SPECIAL ARTICLE

Physical Fitness and Coronary Heart Disease
Some Basic Views
By LOUIS N. KATZ, M.D.

SUMMARY
The purposes of a physical training program are examined and the evidence for the
general and circulatory benefits of physical fitness is discussed. While the proof of
benefits is not established, there is sufficient evidence from current studies to justify
encouragement of the exercise programs. The evidence that exercise lessens experi-
tmental atherogenesis is equivocal. The possibility that physical fitness alters the morbidity
and mortality of coronary sclerosis remains conjectural. Whether a physical fitness
program would (1) lessen the incidence of intravascular thrombosis or atheromatous
ulceration, (2) increase the extent or rate of development of coronary collaterals in
man although the evidence in animals is suggestive, (3) improve the performance
capacity of the heart, (4) decrease the likelihood of arrhythmias, or (5) result in
more efficient bodily responses to the stresses associated with myocardial infarction
is not clear or has not been definitely ascertained because of lack of evidence.

ADDITIONAL INDEXING WORDS:
Cardiac output   Collateral circulation   Exercise test
Oxygen requirement Myocardial infarction Psychological effect
Skin blood flow

WHEN THE EDITOR asked me some months ago to write on this subject, I
felt that I could prepare a script without much ado from the background material I had in
my memory and from work done by my own group. Further thought, however, revealed
that much of what I had to say was based on
my own intuition and on many reports I had
heard or read in which the authors' prejudices frequently colored the conclusions. Their
a priori attitudes could not be separated easily from their findings, and, in many instances,
swayed their judgment when it came to ob-
jectively analyzing the adequacy of design of
their studies. I concluded, therefore, that it
would be best to reevaluate the subject criti-
cally in order to remove the chaff of opinion,
enthusiasm, and emotionalism from the kernels
of proven facts. This led to a rather extensive scrutiny of the more recent literature, the
solicitation of views from a number of workers
in the subject area,
* and a study of the tapes
of a recent meeting on exercise, physical fit-
ness, and the heart.
* In this way, an extensive bibliography was built up. A few of the more
significant recent evaluations are cited as a
guide for further study by those desiring to
delve into the subject more deeply.

When all of this was accomplished, I found
to my surprise that my effort had really not

*See "References" paragraphs nos. 1, 2, and 3.
significantly altered my preexisting views. I could just as well have written the manuscript as originally planned, but my studies did serve to make me surer of my stance. This report, then, is a position paper based on the present attitudes of competent workers in the field. It shows where we are now, as I see it, and not necessarily where we will be in the future, since all the facts are not yet in and many of the conclusions will need more documentation.

There is no doubt that inactivity, as exemplified by protracted rest in bed, reduces the capacity to meet extraordinary demands as well as to perform ordinary daily activity. It is also established that a well-planned program of physical training, so-called conditioning, improves the capacity for exertion. Philosophically, all individuals should be in the “pink of condition” since life is full of unexpected periods of extraordinary exertion resulting from physical and emotional stresses. Man, like all animals, has had to prepare for “fight or flight.”

**Purpose of a Training Program**

The aim of an adult training program to increase physical fitness, not aiming to increase athletic skill and performance or to develop special skills for vocational or avocational activities, is to prepare a person better to meet the unavoidable extraordinary stresses which occur in everyday living. This is accomplished, in part, by improving the mechanical efficiency with which muscular performance is executed, and thus it reduces the oxygen required to do this work. Training leads not only to a smoother integration of the antagonistic and antagonistic muscles used in making the various movements but also to a better integration of the cardiovascular and respiratory responses to the extra demand. Besides, other changes occur that involve an improved capacity by the body to buffer the acids produced, a better elimination of the heat liberated during exercise, a greater blood hemoglobin content, and an augmented store of energy-releasing materials in the muscles, among others. All of these changes raise the maximum capacity for muscular activity to the extent that the rate and maximum amount of oxygen supply to the muscles is augmented so that the onset of exercise oxygen debt capacity is delayed. This plus the lessened oxygen need for any given amount and rate of muscular work, resulting from the improved efficiency with which energy is used in exercise, accounts for the enhanced physical fitness. Besides, a properly scheduled training program voluntarily entered into by an individual motivates him to carry his activity to a higher peak than when not so motivated. In this sense, motivation itself is measured in tests of maximum exercise capacity during training.

