*Reviews*

# Exercise in cardiac rehabilitation

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## Introduction

The notion that exercise is dangerous for patients with heart disease dogged the use of such treatment for the first half of the twentieth century. It was a further 30 years before exercise became accepted in rehabilitation. The controversy is made more difficult by the fact that exercise may be dangerous for some patients in some circumstances.[1]

Exercise is now widely believed to benefit a wide variety of patients with heart disease. However, when it is used to treat cardiac patients, exercise should be approached like any other treatment and thought given to the indications, the contraindications, the mode of action, the type, the dose, the duration of treatment, the expected benefits, and the side effects.

## Indications

### ACUTE MYOCARDIAL INFARCTION

#### *Early mobilisation*

Exercise was initially applied to patients recovering from acute myocardial infarction. In the 1940s and 1950s some of the undesirable sequelae of bed rest were being recognised, at least in some quarters; such complications were deconditioning, boredom, depression, venous thrombosis, urinary retention, constipation, and chest infections. In 1952 Levine and Lown[2] described their "Armchair treatment of acute coronary thrombosis". The natural progression of this approach was a more rapid increase in mobilisation after the infarction, and by the 1970s several controlled trials of early mobilisation had shown that this was a safe approach and lessened the complications mentioned above.[3 4] The result has been a general acceptance of this regimen, and patients with no complications are now likely to be discharged within four or five days, when the risk of dangerous arrhythmias is significantly reduced.

#### *Rehabilitation*

In 1957 Hellerstein and Ford[5] defined rehabilitation as "the process by which a patient is returned realistically to his greatest physical, mental, social, vocational and economic usefulness and, if employable, is provided an opportunity for gainful employment in a competitive industrial world." In 1968, Hellerstein[6] went on to describe the physical training programme he had devised to improve the fitness of "habitually lazy, hypokinetic, sloppy, endomesomorphic overweight males" who were the usual victims of coronary disease. The perceived wisdom of his multidisciplinary approach to the rehabilitation of coronary patients led to widespread adoption of exercise based programmes to treat patients recovering from acute myocardial infarction programmes in which exercise has been a centrepiece for all the other valuable aspects of rehabilitation such as education, risk factor modification, stress management and relaxation, and job counselling. The spread of such programmes in the United Kingdom has been remarkable. When the members of the British Cardiac Society were surveyed in 1970[7], only nine of those who replied could offer some form of exercise based rehabilitation to their patients. By 1988 a further survey found 91 programmes[8] and this had risen to 161 by 1992[9] and 274 by 1997.[10] It has also been apparent that only a minority of patients who might benefit from this treatment are currently able to receive it, mainly through lack of adequate resources. In the United Kingdom, cardiac rehabilitation has seldom been commissioned by purchasers, rather it has been initiated by enthusiasts, mainly nurses, who have seen the unmet need. In this they have been supported by the British Heart Foundation who have given start up grants, which have been responsible for the rapid growth of the facility over the past 10 years.

The post-infarction rehabilitation programme has gradually been adapted over the years to accept all the other cardiac patients who may benefit from exercise training; only rarely are specific programmes used to treat other cardiac conditions, which include the following.

### HEART SURGERY

The great majority of surgical patients included in cardiac rehabilitation programmes have had coronary artery bypass grafting. These patients have the same disease as post-infarction patients and benefit from the full rehabilitation package. An increasing number of those who have had coronary angioplasty are now being included. Other surgical conditions such as valve replacements and heart transplants[11] are also treated, and a potential growth area is patients with implanted defibrillators who may become crippled by disabling anxiety.[12]

### ANGINA PECTORIS

Exercise training may be particularly helpful for anginal patients, particularly when revascularisation is not indicated or is impossible. This indication is discussed further below.

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HEART FAILURE

This has traditionally been seen as a contraindication to exercise but over the past 15 years the literature on the benefits of exercise for these patients has been growing. Indeed it may be these, the most disabled of cardiac patients, who have the most to gain from this treatment.

## Contraindications

There are some absolute contraindications, such as unstable angina, worsening heart failure, critical valve stenosis (mainly aortic), malignant arrhythmias, very recent infarction, and any acute intercurrent medical condition such venous thrombosis or febrile illness.[13] Relative contraindications include severe angina, severe heart failure and non-critical valve lesions, and potentially dangerous arrhythmias.[13] All of the latter may be treated but need much closer supervision than patients with fewer complications.[14] Risk stratification of patients at the onset of an exercise programme takes all these factors and more into account (see below).

