Sidney Cobb, Butler Hospital and Brown University

Before starting out to explore the relationship between workload and coronary heart disease, it is well to define terms and specify the model under consideration. The model is presented in Fig. 1. Starting at the right hand end, we are concerned with coronary disease which is basically atherosclerosis of the coronary arteries. The atherosclerotic process narrows the arteries to the point at which the blood flow to the heart muscle is insufficient. This causes pain known as angina pectoris. If the artery is occluded myocardial infarction with damage to the heart muscle may ensue. Moving to the left in the diagram, there are listed a series of variables mostly physiological that are known to enhance the risk for coronary disease. The evidence for increased risk associated with high levels on these variables is well documented and in most instances replicated. For present purposes, I propose that we accept these associations as given, and address ourselves to the question as to whether these risk factors are influenced by workload. Before going on to that, we should take note of the fact that these risk factors are by no means fully independent of each other. Not only is it known that blood sugar is correlated with catecholamine output and serum cortisol levels but a good deal is known about the mechanisms involved. Other such associations are known among these variables but again we should only have to go into this in detail if we were to find ourselves in a position to write a prediction equation. Unhappily, we are no where near the stage at which that could be done with any validity. The arrows imply a direction of causation but must be accepted with caution because we don't always have good evidence of the direction of causation, if any, in the associations observed. An arrow to an arrow implies an interaction in the statistical sense.

Now we come to workload. On the face of it, one might think this to be a nice simple variable. Unfortunately, this is not the case. We do both mental and physical work. Here we are concerned only with mental work. As a matter of fact, physical work may have some life saving aspects in the event of a coronary occlusion because those who exercise regularly have a more extensive network of blood vessels to the heart muscle so a single obstruction is less likely to be fatal.

Workload has both quantitative and qual-

itative aspects and these are readily separable as demonstrated by (French et al 1965). They found in a study of University faculty and administrators that among professors low self esteem was significantly related to qualitative overload but not to quantitative overload. Quite the reverse was true of the administrators who thought ill of themselves if they were not keeping up with the work but who had no reason to suppose that they were technically qualified to deal with all the problems that they face. "That's what consultants are for." There is little evidence that qualitative overload is associated with coronary disease, so we are concerned with quantitative overload.

Finally quantitative mental work load may be just right for the individual or it may be too little or too much. This is a function of the ability of the in-dividual. What is underload for one man may be overload for another. Work underload has been related to a variety of things from Adam Smith (1776) to the present day but the evidence is meager that it is related to coronary disease. We are then left focussing on quantitative overload of mental work. By and large, I will be reporting studies involving subjective assessment of the overload. It should of course be clear that as pointed out first by Parkinson (1957) and later by Sales (1969) the subjective assessment of what constitutes a full workload may not coincide with that of independent observers.

There are a variety of social variables that contribute to workload. First Kahn et al (1964) have pointed out that those persons who make demands on one are much more apt to be in conflict over priorities, thereby generating overload, than they are to be in direct conflict as to what one should do. Similarly the consequence of role ambiguity is overload for those who in the face of uncertainty try to cover all the fronts. Finally what Terreberry (1968) has called complexification and Lipowski (1973) has referred to as a surfeit of attractive information inputs, also generates a subjective sense of overload of mental work.

It is now appropriate to ask-what is the evidence connecting this kind of overload with coronary disease. The evidence is muddy but certainly quite voluminous. The mud is contributed by a lack of dimensional clarity. Factors of responsibility and emotional arousal are all interwoven in a way which makes it quite



Fig. 1 A model of the possible relationship of workload to coronary heart disease.

possible to interpret these studies in several different ways. Now is not the moment to list these studies and criticize them one by one. Suffice it to say that there is evidence to suggest that work overload particularly among those who are conscientious, ego involved and persistent may be associated with an excess frequency of coronary heart disease.

The remainder of my time will be devoted to an examination of the evidence for an association between quantitative overload of mental work and the risk factors in coronary heart disease. I will make no effort to be all inclusive in the review, for the state of the art is still such that there are many ways to fall short of finding an association that truly exists. Most of these are in the area of measurement of the relevant psycho-social variable. I will therefore emphasize the positive.

