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Daily Stress And Metabolic Control In Older Type Ii Diabetics: A Test Of Mediation By Mood And Energy Balance Changes.

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DAILY STRESS AND METABOLIC CONTROL IN OLDER TYPE II DIABETICS: A TEST OF MEDIATION BY MOOD AND ENERGY BALANCE CHANGES

by

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A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Psychology in the Graduate School, The University of Alabama at Birmingham

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ABSTRACT OF DISSERTATION
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Title DAILY STRESS AND METABOLIC CONTROL IN OLDER TYPE II DIABETICS: A TEST OF MEDIATION BY MOOD AND ENERGY BALANCE CHANGES

Naturally occurring life stress has been implicated in the glycemic control of Type I diabetics, but support for this relationship in Type II diabetics has been inconsistent. This study investigated the relationship between subjective minor stress and glycemic control in older Type II diabetics. This relationship was evaluated by using structural equation analyses to compare three nested causal models that included effects of mood and energy balance changes, with pathways corresponding to direct, mood-mediated, and fully mediated effects of stress.

No support was found for relationships of subjective minor stress and mood with health outcomes in this patient population. Neither health behaviors (eating and activity patterns contributing to energy balance) nor glycemic control measured by the fructosamine and glycated hemoglobin assays were related to stress ratings. No relationship with glycemic control was found in the pathways from energy balance or the three mood variables (depression, anxiety, and anger). Future research should focus on improvement in measurement and conceptual validity of predictor variables, more detailed evaluation of energy balance, and a prospective approach to prediction of glycemic control.

Abstract Approved by: Committee Chairman [signature]

Program Director [signature]

Date 9/21/92 Dean of Graduate School [signature]

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INTRODUCTION: TYPE II DIABETES MELLITUS

Type II diabetes is a chronic condition that usually occurs in middle or late adulthood. Many features of this condition make it an ideal object for the study of stress processes in late life. Specific features of this disease, including its high prevalence, comorbidity, and association with lifestyle factors, underscore the need for behavioral research to advance knowledge of this significant health problem. More generally, diabetes treatment issues and the pathophysiology of the disease provide opportunities for model development in behavioral medicine, particularly for stress processes. The understanding of psychological and physiological relationships may be particularly important in aging, when maintenance of health has a strong influence on quality of life. The following overview presents a rationale for the study of stress processes in older adult diabetics. Specifically, it is proposed that emotional arousal and behavioral factors may contribute to a model in which stress processes may be related to alterations in glycemic control. In order to build an argument for these relationships, some background information on diabetes will be reviewed, along with a rationale for diabetes as a behavioral medicine model with application to aging, justification for a relationship between stress and diabetes control, and a proposal for the consideration of mood and activity as factors influencing diabetes control.

Diabetes is a class of disorders in which chronic hyperglycemia occurs as a result of aberrations in the removal of glucose from the blood by the hormone insulin. Insulin-dependent, or Type I diabetes, generally is diagnosed before age 30 and is characterized by an absence of insulin, which must be administered by injection. In

non-insulin-dependent diabetes, or Type II, there may be either insulin deficiency or decreased responsivity to insulin action. Onset of this type typically occurs after age 40 (Pohl, Gonder-Frederick, & Cox, 1984), and a majority of Type II diabetics are obese (King et al., 1984; Neil, Thomson, Thorogood, Fowler, & Mann, 1989; Pedersen, 1989), perhaps as many as 60 - 90% (Pohl, Gonder-Frederick, & Cox, 1984; Turk & Speers, 1983).

The incidence of clinical diabetes increases with age (American Diabetes Association, 1990; Fitzgerald, Malins, O'Sullivan, & Wall, 1961; Neil et al., 1989). Type II diabetes is about 20 times as common as Type I diabetes, and it is a significant health risk in older adults, a rapidly growing segment of the population. The age-adjusted mortality risk in Type II diabetes has been estimated to be three times that of non-diabetics (Zimmet & King, 1986), and diabetes is the sixth leading cause of death among Americans over the age of 65 (American Diabetes Association, 1990; Minaker, 1990). Patients with this disorder are at risk for the development of eye, kidney, and nervous system pathology, and cardiovascular disease may occur as a complication or co-morbid condition (Neil et al., 1989; Smith, 1986). Co-morbidity is high, making diabetes a major factor in the increasing morbidity observed in late life (Minaker, 1990; Neil et al., 1989).

While there is strong evidence for a significant genetic component in Type II diabetes (Osei, 1990; Pohl et al., 1984), lifestyle factors appear to have some role in its development (Pohl et al., 1984, Zimmet & King, 1986). Risk factors for Type II diabetes include obesity, hypertension, and hyperlipidemia as well as family history of diabetes and race (American Indians, Blacks, and Hispanics having higher risk) (American Diabetes Association, 1990). Studies which have traced the migration of cultural groups from rural to urban settings have noted increases in the prevalence of Type II diabetes, apparently due to the combined effect of diet, exercise, and obesity

(Zimmet & King, 1986). Lifestyle factors are also important in the treatment of diabetes. Many Type II and all Type I diabetics are required to follow a strict regimen, controlling diet and activity, monitoring blood glucose levels, and self-administering injections of insulin. Type II diabetics may be treated with oral agents which alter insulin levels. However, a major focus of treatment for the Type II diabetic is behavioral. Diet and activity modifications are typically used in the management of the disease, and weight loss is often an important goal. Overeating and obesity are treatment targets, most importantly because excess weight appears to contribute to insulin resistance. (Pedersen, 1989). With proper diet and weight loss, improvement in Type II diabetes is often observed (American Diabetes Association, 1990; The National Diabetes Advisory Board, 1987; Uusitupa et al., 1990).

DIABETES AS A MODEL FOR BEHAVIORAL MEDICINE

The importance of behavioral change in diabetes has led researchers to suggest diabetes as a model for behavioral medicine (e.g., Bradley, 1985; Pohl et al., 1984; Surwit, Feinglos, & Scovern, 1983). There are two reasons for this. First are the practical issues. Implementation of care in diabetes highlights some of the treatment issues encountered in other diseases. Whereas many illnesses and conditions require a course of treatment that includes special diets and therapies, such as exercise and medication, diabetes requires life-long implementation of these treatments. The psychological state of the patient is a very important factor influencing the success of the diabetes regimen. For example, the lifestyle changes required in diabetes treatment both impact and are affected by social and family functioning (Kaplan & Hartwell, 1987). Moreover, diabetes treatment is especially regimented, and schedule adherence is crucial because the consequences of blood glucose fluctuations may be severe. While complications may develop in many illnesses in response to poor care, few are as wide-ranging or debilitating as those facing the diabetic. Poor glucose control may have both short- and long-range consequences. However, the long latency before development of severe physical effects may be at odds with short-term reinforcement in diabetes. Hence, issues such as perceptions of risk and the balance of reinforcement in determining self-care behavior are similar to those raised by other health-related behaviors, such as smoking. Diabetes treatment depends on patient self-assessment and self-care. Treatment decisions are often based upon continued self-monitoring by the patient, using both objective indices (blood glucose testing) and subjective symptoms.

Therefore, any of a number of factors influencing the cognitive and emotional state of the individual may affect his or her diabetes.

Psychological state may have direct consequences for diabetes in addition to its effects on self-care behavior. The potential interaction of psychological and physiological well-being in diabetes is of theoretical interest to behavioral medicine. Thus, a second rationale for the study of diabetes is its potential contribution to knowledge of mind-body interactions. A major problem for behavioral medicine has been measuring the interaction of emotional responses to psychological stress with physiological processes and health outcomes. Relationships have been demonstrated indicating that psychological stress has some relationship to physical health (Kasl, 1984; Rabkin & Struening, 1976). However, more studies are needed identifying physiological mechanisms mediating this relationship that may be linked to disease outcome (Kasl, 1984). Glycemic parameters are closely monitored in diabetes, providing readily available indices of physiological alterations that may accompany changes in psychological state. Autonomic and hormonal systems which regulate stress responses are also known to regulate blood glucose concentrations (Barglow, Hatcher, Edidin, & Sloane-Rossiter, 1984; Surwit & Feinglos, 1988; Tarnow & Silverman, 1981). Therefore, a mechanism may be specified which explains associations between stress and physical state in diabetes.

