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Success and Failure of Exercise Training After Myocardial Infarction: Is the Outcome Predictable?

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One hundred fifty-six patients underwent a 5 week daily exercise training program after recovery from acute myocardial infarction. Outcome was assessed on the basis of exercise testing, integrating the measurements into a single outcome measure consisting of three categories (positive, n = 79; negative, n = 42; no change, n = 35). This composite criterion served as the end point for determining the predictability of a positive (training success) and negative (training failure) outcome.

With use of logistic regression analysis, the baseline variables of clinical information, exercise data and psychosocial variables were able to identify patients with training success, as well as patients with failure (correct classification rates 81% and 85%, respectively). The characteristics of patients for whom training was beneficial differed from those of patients with a negative outcome. Work status before infarction was the single most important predictor of success, but it did not determine failure. Psychologic variables (type A behavior, well-being, depression) were important for predicting failure, but not for predicting success. Cardiac state and physical fitness largely determined training success.

It is concluded that the physical benefit of exercise training in patients after myocardial infarction is highly predictable. Validation will make it possible to optimally apply exercise training as a therapeutic modality in these patients.

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Cardiac rehabilitation programs can be expensive and carry a risk (1), and intensive physical training does not always result in improved fitness for all patients (2). Much effort could be saved if a patient's likelihood of obtaining a positive training response could be predicted on the basis of initial data (1). Previous studies (1,3-6) obtained moderate success in such prediction.

In this study, a composite criterion is constructed on the basis of several measurements to differentiate patients who will have a successful response to an exercise program from those who will be unsuccessful (7). In addition, this study uses psychosocial data as predictor variables; these have been successfully used to predict psychosocial outcome (8-11), but have rarely been used to predict a physical training effect (5,12).

The main objective of the study was to predict success or failure of exercise training on the basis of clinical information, psychosocial data and initial exercise testing data.

Methods

Study patients. After discharge following acute myocardial infarction, patients were referred from several hospitals to the regional rehabilitation center at St. Joannes de Deo Hospital. A total of 156 such patients (147 men and 9 women) were eligible for the study. Patients who were referred with a diagnosis other than myocardial infarction and patients who needed individual (psychosocial) help in addition to exercise training were excluded from the study. The median age was 56 years (range 36 to 76). In Tables 1 and 2, the clinical data at entry are separately summarized for the three categories of training outcome.

Procedure. Clinical baseline data and medical history were obtained from the referring cardiologist. At entry, patients were interviewed by a psychologist or social worker, who asked about the patient's appraisal of his or her situation (Table 2). The patients were asked to participate in a study designed to assess the effect of the rehabilitation program. After they consented, they completed additional self-administered questionnaires. In addition, half of the patients were assigned at random to relaxation therapy.

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Table 1. Predictive Variables for Training Outcome: Clinical Information and Exercise Data in 156 Patients With Recent Myocardial Infarction

