Tokai J Exp Chlin Med., Vol. 36, No. 4, pp. 95-99, 2011

Long-term Detraining Increases the Risk of Metabolic Syndrome in Japanese Men

Toshitake MITSUHASHI[*1], Chizumi YAMADA[*1], Ako IIDA[*2], Noboru HIRATSUKA[*1], Fumiyo INABE[*1], Nami ARAIDA[*1], Kengo MORIYAMA[*1], Hitoshi SASAMORI[*3], Norio SASAMORI[*3], Motohiko MIYACHI[*4] and Eiko TAKAHASHI[*1]

[*1]*Department of Clinical Health Science, Tokai University School of Medicine*
[*2]*Sonorous Court Mitaka*
[*3]*Health Planning Center, Makita General Hospital*
[*4]*Exercise Guideline Project, National Institute of Health and Nutrition*

(Received June 23, 2011; Accepted August 11, 2011)

Objective: The aim of the present study was to examine the effect of long-term detraining on metabolic syndrome (MetS).
Methods: 1109 Japanese men were categorized by their exercise habits. Clinical data, number of MetS risk factors, and differences in lifestyle-related behaviors of the non-training group (n = 233) and the detraining group (n = 483) were compared with those of the training group (n = 87).
Results: Waist circumference and body mass index were significantly higher in the non-training group and the detraining group than in the training group, and also higher in the detraining group than in the non-training group. High-density lipoprotein cholesterol (HDL-C) was lower and low-density lipoprotein cholesterol (LDL-C) was higher in the non-training group and the detraining group than in the training group. Both the non-training group and the detraining group had more MetS risk factors than the training group. The odds ratio for smoking was higher in the detraining group than in the training group.
Conclusions: Detraining results in similar degrees of obesity, low HDL-C, high LDL-C, and high MetS risk as non-training. To prevent lifestyle-related diseases, it is particularly important not only to encourage adults to become physically active, but also discourage active young people from discontinuing physical exercise.

Key words: metabolic health, exercise, health behavior, older adults, youth

INTRODUCTION

It is well known that habitual exercise has beneficial effects on health. In addition to amelioration of obesity [1-5], there is ample evidence to show that exercise can prevent or ameliorate risk factors for cardiovascular disease (CVD) such as type 2 diabetes [6-9], hypertension [10, 11], and dyslipidemia [12-16]. Metabolic syndrome (MetS) is characterized by increased insulin resistance associated with central obesity and clustering of metabolic risk factors, including impaired glucose tolerance, hypertension, and dyslipidemia. In order to prevent or ameliorate MetS, it is important to remain physically active [17, 18].

Some people discontinue habitual exercise even though they had exercised regularly during their student days. However, little is known about the effects of long-term detraining on health. It has been reported that short-term detraining (several days to weeks) has negative effects on lipid metabolism, such as increased triglyceride (TG) [19] and decreased high-density lipoprotein cholesterol (HDL-C) [20-23]. Moreover, relatively longer-term detraining (several years) has been reported to increase body mass index (BMI) and adiposity [24, 25], exacerbate lipid metabolism, and decrease bone mineral density [26, 27]. As to the effects of long-term detraining, or detraining for several decades since youth, there has been only one report on the risk of fractures in men [28] but no report focusing on MetS risk factors.

In the present study, in order to examine the effect of long-term detraining on MetS, 1109 Japanese men were categorized into four groups according to their exercise habits (training group, non-training group, detraining group, and others), and the clinical data and numbers of MetS risk factors of the non-training group or the detraining group were compared with those of the training group.