DIABETES IN OLD AGE

Type II diabetes provides an excellent model for the study of stress in the aging individual for several reasons. Diabetes is highly prevalent in old age (Davidson, 1986; Minaker, 1990; Neil et al., 1989), and it is a chronic, lifelong illness that may constitute a strain on the psycho-social resources of the individual. There are many chronic conditions that afflict older adults, and it is important to understand how environmental stress may influence maintenance of physical health. Diabetes is also important in this population because altered regulation of glucose levels appears to occur in aging even without clinical manifestation of this disorder (Minaker, 1990; Minaker, Rowe, Tonino, & Pallotta, 1982; Rowe & Troen, 1980). Relationships between glycemic control and stress may therefore have metabolic implications for older adults with sub-clinical changes in glucose regulation. This shift in glucose metabolism that appears to occur with age is one manifestation of a general trend toward system disregulation in old age (Gregerman, 1986; Rowe & Troen, 1980). Several researchers have observed a decreased physiological adaptation to physical challenge in old age (McCulloch, Plenderleith, & Richard, 1987; Palmer, Ziegler, & Lake, 1978). There is evidence to suggest that in aging the autonomic nervous system may decline in its homeostatic response to stress (Halter & Pfeifer, 1981). Much of the research on stress and health in older adults has focused on how their changing social and psychological milieu may influence responses to stress. Studies of psychosocial adaptation indicate that coping resources are maintained or even enhanced in late life (Irion & Blanchard-Fields, 1987; McCrae, 1982). However, little attention has been given to the possibility that inadequate physiological adaptation

might make older adults more vulnerable to psychological stress. Clinical diabetes may be an exemplar of more general physiological changes that have potential implications for understanding how psychological stress may affect the health of the older individual.

STRESS AND DIABETES CONTROL

There is ample theoretical justification for suggesting that stress may be linked to diabetes. The physiological response to stress, acting through the sympathetic nervous system and the adreno-cortical axis, has profound effects upon the regulation of blood glucose levels (Turk & Speers, 1983). Although susceptibility to Type II diabetes appears to be genetically determined (Osei, 1990; Pohl et al., 1984), stress may play a role in the onset of diabetes (Turk & Speers, 1983). The possibility that psychological factors may account for fluctuations in blood glucose levels has considerable clinical relevance, given that the final treatment goal is stabilization in these fluctuations or achievement of metabolic control.

Acute effects of laboratory stress stimuli on blood glucose have been demonstrated in Type I diabetics, although the direction of observed changes has been inconsistent. That is, Vandenbergh, Sussman, and Titus (1966) found decreased blood glucose following stress exposure, while increased glucose (Carter, Gonder-Frederick, Cox, Clark, & Scott, 1985) and inconsistent glucose responses (Bradley, 1985) have also been documented. Few studies have examined acute effects in a strictly Type II population. Two early studies used a mixed sample of Type I and Type II patients who were subject to an individualized stress interview. The results revealed no effect on blood glucose levels. However, ketone levels and urine output increased compared to a non-stress control day, and blood glucose levels were extremely variable (Hinkle & Wolf, 1952a, 1952b). Naliboff failed to find mean changes in blood glucose in Type II diabetics' response to induced laboratory stress, despite evidence for increased catecholamine and cortisol responses (Naliboff, Cohen, & Sowers, 1985).

As Bradley (1988) points out, there was considerable variability in catecholamine levels in Naliboff's subjects, so that individual differences in glycemic response may have been masked in this study. While the possibility of observing direct effects on blood glucose levels is provocative, the complexities of interpretation of these results merit consideration. Goetsch (1989) has reviewed the methodological and interpretive problems that have plagued this area of research.

There is evidence that the experience of naturally occurring life stress has clinical manifestations in diabetics. Subjectively, both Type I and Type II diabetics report that stress has effects on mood (Cox, Taylor, Nowacek, Holley-Wilcox, & Guthrie, 1984; Gonder-Frederick, Cox, Bobbitt, & Pennebaker, 1986) and physical symptoms (Gonder-Frederick, Cox, Bobbitt, & Pennebaker, 1989; Jacobson, Adler, Wolfsdorf, Anderson, & Derby, 1990). Studies of naturalistic stress in the diabetic population provide further evidence of this relationship. The majority of these studies have focused on Type I patients, who experience greater fluctuations in metabolic control relative to Type II patients as a result of their reliance on exogenous insulin for glucose regulation. Perceived stress (Hanson & Pichert, 1986; Frenzel, McCaul, Glasgow, & Schafer, 1988), major life change (Bradley, 1979; Grant, Kyle, Teichman, & Mendels, 1974), and minor everyday stress (Cox et al., 1984) have been associated with increased blood glucose levels in Type I patients.

Reviewing evidence from animal models and studies of Type I and Type II diabetics, Surwit and Feinglos (1988) have proposed that Type II diabetes may be particularly sensitive to effects of stress. This hypothesis is based on the fact that Type II diabetics often retain the ability to secrete insulin. Therefore, the metabolic effects of the autonomic nervous system may be manifest in the modulation of insulin secretion as well as control of glucose release (Surwit & Feinglos,

1984). This dual control of metabolism by the autonomic nervous system may also increase the likelihood that emotional stimulation may result in alterations in metabolic control in the Type II diabetic. In support of this hypothesis, Surwit and Feinglos (1983) conducted a study selecting Type II patients who reported that stress influenced their glycemic control. Six patients received glucose and insulin tolerance tests before and after a five day relaxation intervention. Glucose tolerance was significantly improved in the intervention group, with no change in insulin sensitivity or insulin response to glucose. Improvements in glucose tolerance in this study were associated with decreases in plasma cortisol levels. Because this study was conducted in a hospital environment, other aspects of the diabetes treatment regimen were well controlled. This increases the likelihood that the effect may be attributed to the intervention. However, the sample was small and chosen for its subjective sensitivity to the effects of stress. A control group demonstrated no change in glucose tolerance. The authors suggest that the mechanism for this effect may be an increase in hepatic uptake (Surwit & Feinglos, 1983). However, until further data is published on the maintenance of this effect, no conclusions can be made about the implications for long-term glycemic control.

Another intervention study randomly assigned 60 older adult retirement home residents to a social activation or control condition (Arnetz, 1984). Both diabetic and non-diabetic participants were included in the study. Over a six month period, staff in the activation condition increased interaction with the residents, and organized activity groups and outings. Blood glucose measurements (representing mean glucose levels over approximately three months) were taken at baseline, and after three and six months of the intervention. For both diabetic and non-diabetic older adults, increases in social activation were associated with significantly improved blood glucose

levels. Residents who changed their social activity level the most exhibited the greatest change in blood glucose values, while no change in blood glucose was observed in the control condition (Arnetz, 1984). One potential problem in interpreting these results is that the social stimulation condition also involved increases in general activity level, as the residents went on outings and had more recreational opportunities. While data on the content of the activities in the two groups is not presented in the report, it is likely that the intervention group was more productive and less sedentary than they had previously been. Thus, they may have experienced changes in mood or well-being and/or physical effects from their increased activity level independent of the social aspect of the intervention. A further problem in this study is that there was no monitoring of the dietary intake of the subjects, so that effects on glucose control may possibly be attributed to dietary changes.

A few studies have used a correlational approach to investigate stress effects on Type II diabetes. In contrast to studies of Type I patients, these have, in general, produced disappointing results. In two studies, measures of glucose control were not associated with perceived stress, family support, or medical care satisfaction (Glasgow & Toobert, 1988), or major life events, health beliefs, social support, depression and anxiety (Wilson et al., 1986), although these variables did influence diabetes self-care activities. However, social support was a significant factor in glycemic control in a study of Type II diabetics who were referred by their physicians for a diet and exercise intervention. In this study, blood glucose levels were significantly correlated with social support satisfaction for women, but negatively correlated with social support satisfaction for men. However, it is likely that this relationship was mediated by the effects of social support on program participation (Kaplan & Hartwell, 1987).

In summary, there is at this time conflicting evidence for a stress effect on metabolic control in Type II diabetes. The two existing intervention studies indicate the possibility that alterations in psychological state have important metabolic consequences in Type II diabetes. However, this effect has neither been isolated in the laboratory, nor generalized in a naturalistic study of a large patient population. Both of the studies reporting this effect included a limited sample of diabetic patients. Furthermore, neither of these studies directly measured the presence of stress. In the Arnetz (1984) study, moreover, the social activation intervention may have produced glycemic effects by increasing subjects' well-being and physical activity.

Naturalistic studies are especially important at this stage of investigation of the stress-metabolic control relationship. By demonstrating associations between real-world life stress and metabolic control in a general patient population, a rationale may be developed for the existence and specification of this relationship and its mechanism. Without the demonstration of this general relationship, evidence from studies of specific sub-groups remains unconvincing.

MOOD AS A MEDIATOR IN THE STRESS-DIABETES RELATIONSHIP

One way that stressful events may affect physiological state is through alterations in mood. Emotional arousal is intimately involved in the stress process. Even subtle emotional stimuli may have the power to elicit neuroendocrine responses (Mason, 1975) which may alter glucose levels. In transactional models of stress, emotional responses to stimuli and appraisal of the emotional significance of stimuli occur throughout the stress process (Folkman & Lazarus, 1988; Turk & Speers, 1983). Indeed, stressful events are distinguished from other events by their potential for eliciting emotional response (Folkman & Lazarus, 1988; Mason, 1975). Of particular relevance to diabetes is the autonomic nervous system arousal that accompanies emotional stimulation during processing of the encounter and which may lead to alterations in glucose regulation (Mason, 1975). Experience of a stressful occurrence may therefore lead to disturbances in mood and metabolic control.