**General Benefits of Physical Fitness**

Many benefits are derived from a proper program to increase physical fitness. The individual has an improved capability for relaxation; he can endure a greater degree of fatigue. His central nervous system shows an improved adjustment to acidemia. He loses some of his fat depots, and muscular tone is augmented. There is less sag to his body. He can do more and recovers from exertion and stress more rapidly. He carries out exercise with less extraneous waste motion.

His respiratory system is improved. He ventilates less for a given exercise and for a given level of oxygen used. The respiratory rate is lower for a given work-load and breathlessness is delayed. Vital capacity is higher and so is the maximum breathing capacity. The wastage from the dead space is lessened by the deeper and slower breathing employed.

His muscles are increased in mass and vascularity. The muscle fibers become larger and redder and contain more myoglobin. Their adenosine-triphosphate (ATP), phosphocreatine and glycogen stores rise.

His liver releases glucose more readily and better metabolizes the acids produced during exercise. The kidneys improve their capability to excrete metabolic acids more rapidly.

Some major changes occur in the blood in association with increased physical fitness. Blood sugar levels remain steadier during exertion and blood lactate rises less. The

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blood volume is increased, as are the amount of hemoglobin and the number of red blood cells. As a result, the oxygen-carrying capacity of the blood is increased.

Circulatory Benefits of Physical Fitness

In the case of the heart, training slows its rate at rest and for each level of exercise below that observed in the untrained person. However, the maximum heart rate which can be developed is not increased. The amount of oxygen available to the body for each stroke of the heart is increased by training.

Increased cardiac output is supplied by increased stroke output in the trained more than in the untrained individual, and the relatively increased stroke output is at the expense of the systolic residue. There is evidence also that the heart hypertrophies. All of these factors tend to increase the maximum cardiac output but more important ensure that the oxygen cost to the heart for any level of work is reduced. The cardiac oxygen requirement for its maximum output need not be greater than that in the untrained state. However, definitive data on this point are lacking.

It is clearly established that the oxygen requirement of the heart for a given work-load is a function of the heart rate and chamber size, and training reduces the rate and size of the heart required to meet a given work-load. This means that the heart rate is slower both at rest and at any given work-load in the trained than in the untrained person. Furthermore, the heart does not increase as much in size in the trained as in the untrained individual when a given work-load is imposed, even though the resting heart size is greater in the trained than in the untrained subject. The greater muscle mass, within limits, in the trained person's heart helps to supply the energy needed by the greater effort of the heart, otherwise requiring cardiac dilatation and acceleration. In addition, the systemic arterial pressure during ejection (at least in the aortic branches) is lower at rest and at any given degree of exercise in the trained than in the untrained individual, and so it lowers the oxygen cost of the heart of any given level of cardiac output. This decrease in blood pressure is due to a reduction in total peripheral resistance. Obviously, the lesser oxygen requirements of the heart of the trained subject, as compared to those of the untrained subject, mean that lower coronary flow rates will be adequate, both at rest and during any level of bodily exertion.

A number of other changes occur in the vasculature and heart. There is an increase in heart size and in the amount of systolic residue at rest. At any exercise level, the heart spends more of its time in diastole in the trained than in the untrained individual. This is due to a slower rate, as well as to a shortening of the ejection period considered in relation to the heart rate. The velocity of contraction is increased (as indicated by dp/dt) suggesting an enhanced contractility, but it could also reflect the increased muscle mass.

There may be a greater ability to redistribute blood from inactive muscles, skin, and splanchnic area to the active muscles, heart, and brain. There is evidence that skin blood flow is less for a given exercise in the trained than in the untrained person.

The Role of Physical Fitness in Cardiac Patients Generally and in Ischemic Heart Patients Particularly

It is the altered behavior of the heart after training, with the resulting decline in its own requirement for oxygen and coronary flow, which holds the promise that training in the cardiac patient, particularly with ischemic heart disease, may be valuable. It is chiefly on this basis that I favor the concept that improved physical fitness is good for such patients. Besides, there is considerable evidence that an exercise program has the added advantage of accelerating the growth of coronary vascular collaterals, particularly when the coronary vasculature has become insufficient to meet ordinary, let alone extraordinary, states of physical or emotional effort. Finally, and not least important, a training program reassures the patient that the physician does not regard him as an invalid, unfit for work or a productive life.
The physician, in considering a training program, must face the dilemma that he really does not know how much of the patient's initial state is due to disease and how much is the result of physical unfitness. The evaluation is not so easy as one might imagine, unless a probe of mild training is tried.