METHODS

Subjects

Of 1467 men who underwent annual health checks at the Health Planning Center at Makita General Hospital between February and March 2007, 1109 men aged 40-74 years, excluding those who were already treated for hypertension, dyslipidemia, or diabetes, were selected. Medical history was surveyed using a self-administered questionnaire. Habitual exercise dur-

Eiko TAKAHASHI, Health Evaluation and Promotion Center, Tokai University Hachioji Hospital, 1838 Ishikawa-machi, Hachioji, Tokyo 192-0032, Japan Tel: +81-42-639-1111 Fax: +81- 42-639-1178 E-mail: etaka@tokai.ac.jp

ing the student days (from primary school to college) was defined as maintaining physical activity ≥ 2 hours a day more than three times a week. Present habitual exercise was defined as maintaining physical activity ≥ 30 min a day more than once a week. Information about exercise habits was obtained through an interview. The subjects were categorized into four groups according to their exercise habits. The training group consisted of individuals who were continuing habitual exercise from youth to the present. The non-training group consisted of those who never had a habit of exercise, while the detraining group consisted of subjects who had exercised regularly during their student days but not at present. Finally, the others group consisted of individuals with other exercise habits. In this study, the clinical characteristics of the detraining group were compared with those of the training group or the non-training group. This study was designed in compliance with the ethics regulations outlined in the Declaration of Helsinki. Anonymized health records were used for analysis, and the privacy of participants was completely protected by unlinkable anonymization.

Measurements and definition of MetS

Anthropometric measurements were performed, and blood samples were obtained after overnight fasting. All measurements were included in the routine health check examinations. BMI was calculated by dividing weight (kg) by height squared (m^2). Waist circumference (WC) was accurately assessed by a trained staff member at the end of expiration in the standing position, measuring the minimum circumference at the level of the umbilicus to the nearest 0.5 cm. Blood pressure was measured at the right upper arm in a sitting position. Glycosylated hemoglobin (HbA1c) was measured by a high performance liquid chromatography (HPLC) method. The value for HbA1c (%) was estimated as a National Glycohemoglobin Standardization Program (NGSP) equivalent value (%) calculated by the formula HbA1c (%) ≈ HbA1c (Japan Diabetes Society, JDS) (%) + 0.4%, considering the relational expression of HbA1c (JDS) (%) measured by the previous Japanese standard substance and measurement methods and HbA1c (NGSP) [29]. Serum lipid levels were measured enzymatically. The following cut-off values were used according to the Japanese definition of MetS [30]: WC ≥ 85 cm, hypertension (systolic blood pressure (BP) ≥ 130 mmHg and/or diastolic BP ≥ 85 mmHg), FPG ≥ 110 mg/dl, triglyceride (TG) ≥ 150 mg/dl, and/or high-density lipoprotein cholesterol (HDL-C) < 40 mg/dl. The presence of WC ≥ 85 cm and two or more of the other risk factors constitutes a diagnosis of MetS. Information about lifestyle-related behaviors, including smoking, snacking, and drinking alcohol (≥ 50 g/day), was obtained using a questionnaire.

Statistics

Data are expressed as means ± SD. StatView-J 5.0 (Statistical Analysis System Inc, Cary, NC, USA) was used for the statistical analyses. Significant differences in age and clinical data among the three groups were evaluated using Scheffe's multiple comparison test. Odds ratios (*OR*) and 95% confidence intervals (CI) were calculated for WC ≥ 85 cm, BMI ≥ 25 cm/m^2, the presence of MetS, and the differences in lifestyle-related behaviors, using the training group as the reference. The numbers of MetS risk factors (hypertension, dyslipidemia, and hyperglycemia) were compared by ridit analysis [31] using the training group as the standard. All p values were two-tailed, and $p < 0.05$ was considered significant.

RESULTS

Table 1 shows the categorization of the groups by exercise habits. The 1109 Japanese men were categorized as follows: training group ($n = 87$), detraining group ($n = 483$), non-training group ($n = 233$), and others ($n = 306$). Those who had not exercised during their student days but started exercise thereafter were included in the others ($n = 72$). The ages ($M \pm SD$) of those in the training, non-training, and detraining groups were 50.8 ± 7.7, 51.4 ± 7.2, and 49.2 ± 7.1 years, respectively. Overall, 93% of the subjects in the detraining group had exercised regularly until they were college students, which indicates that most of them discontinued exercise after they started working. The frequency of present physical activity in the training group was as follows: once a week (36%), twice a week (13%), 3 times a week (19%), 4 times a week (2%), and ≥ 5 times a week (30%).