Minor mood disturbances have been reported to be associated with daily stressful events. Rehm (1978) reported impressive correlations of daily events with self-rated mood. Mood was related to concurrent, but not previous day, events. Overall, 49% of mood variation was attributable to same-day events in this study of college students using a simple daily log of positive and negative experiences (Rehm, 1978). Two other studies reported similar results of lesser magnitude. In one of these, minor stress combined with concurrent physical symptoms was reported to be a major determinant of daily mood (Eckenroade, 1984). Another study used multiple assessments of minor stress using the Hassles Scale (Kanner, Coyne, Schaefer, & Lazarus, 1981) and reported that stress was associated with poorer same-day mood and more diary logged physical symptoms (Delongis, Folkman, & Lazarus, 1988).

Associations of daily events and mood have been shown even when mood is rated by a spouse observer. In two studies, husbands' daily mood recorded by both husbands and their wives on the Nowlis Mood Adjective Checklist (MACL) was associated with daily life events recorded by the husbands (Stone, 1981; Stone & Neale, 1984).

Changes in mood are often associated with blood glucose fluctuations (e.g., Gonder-Frederick et al., 1989). However, a relationship of average blood glucose level (metabolic control) with more stable mood states has not been demonstrated in the Type II diabetic population (Wilson et al., 1986). In one within subjects study of Type II subjects, moods were shown to be related to blood glucose measurements, with negative moods related to glucose changes in either direction. Ratings of "angry-in" and "sad" were related exclusively to high blood glucose levels, while ratings of "frightened" related only to low blood glucose (Gonder-Frederick et al., 1989). Gonder-Frederick and Cox have suggested elsewhere that stress may have differential effects on blood glucose levels, with passive-emotional stress eliciting glycemic responses that are opposite of active anger (Cox et al., 1984; Cox et al., 1986). The possibility that anxiety and anger may differentially affect blood glucose has also been previously suggested (Hinkle & Wolf, 1952b), and may explain the lack of relationship to glycemic control when depression and anxiety are considered together (Wilson et al., 1986). Further elucidation of the relationship of moods to glycemic control has clinical relevance, particularly if sub-groups of patients may be identified who elicit patterns of emotional responses that are associated with blood glucose level. If such groups can be identified, future research might then determine whether modification of the emotional response to stressful events may have positive effects on metabolic control.

ACTIVITY AS A BEHAVIORAL FACTOR IN METABOLIC CONTROL

Daily stress and mood fluctuations are likely to have an impact upon the patient's routine schedule of activities (Kirkley & Fisher, 1988; McCann, Warnick, & Knopp, 1990). This is particularly important in diabetes treatment in which eating habits and level of physical activity affect metabolic control. Participation in physical activity appears to be a significant factor in Type II diabetes, in which the metabolic anomaly produces reduced insulin sensitivity. Aerobic fitness, assessed by maximum oxygen uptake (VO2max), has been shown in normal humans to be related to insulin sensitivity during an oral glucose tolerance test (Heath, Gavin, Hinderliter, 1983). Prospective and cross-sectional studies of physical training in non-diabetic animals and humans provide convincing evidence of an association of exercise with increased insulin sensitivity (reviewed in Heath, et al., 1983). Poor glucose tolerance and clinical diabetes have been observed to be related to both physical inactivity and obesity (Saltin, Lindegarde, Lithell, Eriksson, & Gad, 1980). While inactivity and obesity are often related, a sedentary lifestyle may be an independent factor in the risk of clinical diabetes with obesity (King et al., 1984).

Given that activity level appears to be related to glucose and insulin action, as well as diabetes occurrence, the clinical manifestations of activity participation in diabetes would appear to be important. With exercise training Type II diabetics show increased glucose tolerance, decreased basal insulin, and decreased glucose stimulated insulin (Wasserman et al., 1991). Effects of regular exercise on insulin sensitivity occur even without accompanying weight loss (Wasserman et al., 1991), and overall metabolic control appears to

be improved with exercise training (Reitman, Vasquez, Klimes, & Nagulespara, 1984; Schneider, Amorosa, Khachadurian, & Ruderman, 1984; Trovati et al., 1984). Immediately after exercise Type II patients have been observed to show acute effects, with decreased circulating glucose levels (Minuk, Hanna, Marliss, Vranic, & Zinman, 1980; Wasserman & Vranic, 1988) and increased insulin sensitivity (Wasserman & Vranic, 1988). The effects of regular physical activity may be of short duration, due to the repeated influence of acute physiological changes rather than to chronic, lasting glycemic alterations. If activity effects are relatively transient, this may account for the apparently contradictory findings in some activity training studies, which have reported that exercise had no influence on glycosylated measures of glucose control in Type II patients when the measures were taken several days after termination of activity participation (Heath et al., 1983).

BALANCE OF ENERGY INTAKE/OUTPUT AND DIABETES TREATMENT

Aerobic fitness and calorie expenditure are both important consequences of activity participation in Type II diabetes. Aerobic activity may benefit Type II diabetics directly, through effects on glycemic control (Heath et al., 1983; Reitman et al., 1984; Schneider et al., 1984; Trovati et al., 1984; Wasserman & Vranic, 1988), and indirectly through alterations in mood (Folkins & Sime, 1981), stress responses (Michael, 1957; Sinyor, Schwartz, Peronnet, Brisson, & Seraagnian, 1983), or cardiovascular risk, which is higher in this patient group (Smith, 1986). However, little attention has been given to studying low intensity activity, despite its potential effect on energy expenditure and weight loss. A number of authors have suggested that caloric restriction or correction of obesity, together with increased physical activity, may be a sufficient treatment for Type II diabetes (Berger & Berchtold, 1982; Heath et al., 1983; Koivisto & Sherwinke, 1979; Richter, Ruderman, & Schneider, 1981; Ruderman, Ganda, & Johansen, 1979), at least in its mild forms (Bjornthorpe et al., 1979). Weight loss leads to improved glucose tolerance and often decreases in required medications (American Diabetes Association, 1990; Uusitupa et al., 1990), even with modest caloric reductions (American Diabetes Association). Both dietary intake and caloric expenditure through activity are, therefore, relevant to diabetes treatment. Even light exercise contributes to weight reduction and better glucose control (American Diabetes Association). Several studies which have measured activity have focused on the high intensity range, and reported no relationship with glycemic control (Glasgow & Toobert, 1988; Jarrett, Shipley, & Hunt, 1986). Although the data is not available in these reports, it is quite likely that little variance was

found in the activity measure. High levels of physical activity are especially unlikely among the older adult and the obese, among whom the prevalence of Type II diabetes is greatest.

Interventions do not have to affect high intensity activity to be effective in producing weight loss. One study that compared programmed aerobic exercise with increased lifestyle activities in children indicated that the latter approach, which leads to increased general energy expenditure, is better tolerated and maintained. This study is particularly important in demonstrating that small increases in activity level in a wide variety of leisure pursuits could be effective in achieving weight loss independent of diet. Participants in the lifestyle activity intervention continued to lose weight during maintenance and follow-up periods, while the aerobic exercise participants had returned to baseline weight 17 months later (Epstein, Wing, Koeske, Ossip, & Beck, 1982). In adults, low intensity exercise has proven to be more effective in achieving weight loss (Girandola, 1976). Lifestyle activity may also have beneficial effects on metabolic control. Low intensity exercise has been reported to be related to blood glucose levels in one study of ten Type II diabetic women (Paternostro-Bayles, Wing, & Robertson, 1989).

OBJECTIVES

Type II diabetes is prevalent in older adults, and is but one of many chronic conditions requiring psychosocial adaptation in late life. Furthermore, the study of psychological factors in glucose control in older diabetics may contribute to general knowledge of aging and physiological regulation. Thus, this study will explore in this specific population relationships between psychosocial, physiological, and health-related behavioral factors that are important aspects of understanding more general processes of health and disease in older adults.

While stress has been speculated as an important mechanism for glucose regulation in Type II diabetes, evidence for this hypothesis has been inconsistent. Interventions aimed at reducing responses to stress appear to decrease blood glucose levels. However, a relationship between stress and glycemic control has not yet been demonstrated in a Type II diabetic population. Preliminary data on the relationship of mood to diabetes control indicates that emotional response patterns may influence glycemic fluctuations. Thus, emotional responses to stressful events may be important mediators in the relationship between stress and diabetes control. In addition to direct physiological effects, stress may also have behavioral effects that are potentially important for diabetes treatment. In non-insulin treated diabetics, weight loss is an important goal, and activity together with caloric intake contributes to the balance of energy that determines whether weight is lost or gained. While there is general agreement that activity and caloric intake modification are effective treatments for Type II patients, there is no consensus on what factors influence the achievement of these treatment goals. Furthermore, the

contribution of low intensity leisuretime activity to weight loss and better glycemic control in older Type II diabetics has been largely ignored in the research literature.