For this presentation, I will emphasize cholesterol, blood pressure, catecholamine (adrenaline and nor-adrenaline) output and smoking behavior. Looking first at cholesterol, we go back to the original report of Friedman, Rosenman and Carroll (1958) on tax accountants. It was demonstrated that cholesterol levels rose as tax deadlines approached and fell afterward. Since then, there have been five stud-ies of medical students at examination time each showing a significant increase. Across all individuals in the five studies, the average increase from usual level to exam level is 31 mg%. This is a difference, which if maintained, would increase the probability of coronary disease by about 30%. Sim-ilarly Caplan & French (1968) using both objective and subjective workload measures found associations with concurrent cholesterol levels. Likewise Sales (1969) using an experimental set up to produce overload of mental work with student subjects found a rise in cholesterol in the course of a one hour period that just fell short of significance. I mention this study because it is the one study in which we can be reasonably sure that the independent variable isn't laced with other factors such as negative affect and responsibility for persons.

There seems to be ample evidence that catecholamine output is related to work load. Frankenhaeuser (1971) has shown that mental work increases the output of both adrenalin and nor-adrenalin. This is true whether the mental work is a boring job requiring continuous vigilance or a complex and difficult time paced task. As might be expected, the difficult task increases the output more than the boring task. Similarly Levi (1972) has shown that under an experimental piecework scheme that led to doubling the output of invoicing clerks, the urinary excretion of adrenaline and nor-adrenaline were consistently increased on the days when piecework was the basis of pay.

Since it is known that increased catecholamine output is associated with increased pulse rate, increased blood sugar and increased stickiness of the platelets therefore increase probability of clots forming in the blood vessels and each of these in turn are reasonably well associated with coronary heart disease, we have a pretty strong chain of associations. Incidentally, those of you who are coffee drinkers will be interested to know that coffee interacts with environmental stress. That is, it produces elevation of the catecholamine output only in the presence of stress. (Cobb & Rose, 1973)

The evidence for the association of elevated blood pressure with quantitative overload of mental work is limited but quite striking. Of all the people I have ever seen doing mental work, the air traffic controllers reach the highest levels of rapid accurate performance. These levels of performance are demanded only at intervals. A given controller is not likely to have more than one episode per day of maximum arousal except in bad weather. Though the peaks of workload surmounted by controllers are higher than any that most people can imagine, it is not clear how much these should be seen as overload. Clearly, the men mostly enjoy this work and have selected themselves into this job. However, if the principle dimension of stress contributing to the strain they experience is really overload, then the price they pay is high, for hypertensive disease is about four times as common among air traffic controllers as it is among the fliers who are subjected to the same physical evaluation at the same intervals by the same aeromedical exam-iners (Cobb & Rose, 1973). The probability that this relationship is in fact an etiologic one is increased by the fact that adjusting for age, the frequency of hypertension is greater at airports with high traffic density than it is at airports with low traffic density.

Caplan (1971) has shown an interesting set of interactions. He has demonstrated that the association of workload and diastolic blood pressure is significantly positive only among those who are either flexible, persistent or are unsupported by their subordinates. Neither of these studies are free of contamination with other variables. Responsibility is particularly likely to account for part of the findings, However, until we get studies in which work load and responsibility are measured separately and concurrently, we won't be able to draw clear conclusions.

With regard to smoking Caplan (1971) has produced unequivical evidence that no matter what measure of overload he used, NASA personnel who smoked had higher workloads than those who were ex-smokers or who never smoked. A direction of causation is implied by the fact that the quit rate, i.e. exsmokers divided by all who ever smoked, is highest in those with low workloads.

In conclusion, I feel that I have made a moderately good case for quantitative overload of mental work contributing to coronary heart disease via several paths. The importance of this report lies not in the substantive conclusion which still needs more work but rather in the demonstration that we have come a long way in psychosocial epidemiology in the last dozen years. When I first went to the Institute for Social Research in 1961, my colleagues and I were looking at the association of two global variables social status and dispensary visits. Now I am able to present to you a substan-tial body of evidence relating a single well defined social variable, quantitative overload of mental work, to a single disease entity, coronary disease, via four risk factors, cholesterol, blood pressure catecholamine levels and smoking behavior. In view of our progress in concept formation and measurement, I think some major advances in psychosocial epidemiology are likely in the next ten years.

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