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Metabolic Aspects of Physical Training in Male Patients after Myocardial Infarction

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ABSTRACT

Twenty-six post infarct patients were selected and admitted to hospital 3 months after the onset of the myocardial infarction for an investigation including lipid studies and glucose and fat tolerance tests. After this initial hospital stay the patients were randomly divided into a training (13 patients) and a reference (13 patients) group. During the following 3 months the first group of patients were physically trained (entirely indoors, three sessions a week individually). Thereafter the patients of both groups were readmitted to hospital for a second investigation, identical with the initial one. The oral glucose tolerance (OGT)[1] was improved in the younger (less than or equal to 55 years) patients of the trained group. There were no significant changes of cholesterol or triglyceride levels after the training or reference periods measured 5 days after the last training session.

INTRODUCTION

The risk factors for ischaemic heart disease (IHD), nowadays well known, include cigarette smoking, hyperlipidaemia, reduced glucose tolerance and raised blood pressure (1, 13, 17, 26, 39). Attempts at combating these factors have included recommendations for changes in diet, smoking withdrawal, and different drug therapies. During recent years the interest in physical training as an additional form of therapy in *primary* prevention of IHD has increased. The expected benefits are a decrease of serum triglycerides (TG) and serum cholesterol (CHOL) concentrations (24, 27, 29, 34).

Physical training as *secondary* prevention of IHD has also gained interest because of other benefits such as achievement of a higher physical work capacity, and increased self-confidence of both patient and his relatives (2, 5, 33).

[1] The following abbreviations were used: OGT oral glucose tolerance, IVGT intravenous glucose tolerance.

This report describes experiences of the effect of physical training on plasma lipids and blood glucose metabolism in male patients recovered from their first myocardial infarction.

MATERIAL

Selection of patients

The material was selected from all male patients treated at the University Hospital, Uppsala during the period December 15, 1970–March 15, 1972 for their first myocardial infarction.

Patients 70 years old or older were excluded, as well as all patients with the following conditions: treated diabetes mellitus, diastolic blood pressure exceeding 110 mmHg at rest (indirect method), heart volume exceeding 600 ml/m^2 body surface area (supine posture), cardiac arrhythmias (e.g. regularly recurring VES during exercise, or atrial fibrillation), a history of pain or aching in the back or the larger joints or pulmonary disease. No patients treated with digitalis, beta receptor blocking agents, or lipid lowering drugs were included in the study.

The material is a subsample of the series previously described and compared with the whole infarct population treated at the hospital during a two-year period March 15, 1969–March 15, 1971 (2).

After the above selections there remained 26 patients, who were assigned randomly to two groups, a so-called training group (13 patients) and a reference group (13 patients). The former group underwent a 3-month period of physical training (see below) while the reference group served as a control. Clinical characteristics of the material have been presented elsewhere (2, 3, 4).

Drop-out of patients

Three patients from the trained group and 5 patients from the reference group dropped out from the physical training or were excluded for the following reasons: aggravation of angina pectoris during training (1 patient), reinfarction (1 patient) (not in connection with any training session), ulcerative proctitis (1 patient). One patient did not wish to take part in any follow-up investigations. Four patients dropped out for technical reasons: vasovagal reactions (2 patients), incomplete blood sampling (2 patients).

Table I. *Age, body weight, and blood plasma concentrations of triglycerides and cholesterol before and after the training and reference periods*

		Age (years)	Body weight (kg) Before	Body weight (kg) After	Plasma Triglycerides[a] (mmole/l) I Before	I After	II Before	II After	Plasma cholesterol (mg/100 ml) Before	After
Trained group	Mean	56	75.9	75.5	2.83	2.53	2.64 (0.421)	2.39 (0.379)	266	237
($N=10$)	S.E.M.	2.3	2.5	2.8	0.36	0.30	(−0.945)	(−0.953)	13	9
	Δ ±S.E.M.		−0.4 ±0.7		−0.30±0.25		(−0.042 ±0.044)		−29 ±17	
			ns		ns		ns		ns	
Reference group	Mean	52	76.2	76.2	2.35	2.24	2.29 (0.359)	2.19 (0.340)	289	273
($N=8$)	S.E.M.	3.0	3.3	3.5	0.21	0.17	(−0.962)	(−0.965)	13	13
	Δ ±S.E.M.		0		−0.11±0.13		(−0.019 ±0.024)		−16 ±7	
			ns		ns		ns		ns	

[a] Calculations made without (I) and with (II) logarithmic transfer of the values. The 10 logarithmic values are given within brackets.