## Mode of action

PHYSICAL FITNESS

In normal subjects, exercise training increases aerobic fitness by both central and peripheral effects.[15] Centrally, stroke volume, ejection fraction and rate, and force of contraction of the left ventricle increase in response to exercise. The heart beats more slowly and empties more completely with a greater reserve and higher potential cardiac output. There is also a reduction in central sympathetic tone and increase in red cell mass. Peripherally, there is a more efficient distribution of blood to the working muscles, and these muscles extract a greater percentage of the oxygen from their blood supply, so a lower blood flow is required to fuel any level of exertion. The same amount of activity can be performed for a lower blood flow and a lower cardiac output. These peripheral effects are specific to the muscles that have been trained.

The central and peripheral effects of exercise training in normal people contribute about equally to increases in fitness.[15] In patients with heart disease the central effects are less than in normals and take longer to develop. When patients with heart disease undertake physical training, in the short term the resulting decrease in cardiac workload for any given exercise load is due to a reduction in demand from the working muscles.[16 17] It follows that improvements in performance after training are mainly confined to those exercises that have been included in the training programme, and therefore a patient trained on a bicycle ergometer will not necessarily be able walk any faster. This fact is particularly relevant to most cardiac rehabilitation programmes in the United Kingdom, which typically last 6–12 weeks. However, if exercise training is maintained for a year or more and is sufficiently intense, there will be increases in cardiac performance including increases in stroke volume and ejection fraction and in force of contraction of the left ventricle.[18–20] Studies of these changes, however, have all been performed on low risk younger coronary patients and have not included sicker older patients or those with known poor left ventricular function. One study has measured the results of exercise training on changes in left ventricular function compared with initial left ventricular function; only those with good left ventricular function subjected to intensive exercise showed an improvement in rest peak exercise left ventricular ejection fraction.[21]

MYOCARDIAL BLOOD SUPPLY

For patients with coronary artery disease, a highly desirable outcome of physical training would be improved blood flow to the heart muscle. Exercise testing of angina patients after exercise training shows that they can achieve a higher heart rate before they develop chest pain[22] and also a higher heart rate at the onset of ischaemic changes shown on the electrocardiogram.[22 23] Myocardial perfusion imaging confirms that improvements in physical fitness are accompanied by improved perfusion,[24] although the exact mechanism is uncertain. Exercise programmes that have been combined with lipid lowering, by either diet or drug treatment, may produce reversal of coronary atheroma for some patients,[25 26] particularly if the training is both vigorous and maintained for many years.[27] The amount of exercise needed to produce reversal of coronary narrowing without the use of other interventions is, however, large, considerably more than is routine in most cardiac rehabilitation programmes.[28] It is proposed that training also increases collateral blood vessels, although this has not been confirmed by angiography.[29] The reason may be that angiography is performed at rest whereas collaterals would be expected to open up during exercise.

## Type of exercise

Exercise can be divided into two types, isotonic (often referred to as aerobic), which involves much movement and little strength, and isometric, which involves much force but little movement. Most exercises are mixtures of the two types with one or the other predominating. For many years it was thought that only "aerobic" exercise was suitable for cardiac patients and that isometric training would be dangerous by raising the blood pressure and overloading the heart. Over the past 10 years, however, the value and safety of combining moderate strength training with aerobic training for cardiac patients has been recognised and shown to enhance fitness.[30–32] High resistance training alone also increases fitness but not so rapidly as aerobic training.

Strength training has the advantage of reassuring the patient that he or she is fit to undertake tasks, either at work or at leisure, which need muscular effort, thus enhancing one aspect of quality of life.[33]

## Dose

For exercise, the dose involves frequency, intensity, and duration.

