A System Dynamics Model to Examine the Effectiveness of Research and Education in Reducing Societal Costs Due to Low Back Pain

William L. Cats-Baril, Ph.D.
University of Vermont

Wilfred Roth, Ph.D.
University of Vermont

Richard H. Zeliff
University of Vermont

ABSTRACT

Low Back Pain (LBP) is the most common cause of work loss after the ordinary cold, and is the single greatest source of compensation payments. In the U.S., it is estimated that one million workers sustain a low back injury every year, and that 217 million work days are lost annually at a cost of 11 billion dollars for males aged 18-55 alone. In an effort to better understand how to control the economic impact of this disorder, a System Dynamics model is being developed. It is hoped that the model, by generating scenarios on the cost effectiveness of different interventions, will provide useful insight into specific policies to fund research addressing the causes of LBP disability.

1. INTRODUCTION

It is not surprising that containment of health costs has been on top of the political agenda for some time. Health costs, adjusted for inflation, have increased continuously and dramatically over the last 25 years both on a per capita basis and as a percentage of the gross national product (Economic Report of the President, 1983). Attempts to curb costs have failed in the past and it is too early to tell whether more recent strategies, like the Medicare new method of payment by diagnosis-related groups, will be effective (Vladeck, 1984).

The basic question, of course, is whether we, as a society, are healthier because of these expenditures. A no less relevant question is whether the improvement in general health has been cost effective. While statistics seem to answer the first question affirmatively, they tend to deny the second. Indeed, as Luginbuhl, et al (1981) have pointed out, the increase in health costs, as a percentage of the gross national product, is disturbing since it suggests that "investment" in health care may not return its costs in increased productivity.

The notion of looking at health care under an investment criterion is particularly relevant in an era of budgetary constraints. Still, performing cost-benefit analyses on specific illnesses and their respective treatments is difficult. Assessing the impact of intervention and rehabilitation efforts requires an analysis of not only the medical costs of the intervention itself, but also of the compensation and lost productivity costs that could be incurred.

The work presented here addresses these issues in the context of low back pain (LBP). The successful rehabilitation of LBP sufferers is a matter of critical medical and socio-economic importance. This disorder is mankind's major muscoloskeletal complaint, is the second most common cause of work loss after the ordinary cold, and is the single greatest source of compensation payments (Kelsey, et al, 1979).

Specifically, the questions we want to answer are whether we could save society money in the long run by funding research into preventing and treating LBP injuries and disabilities and, if so, how much? That is, we want to determine the effect of several levels of funding, coming from federal and private sources, on reducing the total costs to society of LBP impairment and disability.

To explore these questions we developed a System Dynamic model that simulates the migration of healthy individuals to various states of disability. The model computes the net costs to society, assesses the pressures that those costs may exert on research funding mechanisms, assumes different efficiencies for medical and behavioral interventions, and calculates the resulting number of disabled individuals. Various scenarios can be developed by changing a variety of societal factors.

The paper is organized in four sections. The first section examines the importance of LBP in terms of its incidence and costs, and discusses the difficulties involved in treating the disorder. The second section decribes the System Dynamics model in detail. The third section addresses the assumptions on which the model is built and the range of possible scenarios that the model can generate. Finally, the paper concludes with a note on the validity and reliability of the model and some comments on future research.

2. BACKGROUND

The cumulative effects of LBP in America are staggering. Estimates of the percentage of Americans who have had LBP at some point in their lives range from 65% to 80% (Murphy and Cornish, 1984). According to the National Center for Health Statistics (1981), impairments of the back or spine (excluding spinal cord injury) are the major cause of impairment in the U.S., after hearing and sight impairments, affecting 9,365,000 persons (4.41% of the population). Furthermore, disabling impairments of the back or spine are the leading cause of disability in this country, affecting 2,391,000 persons (1.13% of the population) in 1977. Moreover, the rate of impairment is increasing.

Indeed, while from 1974 to 1978 the general population increased 4.8%, LBP related impairments went up by 21%. The Bureau of Labor Statistics reported that one million workers sustained a low back injury in 1980 alone. Frymoyer, et al (1983) estimate that 217 million work days are lost annually at a total cost of 11 billion dollars for males aged 18 to 55. The result in terms of economic impact is calculated to be in excess of 20 billion dollars per year.