	Success (n = 79)	No Change (n = 35)	Failure (n = 42)	p*	p†
Age (yr)	55 ± 8	56 ± 11	56 ± 7	NS	NS
No. of men	77 (98)	33 (94)	37 (88)	0.07	0.05
Clinical data					
Preinfarction					
Angina pectoris	10 (13)	4 (11)	12 (29)	NS	0.05
Smoking (cigarettes/day)	15 ± 14	19 ± 16	12 ± 11	NS	0.02
Previous infarction	7 (9)	3 (9)	6 (14)	NS	NS
Previous CABG	—	—	3 (7)	0.10	0.01
Beta-blockers	9 (11)	1 (3)	6 (14)	NS	NS
Diuretics	7 (9)	1 (3)	1 (2)	0.08	NS
Anginal med	4 (5)	1 (3)	8 (19)	0.10	0.01
Infarction					
Large	22 (28)	18 (51)	14 (38)	0.06	NS
Anterior	22 (28)	13 (37)	18 (43)	0.10	0.09
Complications	9 (11)	9 (26)	9 (21)	0.07	0.10
Postinfarction					
Angina	19 (24)	6 (17)	15 (36)	NS	0.07
Heart glycosides	8 (10)	6 (17)	9 (21)	0.07	0.09
Anginal med	19 (24)	5 (14)	7 (17)	NS	NS
Exercise testing					
Start of training (weeks after hospital discharge)	5.0 ± 1.4	4.7 ± 1.5	5.8 ± 2.9	NS	0.05
Work capacity‡	86 ± 16	91 ± 18	92 ± 22	0.06	NS
Maximal work load (W)	132 ± 21	137 ± 23	133 ± 25	NS	NS
Heart rate (beats/min)					
Rest	76 ± 14	79 ± 16	86 ± 20	0.03	0.02
60 W	99 ± 16	103 ± 17	109 ± 19	0.008	0.009
Maximal	133 ± 22	137 ± 24	138 ± 25	NS	NS
Blood pressure (mm Hg)					
Systolic rest	131 ± 17	129 ± 19	128 ± 16	NS	NS
Systolic maximal	159 ± 25	155 ± 22	155 ± 18	NS	NS
Chest pain	11 (14)	1 (3)	8 (19)	NS	NS
ST abnormalities	30 (38)	6 (17)	12 (29)	0.07	NS
Arrhythmias	4 (5)	6 (17)	7 (17)	0.02	NS

*Training success versus failure or no change; †training failure versus success or no change. ‡Maximal work load as percent of normal. Data are reported as number of cases or mean values ± SD. Percentages are shown in parentheses. CABG = coronary artery bypass graft surgery; med = medication.

Graded exercise testing was performed on a bicycle ergometer before and after the physical training.

Psychologic questionnaires. These included the following: *1) Heart patients psychologic questionnaire* for measurement of the well-being of patients with cardiac disease (13), consisting of four scales: well-being, subjective invalidity, despondency and social inhibition; *2) anxiety measured by the state trait anxiety inventory (STAI) in two modes:* state and trait anxiety (14); *3) sleeping habits*, consisting of questions about hours of sleep, daytime naps and quality of sleep (15); and *4) functional symptoms*, consisting of complaints not typical of angina pectoris. In addition, the following questionnaires referred to the preinfarction period: *5) Jenkins activity scale* for type A behavior (16); and 6) *Maastricht questionnaire* to evaluate vital exhaustion and depression (17).

Exercise testing. After an adaptation period on the bicycle ergometer, the test began with a 1 min period of cycling at 60 cycles/min without load and then for 2 min at 60 W. The test continued by increasing the work load by 30 W every 2 min until symptoms limited further exercise or the physician terminated the test. The occurrence of angina pectoris, ST segment abnormalities and severe arrhythmias were noted. ST abnormalities were mostly ST depressions ≥2 mm, horizontal or downsloping, occurring during or immediately after the test. Electrocardiographic lead CM_5 was recorded during the last 30 s before the work load was increased. Blood pressure was measured by cuff sphygmomanometry before the test and at maximal work load.

Rehabilitation. All patients underwent a physical conditioning program, consisting of 5 weeks of interval exercise training on a bicycle ergometer, once a day for 30 min.

Table 2. Predictive Variables for Training Outcome: Psychosocial Information in 156 Patients With Recent Myocardial Infarction

	Success (n = 79)	No Change (n = 35)	Failure (n = 42)	p*	p†
Interview					
Work before infarction	60 (76)	18 (51)	23 (55)	0.005	0.10
Infarction experience					
Doubt of diagnosis‡	8 (13)	2 (7)	2 (8)	NS	NS
Seriously ill‡	29 (45)	13 (45)	19 (70)	NS	0.04
Infarction cause clear	48 (61)	23 (70)	20 (48)	NS	0.10
Optimistic for future‡	49 (78)	21 (72)	17 (63)	NS	NS
Expects full recovery of activities‡	42 (67)	22 (85)	21 (75)	NS	NS
Questionnaires					
Vital exhaustion	90 ± 22	86 ± 19	92 ± 26	NS	NS
JAS (type A)	121 ± 13	121 ± 13	116 ± 14	NS	0.06
Sleep quality	7.2 ± 2.3	7.9 ± 2.4	7.5 ± 2.7	NS	NS
Siesta (quarter of hours)	3.5 ± 1.7	3.9 ± 1.5	4.3 ± 1.5	0.04	0.03
Functional complaints	35 ± 7	33 ± 7	37 ± 9	NS	0.10
Anxiety state	38 ± 10	34 ± 8	37 ± 12	NS	NS
Anxiety trait	37 ± 9	34 ± 9	37 ± 10	NS	NS
Well-being	25 ± 7	28 ± 6	27 ± 8	0.09	NS
Invalidity feelings	25 ± 6	25 ± 6	26 ± 6	NS	NS
Despondency	16 ± 4	14 ± 3	17 ± 5	NS	0.08