FREQUENCY

The American Heart Association[34] recommends for cardiac patients a frequency of between two and four times a week, although there is little evidence to support this figure. Most trials of physical training have used three or four weekly sessions. It has been shown that, for early post-infarction exercise training, a programme of two sessions a week is as effective as three.[35] Increasing from three to five sessions does not seem to produce much further benefit for normal middle aged men.[36]

INTENSITY

The usual recommendation for exercise intensity for cardiac patients is to reach a target of between 70 and 85% of maximum heart rate, which should be determined from an exercise test.[37] The American Heart Association advises a level of between 50 and 80% of maximum oxygen uptake, also decided from an initial exercise test with the lower end of this range for the higher risk patients.[34] Very low level exercise does not increase physical fitness, with a threshold for benefit of between 40 and 60% of maximum oxygen uptake.[38] The benefit produced by very intense exercise (in excess of 85% of predicted maximum heart rate) is relatively modest and overridden by an increase in the risk of dangerous cardiac arrhythmias.[39] Several recent trials have shown that moderately low level exercise applied to groups of post-infarction patients produces similar increases in aerobic capacity to high intensity exercise.[40 41] However, very intense exercise does produce considerable increases in fitness[42] and a positive effect on exercise induced ejection fraction increase, which is not found with moderate exercise.[21]

DURATION

The duration of exercise shown to increase fitness varies from 20 to 60 minutes.[37] Longer sessions may increase fitness but at the cost of an increase in musculoskeletal injuries.

When patients start on an exercise programme, they may not be able to sustain the necessary intensity and duration of exertion, and therefore these should be increased gradually to the recommended levels.

## Duration of treatment

The intention of most exercise based cardiac rehabilitation programmes is to start the patient on a course of exercise, which will continue as long as possible after the period of supervision. Most cardiac rehabilitation programmes supervise their patients over 6–12 weeks,[8] although some programmes last up to two years. These longer term exercise training programmes may have a greater benefit on prognosis than short term programmes.[43] The longer a programme lasts the greater the drop out rate,[44] but long term compliance is improved by long term supervision and developments in the exercise programme.[45] Certainly those who continue to exercise in the long term gain extra benefits such as greater increase in aerobic capacity and a slowing or reversal in the usual age related decline in performance.[46]

## Practical aspects

In the United Kingdom most cardiac rehabilitation programmes are run by nurses or physiotherapists with help from a multidisciplinary team, which in some cases includes sports scientists or other[10] exercise specialists. The programme is divided into four phases.[13] Phase 1 covers the time in hospital after acute myocardial infarction, and exercise is limited to gradual mobilisation including stair climbing to prepare the patient for discharge. Phase 2 includes the first few weeks at home when the main exercise, usually unsupervised, is a progressive walking programme. Ideally the patient is sent out with clear written guidance, and supplementary support can be given by telephone contact with the coronary care unit or by direct contact with a primary care team. Phase 3 is the supervised exercise programme which is the centrepiece of a package of care which includes education, dietary instruction, risk factor monitoring, stress management, and relaxation training. Phase 4 is the long term exercise to which it is hoped that most patients will adhere. In practice more than 50% will drop out of regular vigorous exercise once the supervised programme is over. A necessary prerequisite to phase 3 is the exercise test.

EXERCISE TESTING

All patients with known heart disease should be exercise tested before entering an exercise programme.[34] The following essential information can be obtained from the test. (*a*) The existence of reversible ischaemia. This is common in post-infarction patients and is not rare in patients after a bypass. A substantial proportion of those with exercise induced ischaemia do not suffer pain, so called silent ischaemia. Those who recommend exercise for coronary patients need to know whether their patients are likely to develop ischaemia during a session so that the level of exercise can be modified and prophylactic trinitrate used. Most post-infarction patients with positive exercise tests are referred for coronary angiography. (*b*) The level of fitness. This allows an appropriate level of exercise to be prescribed, may contribute to risk stratification, and gives a baseline figure against which future performance can be compared. (*c*) The appropriate heart rate response for improving physical fitness. Many cardiac patients will be taking medication (β-blockers, some calcium channel blockers, angiotensin converting enzyme (ACE) inhibitors, antiarrhythmics) which modify resting and exercise heart rates. (*d*) Blood pressure response. Patients with very poor left ventricular function and those taking some drugs show a paradoxical fall in blood pressure with exercise and are more susceptible to faintness during sessions. (*e*) Rhythm disturbance. Patients who develop arrhythmias during the test, particularly high grade ventricular arrhythmias, demand careful handling[14] and may need a change in medication before the start of the course.