In this study, therefore, a model is proposed to test the relationship between the experience of stressful environmental conditions and disease factors in older Type II diabetics, particularly levels of blood glucose. Included in the model are mood and behavioral factors contributing to energy balance, caloric intake and level of activity. Specifically, this model will test the relationship of daily stress, mood, and "energy balance"--an activity-diet variable, to metabolic control.

Specific Aims and Statement of the Model

The objective of this research is to investigate relationships between stress and health outcomes in older adults by examining fluctuations in subjective minor stress and glycemic control in older Type II diabetics. Specifically, a causal model will be developed to evaluate the statistical effect of stress on glycemic control in this patient population. As reviewed above, mood and behaviors contributing to energy balance may also be related to glycemic control. A second aim of this research is to evaluate possible mediating effects of these variables in the stress-glycemic control relationship. In order to meet these objectives, three causal models will be proposed and compared. These models are stated in the following specific hypotheses:

1. Stress, mood, and the diet-activity variable ("energy balance") will each have direct effects on glycemic control (see Figure 1).

2. In addition to a direct effect, stress effects on glycemic control will also be mediated by mood (see Figure 2), and this model will provide a better over-all fit to the observed correlational data than Model 1.

3. Stress effects on glycemic control will be mediated by both mood and energy balance, and this model will provide a better overall fit of the observed correlational data than Model 1 or Model 2 (see Figure 3).

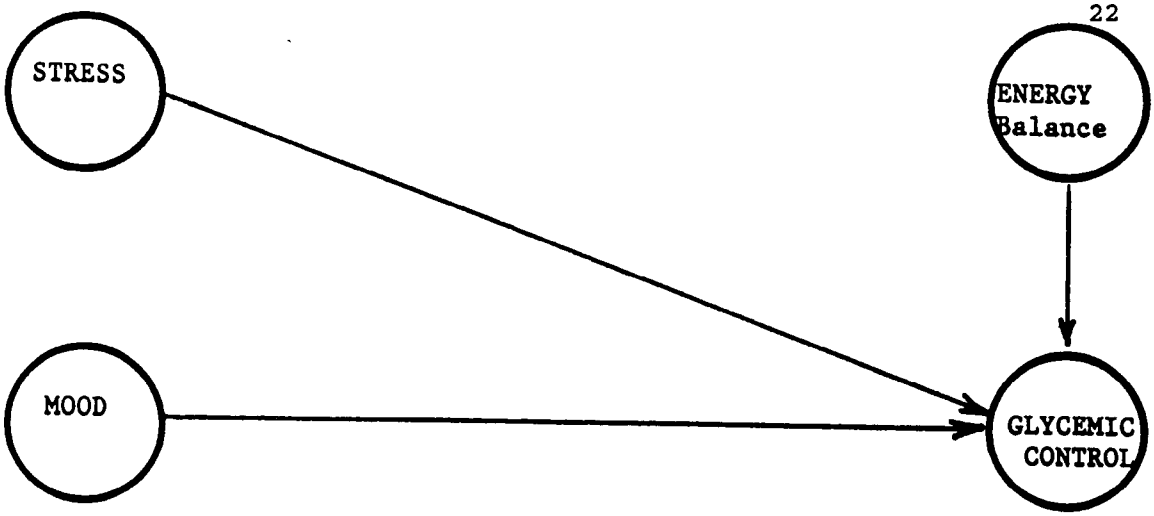

Figure 1. Direct Effects Model.

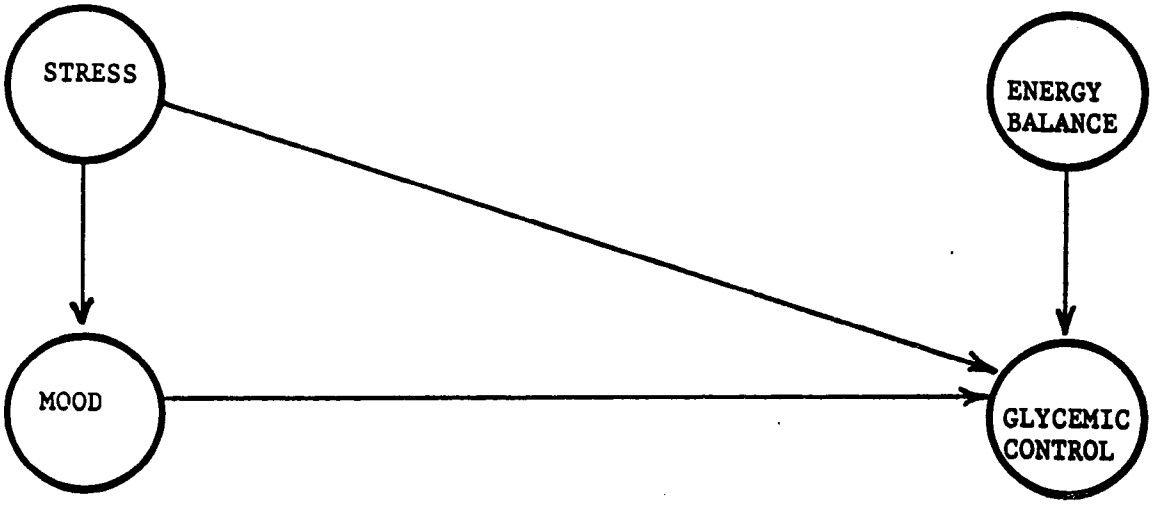

Figure 2. Model with Mediation by Mood.

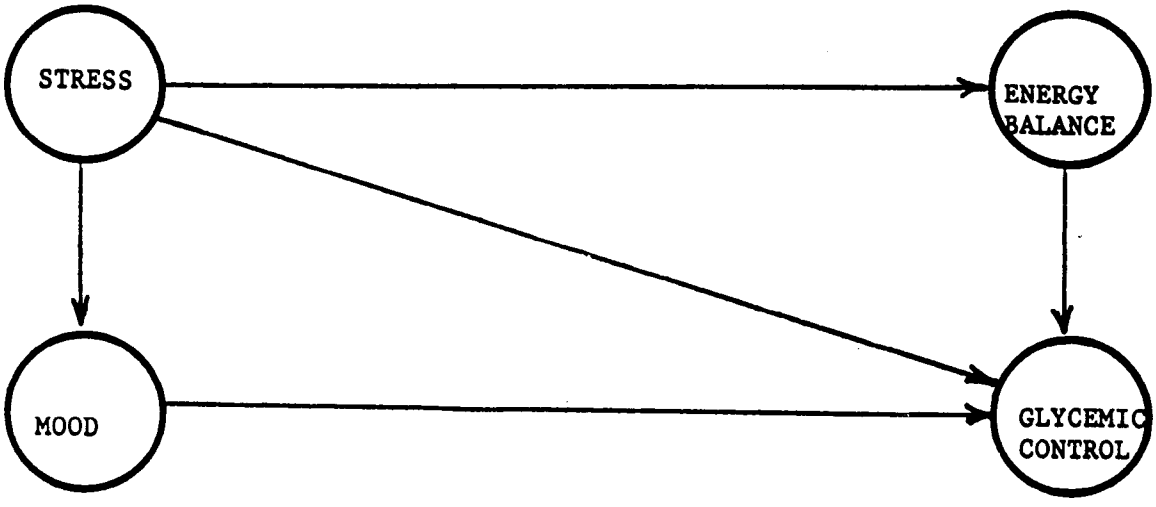

Figure 3. Model with Mediation by Mood & Energy Balance.

METHOD

Subjects

Adult volunteers with Type II diabetes were recruited from the patient population at the Diabetes Research and Training Center at the University of Alabama at Birmingham, beginning with a comprehensive review of over 1,600 medical charts. Approximately 28% were found to fit the following inclusion criteria: (a) diagnosed with Type II diabetes, (b) aged 59 or older, and (c) free from comorbid conditions, that may affect study measures. Medications that qualified for exclusion were: "beta-blocker" hypertension medications that may interfere with the physiological response to stress and psychotropics because of their mood regulating effects. Exclusionary diagnoses included: hypothyroidism which may affect weight regulation, psychiatric diagnoses, severe neuropathies that may indicate autonomic system dysfunction, and any severe debilitating cognitive, sensory, or physical condition that may impair subjects' ability to respond to questions or limit subjects' physical activity.

The most common reason for medical exclusion in the sample was current prescription for psychotropic medication or presence of a psychiatric diagnosis (32%), followed by use of beta-blocker medication (24%), and diagnosis of hypothyroid dysfunction (18%). Other reasons for exclusion included chronic conditions such as neuropathic, cardiovascular, pulmonary or degenerative joint disease that had been medically documented as severe or debilitating (11%), presence of sensory or physical incapacity (9%), and neurological conditions affecting cognitive function (6%). Other inclusion criteria, (d) retirement from regular employment, and (e) physically and cognitively able to function autonomously, were assessed at a later point.