Despite these alarming statistics, the dynamics of LBP are still not well understood. Further research in at least two areas needs to be done. First, the risk factors which can bring on, and/or increase the severity and duration of, LBP have not been fully determined. Several epidemiologic studies have identified specific factors, but do not agree on their significance. This problem is due, in part, to the large number of risk factors that have been proposed. Recently, for example, a panel of experts identified 104 potential ones (Cats-Baril, 1984). These included the psychological profile of the individual, his overall fitness, whether he had a previous back injury, how compensable his injury is, his age, his education, the amount of lifting and vibration on the job, and the method of payment at work, among others.

Second, the identification of the etiology of LBP complaints has also proven to be difficult. Although certain congenital and acquired lesions, acute trauma and other causes can be identified in some cases, the majority of low back complaints have defied precise structural diagnosis. Even with the use of the latest diagnostic techniques, no more than 50% of LBP sufferers receive a definite diagnosis.

Frymoyer (1984) has pointed out that because accurate diagnosis is so elusive, it is not surprising that treatment programs and rehabilitation efforts for LBP sufferers often fail. Indeed, when treatment programs - e.g., physical therapy, pain medication, bracing, electric stimulation, etc. - have been tested by prospective randomized clinical trials, they have not shown a significant effect. It is safe to assume that if treatments could be geared toward specific and demonstrated factors causing LBP, their effectiveness would be much higher.

The overview of LBP therefore portrays an extremely common, frequently disabling clinical syndrome, often of undetermined etiology, for which acute and chronic treatment programs may yield low symptomatic relief and ineffective rehabilitation, particularly when a precise diagnosis is not available. The high prevalence in the working population, the resultant disability and its socio-economic impact suggest a critical need for a better understanding of this problem.

In an effort to assess the potential impact of further research in LBP - research that would develop more effective treatments and prevention programs - and to determine the cost-effectiveness of funding such research, a System Dynamics model was developed.

3. THE MODEL

The System Dynamics model consists of two major subsystems: the problem subsystem which models the migration of individuals between the various states of LBP disability, and the control subsystem which comprises the costing and the funding and intervention policy sectors. The causal diagram is shown in Figure 1.

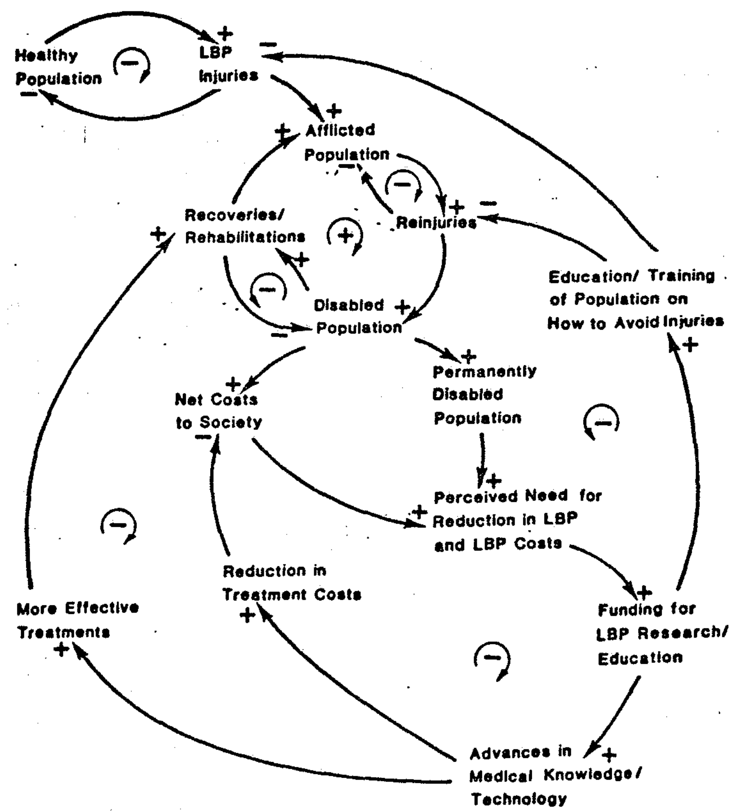

FIGURE 1: Causal Loop

3.1. THE PROBLEM SUBSYSTEM

The problem subsystem consists of eight sectors. Each sector consists of a level and all the inflowing and outflowing rates. The sectors are the following: the Healthy Population, the Injured But Functionally Recovered, the Short-Term Disabled, the Long-Term Disabled, the Rehabilitated Population, the Short-Term Disabled After Rehabilitation, the Long-Term Disabled After Rehabilitation and the Permanently Disabled. All population birth rates have been combined to

Hickman, 1972; White, 1969). So, while it is conceivable that some individuals may decide to return to the work force, in one way or another, after a disability of more than a year, the likelihood is almost negligible. The model assumes that no individual who has been classified as permanently disabled returns to work, i.e., the model assumes that they will remain disabled until they die and computes compensation and lost productivity costs accordingly.