In the United Kingdom most cardiac rehabilitation programmes are performed in hospital gymnasia using circuit training supplemented by "homework" which may be a home based circuit or walking. Sessions are held between one and three times a week and the course usually lasts 6–12 weeks.[47]

## Benefits of exercise

### INCREASED PHYSICAL FITNESS

Community surveys have shown that the general level of fitness in this country is deplorably low,[48] and patients who suffer coronary problems have even lower levels. The improvements achieved by physical training as described above are of obvious benefit to the daily activities of cardiac patients. The energy costs of a wide variety of activities both at work and leisure have been estimated,[49 50] and can theoretically allow prediction of the ability of cardiac patients to perform such tasks. In the United Kingdom the ability to regain a licence to drive a large goods or passenger carrying vehicle depends on the completion of nine minutes of the Bruce protocol treadmill test, a feat that may only be possible after exercise training.

One group that may have most to gain is patients with cardiac failure.

#### *Exercise in heart failure*

Heart failure was thought to be a contraindication to exercise training, but Conn *et al*[51] in 1982 showed that an increase in exercise capacity of around 20% could be achieved by patients with ejection fractions of between 13 and 26%. This was confirmed by Sullivan *et al*[52] in 1989, and since then an increasing literature has added to knowledge of physical training in heart failure.[53 54] Cardiac failure leads to a considerable reduction in physical activity, which produces muscle wasting. This in turn makes exercise harder, further reducing physical efforts and a spiral of deterioration is produced.[55] Exercise, even at relatively low level—that is, about 55% of maximum heart rate[56]—can reverse this process and bring about a useful increase in quality of life.[57] This increase in functional capacity is achieved by a combination of increased muscle metabolism,[58] reduced vascular resistance in the working muscles,[59] reduced sympathetic tone,[57] and perhaps improvements in cardiac performance.[52 57] One possible mechanism is an increase in early diastolic filling after physical training.[60]

### REDUCED ANGINA

The threshold for angina occurs at a fixed "double product" (the product of heart rate and systolic blood pressure) for any individual.[61] An increase in fitness reduces the heart rate and blood pressure responses to exercise[23] and would therefore be expected to raise angina threshold. Nearly all trials of training for coronary patients have indeed shown a great reduction in angina frequency and an increase in angina threshold.[62 63] Exercise training has been found to be as effective for angina as β blockade[22] and also to reduce the total ischaemic burden.[64]

### ENHANCED CORONARY BLOOD FLOW

This effect, discussed above (myocardial blood supply), may reduce angina, lessen the size of future infarction, and play some part in the mortality reduction which follows exercise based cardiac rehabilitation (see below).

### REDUCED ARRHYTHMIAS AND HEART RATE VARIABILITY

Ventricular ectopic beats are common in normal people but much more common and more frequent in patients recovering from myocardial infarction. Frequent ventricular ectopics are one of the risk factors for sudden death after an infarction.[65] Exercise training increases the cardiac threshold for ventricular ectopic activity, and controlled trials have shown that ectopic beats are less prevalent in trained than untrained post-infarction patients.[66] Increased ventricular ectopic activity is associated with increased sympathetic and decreased parasympathetic tone,[67] which also produces a reduction in heart rate variability,[68] an effect enhanced by β-blockade.[69] Reduced heart rate variability is associated with increased mortality after infarction[70] and can be improved by exercise training.[71] A recent trial of exercise training soon after acute myocardial infarction has, however, failed to show a difference in heart rate variability or baroreflex sensitivity between the treated and the control groups.[72]

### IMPROVED LIPID PROFILES

Individuals who take regular vigorous exercise have much healthier blood fat profiles than their sedentary peers.[73] Controlled trials of exercise rehabilitation have shown that coronary patients can benefit from this effect with lowering of total cholesterol and a rise in high density lipoprotein cholesterol,[74 75] but the level of exercise needs to be high, equivalent to running 15 miles a week,[76] a much greater exercise load than is used in most cardiac rehabilitation programmes in the United Kingdom. This benefit of exercise is enhanced if the patient can lose weight but is lost if the patient gains weight.[77] Exercise also produces an acute reduction in triglyceride level which is maintained for about 48 hours.[73] Those who continue to exercise three or four times a week therefore keep their serum triglyceride down.