*Training success versus failure or no change; †training failure versus success or no change; ‡n = 117. Data are reported as number of cases or mean values ± SD. Percentages are shown in parentheses. JAS = Jenkins activity scale.

Training was done in groups of four patients supervised by two physical therapists. Each patient exercised up to 70% to 80% of the maximal heart rate (Karvonen method) attained at pretraining exercise testing. Half of the patients also underwent individual relaxation therapy. Relaxation training was given once a week in six individual sessions of 1 h duration. Several procedures for active and passive relaxation were employed, with a respiratory technique (18) as a core.

Outcome criterion: training benefit. To obtain a single measure indicating the efficacy of physical training, the measurements obtained at exercise testing both before and after training were integrated into a composite criterion. With this criterion, patients were classified as follows: 1) patients with little or no change, 2) patients whose condition improved (success), or 3) patients whose condition deteriorated (failure) (7). In the flow chart in Fig. 1, four levels are shown according to their clinical relevance: signs of cardiac dysfunction (ST abnormalities, angina pectoris, serious arrhythmias), maximal work load, heart rate and systolic blood pressure response. At each of these levels, a patient could be assigned to "success" or "failure" when a significant change in the particular measurement had occurred. For cardiac signs, a negative change had priority over a positive one. Levels 2 to 4 represented physical fitness. Dropouts were included and classified as far as possible on the basis of the reason for not completing the training program. Patients who stopped the training because they resumed their normal daily activities were classified in the success group. Patients who stopped the training for cardiac problems were classified in the failure group. Patients who stopped for other reasons were assigned to "no change." Thus, all subjects were classified.

Statistical analyses. The association of training outcome with data at entry was analyzed in two ways. Univariate association, with the baseline characteristics as predictor variables, was tested with 1) chi-square analysis for contingencies in case of variables of nominal or ordinal level; and 2) Student's *t* test in case of variables of interval level.

Stepwise logistic regression analysis was used to predict the outcome based on sets of variables. Predictions were first made using variables from four sets of variables: 1) medical history and hospital records, 2) interviews, 3) exercise testing, and 4) psychologic questionnaires, with all sets taking into account age and gender (see Appendix A). Missing values were assigned to a middle category in the case of discrete variables, and to the mean values in the case of interval variables. Next, selected variables from the medical and exercise data were combined to investigate the predictive value of information that is routinely available in a rehabilitation clinic. Ultimately, selected psychosocial data were included, with the exception of incomplete interview variables. The criterion for inclusion of variables was $p < 0.10$; for exclusion, it was $p > 0.15$.

The performance of the resulting logistic function is expressed through its classification rates. This function