What remains to be proven is that such a training program actually is of benefit and carries no undue hazard to the patient. The possibility of the latter demands careful evaluation by the physician and constant supervision by him. The patient should be informed of the signs and symptoms which indicate that he is doing too much or is accelerating his training schedule too rapidly. Some success has been attained by having the program carried out by groups of patients under trained supervisors. However, the final check is that of the physician and of the patient himself. The success of the entire program is determined by this. It, therefore, behooves the physician to become knowledgeable as to details of the proper training program before advising it for any of his patients.

This report will not cover such details, but two points in this connection should be emphasized. The first is that, at each stage, the training program must use exercise which approaches at least 50% or more of the limits of effort of which the patient is capable in terms of exhaustion, chest discomfort, and shortness of breath. Indeed, it has been observed that mild angina pectoris may disappear if such exercise is continued! Perhaps this disappearance is another manifestation of "second wind." However, these signs and symptoms brought on by exertion adequate for the training must not be allowed to persist too long nor should they increase after exercise has stopped. Obviously, an exercise "walk through" should be performed with great caution in the face of moderate or severe angina, since it may represent advanced ischemia of the heart.

The attitude of urging an adequate training program is a difficult one for the physician to assume, particularly if he himself is old enough to have lived through the period when almost any patient who had recovered from a recent myocardial infarct was considered to be totally disabled. Such a patient usually was retired and urged to go to a warm part of the country, to travel, or just to vegetate, thereby often making his life a thoroughly unhappy and useless one. It is no wonder, then, that such patients often were not cardiac cripples but rather psychological ones! If this complete invalidism did not occur, especially because of financial reasons, the patient's job was changed and he was afflicted with so many "don'ts" that life became hardly bearable. The cardiac patient made into a psychological cripple had his life full of disabling phobias. Perhaps the trend to encourage vigorous physical training programs today is a reaction to these previous medical attitudes, a reaction which must not be allowed to swing too far the other way.

When physical exertion is carried out at near capacity, the hazard of ventricular fibrillation, resulting from the development of ventricular premature systoles, should be considered. Professionals trained in cardiac resuscitation should be available (and even appropriate defibrillation apparatus) should this extremely unlikely event occur. Further, the patient should be educated to recognize cardiac irregularities when they appear and should stop the exercise at once when this happens.

A training program is best begun and continued for some time under professional supervision, or at least in groups, rather than by the patient alone. Only after he has been through the program and knows how to continue and what danger signs to watch out for, can the patient himself undertake to maintain the periodic exercise schedule prescribed to keep him fit.

The Exercise Test

The physician in meeting this task of proper management, first of all, requires a complete evaluation of the patient's status from time to time. While history taking and physical examinations still form the backbone of this evaluation, there are a number of special
tests, among them exercise tests, which can help to properly classify the patient's capacity to meet extraordinary loads.

In the cardiac patient, especially one with ischemic heart disease, or in the individual who is coronary prone, there is a particular need to evaluate the response to some sort of exercise test. This test may involve measuring the severity and duration of exercise which leads to ischemic alterations of the electrocardiogram (ST-T), or estimating the hemodynamic response of the cardiovascular system to several levels of standardized exercise, or both. It is agreed that leg exercises carried out in the erect position give the best estimate of the state of the cardiovascular system. Steps, bicycle ergometers, and treadmills have, thus, been employed in electrocardiographic and hemodynamic evaluation. The ultimate standardization of apparatus to be used, the duration or the intensity of exercise, or the criteria to be employed in estimating the effect of exercise upon the heart and blood vessels have not yet been fully agreed upon.

**Evaluation of the Training Program**

Evaluating the efficacy of a physical training program is difficult because other "conditioning" maneuvers are commonly carried out at the same time. Weight reduction is attempted in those who are obese, and attempts are made to lessen or stop cigarette smoking in excessive smokers and to introduce a more prudent diet for those who have become habituated to the gluttonous American diet. It is difficult to determine how much benefit is to be attributed to these other factors and how much to the actual physical training itself. Ultimately, if a scientifically acceptable answer is to be obtained, the other variables aside from physical training will have to be eliminated. The patient's regimen will have to be kept constant except for the physical training program.