Since part of their BMI data when they were 20 years of age were available, we have analyzed the data as below.

training group ($n = 56$; 64% of total, $M = 20.9$, $SD = 1.6$)

detraining group ($n = 360$; 75% of total, $M = 21.3$, $SD = 2.6$)

non-training group ($n = 144$; 62% of total, $M = 21.1$, $SD = 2.6$)

There were no statistical differences among all the groups by Scheffe's multiple comparison tests.

The clinical characteristics according to exercise habits are shown in Table 2. WC and BMI were significantly higher in the non-training and the detraining groups than in the training group. Moreover, the detraining group had a significantly higher WC and BMI than the non-training group. HDL-C was significantly lower and low-density lipoprotein cholesterol (LDL-C) was significantly higher in the non-training and the detraining groups than in the training group. TG and total cholesterol (TC) tended to be higher in the non-training and the detraining groups than in the training group. Table 2 illustrates the numbers of MetS risk factors present according to exercise habits. On ridit analysis, the values of the mean ridit for the non-training group (0.616, $p < 0.01$) and the detraining group (0.596, $p < 0.01$) were significantly higher using the training group as the standard (mean ridit: 0.5). The result of ridit analysis demonstrated that both the non-training and the detraining group had significantly more MetS risk factors than the training group. However, there was no difference between the non-training group and the detraining group on ridit analysis.

The *OR*s and 95% CIs for the presence of obesity and MetS, and differences in lifestyle-related behaviors are shown in Table 3. The *OR*s for WC ≥ 85 cm, BMI

Table 1 Categorization of the groups according to exercise habits

	Exercise habits		Subjects	
Category	Student days	Present	*n*	(%)
Training	≥ 2 hours/day and ≥ 3 times/week	≥ 30 mins/day and ≥ once/week	87	(7.8)
Non-training	none	none	233	(21.0)
Detraining	≥ 2 hours/day and ≥ 3 times/week	none	483	(43.6)
Others	any other patterns of exercise habits		306	(27.6)
Total			1109	(100)

Table 2 Comparison of clinical characteristics by exercise habits

	Training	Non-training	Detraining
WC (cm)	81.1 ± 5.7	86.8 ± 9.9**	88.8 ± 8.4**,#
BMI (kg/m^2)	22.8 ± 2.2	24.0 ± 3.7*	24.9 ± 3.3**,##
SBP (mmHg)	125.8 ± 16.9	130.1 ± 18.0	128.8 ± 17.2
DBP (mmHg)	74.8 ± 11.1	78.0 ± 11.3	77.3 ± 12.3
FPG (mg/dl)	104.4 ± 17.0	109.7 ± 23.7	109.0 ± 24.0
HbA1c (%)	5.6 ± 0.5	5.8 ± 1.0	5.8 ± 0.9
TG (mg/dl)	122.9 ± 134.3	137.0 ± 86.3	145.5 ± 108.2
HDL-C (mg/dl)	64.6 ± 16.5	59.1 ± 16.6*	58.1 ± 14.5*
LDL-C (mg/dl)	134.7 ± 33.2	147.6 ± 36.7*	147.8 ± 37.8*
TC (mg/dl)	202.1 ± 33.4	209.2 ± 33.1	209.4 ± 35.2
No. of MetS risk factors			
0	35 (40%)	61 (26%)	137 (28%)
1	35 (40%)	84 (36%)	176 (36%)
2	14 (16%)	61 (26%)	133 (28%)
3	3 (3%)	27 (12%)	37 (8%)
Mean ridit	0.500	0.616**	0.596**

Data are M ± *SD* or *n* (%). BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol
*: $p < 0.05$, **: $p < 0.01$ relative to training group, #: $p < 0.05$, ##: $p < 0.01$ relative to non-training group (Scheffe's multiple comparison test)