GENERAL PROCEDURE

Three and six months after the onset of the acute myocardial infarction the patients were readmitted to hospital for investigations, which have been described previously (2, 3). In addition during the last year of the study oral and intravenous glucose tolerance tests and also an intravenous fat tolerance test were performed on different days before and after the training or reference periods. Furthermore, adipose tissue biopsies were taken for determination of fat cell size. The patients of the trained group were then trained 3 times weekly as previously described (3). Each session started with 10 min rest, and this was followed by 10 min of calisthenics under the leadership of a qualified physiotherapist. This was followed by three 10-min sessions of cycling on an ergometer bicycle with varying work loads. The training session ended with 10 min rest on a couch. It was considered desirable that the work load should reach but not exceed the pain threshold for the patients with angina pectoris.

No instructions were given to the patients concerning dietary modifications.

METHODS

The patients came to the laboratory in the morning after fasting and refraining from smoking since the night before. Teflon catheters (Stille Infart 1.15 mm, Stockholm) were inserted percutaneously in a cubital vein for blood sampling.

Determinations of the plasma concentrations of cholesterol and triglycerides were made by an autoanalytical technique (32). The blood glucose concentrations were determined on venous blood plasma by the glucose oxidase method (21). The serum insulin concentration was determined by a "solid phase" radioimmunological technique (Phadebas Insulin Test, Pharmacia) based upon the method described by Wide & Porath (40). The serum uric acid was analysed by a method described by Sobel & Kim (36). The oral glucose tolerance (OGT) test was performed as follows: the patient drank about 200 ml water containing 100 g glucose. Blood samples for analysis of glucose and insulin concentrations were taken immediately before (0), 30, 60, and 120 min after ingestion of the glucose.

For the intravenous glucose tolerance (IVGT) test, 0.5 g glucose per kg body weight was given intravenously during 2 min in the form of a 50% solution. Blood samples were taken for determination of blood glucose before and 20, 30, 40, 50 and 60 min after, and of serum insulin before and 4, 6, 8, and 60 min after the start of the glucose injection. Early insulin response was calculated according to the method of Thorell et al. (38). The IVGT was expressed as the K value calculated from the formula $0.693 \times 100/$ glucose half time (25).

The intravenous fat tolerance test (IVFTT) was performed in accordance with the method of Carlson & Rössner (16).

The fat cell diameter was measured on cells obtained by adipose tissue biopsy according to the method of Sjöström et al. (35).

Statistical concepts and methods as described by Hoel were used (22).

RESULTS

No significant differences were found between the trained and the reference group with respect to age, height and body weight (Table I). In the 10 patients of the trained group the mean age was 56 years, the initial weight 75.9 and the final weight 75.5 kg, and the mean height 176 cm. In

Table II. *Age, body weight, and intravenous fat tolerance and fat cell diameter before and after the training and reference periods*

		Age (years)	Body weight (kg) Before	Body weight (kg) After	Intravenous fat tolerance, K (%/min) Before	Intravenous fat tolerance, K (%/min) After	Fat cell diameter (μ) Before	Fat cell diameter (μ) After
Trained group	Mean	53.6	76.4	75.6	2.64	3.11	89.9	85.4
	S.E.M.	2.1	3.2	3.8	0.66	0.83	6.58	4.00
	Range	44–59	65.1–89.8	63.1–94.0	0.7–5.1	1.1–7.7	61.5–108.0	67.8–93.6
	N	7	7		7		6	
Reference group	Mean	58.7	75.4	75.2	3.53	4.05	89.4	89.0
	S.E.M.	6.6	4.0	4.1	0.53	0.51	3.44	5.13
	Range	49–66	63.4–94.6	61.6–95.2	2.2–6.0	2.6–6.0	72.8–99.0	66.0–100.7
	N	7	7		7		6	

the 8 patients of the reference group the corresponding figures were 52 years, 76.2 and 76.2 kg, and 174 cm.