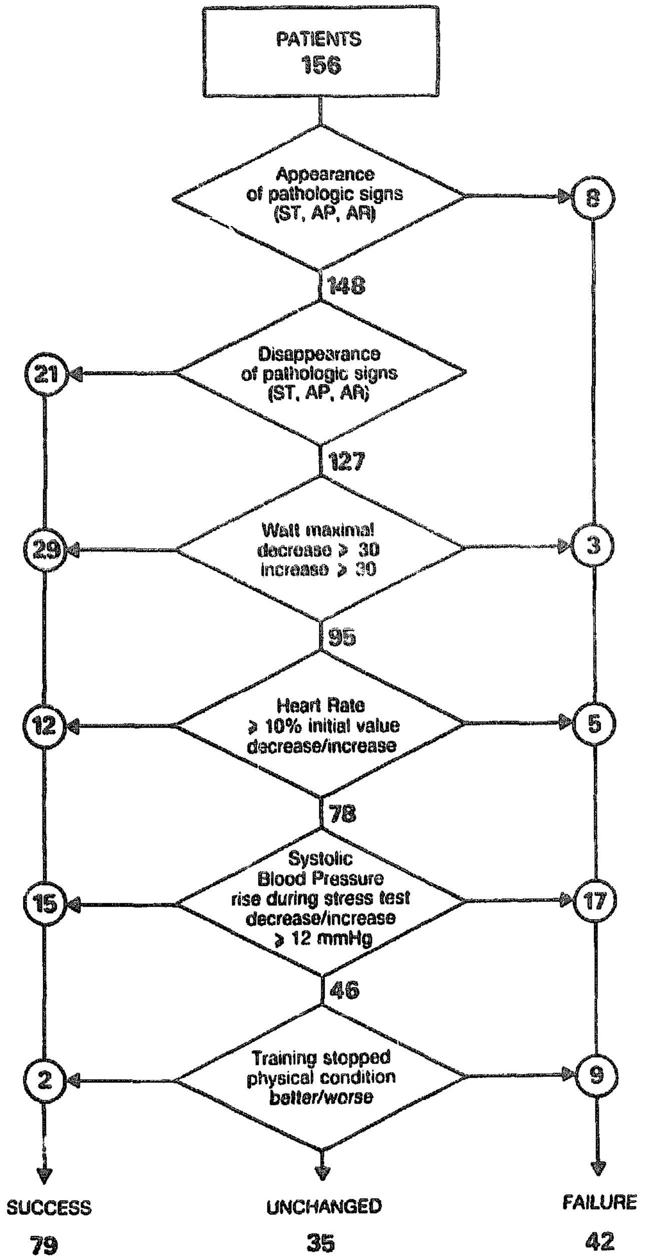

Figure 1. Flow chart for determining success or failure of exercise training in 156 patients with recent myocardial infarction. AP = angina pectoris; AR = arrhythmia; ST = ST segment abnormalities; Watt maximal = maximal work load achieved.

consists of an equation that includes the selected variables with their regression coefficients and a constant. For each patient, the equation yields an estimation of the probability of the particular outcome (either success or failure). Comparing the estimated outcome with the actual outcome at different levels of probability, the power of the logistic function to classify the patient correctly is shown. The rates for the classification with the highest percent of correctly classified patients are given for each function. The variables selected in the final analyses are presented in Appendix B.

Results

Baseline clinical features (Table 1). A total of 156 patients with recent myocardial infarction were admitted to the study. Three patients had previous coronary artery bypass grafting, 16 had experienced recurrent infarction and 26 had a history of angina pectoris. Classification of infarct size was made according to peak serum enzyme levels. In 47 patients, the infarct was considered small, in 49 patients medium and in 52 large. In eight patients, serum enzyme levels were not available, and these patients were included in the medium category. In-hospital signs of heart failure (hypotension, cardiothoracic ratio >50%, pulmonary congestion) were present in 27 patients (17%). On average, patients were hospitalized for almost 3 weeks. Postinfarction angina was present in 26% of the patients.

Training outcome. The exercise program was completed by 139 of the 156 patients. Mean maximal work load increased from 134 to 142 W ($p < 0.0001$) and heart rate at highest equal work load level decreased from 134 to 129 beats/min ($p < 0.0001$). Maximal work load increased by ≥30 W in 39 patients (28%) and decreased in 7 patients (5%). Before exercise testing, 41% of the patients achieved a work load of ≥90% of the normal value. After training, 58% of the patients achieved this work load. On average, blood pressure changes were negligible. ST abnormalities were found in 44 patients before and in 34 patients after training. These abnormalities disappeared in 16 patients and newly appeared in 6 patients. Exercise-induced chest pain was present in 18 patients before and in 12 after training; it disappeared in 10 patients and newly appeared in 4 patients. Serious arrhythmias were present in 14 patients and developed in 1 additional patient after training.