Table 3 Odds ratios and 95% confidence intervals for WC ≥ 85 cm, BMI ≥ 25 kg/m^2, the presence of metabolic syndrome (MetS) and the differences in lifestyle-related behaviors

	Non-training	Detraining
WC ≥ 85 cm	5.98 (3.34 – 10.70)	10.30 (5.91 – 17.96)
BMI ≥ 25 kg/m^2	6.94 (3.06 – 15.70)	9.02 (4.08 – 19.93)
MetS	3.82 (1.75 – 8.35)	4.28 (2.02 – 9.08)
Smoking	1.32 (0.78 – 2.25)	2.01 (1.23 – 3.29)
Snacking	1.33 (0.68 – 2.60)	1.88 (0.93 – 3.78)
Drinking (≥ 50 g/day)	1.64 (0.78 – 9.43)	1.88 (0.93 – 3.78)

The training group was used as the reference

≥ 25 kg/m^2, and the presence of MetS were significantly higher in both the non-training and the detraining group in contrast to the training group (referent group). Compared with the training group, the *OR* for smoking was significantly higher in the detraining group. Although the detraining group showed higher *OR*s compared with the non-training group, there were no significant differences in *OR*s for snacking and drinking alcohol (≥ 50 g/day).

DISCUSSION

In subjects undergoing regular health check-ups, the influence of long-term habitual exercise on MetS was evaluated. While other studies examining the effects of detraining on MetS risk factors have been limited to a few years of detraining, the present study is the first to examine the effects of detraining over several decades, starting from student days. The prevalence of obesity and MetS was significantly increased in the detraining group (discontinued exercise), compared to the training group (continued exercise). In other words, detraining led to obesity to the same extent as in the non-training group, and the risk of MetS was clearly increased.

Since this study was a cross-sectional study, all of the subject s data from their school days were not available. However, the analysis of more than 60% of subject s BMI data when they were 20 years old indicated that there were no statistical differences among all the groups by Scheffe s multiple comparison tests. These results suggested that although their BMI were almost same when they are 20, BMI has changed afterward probably due to their different excise habits.

MetS risk factors include obesity, impaired glucose tolerance, hypertension, and dyslipidemia (high TG and low HDL-C). In the present study, changes in obesity and HDL-C were noted. WC and BMI, indicators of central and overall obesity, respectively, were both increased with detraining in comparison to the training as well as the non-training groups. WC measurements can vary greatly depending on the examiner, but in the present study, a single pre-trained examiner took all measurements, thus ensuring highly reliable data. With detraining, obesity progressed due to a decrease in energy expenditure, but a questionnaire was used to confirm whether there were also other changes in lifestyle habits. The results showed no differences in frequency of snacking or drinking alcohol.

The effects of aerobic exercise on lipid metabolism (TG, HDL-C, TC, and LDL-C) have been reported in several subject populations. For example, in healthy males aerobic exercise decreased TC and TG and increased HDL-C [12], in obese subjects it decreased TG [14], in elderly subjects (age ≥ 50 years) it decreased TC and LDL-C and increased HDL-C [15], and in CVD patients aerobic activity decreased TG and increased HDL-C [16]. On the other hand, increases in TG [19] and decreases in HDL-C [21−23] have been observed within a short period of a few days to few weeks of detraining. The reason for this is thought to be a loss in the enhanced activity of lipoprotein lipase provided by exercise [20, 21]. In our study, HDL-C significantly decreased, and LDL-C significantly increased in the non-training and the detraining groups compared to the training group.

In the present study, habitual exercise during student days was defined as physical activity ≥ 2 hours a day at least 3 days a week, and present habitual exercise was defined as physical activity ≥ 30 minutes a day at least once a week. This was done because, among respondents who regularly exercised during school days, exercise frequency was ≥ 3 days a week in 99%, and exercise time during each bout was ≥ 2 hours in 93%. On the other hand, approximately half of respondents who presently exercised did so at a frequency of 1 to 2 days per week. In addition, to eliminate variations due to different interviewers, the survey on habitual exercise was conducted using an interview format by a single investigator. In our study, the training group had less obesity, higher HDL-C, and lower LDL-C than the detraining group. Thus, it is clear that continuing exercise even once per week is important in preventing lifestyle diseases, and discontinuing exercise is just like having never exercised. Since the present study specifically focused on the effect of long-term detraining on MetS, whether beneficial effects of exercise are observed in subjects who had not exercised during their student days but started exercise thereafter was analyzed separately.