Employed patients were excluded because the pattern of their activities would be determined by work requirements, rather than leisuretime, while disabled patients would be restricted in activity due to other extraneous factors.

Of 270 eligible patients who had clinic appointments scheduled during the seven month recruitment period, 160 were contacted in the clinic and invited to participate. After a brief explanation of the study, 11% of these patients declined to participate. The remaining 143 patients consented and were administered a simple screening assessment. Fifteen percent of these patients were excluded at this juncture, because either they were not retired from employment or they did not qualify for full independent performance of Instrumental Activities of Daily Living (Lawton & Brody, 1969). Of the remaining 119 patients accepted as study participants, 39% percent subsequently dropped out of the study, leaving a final sample of 72 patients.

Examination of the reasons for non-completion revealed that: 45% were unable to be contacted for later portions of the data collection because they were not reachable by telephone in spite of multiple daily attempts during the two week period prior to the next clinic visit or they missed their next clinic appointment, 21% had changed their minds between the clinic contact and the telephone assessment conducted later (see below), 6% exhibited memory problems or confusion that inhibited data collection during the telephone contact, 4% exhibited hearing deficits that prohibited clear telephone communication, 4% refused at the telephone contact because of family death or illness, and one subject died during the study.

In order to increase the sample pool, several Birmingham area endocrinologists were contacted, leading to an attempt to recruit patients through the Brookwood Diabetes and Endocrinology Association Clinic. In this clinic, 420 of 691 patients were identified who were Type II diabetics aged 59 or older, 58 of whom had scheduled

appointments during the two month recruitment period at this clinic. These charts were reviewed, and 26 patients were excluded according to the medical criteria outlined above. Thirty-two patients were contacted, and 24 of these (75%) declined to participate in the study. Because of this high refusal rate, the number of potential subjects did not proportionately contribute to the sample. They were, therefore, not included in the final sample.

Table 1

Sample Characteristics

Variable	M	SD	Range	Mdn	%
Demographics					
Age (yrs)	69.4	5.8	59-84		
Years retired	8.5	6.1	1-29		
Occupation[a]				Skilled work[b]	
Current income				$10-11,999	
Pre-retiring income				$12-14,999	
Years education			0-17+	12	
Married					58%
Female					61%
Ethnic minority					53%
Medical information					
Years diagnosed	12.2	8.7	0-40		
Years w/MD	0.32	0.85	0-3		
Pre-study HbA1	10.48	3.0	6.0-20.6		
Insulin					61%
Oral agents					25%
Diet only					14%

[a] Former occupation of subject or head of household.

[b] Skilled worker category, e.g., craftsman, foreman, advanced clerk.

Sample characteristics are presented in Table 1. The typical subject was a married, African-American female, 69 years old, with a high school education, who was herself or was married to someone employed as a skilled worker now retired for 8.5 years. Medically, she was prescribed insulin, had been diagnosed with diabetes for 12 years, and had been with her doctor for less than a year.

Some differences were noted in comparisons with the 47 patients who did not complete the study, using *t*-tests for the difference between means (Hays, 1981). Patients who did not complete the study were more likely to belong to a white ethnic group ($t = -3.44$, $p < .01$), had lower current income level ($t = 2.07$, $p < .05$), had worked in a slightly lower status occupation ($t = 2.11$, $p < .05$), had been retired for a longer period ($t = -2.34$, $p < .05$), and had a longer history of a relationship with their diabetes physician ($t = -2.35$, $p < .05$). Non-completers did not significantly differ from those who finished the study in other demographic and illness-related characteristics.

Procedure

The research protocol had been approved by the Institutional Review Board for Human Subjects Use. Potential participants were identified through medical chart review and then typically met in the clinic at their next regularly scheduled visit. These patients were approached in the waiting area and invited to "participate in a study to help us learn more about how things in everyday life can affect diabetes." Interested individuals were then provided with a brief overview of the study protocol and asked if they were willing to proceed with the screening questions. A brief inquiry followed, including demographic information, verification of retirement status, and administration of the Instrumental Activities of Daily Living inventory (Lawton & Brody, 1969) to ensure that the potential volunteer was physically and cognitively unrestricted in his/her activities.

Patients who were not able to independently care for themselves were thanked and informed that we would call them if they were needed for our study. Those who reported continued employment were similarly informed. Willing participants who met the screening criteria were read aloud a written consent form, a copy of which was provided to them. All participants verbally indicated understanding of this form before signing it.

Towards the end of the study, a small proportion of patients (10%) were recruited by letter rather than personal contact, in order to reduce the lag time between the initial contact and the final data collection, which might otherwise be several months. These individuals were contacted in advance of a regular clinic visit, and provided with copies of the study measures as well as a consent form, which they returned by mail. Patients were then contacted by phone to invite participation, and clarify questions and reiterate the requirements and time schedule of the protocol.

Following recruitment, the protocol involved the collection of information regarding the subject's stressful events, moods, total food intake, and activities during three separate days. These data were obtained in a telephone interview two weeks prior to the subject's next clinic visit. For the majority of subjects, this occurred two to four months following the initial contact. Each subject was contacted three times and administered a telephone interview that included: the Hassles Scale, the Profile of Mood States, and a Diet and Activity structured interview (see below).

At the clinic visit following the collection of interview data, a blood sample was obtained for the glucose assays. Samples were processed by the University Hospital laboratory for the HbA1 assay, as is customary for clinic patients, and a serum sample was then frozen, and transported for processing to Roche Biomedical Laboratories, Incorporated, in Birmingham, Alabama.

Measures

Demographic and medical information was recorded from both the medical record and the initial screening interview. This included: age, sex, marital status, ethnic group, current diagnoses, medications, glucose levels, years with physician, years diagnosed, height and weight. When possible, data recorded from the record was verified by inquiry of the patient. Patients also provided information on education, occupation, income, and years retired.

Stress was measured using the revised Hassles Scale (Delongis et al., 1988). This instrument lists 53 potentially stressful areas of everyday life (e.g., social commitments, transportation difficulties). Subjects were asked to rate "how much of a hassle" each item was on that day, on a 4-point scale ranging from none (0) to a great deal (3). This revision of the original Hassles and Uplifts Scale (Kanner et al., 1981) omits item references to psychological or somatic symptoms, thus addressing previous criticisms of daily minor stress measurement (Dohrenwend, Dudsen, & Shrout, 1985). To be consistent with this approach, three other items pertaining to health, eating, and medications were inquired but were not scored, because of potential relationships with the dependent measure of glucose control. Items that do not pertain to late life were eliminated in the interest of parsimony (e.g., contraception), leaving 44 items. Assessments were obtained over 24-hour periods, rather than using retrospective reports over longer time frames. Stress was indexed by the sum of the intensity of hassles scores for each of the three assessments. Test-retest reliability and construct validity have been demonstrated for this instrument (Delongis, 1984; Delongis et al., 1988).

Mood states were assessed for each day using a modification of the Profile of Mood States (McNair, Lorr, & Droppleman, 1971). This inventory presents a list of mood descriptors, each of which is rated on a 5-point scale, not at all (0) to extremely (4). Separate scores

are derived for subscales in the inventory by summing relevant items. Three sub-scales ("vigor/activity", "fatigue/inertia", and "confusion/bewilderment") were eliminated from the inventory, as they do not represent variables of interest in the mood domain. Furthermore, the "vigor/activity" and "fatigue/inertia" sub-scales may overlap or be confounded with the assessment of the day's activities. The instructions were also altered, directing the subject to assess his/her moods for the entire day, rather than how she or he was feeling currently. The modified POMS consisted of 42 items, providing a briefer assessment than the original 65 item scale. These alterations were not expected to influence the quality of information obtained and are similar to modifications that have been previously employed (Steptoe & Bolton, 1988). The remaining scales were: "tension/anxiety" (8 items), "depression/dejection" (15), and "anger/hostility" (12), as well as seven unscored items.

Diet and Activity information was obtained simultaneously during the three assessments, using the "stream of activity" technique suggested by Barinowski (1988). In this method, the day is divided into time segments (e.g. pre-breakfast, mid-morning, lunch) and activities are reported sequentially within each segment. Prompts were provided in order to elicit more specific information. For example, in response to the request, "Tell me everything you did between lunch and dinner," a subject may respond, "I did housework." The interviewer would then proceed to determine the nature of the housecleaning activities and any additional work involved, such as lifting or climbing stairs. A list of standard prompts was kept to guide interviewer questions. Data supporting the validity of this technique is provided by Barinowski (1988).