Seventeen patients did not complete the program. Two had fully resumed their activities and were considered to have had a successful outcome. Nine patients had to stop because of cardiac problems and were classified in the failure group. The remaining six patients stopped for noncardiac reasons and were classified as having no change. In the flow chart (Fig. 1), it is shown that training was successful in 79 patients (51%) and unsuccessful in 42 patients (27%). The remaining 35 patients (22%) showed no substantial change. Outcome differed for the two treatment modalities. The addition of relaxation therapy had a positive effect on training benefit (success: 46% in those without such versus 55% in patients with such therapy, failure: 33% versus 20%, respectively).

Univariate Analyses

Training success. About half of the patients benefited from the training program. Compared with those without benefit, in the training group with benefit, there were fewer women, more patients used diuretic drugs and fewer had

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Table 3. Performance of Variables Predicting Training Success

	Sets of Predictor Variables					
	A	B	C	D		
Performance Rates	Clinical	Interview	Exercise	Psychologic	A+B+C	All
Correctly classified (%)	60	62	65	60	76	81
Sensitivity (%)	86	76	73	79	75	77
Specificity (%)	33	47	57	42	78	84
True positive (%)	58	63	64	58	78	84
True negative (%)	69	68	67	65	75	78

A = diuretic and antianginal medication preinfarction, heart failure; B = work status; C = gender, maximal work load, heart rate at maximal work load and at 60 W, maximal blood pressure, arrhythmia; D = type A behavior, daytime nap; A+B+C = gender, antianginal medication, angina pectoris pre- and postinfarction, work status, maximal work load, heart rate at 60 W, maximal blood pressure, arrhythmia, ST abnormality; All = variables listed in Appendix B.

anginal medication before infarction; a large or anterior infarction and signs of heart failure were less common and fewer patients used cardiac glucosides after discharge. Likewise, at exercise testing, rest and submaximal heart rates were significantly lower, ST abnormalities were more common and arrhythmias occurred less frequently. More patients with training benefit had worked before their myocardial infarction. They were slightly more optimistic about the future; however, fewer expected to resume their activities fully. They felt less well, but needed less rest during the day.

Training failure. A substantial percent of patients (27%) had a negative outcome. Compared with patients with success or with no change, more patients with training failure had angina pectoris, had used antianginal drugs before myocardial infarction. They smoked less. In all three patients with previous coronary artery bypass graft surgery, exercise training had a negative outcome. Infarct size did not differ, but an anterior location and signs of heart failure occurred more often. After hospital discharge, more of these patients had anginal symptoms and used a glucoside. Antianginal medication was not different. Training started significantly later after infarction and heart rates at rest or at a low work load were substantially higher. They did not differ in work status. In appraisal of their illness, more had felt seriously ill and fewer were optimistic about the future or had a clear idea about the cause of their infarction. They tended to be less active (type A), take longer daytime naps, have more functional symptoms and feel more depressed.

Multivariate Analyses

Training success. The four sets of variables (clinical, exercise, interview, questionnaires) had an approximately identical (range 60% to 65%) ability to predict training success (Table 3). With clinical and exercise data, including work status, a correct classification was attained in 76%. When psychological questionnaires were added, 81% could be correctly classified: 77% of patients with a good training result (sensitivity) and 84% of patients without benefit (specificity) could be properly assigned. Thus, the conclusion that success is predictable to a high degree when all sets of data are combined is justified. The variables selected in the logistic regression analysis are shown in Appendix B. Variables of high predictive value were maximal blood pressure, work status, heart rate, daytime naps, ST abnormality,

Table 4. Performance of Variables Predicting Training Failure

	Sets of Predictor Variables					
	A	B	C	D		
Performance Rates	Clinical	Interview	Exercise	Psychological	A + C	A + C + D
Correctly classified (%)	76	76	79	78	78	85
Sensitivity (%)	26	41	50	26	57	69
Specificity (%)	94	89	90	98	86	90
True positive (%)	61	57	64	85	60	73
True negative (%)	78	80	83	78	78	89

A = gender antianginal medication preinfarction, smoking; B = gender, illness experience, doubt of diagnosis, view of future, expected recovery, attributed cause infarction; C = gender, rest heart rate, chest pain, arrhythmia, start of training; D = type A behavior, daytime nap, well-being, despondency; A + C = gender, antianginal medication preinfarction, rest heart rate, start of training; A + C + D = variables listed in Appendix B.

maximal work load and angina both before and after myocardial infarction.