With respect to lifestyle habits, snacking and drinking alcohol did not differ among the three groups, but smoking was more common in the detraining group than in the training group. This suggests that discontinuing exercise may have an adverse impact on other lifestyle habits. Detraining might also cause unhealthy dietary habits leading to obesity. However, our survey was limited to snacking, which may not be enough to demonstrate the dietary causes of detraining-induced obesity. In order to clarify this question, we have already started another study to examine the impact of dietary habits on detraining-induced obesity using different subjects.

The limitations of this study include its cross-sectional design and the fact that test values were compared only during the survey period. Baseline (student days) and interim clinical data were not obtained. Moreover, although the type of habitual exercise during the student days was surveyed in detail, due to the wide variety of exercise types, this variable was excluded from our analysis. Indeed, since exercise type (e.g., aerobic, endurance, resistance) and intensity may have different effects on each parameter, this is an issue for future investigation. Furthermore, although the importance of continuing exercise was demonstrated, frequency was not evaluated. Thus, when conducting a longitudinal study on the influence of detraining on MetS, a study designed to clarify the above points is necessary.

In conclusion, detraining (discontinuing exercise) led to obesity and lower HDL-C, to the same extent as in the non-training group, MetS risk factors were increased, and LDL-C was increased. Therefore, guidance to adults to continue present physical exercise, and guidance to youth not to discontinue physical exercise, must be provided to prevent future lifestyle-related diseases.

ACKNOWLEDGEMENTS

The authors declare no conflicts of interest.