Effect of training on lipid metabolism

There were no significant changes of the mean plasma TG concentration after the training or reference period. In the training group there was a reduction of 0.30±0.25 mmoles/l (11%) compared with 0.11±0.13 mmoles/l in the reference group (Table I). In the trained group 6 of the patients achieved a decrease in plasma TG. All these patients had initial TG values more than 1.90 mmoles/l.

Table III. *The effect of physical training on fasting blood glucose, and serum insulin, oral glucose tolerance, intravenous glucose tolerance and the serum insulin response after glucose given orally and intravenously*

Mean values ± standard errors of the means (S.E.M.) are given

		N	Age (years)	Body weight (kg)	Oral glucose test: OGT (mg/100 ml) 0′	OGT Sum (0–60–120′)	Insulin (microunits/ml) *N*	Insulin 0′	Insulin Sum (0–60–120′)
Trained group									
Total	Before	8	52.4 ±3.1	80.8 ±3.7	81 ±3	328 ±22	8	12 ±2	175 ±39
	After			81.0 ±4.2	81 ±2	298 ±15		14 ±2	151 ±28
≤55 years	Before	5	47.0 ±2.3	81.1 ±5.4	82 ±4	350 ±20 **	5	11 ±21	146±32
	After			82.1 ±6.0	81 ±4	294 ±16		14 ±2	134 ±33
Reference group									
Total	Before	9	54.4 ±3.0	77.3 ±2.6	85 ±4	349 ±33	7	19 ±5	228 ±93
	After			76.1 ±3.1	83 ±5	374 ±25		14 ±3	178 ±57
≤55 years	Before	5	48.4 ±3.3	78.2 ±4.4	86 ±8	314 ±32	5	17 ±3	131 ±27
	After			76.8 ±5.6	83 ±8	354 ±42		11 ±2	108 ±17

** $P < 0.01$ (significance for paired differences), *N* = number of patients.

The OGT test and IVGT test were performed as described under Methods. OGT is expressed as the fasting blood glucose (0) and the sum of the values for blood glucose concentration at O, 60 and 120 min after the glucose intake. Serum insulin values during the OGT test are presented in the same way. IVGT is presented as the K value (25) and the serum insulin response during the IVGT test is expressed as early response (38) (see under Methods) and the concentration 60 min after glucose injection.

Neither were there any significant changes of the mean plasma cholesterol concentration. In the trained group there was a reduction of 11% of the pretraining value, on the average, from 266 to 237 mg/100 ml. In the reference group the cholesterol value decreased from 289 to 273 mg/100 ml (Table I).

There were no significant changes in body weight after the training or reference period (Table I).

As shown in Table II there were no significant changes of fractional removal rate of exogenous triglycerides (intravenous fat tolerance) after the training or reference periods. Neither were there any significant changes of the fat-cell diameter.

Effects of training on carbohydrate metabolism

In a sample of patients investigated during the last year of the study, oral and intravenous glucose tolerance and serum insulin were investigated before and after the training and reference periods. Results of these investigations are presented in Table III. No changes in fasting blood glucose concentrations were obtained in any group, which is in agreement with results for the whole material presented elsewhere (4). A significant improvement in glucose tolerance (lower sum of glucose values 0–60–120 min (6) after the ingestion of glucose) was obtained in the younger patients (less than or equal to 55 years) of the trained group as measured by OGT. The sum decreased from 350±20 to 294±16 mg/100 ml ($P<0.01$). There were no significant changes of the insulin concentrations. IVGT did not change significantly in any group and neither did the early insulin response.

ntravenous glucose test				
IVGT		Insulin (microunits/ml)		
N	K-value	N	Early response	
7	1.3±0.2	4	63±13	34±10
	1.1±0.1		43±17	32±10
4	1.4±0.3			
	1.2±0.2			
8	1.0±0.1	4	103±48	39±10
	1.1±0.1		97±48	33± 5
	1.1±0.2			
	0.9±0.1			

Effect of training on serum uric acid concentration

The serum *uric acid* was measured before and after the training and the reference period. The changes were not significant. In the trained group the value before training was 6.4 ±0.2 and after 5.8 ±0.3 mg/100 ml. In the reference group the before-value was 6.0±0.4 and the after-value 5.6 ±0.4 mg/100 ml.