We need more clinical evidence before proposed elaborate training programs can be accepted as definitely useful for cardiac patients. Even then, the question may remain as to how much of the success of the program relies on pure ceremony, the enthusiasm of the program leaders, and participants psychologically conditioning the patient to believe that he is becoming better. Responses to exercise tests which approach maximal capacity may show improvement because the patient is motivated to try harder or is more confident. Should long-term follow-up prove that morbidity and mortality from ischemic heart disease are statistically reduced by the physical training program, however, then it really does not matter whether it is the fitness of the patient or the ceremony which is responsible. To distinguish the factor which is operative, one could, if so inclined, introduce another elaborate enthusiastically supported program not involving training, to improve fitness to test which of the two, ceremony or improved fitness, is responsible for the better record against morbidity and mortality. One could use psychiatric tests to help define how much of the improvement is due to emotional rehabilitation.

It can be argued that a program involving other variables to reduce risk, besides that leading to improved fitness, may be better than a program solely for improving fitness. Realistically, however, all of this is beside the point, since the evidence to date has not offered any convincing proof that the various physical training programs, whether or not combined with other changes in regimen, have in reality affected the morbidity and mortality rates of patients with ischemic heart disease. The programs, therefore, offer a promise but benefit is not yet an established fact.

**What Is to Be Gained from a Program to Improve Fitness?**

Let us, finally, examine the reasons for encouraging such physical training programs and what they might accomplish even though the final proof of the value of such a program is still pending. This can be done best by posing a number of questions and attempting to answer them.

1. Does training to improve physical fitness inhibit the basic vascular disease—atherosclerosis? The evidence favoring that it does
comes from two sources: (1) epidemiological studies, both prospective and retrospective, on the effect which occupation and mode of life have on the incidence and prevalence of ischemic heart disease; and (2) the influence of exercise, in animal studies, on the induction of lesions by an atherogenic dietary regimen, used alone or in combination with other modifying factors.

While there is evidence that coronary disease proneness is related to occupation, and the extent of physical activity of the subject, even the most ardent protagonists admit that preselection has not been ruled out. Furthermore, the ratio of the incidence and prevalence of ischemic heart disease between subjects performing heavy work and those doing light work and leading a sedentary existence is small enough to lead skeptics to doubt that it is significant considering the other variables involved, and uncontrolled, in this disease of multifactorial origin. At present, therefore, epidemiology, while suggestively favorable, has not given an unequivocal answer.

The evidence that exercise lessens experimental atherogenesis, in the presence of an atherogenic regimen, is equivocal. There are a number of negative reports and there are objections to the design of the studies of some of the positive reports. Comparisons of wild with tame animals of the same species do show that the wild animals do have less atherosclerosis than the tame ones, but whether this is due to physical fitness, to confinement per se, or to dietary, genetic, or other factors has not been established.

2. Does physical training to improve physical fitness reduce the morbidity and mortality resulting from coronary atherosclerosis? As alluded to above, this question also has not yet been completely answered. If physical fitness lessened the occurrence of coronary atherosclerosis, there would be a lessening of the clinical, and even of the occult manifestations of the disease in the entire population—and lessened morbidity would tend to lessen mortality in the population.

Even in the presence of coronary atherosclerosis, improved physical fitness might alter morbidity and mortality by modifying the immediate precipitating causes. This subject can be developed in terms of a series of questions:

a. Does a physical fitness program lessen the incidence of intravascular thrombosis or atheromatous ulceration? Can it facilitate lysis of thrombi or fibrosis within atheromata? Any one of these factors might lessen the occurrence of overt clinical manifestations of ischemic heart disease or lessen the magnitude of the process which is damaging to the heart. The evidence on this point is, to say the least, far from clear.

b. Does the extent or rate of development of coronary collaterals increase sufficiently from the physical fitness training program to lessen appreciably the coronary insufficiency induced by the coronary occlusive process? Is it equally effective regardless of the rate of development of the primary occlusive process? If the process of collateral development can be significantly augmented by training and improved fitness, then the severity of the cardiac handicap and the resulting mortality can be reduced significantly. The evidence in animals is suggestive, but direct data in man are lacking.

3. Does the improvement in the performance capacity of the heart, which doubtless does result from the training program, permit the patient to meet better the demands on this pump which otherwise would lead to serious clinical consequences or might even be fatal? No clear answer is forthcoming.

4. Is the heart in the physically fit person subjected to a coronary occlusion less prone to arrhythmias than the heart of a less fit person? This is important since arrhythmias can lead to both clinical disability and death. No evidence is available on this point.