### LOWERED BLOOD PRESSURE

Treatment of hypertension has a smaller effect on risk of heart attack than on risk of stroke. One reason may be that commonly used hypotensive drugs have adverse effects on blood lipids. Non-pharmacological treatments for hypertension do not have this disadvantage, and exercise training has been shown to lower blood pressure at rest and during exercise in hypertensive coronary patients and may lessen the need for drug therapy.[78]

### IMPROVED THROMBOLYSIS

A high level of plasma fibrinogen and low fibrinolytic activity are powerful risk factors for

coronary disease,[79] and cigarette smoking probably exerts much of its atherogenic effect by this route.[80] Fibrinolytic activity is increased by exercise in normal subjects, and the more vigorous the exercise the greater the response.[81] Patients after infarction[82] and coronary bypass grafting[83] have been shown to respond similarly.

### WEIGHT LOSS

Obesity is a weak independent risk factor for coronary disease but being overweight increases blood pressure and blood cholesterol. The effects of exercise training on weight loss in obese cardiac subjects are disappointing,[84] but some controlled trials of cardiac rehabilitation have shown a weight loss in the treated group.[85] However, a failure to reduce body weight may be due to an increase in lean muscle mass rather than a failure to reduce body fat,[86] and this has also been found in controlled trials.[87] If the patient takes a great deal of exercise, equivalent to running 15 or more miles a week, weight loss is likely. Lesser physical endeavours should be combined with reduced calorie intake.

### PSYCHOLOGICAL BENEFIT AND IMPROVED QUALITY OF LIFE

The psychological state of the coronary patient affects not only the quality of life but also the prognosis, depression being a risk factor for death over the year after myocardial infarction.[88] Cardiac rehabilitation can contribute to the psychological wellbeing of cardiac patients,[63 89] but probably not to the extent to which most programme coordinators believe. Controlled trials have shown that exercise is an effective treatment for depression.[90] In post-infarction patients, controlled trials have shown that exercise rehabilitation can produce significant benefits such as increased confidence, wellbeing, and happiness with decreases in anxiety and depression.[91] These benefits, however, are small and relatively short lived if exercise alone is used to treat the patient.[92] A meta-analysis of the effect of controlled trials of exercise on anxiety and depression in coronary patients indicated a small benefit for both of these common problems.[93] The addition of stress management and relaxation treatment significantly enhances the effect of the exercise-only approach.[94] A further meta-analysis by Linden *et al*[95] concluded that the addition of psychosocial treatments not only reduces psychological distress but also morbidity, risk factors, and mortality. Exercise may also improve the mental activity of elderly demented cardiac patients.[96]

Oldridge[97] has calculated the cost per quality adjusted life year (QALY) gained by cardiac rehabilitation, using a "time trade off" method. In this system, the patient estimates how many years of perfectly healthy life he or she would exchange for a normal life expectancy in the present state of health. The result is added to the life years gained, adjusted for any loss of quality, to give the total QALYs gained. This amounts to 0.071 QALYs per person rehabilitated which, at a cost of £200 gives a figure of £2817. This is similar to the estimated cost per QALY gained by bypass grafting for left main-stem coronary stenosis.

### RETURN TO WORK

Most people in employment before their heart attack will return to work, sometimes in modified form, after three to six months.[98] For some, however, particularly those nearing retiring age, the attack, or heart surgery, may be a helpful opportunity for the patient to retire from a job that is irksome or even damaging to health. Some controlled trials of rehabilitation have shown an improved return to work for the intervention group,[99–101] but many have not.[102] The rehabilitation setting, however, can be used to ensure an earlier return to work for treated patients,[103] and the physical training element can allow recovery of the large goods vehicle or passenger carrying vehicle license, both of which require the patient to perform nine minutes of the Bruce protocol treadmill test without any change in ischaemia observed on the electrocardiogram. For a minority of patients disabled either physically or psychologically by their attack, formal rehabilitation has been shown to result in renewed employment.[104]

### IMPROVED SURVIVAL

Regular vigorous exercise provides primary prevention of coronary artery disease.[105 106] None of the randomised controlled trials of exercise based cardiac rehabilitation have been large enough to show a statistically significant decrease in mortality in the treated group, but over the past 10 years there have been several meta-analyses of the combined results of all the randomised controlled trials reported. These have involved up to 4500 patients and all agree that there is a reduction in death rate of between 20 and 25% in the treated groups.[84 107 108] There is a greater advantage to patients treated with a multidisciplinary approach than those taking part in exercise programmes alone.[109]

There are several mechanisms by which exercise may improve the survival of patients with coronary disease as discussed above. They include improved coronary blood flow, decreased ventricular arrhythmias, improved lipid profiles, lowered blood pressure, improved fibrinolysis, weight loss, and reduced depression.