Data for activity consisted of lists of activities reported by subjects for the interview day. Values for energy expenditure for each activity were provided by standard tables (Heywood, 1984). The total

energy cost of each reported activity was determined by multiplying the standard energy cost listed in the table (expressed in Kcal/min/kg), by the subject's weight (kg) and the activity duration (min). This value was then summed for all activities reported for the 12 most active hours of that subject's day.

Because mealtimes served as time cues in the activity assessment, diet and activity recall was assessed simultaneously. Diet information was similar to the 24-hour-recall, which is a standard nutritional assessment method with acceptable validity (Block, 1982) that has been successfully used with older adults (Madden, Goodman, & Guthrie, 1976). Computer software (the Food Processor II, ESHA Research, Salem, OR) was used to calculate caloric intake from dietary data. For each of the three assessments, a calorie intake/output index was obtained by an additive combination of kilocalories obtained from diet and activity information. Energy balance was represented in the model by the three intake/output indexes, reflecting separate occasions.

Glycemic control was measured with HbA1 and fructosamine, two assays that test for blood glucose concentrations. The HbA1 assay is a widely accepted, reliable measure of glycosylated hemoglobin that provides an index of average glucose levels over the preceding two months (Bunn, 1981). The University Hospital Laboratory uses an affinity chromatography method of isolating the hemoglobin, provided by Isolab, Incorporated (Akron, OH). This method is reported to have acceptable precision and reproducibility (Abraham et al., 1983) and correlates well with other established methods of determining HbA1 (Abraham, Perry, & Stallings, 1983; Willey, Rosenthal, & Caldwell, 1984). The coefficient of variation reported in the manual is less than 3% (Isolab, Inc., 1986).

The fructosamine assay is a newer measure of glycosylated protein, distinguished from HbA1 and its fractions (e.g., HbA1c) by its shorter half-life (Service, O'Brien, & Rizza, 1987). Thus, this assay

provides an index of average blood glucose level over a time period of one to two weeks, making it more sensitive to short-term glycemic changes (Baker, Johnson, & Scott, 1984). Fructosamine correlates moderately with fasting plasma glucose (r = .76) (Baker, O'Connor, Metcalf, Lawson, & Johnson, 1983) and with HBA1c (r = .70 to .80) (Baker, O'Connor, Metcalf, Lawson, & Johnson, 1983; Smart et al., 1988). Reliability of the procedure is good; Baker et al. (1983) report a variation of only 2.8% in their daily study of patients over one to three weeks.

The laboratory procedure for this assay is available commercially. Roche Diagnostic Supplies (Montclair, NJ) supplied the materials needed for the assays by donating 100 RoTag test kits. RoTag is a kit comprised of a chemical reagent and calibrator used for colorimetric tests of the amount of glycated proteins in human serum. As noted above, blood was drawn by clinic staff as part of the routine clinic procedure. Frozen serum samples were transported by research staff in a cooler to the Roche Biomedical Laboratories in Birmingham, Alabama within 48 hours of specimen collection. As indicated in the test kit manual provided by Roche (1988), storage of samples is acceptable within guidelines for temperature range and time limits up to thirty days.

Data Analysis

The proposed conceptual model was tested using confirmatory path analytic techniques (LISREL). Some authors caution against using this technique with sample sizes less than 100 (e.g., Boomsa, 1985), largely because of the increased probability of non-convergence and improper (e.g., "Heywood") solutions. However, smaller sample sizes may be acceptable if a proper ratio is maintained between sample size and free parameters (Bentler & Chou, 1987). This ratio is typically recommended to be between five and ten subjects for each of the free parameters (Bentler & Chou, 1987; Francis, 1988). The models tested in this study

were well within this range, with 14 to 24 subjects for each free parameter. Following recommendations for model testing (Bentler & Chou, 1987; Long, 1976), nested model comparisons were made and tested using the difference in Chi-square (Bentler & Chou, 1987; Hayduk, 1987; Long, 1976). To assure that simpler models did not function better to explain the data, the proposed model (Model 3) was compared to two more parsimonious models (Model 1 and Model 2) each representing the fixing of a single parameter. Other estimators were used in addition to Chi-square because the latter test statistic may have insufficient power when sample size is low (Boomsa, 1985) and is not robust to deviations from multivariate normality (Bentler & Chou, 1987; Boomsa, 1985; Saris & Stronkhurst, 1984). In addition to model estimates, tests of the individual beta weights were conducted to see if individual paths in the model were significant.

RESULTS

Descriptive Data

In several cases, the required protocol of three interviews could not be completed in the time interval between the first telephone interview and the scheduled clinic appointment. In these cases (n = 9), mean values were inserted for the key variables, based upon responses provided in Interviews 1 and 2. To determine whether these cases may differ from the rest of the sample in any other respect, the means for all health, demographic, and research variables were subjected to t-test comparisons. One significant finding indicated that the pre-retirement income for the missing group was slightly less than that of the full sample (t = -2.02, p < .05). Because none of the other variables exhibited differences and no theoretical rationale could be found for this isolated effect, this finding was attributed to Type I error, made more likely by the use of 20 t-tests.

The mean Hassles score decreased at each time period (M = 4.3, SD = 4.1 at Time 1, M = 3.3, SD = 3.9 at Time 2, M = 3.0, SD = 4.6 at Time 3). The least frequent item was "your drinking" (n = 0), followed by: "home entertainment" (n = 1), "your smoking" (n = 2), "intimacy" (n = 2), and "sex" (n = 2). Further frequency analyses of the individual scale items is presented in Table 2.

For the Profile of Mood States, separate means were derived for the subscales representing depression, anxiety and anger. Means for these subscales were: 3.44 (SD = 5.45), 5.73 (SD = 5.33), 3.46 (SD = 3.45), respectively.

A frequency analysis of the mood subscales indicated that subjects described themselves as "sad" in 21% of the protocols, which was the most frequent category. Less than 3% of the protocols

indicated feeling "miserable" or "desperate." The most frequent endorsement in the anxiety subscale was the descriptor "not relaxed," which was endorsed in 75% of the protocols. The next frequent anxiety category was "tense," which was endorsed by 21% of the protocols. Only 3% of the protocols indicated "panicky" feelings. For the anger sub-scale, the most frequent endorsement was feeling "bitter," indicated by 24%, followed by "annoyed" with 15% of the subject protocols. Feeling "rebellious" or "spiteful" was indicated in less than 3% of the protocols.

Table 2

Most Frequent Hassles Items

Item	Proportion endorsed[a]	M rating[a]	SD
1. "health of family"	0.23	1.42	2.20
2. "the weather"	0.19	0.81	1.57
3. "your physical abilities"	0.17	0.72	1.28
4. "news events"	0.16	0.66	0.88
5. "your children/grandchildren"	0.13	0.52	1.18

[a] Based on the 216 protocols in the three assessments.

Descriptive data on energy expenditure is shown in Table 3. Because many published tables showing typical levels of energy expenditure are categorized by gender, the data are presented separately for males and females to allow comparisons to normal data. For example, Durnin and Passmore (1967) reported minimum energy expenditures of 1750 Kcal/day for men and 1490 Kcal/day for women among community living, retired older adults, with mean levels of 2330 Kcal/day and 1990 Kcal/day for each gender, respectively. Comparing the present data for the three interviews combined, to these figures, 56% of the male subjects fall below the minimum daily energy expenditure reported in this previous study, with 88% below the mean. For female subjects, 33% of the sample fall below the minimum Kcal/day reported by Durnin and Passmore (1967), with 87% below the mean.

Table 3

Activity and Diet Data by Gender

Kcal/day	Mdn	SD	Range
	Males[a]		
Interview 1			
Expended	1703	442	946-3065
Consumed	1332	451	486-2296
Interview 2			
Expended	1660	655	1131-4593
Consumed	1480	397	697-2161
Interview 3			
Expended	1702	492	1278-3532
Consumed	1384	430	716-2622
	Females[b]		
Interview 1			
Expended	1646	439	807-2895
Consumed	1266	344	953-2650
Interview 2			
Expended	1633	344	953-2650
Consumed	1241	377	680-2405
Interview 3			
Expended	1650	364	717-2623
Consumed	1213	386	704-2381

[a] Mean Body Mass Index (kg/m^2) = 28.2, SD = 4.0.

[b] Mean Body Mass Index = 30.7, SD = 4.9.

The mean value of the fructosamine measure was 3.34 mmol/l (SD .75, range 2.1-6.1). This reflects a generally elevated level of average blood glucose concentration over the previous two weeks, compared to a normal reference range of 1.5-2.7 mmol/l (Roche, 1988).

