed in the WA-high subgroup. We could not find a clear reason for this result, or for the lack of any significant difference in the change in serum glucose between WA-low and WA-high. Although we only collected a 2-day dietary record before and after the intervention, average energy intake decreased slightly in both WI (-30 kcal/day) and WA-low (-49kcal/day), but increased slightly in WA-high (+20 kcal/day). The differential change in intake of energy and/or specific nutrients was one possible reason that WA-high had neither a decrease in body weight nor a greater decrease in serum glucose than did WA-low.

A number of limitations must be acknowledged. The most serious limitation of this dataset was the lack of data on HbA1c, other parameters for glucose metabolism, and information on the duration of diabetes or hyperglycemia in the participants. In this trial, serum glucose was measured under well-controlled conditions in the practical setting (finished dinner before 8 PM and not participating in exercise on the day before the measurement). Serum glucose was measured within 2 to 3 days after the last exercise program of the intervention. However, the intervals between the last meal and blood collection and between the last exercise program and blood collection were unknown because we lacked data on the times of dinner and of blood collection. In addition, there were no data on nutritional intake associated with dinner.

Another important limitation was that we could not eliminate the effects of changes or differences in dietary intake. In this trial, only 2-day dietary records were collected before and at the end of the intervention; therefore, dietary intake during the intervention is unknown. This trial provided an exercise program without any dietary intervention. It may be that the lack of significant changes in body weight in the WA-high subgroup in spite of greater exercise time reflects this subgroup's increase in their dietary intake, which also affected changes in serum glucose.

In addition, the present study is only a reanalysis of data collected about 20 years ago; therefore, allocation of subjects to groups and subgroups was not random, but post hoc, according to the duration of exercise. Hence, a future well-controlled study is needed to clearly examine the acceptable lapse period in exercise training for people with hyperglycemia.

In conclusion, development of exercise interventions for people with hyperglycemia should take into consideration not only the optimal duration of exercise, but also the maximum inter-session interval.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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