These meta-analyses have also shown no difference in recurrent non-fatal infarction between treated and control groups, but it is interesting to note that the five controlled trials that have followed the patients for five years or more have all shown lower reinfarction rates for the treated groups.[100 110–113]

## Side effects

### VENTRICULAR FIBRILLATION/MYOCARDIAL INFARCTION

The most serious complications of exercise treatment for cardiac patients are acute infarction and sudden death, usually from ventricular fibrillation. These are most likely in patients with exercise induced ischaemia and those with

severe ventricular damage.[114] Ventricular fibrillation is 100 times more likely during exercise than at other times, but is still very rare during supervised exercise rehabilitation, between once per 33 000 patient hours[115] and once per 112 000 patient hours of exercise.[116] Myocardial infarction is even rarer during the rehabilitation programme.

### ANGINA PECTORIS

Angina is an inevitable consequence of exercise training among patients with residual coronary narrowing but can be minimised by careful exercise load prescription, adequate warm up routines, and the use of glyceryl trinitrate before the session. Angina should be kept to a minimum; left ventricular contractility may be impaired not only during an episode of ischaemia but for several hours after, a phenomenon known as myocardial stunning.[117]

### INFARCT EXPANSION?

After large myocardial infarcts a process of remodelling takes place with myocardial thinning at the site of damage and dilatation of the left ventricle.[118] Jugdutt *et al*[119] examined the possibility that infarct expansion may be worsened by exercise in a randomised controlled trial of physical training for 46 patients with anterior Q wave infarcts. Of 22 who were enrolled, 13 completed the programme and six of those showed topographical and functional deterioration. Other studies have claimed to disprove this effect, but the results do not always seem to support this assertion. Jette *et al*[120] exercised 10 men with ejection fractions below 30%, two of whom developed left ventricular failure. The remainder showed an increase in work capacity and peak oxygen consumption but an increase in mean pulmonary wedge pressure. Nevertheless they claim that "training did not cause further deterioration in ventricular function". Tavazzi and Ignone[121] found that patients with left ventricular dysfunction and low cardiac output failed to increase their exercise capacity or to show the expected fall in pulmonary artery diastolic pressure with training. The same group, however,[122] went on to randomise 49 patients with anterior Q wave infarcts to training or no exercise at four to eight weeks after the attack and found the degree of remodelling in the two groups to be the same. Further reassurance is provided by the finding that left ventricular mass, volumes, and ejection fraction did not change in either group in a controlled trial of high intensity exercise in men with post-infarction left ventricular dysfunction.[123] It has been shown that reduced left ventricular function can be improved by exercise in patients with chronic coronary disease, perhaps by improving myocardial perfusion.[124] Whether this is also true for patients recovering from a large anterior myocardial infarction is not yet clear, and such patients should certainly be treated with caution.

### OTHERS

Other side effects of exercise for cardiac patients include transient arrhythmias and angina pectoris, which are very common, hypotension, which is less common, and musculoskeletal injuries, which should be rare in a well organised programme.

All these exercise induced problems should be kept to a minimum by careful risk assessment of the participants, by appropriate exercise prescription, by a well designed exercise course, and by attention to adequate warming up and cooling down routines.

## Conclusion

Ever since the early writings of Hellerstein, exercise has been the centrepiece of most cardiac rehabilitation programmes. It deserves this place as it contributes to both of the two aims of this treatment, to return the patient to good health as rapidly as is safe and to reduce to a minimum the risk of recurrence of the cardiac illness.

However, there are considerable problems in providing exercise based rehabilitation to all who need it or may benefit from it. In the United Kingdom probably less than 20% of eligible patients take part in cardiac rehabilitation programmes.[125 126] A lack of funding is one undoubted reason for this low take up, but patient factors are also important both in the decision to join the programme[127] and, once enrolled, the decision to adhere to the course.[128]

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