Measure Reliabilities

To determine reliability for the fructosamine test, ten of the serum samples were divided and submitted in separate batches. Tests indicated a high degree of accuracy in the laboratory procedure (r = .92, $p < .001$). In addition, the fructosamine test was repeated for four patients, whose blood samples were collected twice because scheduling changes prevented the collection of interview data prior to the initial assay. Although this constitutes a very small sample, a correlation coefficient was calculated as an estimate of test-retest reliability (r = .88) over a mean interval of 2.8 months. For the HbA1 measure, which is routinely obtained from patients, pre-study values

were available for comparison to the value obtained at the clinic visit following the interviews. This correlation was also quite high, (r = .73, p < .001), reflecting the relative stability of this measure over time periods of several months. The mean value of the difference between prestudy HbA1 and the HbA1 used for the dependent measure was 7.7 mm/l (SD = 5.6), over a time period ranging from 2 to 37 months.

For the Hassles Scale, test-retest correlations were moderate for the three measurement points. Values were consistent, however, for the correlation between the first and second interviews (r = .67), the correlation between the second and third interviews (r = .67), and the correlation between the first and third interviews (r = .54). Internal consistency was moderately high for the Hassles Scale (Cronbach's alpha = .65 at Time 1, .72 at Time 2, .79 at Time 3). Test-retest reliability for the Profile of Mood States was variable for the three sub-scales. The Anger scale demonstrated little replication with r < .10 for the three assessments. The Depression scale had moderate reliability (Time 1 and Time 2: r = .58, Time 2 and Time 3: r = .42, Time 1 and Time 3: r = .43). For the Anxiety scale, test-retest correlations were also moderate (Time 1 and Time 2: r = .65, Time 2 and Time 3: r = .69, Time 1 and Time 3: r = .55.) Internal consistency varied considerably for the Anger scale (Cronbach's alpha = .40 at Time 1, .63 at Time 2, .97 at Time 3, for the 13 items). For the Depression scale and the Anxiety scale internal consistency was fairly good (Cronbach's alpha for Depression: .75 at Time 1, .74 at Time 2, .78 at Time 3, for the 15 items; Cronbach's alpha for Anxiety: .51 at Time 1, .78 at Time 2, .76 at Time 3, for the 9 items.)

Preliminary Analyses

A matrix of the zero-order Pearson correlations of the primary demographic and proposed model variables is presented in Table 4. Examination of the distributions of the variables in the proposed model indicated considerable deviations from normality. With the exception

of the energy balance variable at Time 1 (skew = -.32), all observed variables showed a positive skew, ranging from 0.44 to 3.8. The stress and mood variables showed the most marked skew (Hassles mean skew = 2.2, Mood mean skew = 2.8). The departure from normality found in these data may increase the probability that the model would be rejected, particularly with the small sample size in this study (Boomsa, 1985; Saris & Stronkhurst, 1984). The use of normal transformations of the data has been endorsed by several authors (Bentler & Chou, 1987; Herting & Costner, 1985, Long, 1976), as structural equation analyses are based on an assumption of multivariate normality. These observed variables were therefore subjected to logarithmic transformation, and the corrected variables (mean absolute skew = 0.32) were utilized in all further analyses. However, despite general acceptance of this approach, the full implications of this strategy on covariance structures is not yet fully understood (cf. Hayduk, 1987).

The first stage in the analysis of the model was examination of the observed variables that contribute to latent factors. First, a correlation matrix was constructed, using the three hassles variables, the nine mood variables, the three energy balance variables, and the two glucose control variables. A confirmatory factor analysis was then conducted to test the usefulness of these variables as indicators of a latent variable model representing stress, mood, energy balance, and glucose control. Following suggestions made by Hayduk (1987), measurement errors for each indicator were fixed using estimates of the reliability of the variables to specify error variance. This procedure takes advantage of the flexibility of the confirmatory factor analysis model, allowing partitioning of selected matrices in order to more precisely specify the sources of variance.

Table 4

Matrix of Pearson Correlations Among the Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	1.00													
2. Sex	.02	1.00												
3. Ethnic	-.01	-.19	1.00											
4. Years diagnosed	-.05	-.03	-.07	1.00										
5. Body mass index	-.11	.26	-.14	-.09	1.00									
6. Total Hassles score	-.19	.29*	.24	.02	.08	1.00								
7. Total Mood score	-.26	.14	.19	.05	.15	.49**	1.00							
8. Depression score	.16	.23	.21	.05	.24	.62**	.79**	1.00						
9. Anxiety score	-.14	.17	.23	-.01	-.08	.54**	.56**	.52**	1.00					
10. Anger score	-.21	.10	.20	.09	.20	.34*	.77**	.47**	.51**	1.00				
11. Energy balance	-.04	.05	-.17	-.07	.59**	.00	.02	.11	-.03	.00	1.00			
12. Fructosamine	.12	.06	-.19	.29*	-.05	.03	-.11	-.05	-.02	-.20	-.15	1.00		
13. HbA1	.07	.18	-.24	.19	.10	.02	.01	.07	-.01	-.14	.00	.71**	1.00	
14. Medication type	-.13	.13	-.06	.10	.12	.11	.27	.21	.07	.07	-.04	-.24	-.05	1.00

Note. HbA1 = post-study glycossylated hemoglobin A1. *$p < .05$. **$p < .01$.

The confirmatory factor analysis test of the measurement model was conducted separately using the scores for the depression, anxiety, and anger portions of the mood inventory to represent the three mood variables.[1] These analyses indicated a very poor fit for the proposed measurement model, with highly significant Chi-square values obtained. Chi-square was highly significant for the measurement model representing each mood sub-type (e.g., for the analysis using anger as the mood variable, Chi-Square, 49 $\underline{df}$ = 6152.7, $\underline{p}$ < .0001). This outcome indicates that a multiple indicator latent variable model was not successful in representing the concepts of interest.

Because the measurement model did not produce a good representation of the proposed latent variables, some modification was necessary in order to proceed with testing the conceptual model. Each of the proposed indicators for the latent variables was a repeated measurement of a single scale. The advantage of the multiple indicator approach is that a latent variable can be measured in several different ways, with expected convergence on the latent variable. This provides support for the proposition that the latent concept has been represented in the measured variables. When the proposed indicators do not converge, the researcher is faced with a difficult decision. One possiblity is to discard any measures that appear to be outliers and retain the indicators that appear to converge on the proposed concept. However, this cannot be done if there is no clear relationship between some of the proposed indicators. One recommendation in this case is to employ the indicator that shows the strongest relationship with the proposed model (Hayduk, 1987). However, for some latent predictor variables in this study each of the indicators was a repeated measure

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[1]An analysis using the three mood variables combined into a single measure of negative mood was conducted, but this procedure weakened the relationships in the model, particularly with the dependent variable (T= -.44; see below for explanation of this statistic). Examination of the table of correlations shows discrepancies between the mood variables in their respective relationships with other variables in the model.

at a particular time point. Thus, if Time 1 Hassles score was chosen as the indicator for the latent variable stress (with Time 2 & 3 Hassles discarded), an awkward conceptual problem would be encountered if the indicator for Mood was selected from the Time 2 or 3 measure. That is, rather than drawing upon observations made simultaneously, a problematic time confound would be introduced to the data.

There appeared to be two choices for the planned analyses. All latent variables could be represented by indicators from all three time points. Alternatively, it would be possible to eliminate the variance introduced by the multiple timepoints and arbitrarily use only the indicators from any single time point. In the absence of convincing arguments for either, both of these analysis strategies were pursued. While either procedure precludes the possibility of using the two-stage strategy of establishing a measurement model prior to the test of structural relations, (Herting & Costner, 1985), the comparison of structural relations using nested models is considered by many authors to be a sufficient model test (reviewed in Hayduk, 1987).

Test 1 of the Proposed Models

In order to build a model representative of the three time points for predictor variable, summary scores were calculated using the mean scores for the three measurements of each variable: hassles, the three mood dimensions, and energy balance. Because the indicator variables representing glucose control represented two separate tests taken from a single time point, this procedure was waived for these variables. Thus, the dependent variable remained a true "latent" variable, with values from both the fructosamine and the glycated hemoglobin tests.

Tests of the relationships between variables were then conducted by comparing the three proposed nested models, using structural equation modeling. Each of the proposed conceptual models was tested separately using the three mood variables. A summary of these analyses

for the models representing tests of the direct, partially mediated, and fully mediated effects is shown in Table 5

Table 5.

Chi-squares Obtained for Structural Equation Model Tests Including Each Mood Variable Separately

Model	Df	Depression	Anxiety	Anger
1 Direct effects	8	43.24	29.51	14.63
2 Partial mediation	7	16.44	9.50*	5.95*
3 Full mediation	6	15.94	9.50*	5.88*

* Chi-square is non-significant, $p > .05$

These data indicate that using depression scores as the mood variable does not produce a significant fit to the data. In Model 2, when anxiety is employed as the mood variable, a good overall fit is obtained, and using the difference in Chi-square test, it is a significant improvement over the first anxiety model (Chi-square difference, 1 df = 20.01). The addition of a second mediating path (Model 3) does not improve the fit. In Model 2, using anger as the mood variable, a good fit is also obtained, and it is a significant improvement over Model 1 (Chi-square difference, 1 df = 8.68). Again, the addition of a second mediating path (Model 3) does not improve the fit.