REFERENCES

1) Williamson DF, Madans J, Anda RF, Kleinman JC, Kahn HS, Byers T. Recreational physical activity and ten-year weight change in a US national cohort. Int J Obes Relat Metab Disord 1993; 17: 279-86.
2) Sternfeld B, Wang H, Quesenberry CP Jr, Abrams B, Everson-Rose SA, Greendale GA, *et al*. Physical activity and changes in weight and waist circumference in midlife women: findings from the Study of Women's Health Across the Nation. Am J Epidemiol 2004; 160: 912-22.
3) Kimm SY, Glynn NW, Obarzanek E, Kriska AM, Daniels SR, Barton BA, *et al*. Relation between the changes in physical activity and body-mass index during adolescence: a multicentre longitudinal study. Lancet 2005; 366: 301-7.
4) Hankinson AL, Daviglus ML, Bouchard C, Carnethon M, Lewis CE, Schreiner PJ, *et al*. Maintaining a high physical activity level over 20 years and weight gain. JAMA 2010; 304: 2603-10.
5) Dwyer T, Ponsonby AL, Ukoumunne OC, Pezic A, Venn A, Dunstan D, *et al*. Association of change in daily step count over five years with insulin sensitivity and adiposity: population based cohort study. BMJ 2011 Jan 13; 342: c7249. doi: 10.1136/bmj.c7249.
6) Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, *et al*. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. Diabetes Care 1997; 20: 537-44.
7) Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, *et al*. Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med 2001; 344: 1343-50.
8) Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, *et al*. Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002; 346: 393-403.
9) Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. Diabetes Care 2007; 30:744-52.
10) Grassi G, Seravalle G, Calhoun D, Bolla GB, Mancia G. Physical exercise in essential hypertension. Chest 1992; 101: 312S-14S.
11) Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA, *et al*. Exercise and hypertension. Med Sci Sports Exerc 2004; 36:533-53.
12) Kelley GA, Kelley KS. Aerobic exercise and lipids and lipoproteins in men: a meta-analysis of randomized controlled trials. J Mens Health Gend 2006; 3: 61-70.
13) Kelley GA, Kelley KS. Aerobic exercise and HDL2-C: a meta-analysis of randomized controlled trials. Atherosclerosis 2006; 184: 207-15.
14) Kelley GA, Kelley KS, Vu Tran Z. Aerobic exercise, lipids and lipoproteins in overweight and obese adults: a meta-analysis of randomized controlled trials. Int J Obes (Lond) 2005; 29: 881-93.
15) Kelley GA, Kelley KS, Tran ZV. Exercise, lipids, and lipoproteins in older adults: a meta-analysis. Prev Cardiol 2005; 8: 206-14.
16) Kelley GA, Kelley KS, Franklin B. Aerobic exercise and lipids and lipoproteins in patients with cardiovascular disease: a meta-analysis of randomized controlled trials. J Cardiopulm Rehabil 2006; 26(3): 131-9.
17) Lakka TA, Laaksonen DE. Physical activity in prevention and treatment of the metabolic syndrome. Appl Physiol Nutr Metab 2007; 32: 76-88.
18) Strasser B, Siebert U, Schobersberger W. Resistance training in the treatment of the metabolic syndrome: a systematic review and meta-analysis of the effect of resistance training on metabolic clustering in patients with abnormal glucose metabolism. Sports Med 2010; 40: 397-415.
19) Hardman AE, Lawrence JE, Herd SL. Postprandial lipemia in endurance-trained people during a short interruption to training. Appl Physiol 1998; 84: 1895-901.
20) Herd SL, Hardman AE, Boobis LH, Cairns CJ. The effect of 13 weeks of running training followed by 9 d of detraining on postprandial lipaemia. Br J Nutr 1998; 80: 57-66.
21) Mankowitz K, Seip R, Semenkovich CF, Daugherty A, Schonfeld G. Short-term interruption of training affects both fasting and post-prandial lipoproteins. Atherosclerosis 1992; 95: 181-9.
22) Motoyama M, Sunami Y, Kinoshita F, Irie T, Sasaki J, Arakawa K, *et al*. The effects of long-term low intensity aerobic training and detraining on serum lipid and lipoprotein concentrations in elderly men and women. Eur J Appl Physiol Occup Physiol 1995; 70: 126-31.
23) Slentz CA, Houmard JA, Johnson JL, Bateman LA, Tanner CJ, McCartney JS, *et al*. Inactivity, exercise training and detraining, and plasma lipoproteins. STRRIDE: a randomized, controlled study of exercise intensity and amount. J Appl Physiol 2007; 103: 432-42.
24) Petibois C, Cassaigne A, Gin H, Déléris G. Lipid profile disorders induced by long-term cessation of physical activity in previously highly endurance-trained subjects. J Clin Endocrinol Metab 2004; 89: 3377-84.
25) Williams PT, Thompson PD. Dose-dependent effects of training and detraining on weight in 6406 runners during 7.4 years. Obesity (Silver Spring) 2006; 14: 1975-84.
26) Valdimarsson O, Alborg HG, Düppe H, Nyquist F, Karlsson M. Reduced training is associated with increased loss of BMD. J Bone Miner Res 2005; 20: 906-12.
27) Nordström A, Olsson T, Nordström P. Bone gained from physical activity and lost through detraining: a longitudinal study in young males. Osteoporos Int 2005; 16: 835-41.
28) Nordström A, Karlsson C, Nyquist F, Olsson T, Nordström P, Karlsson M. Bone loss and fracture risk after reduced physical activity. J Bone Miner Res 2005; 20: 202-7.
29) The Committee of the Japan Diabetes Society on the diagnostic criteria of diabetes mellitus. Report of the Committee on the classification and diagnostic criteria of diabetes mellitus. J Diabetes Invest 2010; 1: 212-28.
30) Teramoto T, Sasaki J, Ueshima H, Egusa G, Kinoshita M, Shimamoto K, *et al*. Metabolic syndrome. J Atheroscler Thromb 2008; 15: 1-5.
31) Bross IDJ. How to use ridit analysis. Biometrics. 1958; 14: 18-38.