3.2. THE CONTROL SUBSYSTEM

The Control subsystem consists of two sectors: the Cost Accumulation sector, which comprises the equations for computing the annual monetary costs incurred by society due to LBP, and the Cost Containment sector, which comprises the equations for determining the treatment cost rates, the injury rates and the success rates of rehabilitation and recovery. Both sectors are discussed below and the Cost Containment sector is shown in Figure 3.

3.2.1. THE COST ACCUMULATION SECTOR

The Cost Accumulation sector is composed of four elements: the aggregate treatment costs, the aggregate productivity costs, the aggregate compensation costs, and the net costs to society which is simply the sum of the three aggregate costs. In the model, all costs are treated as auxiliaries

The treatment costs are derived from the levels in the problem subsystem in which medical and rehabilitation costs are incurred. Specifically, the treatment costs, on a per patient per year basis, are accumulated from the LTDISR, LTDIS, STDISR and STDIS levels.

Productivity costs can be incurred for two reasons: either because of time lost from work (e.g., individuals in the STDIS, LTDIS, STDISR, LTDISR, and PERMD populations), and/or because of lower work efficiency for a proportion of the IBFR and REHAB populations.

The compensation costs represent the total value of all transfer payments made to people with compensable LBP injuries. Snook and Jensen (1984) estimate that the mean compensation cost is $6,000. They also estimate that disability payments constitute 67% of the total LBP costs, with up to 90% being accounted for by the PERMD population.

3.2.2. THE COST CONTAINMENT SECTOR

One of the purposes of this model is to reflect the effects of additional expenditures for research and education on LBP on the net costs to society. A positive effect, i.e., lowering of costs, can be achieved in at least four ways: by lowering the treatment costs, by reducing the injury and reinjury rates, by increasing the effectiveness of the rehabilitation and treatment efforts, and by more strict and vigilant compensation laws.

form the Aggregate Birth Rate which flows only into the Healthy Population level. Also, while each sector has a corresponding death rate, the death rates, for simplicity sake, are not mentioned **in** the description of each of the sectors provided below. The flow diagram is shown in Figure 2.

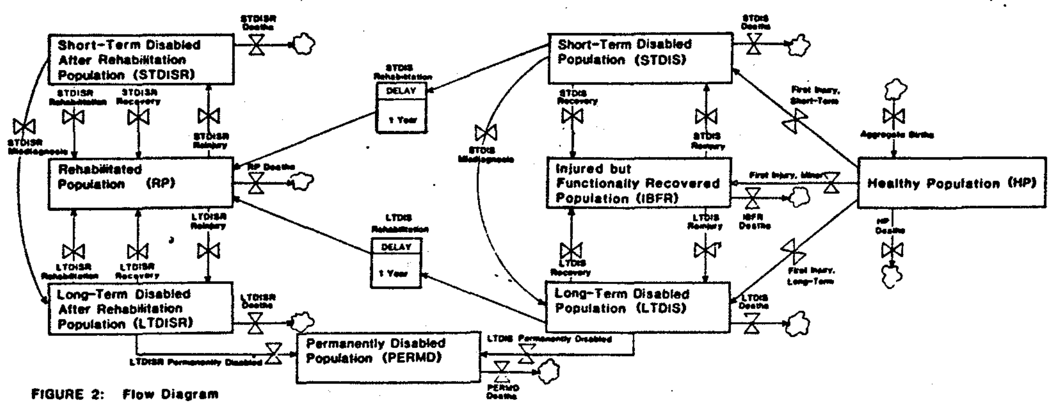

FIGURE 2: Flow Diagram

3.1.1. THE HEALTHY POPULATION

Individuals in the Healthy Population (HP) are adults (defined as older than 18 years old) who have never experienced LBP. They leave the Healthy Population either by dying or by suffering their first instance of LBP. Once an individual has suffered a LBP episode, he is never again considered part of the Healthy Population.

This first LBP occurence can result in one of three specific outcomes: a) no disability - the individual has some discomfort but does not miss any work; b) short-term disability - the individual misses up to three months of work as a result of the LBP episode; or c) long-term disability - the individual is unable to show up for work for more than three months. Each of these injury rates are established in terms of annual percentages of the HP.