Training failure (Table 4). The percent of training failures correctly classified did not differ for the four sets of variables (range 76% to 79%). Overall, the performance was better than that for predicting training success, which is attributed mainly to the high specificity. The combination of clinical and exercise data increased the sensitivity, but did not improve overall classification (78%). With the addition of psychological questionnaires, 85% of these patients were correctly classified; 69% of the patients with training failure and 90% without training failure were properly assigned. It can be concluded that training failure is highly predictable when psychologic data are added to clinical and exercise data. Variables used in the final analysis are shown in Appendix B. Despondency, type A behavior, antianginal medication before myocardial infarction and feelings of well being were particularly powerful, followed by physical variables (start of training, arrhythmias during exercise testing and rest heart rate).

Discussion

Experts state (19,20) that cardiac rehabilitation programs should not be applied uniformly or indiscriminately, but should be tailored to the physical and psychologic condition of the individual patient. Intensive exercise training is expensive (1) and although many patients improve physically, others do not and some even experience adverse effects (2,21). The degree of in-hospital deconditioning and the need for subsequent reconditioning vary greatly among patients. Moreover, rehabilitation can be implemented through other treatments such as behavior modification, counseling and patient education (22). To determine which patients will not benefit from exercise training, it is necessary to be able to predict training outcome (1,3–6).

Evaluation of training. In this study, the outcome was assessed by exercise testing variables of cardiac dysfunction and physical fitness. This composite criterion is an application of the primary purpose of exercise training. It is utilized as an indicator for intensive (daily) physical training. Obviously, this criterion does not fully evaluate rehabilitation outcome (for example, psychosocial measurements are not included). This criterion differs from any single measure used in other studies (for example, it does not correlate with the criterion of percent normal maximal work load at the end of rehabilitation used by Fioretti et al. [3,4]). Also, patients with negative changes after rehabilitation (training failures) were distinguished from patients with benefit (training success).

Success implied an improved physical state (training response) that could be attributed to exercise. Thus, for "successful" patients, intensive training seems to have been appropriate (7). However, training success does not necessarily imply psychosocial recovery (23). A "failure" implies that the patient became less tolerant to the stress of effort. Because this is opposite to the purpose of training, intensive exercise seems not to have been indicated. Instead, less intensive exercise or other treatment strategies may have been a more appropriate way of rehabilitation. Failure does not mean that training was unsafe or that cardiac complications occurred during exercise. Indeed, patients with training failure may receive psychosocial benefit of rehabilitation.

Predicting training success. For 79 (59%) of the 156 patients with myocardial infarction, the training was beneficial. On the basis of initial information, 81% of these patients could be identified. Although higher than sensitivity (77%), specificity (84%) was equal to the true positive value: for 84% of the patients who were predicted to have a successful outcome, training was actually beneficial. Training success did not depend on infarct characteristics (size, location), duration of hospital stay or age. Classification was optimal when medical data, initial exercise testing and psychosocial information were combined for prediction. Work status before infarction was the single most important predictor, possibly reflecting the motivation of the patient.

Initial fitness. Fitness and cardiac condition, indicated by lower heart rate, the ability to generate higher blood pressure during exercise and absence of angina, arrhythmia and signs of heart failure in the hospital, were also important for success. This indicates that a good physical state is conducive to training success. The need for less daytime rest or naps for patients with a successful outcome may also be attributed to this. Conversely, a low initial maximal work load (indicating a poor state of fitness) and silent ischemia were also favorable for predicting success. Possibly, initial fitness indicates the ability to sustain progressive effort, on the one hand, and, on the other hand, it offers little room for improvement (1). The positive role of ST abnormalities during exercise is not confirmed by others (1,3,4,24); one explanation is that in our study, ST abnormalities decreased significantly during rehabilitation (mainly among patients who underwent relaxation therapy), which contributed to the outcome criterion (7).