DISCUSSION

It has been known for some years that physical effort of long duration reduces the TG level in the blood of healthy men (14, 15). Holloszy et al. (24) studied 15 healthy middle-aged men and noted a TG reduction of 40% towards the end of a 6-month period of physical training. Keul et al. (27) found that even a 4-week period of training reduced the fasting level of TG by 35% in men aged 20–30 years and by 15% in men 50–60 years old. Siegel et al. (34), however, found no significant change in the TG level on training of blind patients, while Mann et al. (29) obtained increased levels after a period of physical training of healthy middle-aged men. This elevation, however, was considered to be caused by an increased intake of carbohydrates during the training period. The body weight was unchanged.

Most authors now agree that physical training gives a sustained reduction of the plasma TG in healthy persons, at least with a training session two or three times weekly. This would mean that one of the risk factors for the occurrence of ischaemic heart disease would be reduced considerably (17).

After training of a group of middle-aged patients with previous myocardial infarction, and excluding those who did not show any circulatory training effect, Björntorp et al. (6) noted a significant reduction of the TG levels after training. However, these authors also observed a significant decrease in body fat during training.

In the present study, no significant correlation could be established between training effect and TG reduction. Neither was there any decrease in body weight during the training period. Furthermore, in this series a limited number of 10 post-myocardial infarct patients were trained and the blood samples for plasma lipid determination were taken only once 5 days after the last training session. It is possible that the non-significant reduction of 11% of the pretraining value might have been more pronounced if blood samples had been taken 2 or 3 days after the last training session (24).

An elevation of the plasma cholesterol concentration is believed to comprise an important risk factor for ischaemic heart disease (26). Several authors have reported a reduction of the cholesterol level after increased physical activity or training in healthy persons (12, 19, 29, 30), while others have found no change in the value after a training period (20, 37). The plasma cholesterol concentration has been reported to be lower after physical training even in the absence of simultaneous body weight reduction (18, 28, 34). On training of patients with earlier cardiac infarction Björntorp et al. (6) found no significant decrease of the plasma cholesterol, and neither was any significant reduction noted in the present series.

Björntorp et al. (7) have recently made a comparison of glucose tolerance (OGT) in trained and untrained healthy middle-aged men. They found that the trained men had a significantly higher glucose tolerance and lower plasma insulin values on oral glucose loading. Furthermore these subjects achieved a lower fat cell weight and a higher removal rate of exogenous triglycerides. In the present series of patients an improved OGT was achieved in the younger trained patients (less than or equal to 55 years). The corresponding serum insulin values were non-significantly lower after training. In a study of the effect of training after myocardial infarction, Björntorp et al. (6) have recently also found a slightly increased glucose tolerance after training (significant decrease of the 90 min value on oral glucose loading), but especially noted lower plasma insulin values after OGT. Improvement of IVGT after training of patients with asymptomatic glucose intolerance has also been achieved by others (9). It has been postulated that the physical training, which among other effects increases the aerobic capacity of the skeletal muscles (8, 23), makes the trained muscle better equipped to oxidate energy-rich substrates of different kinds (both carbohydrates and lipids).

Elevated serum uric acid concentrations have been related to an increased risk for ischaemic heart disease (31). After a period of physical training in healthy men, both reduced and unchanged serum uric acid levels have been reported (10, 11). The reduced levels have been explained by an increase of the plasma volume caused by the training, and possibly also by an increased excretion of uric acid. In the present series a significant increase of the blood volume was noted (2), but there were no significant changes of the serum uric acid and thus no training effect achieved.

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