3.1.2. THE INJURED BUT FUNCTIONALLY RECOVERED POPULATION SECTOR

Individuals in the Injured But Functionally Recovered (IBFR) population are those individuals who have suffered at least one episode of LBP but have not had to change their employment situation in any way. There are three paths leading to IBFR: a) from HP via a first ever LBP episode with no disabling consequences; b) from the Short-Term Disabled Population via a recovery from a LBP disabling episode no longer than three months; or c) from the Long-Term Disabled Population via a recovery from a LBP disabling episode longer than three months.

Individuals in the IBFR population have a higher susceptibility to LBP, thus, the reinjury rate of this population is higher than the rate of first injury for the healthy individuals.

3.1.3. THE SHORT-TERM DISABLED POPULATION SECTOR

The Short-Term Disabled (STDIS) population is made up of those individuals who are unable to work for more than one day but less than three months. While this definition is arbitrary, it has been suggested as a good operational benchmark by physicians and physical therapists (Cats-Baril, 1984).

The STDIS population is fed by two rates: the initial injury rate from HP and the reinjury rate from IBFR. There are three ways of leaving STDIS: a) through recovery from the LBP episode to the IBFR population; b) through misdiagnosis - some patients remain disabled longer than three months and should have been diagnosed as long-term disabled in the first place - to the Long-Term Disabled population; or c) through rehabilitation (assumed to last one year) to the Rehabilitated population.

The distinction between recovery and rehabilitation is critical. Recovery from LBP is spontaneous in at least 50% of the cases and requires minimal treatment and medical intervention (e.g., bed rest). Recovery means that individuals can return to their former employment status and to their former lifestyles with minimal, or no, changes.

Rehabilitation, on the other hand, usually occurs at a substantial cost and has been defined to imply that the individuals must change their employment status: either change jobs or drastically alter their present workplace. Rehabilitation is much more costly than recovery.

It is important to note that once an individual has been rehabilitated he 'forever' leaves the IBFR population sector to become part of the Rehabilitated population.

3.1.4. THE LONG-TERM DISABLED POPULATION SECTOR

Individuals in the Long-Term Disabled (LTDIS) Population are those indiviuals who have been unable to work for more than three months. The three ways of reaching this population have been mentioned before: a) through an initial serious injury from HP; b) through a reinjury from IBFR; or c) through misdiagnosis of a short-term disabling injury from STDIS.

Individuals can leave the LTDIS population by recovering from the injury and going back to their former employment, and thus, back to IBFR. They can also go through a rehabilitation effort (assumed to last a year), change employment and join the Rehabilitated population. Finally, they can deteriorate and become permanently disabled. Typically, individuals who have been disabled for more than a year and are getting some form of compensation seldom return to any form of gainful employment.

3.1.5. THE REHABILITATED POPULATION SECTOR

The Rehabilitated (REHAB) population is made up of individuals who have undergone some sort of rehabilitation because of a LBP impairment. By definition, these individuals have changed jobs because of their affliction, though they may be leading an otherwise normal life.

REHAB can be reached not only from STDIS and LTDIS, as described above, but also by recovering from short and long term reinjuries. While people who have had a LBP injury severe enough to merit rehabilitation are highly susceptible to recurrences, it is not clear that the reinjury rates should be higher than those for the IBFR population. On the one hand, individuals in the REHAB population have fragile backs. On the other, they have been exposed to substantial education efforts (e.g., back school) and they have curtailed activities that would expose them to a reinjury.

3.1.6. SHORT-TERM DISABLED AFTER REHABILITATION POPULATION SECTOR

Individuals enter the Short-Term Disabled After Rehabilitation (STDISR) Population by reinjuring themselves after having received rehabilitation for a previous injury. As in the case of STDIS, most individuals go back to work after three months, and thus, back to REHAB. The small, misdiagnosed percentage that does not, is transferred to the Long-Term Disabled After Rehabilitation population.

3.1.7. LONG-TERM DISABLED AFTER REHABILITATION POPULATION SECTOR

The Long-Term Disabled After Rehabilitation (LTDISR) Population include those people who are disabled for more than three months and who have been rehabilitated at least once before. Individuals can either recover and go back to REHAB, or, if their disability lasts more than one year, become permanently disabled. The proportion of individuals from LTDISR who become permanently disabled is greater than the proportion of individuals who become permanently disabled from the LTDIS population due to a greater proportion of chronic LBP sufferers in the REHAB population.