5. Finally, does the entire virtue of physical training in this regard depend on a more efficient bodily response to the stresses associated with acute myocardial infarction? Doubtless, training has this effect to some extent, but would the gain so achieved lead
to a significant difference in the magnitude of the illness and forestall a fatal outcome? The answer is not yet at hand.

Some will argue that the training program is nothing more than a positive approach to ischemic coronary disease, an approach in which the patient feels that something is being done—in fact, an approach in which he himself is doing something active to help himself overcome the handicap, real or imagined, of this disease. Hence, the total effect of training could be psychological. If so, could this be sufficient justification for the training program? My own answer would be emphatically "yes." The patient is kept aware of his potential danger, but in an agreeable rather than a fearful way. He is, therefore, more amenable to the advice given him by his physician who is, in this program, an interested, constantly available advisor. Furthermore, the patient can be trained to recognize and report events which can be dealt with by the physician. Without this program, such events might be suppressed through fear or ignored because of the trouble involved in informing the physician, who in the patient's view might then be less concerned with him on a day to day basis, and not so closely identified as his personal friend and interested advisor. Were this the only role of the training program, it would be helpful in my own view, since morbidity and mortality per se could thereby be affected.

For those readers who are seeking a simple yes and no answer to the value of physical fitness, I am afraid that this position paper will not be satisfying. While some of this dissatisfaction may be ascribed to the manner in which I have presented the subject, it is, as any fair-minded person will concede, mainly due to the unsatisfactory state of the evidence on the subject. Hopefully, time and more perceptive study will resolve this uncertainty, and a more positive answer of yea or nay can then be given.

References

1. The following persons working in this field have been kind enough to express their views by letter. These I have found extremely helpful; some have also sent me reprints of their studies, as well as references to work of theirs and that of others:
   Dr. Robert A. Bruce, Seattle, Washington
   Dr. Edward E. Gordon, Chicago, Illinois
   Dr. Herman K. Hellerstein, Cleveland, Ohio
   Dr. Albert A. Kattus, Jr., Los Angeles, California
   Dr. Ancel Keys, Minneapolis, Minnesota
   Dr. Moosa Najmi, Philadelphia, Pennsylvania
   Dr. John Naughton, Oklahoma City, Oklahoma
   Dr. Wilhelm Raab, Burlington, Vermont
   Dr. Howard B. Sprague, Cambridge, Massachusetts
   Dr. Jeremiah Stamler, Chicago, Illinois
   Dr. Henry L. Taylor, Minneapolis, Minnesota
   Dr. Howard B. Burchell, Editor of Circulation, was very helpful by sending me a number of recent citations on the subject.

   I have used some of my own work and that of some of my associates in preparing this report and several of them have contributed suggestions in proofing the preliminary draft: Drs. R. Pick, A. Shaffer, L. Hirsch, and A. J. Miller. Dr. A. M. Katz of New York, New York, was also helpful in this regard. Miss Bernice Ortelep, Librarian at our institution, prepared a recent bibliography to help my reading.

2. Tapes of the Symposium on Exercise and the Heart held at the University of Washington, Seattle, Washington, in June 1966 as, "Three Days of Cardiology," under the chairmanship of Dr. Robert A. Bruce.

3. Selected References for Further Study by the Interested Reader. Where possible the latest report is given in preference to earlier citations so that the reader may be more apt to find a more complete and up-to-date list of earlier references:


64. Taylor, H. L., and Stamler, J.: Exercise and


Bureaucracy

Suppose we formed this view of doctors and captains and then held a council at which the following decree was passed.

Neither medicine nor seamanship may be trusted in future with absolute control in its particular sphere, either over slaves or over free citizens. We therefore resolve to gather together an assembly of all, or of the wealthy among, the people. It shall be lawful for men of no calling or men of any other calling to advise this assembly on seamanship and medicine—that is to say, on the drugs and surgical instruments appropriate to the treatment of the sick, on ships and their tackle, on the handling of vessels, and on perils of the sea, including risks arising from wind and tide, risks arising from encountering pirates, and risks arising from maneuver of warships against enemy warships in the event of a naval engagement.

So much for the decree on these matters. The executive is to embody this decree of the assembly of the people—based, you remember, on the advice of a few doctors and sailors maybe, but certainly on the advice of many unqualified people too—in laws which they are to inscribe on tablets of wood and of stone, and in the case of some of the rules so resolved upon, they must see that they find their place among the unwritten ancestral customs. Thereafter forever medicine and navigation may only be practiced according to these laws and customs.

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