Predicting training failure. Training failure occurred in 42 patients (27%). The overall 85% predictive result in these patients was higher than that in those with training success. Taking this percent as a criterion, sensitivity was low (69%) and specificity high (90%). Thus, not all patients with training failure could be identified. However, 73% of the patients who were predicted to have a training failure had a negative outcome. The performance was optimal when all sets of variables were analyzed jointly. Psychologic variables in particular were able to identify patients with training failure; they enhanced the sensitivity and true positive value discernibly.

The two logistic functions predicting success and predicting failure shared five factors, but in opposite directions:

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gender, antianginal medication before infarction, sleeping habits after infarction and heart rate and arrhythmias during initial exercise testing. The small number of women (6%) signifies that relatively few women had been referred for rehabilitation. Possibly, the reasons for referring these women also determined a negative outcome. This may explain why few women had training success (selection bias). Moreover, when relaxation was added to training, gender had no relation to outcome. It should not be concluded, therefore, that training is particularly indicated for men.

The contribution of clinical information to prediction of patients with training failure was less than the contribution to the prediction of those who benefited. Thus, severity of infarction does not seem to be a contraindication to exercise as a therapeutic modality in rehabilitation. Bivariately, however, a cardiac history, in particular of angina pectoris, is associated more often with training failure than with training success.

Psychologic determinants. It is surprising that psychologic data were among the variables that predicted training outcome. It may be recalled, however, that from the very beginning of cardiac rehabilitation, for instance in the work classification units (25), psychosocial determinants were found to be of importance in the patient's recovery. The positive role of type A behavior supports the findings of Rejeski et al. (5). It seems plausible that an active disposition, as well as work status, and the absence of depression facilitate the motivation for exercise and rehabilitation. That psychosocial components are such determining features suggests that psychosocial interventions could alter the outcome of training. This is an exciting idea, because it would create treatment options for patients who are in need of rehabilitation but who would be likely to experience training failure if exercise was the only treatment. In this study, the addition of relaxation therapy to the exercise program substantially reduced the risk of failure.

Conclusions. It is possible to predict both success and failure of exercise training on the basis of initial data. These data not only were clinical or derived from exercise testing, but also were psychosocial. Furthermore, in predicting training outcome, success and failure must be clearly distinguished. Absence of benefit does not necessarily imply failure. Our study shows that the characteristics of patients for whom training is most appropriate differ from those who should not start training because of an anticipated negative outcome. Before the prediction rules can be justifiably applied, cross-validation in a larger group of patients is needed (26).

Two prediction rules should be looked for: one set of variables estimating the probability of success for a given patient, the other one estimating probability of failure. Validation will make it possible to optimize the application of exercise training as a therapeutic strategy in patients with recent myocardial infarction.

Appendix A

Variables Used as Predictors in the Stepwise Logistic Regression Analysis

- Clinical: before infarction
  - Hypertension
  - Physical fitness
  - Smoking
  - Angina pectoris
  - Coronary bypass surgery
  - Previous infarction
  - Cardiac medication
    - Beta-adenergic blockers
    - Digoxin
    - Diuretic drugs
    - Antianginal drugs
    - Antiarrhythmic drugs
- Clinical hospital
  - Infarction size
  - Infarction location
  - Mild heart failure
  - Medication at discharge
    - Beta-adrenergic blockers
    - Digoxin
    - Diuretic drugs
    - Antianginal drugs
    - Antiarrhyhthmic drugs
  - Angina pectoris at discharge
- Interview
  - Marital status
  - Work status
  - Job level
  - Infarction appraisal
    - Pain experience
    - Illness experience
    - Doubt of diagnosis
  - View of future
  - Wishes early start of rehabilitation
  - Expectation of activity resumption
  - Cause of MI clear
  - Attributed cause of MI
    - Stress
    - External
    - Risk factors
    - Psychic
- Exercise testing
  - Weeks after hospital discharge
  - Maximal work load
  - Work capacity
  - Maximal heart rate
  - Rest heart rate
  - Heart rate at 60 W
  - Rest diastolic blood pressure
  - Rest systolic blood pressure
  - Maximal systolic blood pressure
  - Systolic pressure increase
  - Chest pain
  - ST abnormalities
  - Arrhythmias
- Psychologic questionnaires
  - Sleep quality (before and after MI)
  - Siesta time (before and after MI)
  - Vital exhaustion before MI
  - Type A (JAS) before MI
  - Functional complaints
  - Sense of well-being
  - Feelings of invalidity
  - Despondency
  - Anxiety state (STAI-S)
  - Anxiety trait (STAI-T)