3.1.8. THE PERMANENTLY DISABLED POPULATION SECTOR

The Permanently Disabled (PERMD) population consists of those individuals who have not worked for at least one year. PERMD can be entered only from LTDIS and LTDISR. Evidence shows that the probability of symptomatic relief and return to work at one year is 20%, and for more than a year the probability is nil (Beals and

The Cost Containment sector is "driven" by a combination of the total cost to society and the number of permanently disabled individuals (i.e., the size of the PERMD population). This combination affects the level of funding made available for research and education. Different levels of funding achieve different increases in the effectiveness of all treatments and rehabilitation programs, including better prevention. The table functions linking total costs and the number permanently disabled to funding levels, and funding levels to increase effectiveness of treatments have been assumed, initially, to be linear.

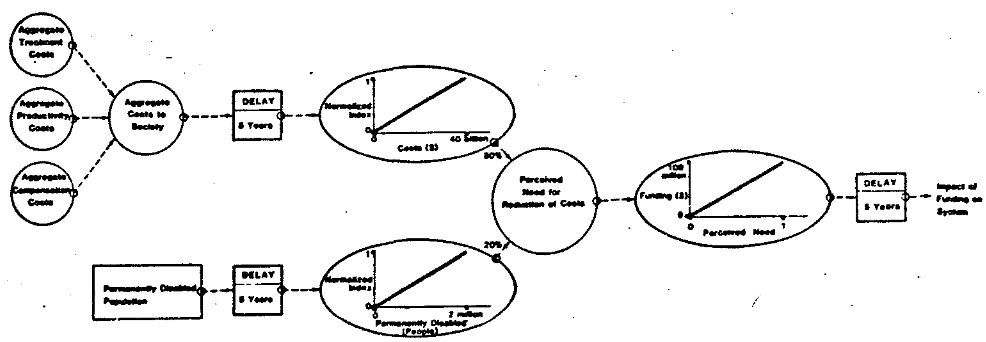

FIGURE 3: Cost Containment Sector (Original Assumptions)

4. ASSUMPTIONS

The purpose of the model is to explore the economic impact of different policies to fund research and education to prevent and lessen the incidence of LBP. In order to achieve this purpose, the model permits changing several types of assumptions. Different scenarios can be developed by changing the assumptions of: a) the demographic, occupational and lifestyle profile of the population, b) the effect of differently designed workplaces, c) the driving forces of federal and private funding for research and education in LBP, and d) the relation between funding and the increased effectiveness of various interventions.

The assumptions behind changes in the demographics of the population and the advent of the factory of the future affect directly the rates at which individuals are hypothesized to get injured, reinjured and disabled. For example, since the general population is getting older as a whole, and since the likelihood of having LBP increases with age, it is fair to assume that the incidence of LBP will tend to increase. On the other hand, the population is much more aware of the importance of fitness, and since level of fitness is negatively correlated to the likelihood of LBP disability, the trend toward lighter foods, less smoking and drinking, and more exercise could reduce the incidence of LBP.

Changes in the occupational profile of the population and the general working conditions may also have an effect on LBP. For example, as a greater proportion of the population is employed in delivering services, and as the industrial workplaces continue to be changed by automatization, robotics, and better ergonomic design of workstations and machinery, it can be expected that LBP disability from injuries on the job will tend to go down. Also, the likelihood of LBP disability has been negatively correlated with years of education. Accordingly, as the educational level of the general population increases, a decrease in disability due to LBP can be expected.

An important factor influencing the rate of rehabilitation, and thus disability, is the compensation law. The more generous the compensation and the more lax the criteria to qualify for it, the less likely it is that people will go back to work. Given the nature of LBP, malingerancy is fairly common. Consequently, it can be expected that other economic factors may affect the "willingness" of an individual to become "disabled". For example, the rate of unemployment (the more difficult it is to find a job, the less likely that someone would let it go) and the federal and state deficits (the larger the deficits, the more stringent the compensation laws) can be expected to influence the disability rates.

Another relevant set of assumptions is the one dealing with the forces that drive the funding of research in this area. At present, the model assumes that funding is a function of the total costs incurred by society and the total number of permanently disabled individuals. The initial form of this function consists of an "urgency" index determined through a weighted average which assigns, quite arbitrarily, total costs four times as much weight as it does to the number of permanently disabled individuals. A delay of five years has been introduced to reflect the lag between the time the "urgency" index is known and the time when the funds are made available (see Figure 3). A factor that needs to be incorporated in the model is the impact of government deficits, unemployment rate, and other economic activity indicators on the political will to allocate funds for LBP research.