JAS = Jenkins activity scale; MI = myocardial infarction; STAI = state trait anxiety inventory.

Appendix B

Details of the calculation of the logistic function are given below. The formula results in the probability of success or failure, respectively, for a given patient:

$$p = \frac{1}{1 + \exp^{-(a\ +\ b_1x_1 + b_2x_2 \cdots + b_nx_n)}} .$$

The probability (p) ranges between 0 and 1. In case of success, the following variables (X), their coefficients (b) and the constant value (a) constitute the equation.

Probability of Success	High	
Gender*	1 × −2.21 =	−2.21
Work†	1 × −0.65 =	−0.65
Anginal complaints before MI‡	0 × −1.32 =	0
Diuretic drugs before MI‡	1 × 1.63 =	1.63
Signs of heart failure in CCU‡	0 × −1.01 =	0
Anginal complaints after MI§	3 × −0.58 =	−1.74
Antianginal medication after MI‡	1 × 0.94 =	0.94
Maximal work load	120 × −0.02 =	−2.40
Heart rate at 60 W	80 × −0.03 =	−2.40
Maximal systolic blood pressure	160 × 0.03 =	4.80
Arrhythmia‡	0 × −1.27 =	0
ST abnormality‡	1 × 1.23 =	1.23
Sleeping quality	6 × −0.25 =	−1.50
Constant		8.36
Sum		6.06
Exp (−sum)		0.0023
$p = \dfrac{1}{1 + \exp(-\text{sum})}$		0.99

*Male = 1, female = 2; †full time = 1, part time = 2, none = 3; ‡present = 1, absent = 0; §absent = 1, possibly present = 2, present = 3; CCU = coronary care unit; MI = myocardial infarction.

Thus, the probability of success is very high (p = 0.99) in the case of a male patient who worked full-time, used diuretic drugs but not anginal medication, did not develop signs of heart failure in the coronary care unit, had no anginal complaints at hospital discharge, used anginal medication, reached a moderate work load during exercise testing, did not have a high heart rate at a low work level, generated a sufficiently high systolic blood pressure during effort, did not have serious arrhythmias, had ST abnormality and slept poorly. In the case of the variables having opposite values, the probability of success is very low (p = 0.0003).

Likewise:

Probability of Failure	High	
Gender*	2 × 0.79 =	1.58
Antianginal medication before MI†	1 × 1.75 =	1.75
Rest heart rate	95 × 0.03 =	2.85
Arrhythmia†	1 × 1.16 =	1.16
Start of training‡	6 × 0.24 =	1.44
JAS	110 × −0.04 =	−4.40
Daytime nap§	6 × 0.19 =	1.14
Well-being	28 × 0.09 =	2.52
Displeasure	20 × 0.20 =	4.00
Constant		−5.23
Sum		6.81
Exp (−sum)		0.0011
$p = \dfrac{1}{1 + \exp(-\text{sum})}$		0.99

*Male = 1, female = 2; †present = 1, absent = 0; ‡weeks after hospital discharge; §quarters of hours. MI = myocardial infarction.

The probability of failure is very high (0.99) in the case of a female patient who used anginal medication before infarction, started rehabilitation late, had a high rest heart rate during initial exercise testing as well as arrhythmias during effort, did not show type A behavior, took long daytime naps and reported mood disturbances but still felt well. The probability of failure is very low (p = 0.12) when the same variables have opposite values.

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