Funding of LBP research is assumed to increase the effectiveness of not only medical treatments but also rehabilitation programs, educational efforts, and preventive interventions. As the effectiveness of these programs increases, the injury, reinjury, and permanent disability rates decrease, and the time needed for rehabilitation is shortened. A delay of five years between the time when the funds are made available and the time when the population starts feeling the effects of improved treatments, has been incorporated.

Finally, the model assumes that the birth and death rates are equal for all the populations with the exception of the death rate for the Permanent Disabled (PERMD) population. While this population is less exposed to life threatening situations (e.g.,driving), they tend to exhibit higher rates of depression, alcohol and drug abuse, and low cardiovascular fitness leading to a higher death rate for this population.

5. CAVEATS

We are in the process of refining the model and are starting to compare different policies. The model has proven to be well behaved and stable. It has been tested under extreme conditions and has shown remarkable robustness.

However, trying to understand the economic effect of increased funding for research and education in LBP is fraught with inherent difficulties. To a large extent, these difficulties are due to the lack of accurate data relating to the various injury rates, to the costs attributable to the different categories of disability, to the effect of better prevention, treatment and rehabilitation on the specific populations, etc.. While establishing base-rate data is essential in this type of modeling, very little information is available, and what is, is often in formats that do not match and is often contradictory.

Another peculiarity that makes modeling LBP difficult, is the smallness of a number of critical coefficients leading to specific rates. For example, the rate of injury from the Healthy Population (HP) to Long-Term Disabled (LTDIS) is only .0008. A minor change in this constant will appreciably alter the LTDIS population and thus the costs associated with that population. In turn, this change will produce a large change in the funding available for research and education and this will affect other variables as the various feedback loops adapt to the altered injury rate.

Until accurate data are available for all the sensitive constants in the model, the simulation should be studied with regard to general system behavior rather than be used to forecast specific numerical results.

REFERENCES

Beals, R. K. and N. W. Hickman, "Industrial Injuries of Back and Extremeties: Comprehensive Evaluation - Aid in Prognosis and Management: Study of One Hundred and Eighty Patients," Journal of Bone Joint Surgery, Volume 54A, Number 10, 1972, pp. 1593-1611.

Cats-Baril, W. L., "Developing a Predictive Model of Low Back Pain: A Deductive Methodology," Vermont Rehabilitation Engineering Center, Working Paper, November 1984.

Economic Report of the President, U.S. Print Office, Washington, D.C., 1983, pp. 172-179.

Frymoyer, J. W., State-of-the-Science: Low Back Pain, Manuscript, Department of Orthopaedic Medicine, University of Vermont College of Medicine, 1984. (C.V. Mosby Co., in press).

Frymoyer, J. W., Pope, M. H., Clements, J. H., Wilder, D. G., MacPherson B., and T. Askikaga, "Risks Factors in Low-Back Pain. An Epidemiological Survey," Journal of Bone Joint Surgery, Volume 65A, Number 2, 1983, pp. 213-218.

Kelsey, J. L., White, A. A. III, Pastido, H. and G.E. Bisbee, "The Impact of Musculoskeletal Disorders on the Population of the United States," Journal of Bone Joint Surgery, Volume 61A, Number 7, 1979, pp. 959-964.

Luginbuhl, W. H., B. R. Forsyth, G. B. Hirsch, and M. R. Goodman, "Prevention and Rehabilitation as a Means of Cost Containment: The Example of Myocardial Infarction," Journal of Public Health Policy, Volume 2, Number 2, 1981, pp. 103-115.

Murphy, K. A. and R. D. Cornish, "Prediction of Chronicity in Acute Low Back Pain," Arch Phys Med Rehabil, Volume 65, Number 2, 1984, pp. 334-337.

National Center for Health Statistics, Series 10, No.134, Prevalence of Selected Impairments, United States 1977, DHSS publication (PHS) 81-1562, Hyattsville, MD, 1981.

Snook, S. H., and R. C. Jensen, "Cost," In Pope, Frymoyer and Andersson (eds.), Occupational Low Back Pain, Praeger Press, New York, N.Y., 1984.

Vladeck, B. C., "Medicare Hospital Payment By Diagnosis-Related Groups," Annals of Internal Medicine, Volume 100, Number 4, 1984, pp. 576-591.

White, A. A., "Low Back Pain in Men Receiving Workmen's compensation," Canadian Medical Association Journal, Volume 101, Number 1, 1969, pp. 61-67.