By dividing the coefficient estimates by their standard errors, tests of the significance of individual paths can be conducted, as suggested by Hayduk (1987).[2] The two significant models are depicted in Figures 4 and 5, with standardized coefficients indicating the significance of paths in the model. In both the anxiety and the anger models, only the path between stress and mood is significant. This indicates that, although the mood-mediated model appears to fit the data well overall, the pathway between stress and mood (employing

[2]The resulting statistic, known as T, is interpreted like a standard score, so that +/- 1.96 yields the 95% confidence interval.

anxiety or anger) is the only one in the model that shows a relationship that is stronger than chance.

Test 2 of the Proposed Models

The three proposed models were then tested using only the data obtained at Time 1 for the stress, mood and energy balance variables. Tests of the relationships between variables were again conducted by comparing the three proposed nested models, using structural equation modeling. As with the previous analyses, each of the proposed conceptual models was tested separately using the three mood variables. A summary of these analyses is shown in Table 6.

Table 6

Chi-squares Obtained for Structural Equation Model Tests Including Only Time 1 Data with Each Mood Variable Tested Separately

Model	Df	Depression	Anxiety	Anger
1 Direct effects	8	22.15	15.62	14.95*
2 Partial mediation	7	8.07*	6.52*	6.43*
3 Full mediation	6	6.97*	4.90*	4.74*

* Chi-square is non-significant, $p > .05$

Using the difference in Chi-square test, Model 2 provides an better fit to the data than Model 1 for the analysis employing the mood variable depression (Chi-square difference, 1 df = 14.08, $p > .05$), anxiety (Chi-square difference, 1 df = 9.1, $p > .05$), and anger (Chi-square difference, 1 df = 8.52, $p > .05$). Model 3 does not provide an improvement in fit in any of these analyses. Tests of the individual paths were then conducted for each of the Model 2 analyses. As with the previous analyses, none of the pathways in the model were significant, except for the one between stress and mood. Thus, the two analysis strategies appeared to be equivalent. Both approaches indicate that Model 2 fits the data the best, but neither analysis approach produces data supporting predictive relationships within the model. Further exploration of Model 2 was pursued to investigate the

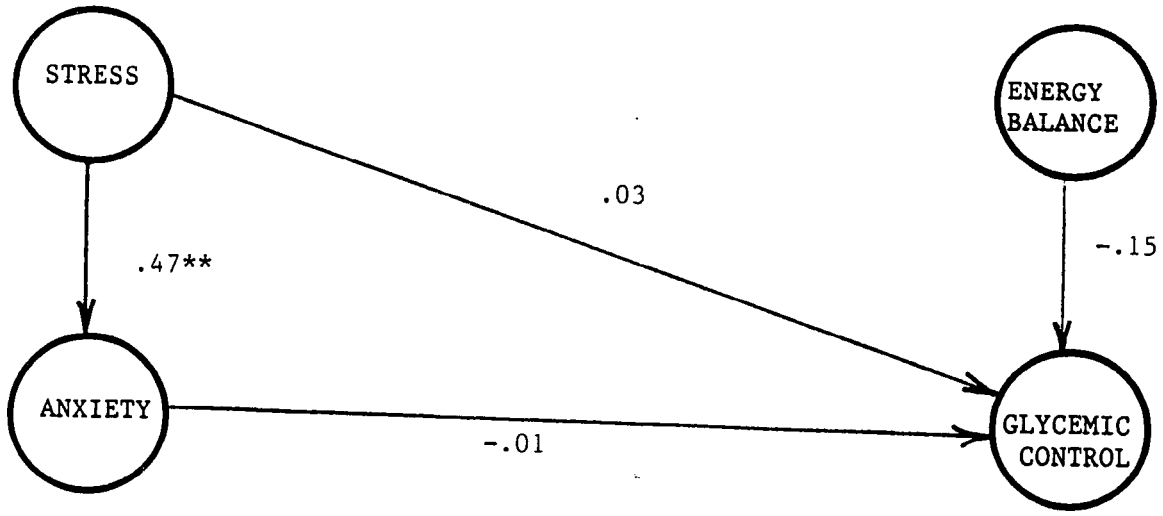

Figure 4. Anxiety Model with Mood Mediation.

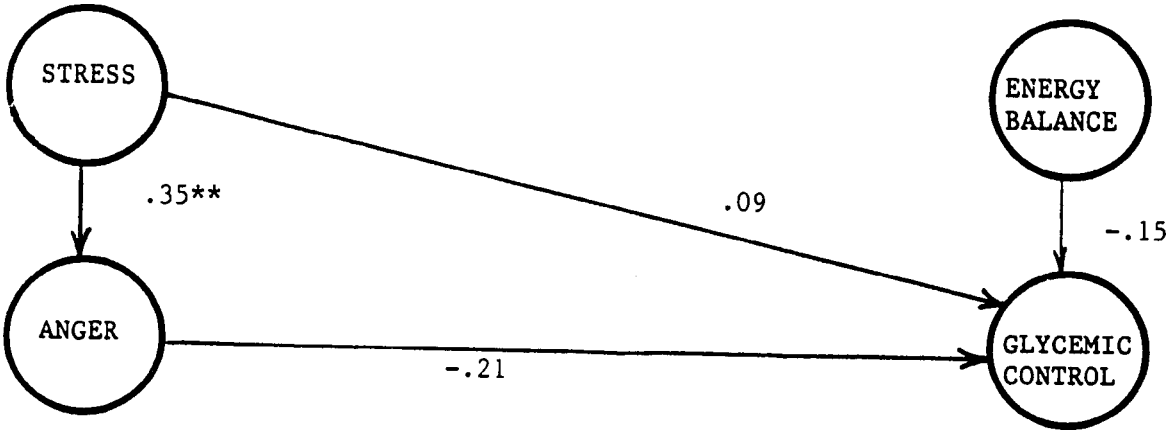

Figure 5. Anger Model with Mood Mediation.

possiblity of improving these predictive relationships. These follow-up analyses were conducted using the results from the first test of the model. This strategy was chosen because it most closely approximates the original study design, which included information from three time points. However, it should be acknowledged that a problem in the validity of these measures is indicated by the poor measurement model obtained (as discussed above.)

Follow-up Analyses

Because the Chi-square test is sensitive to sample size, one other test of model fit was also employed. The Goodness of Fit Index is a summary index of model fit, but it is not a statistical parameter and thus is not subject to considerations such as sample size and assumptions of normality (Herting & Costner, 1985). This index ranges from zero to one, with values close to one indicating a good model fit. For the two models found to produce significant Chi-squares, the Goodness of Fit Index (GFI) also indicated a good fit: for Model 2, with partial mediation and anxiety as the mood variable, GFI = .949; for Model 2, with partial mediation and anger as the mood variable, GFI = .969. Thus, the GFI findings provide support to the Chi-square tests of the model, suggesting that the relatively smaller sample size did not unduly influence the Chi-square results.

Analyses were also conducted to investigate further the relationships of the variables within the model. To address the question of whether variables outside the model may influence within-model relationships, a series of multiple regression equations were conducted with demographic and medical variables entered as a block to predict stress (average Hassles score) or glycemic control (fructosamine and glycated hemoglobin). These analyses revealed that the variable "physician" had a strong unique predictive relationship with glycemic control. Other variables such as "medication-type", "body mass" index, and "years diagnosed" were not unique predictors of

glycemic control. Sex and ethnic status were strong unique predictors of stress, and ethnic status was also uniquely correlated with "physician". These observed relationships were then used to test a revised model (see below) using structural equation analyses.

With regard to the energy balance variable, some question remains whether the use of this summary measure may obscure relationships of its components, diet and activity, with other model variables. To address this point, a multiple regression analysis was conducted entering separately variables representing total calories consumed, total calories expended, and energy balance. None of these variables had unique relationships with fructosamine. Examination of the Pearson correlation matrix of these three variables with fructosamine reveals the strongest relationship to be with calories expended (r = -.22, p = n.s.).

Using the results of these post hoc analyses to maximize predictive power, structural equation analyses were again conducted to see if Model 2 may be improved. In this model "Calories expended" replaced "Energy balance," and a specified relationship was introduced with the Body Mass Index.[3] Other modifications were also made to increase the power of the model. Because the Anger score had shown the strongest relationship with glycemic control in the previous analyses, this mood-type was tested first. Glycemic control was represented only by fructosamine, the indicator that appeared most related to other model variables. Two criteria for improvement were employed. The difference in Chi-square test was used to determine whether the post hoc model provides a better fit to the data. Secondly, the path

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[3] Because the calculation of Calories expended was based upon the weight of the subject, a relationship of specific magnitude could be entered into the model. This partitioning of known sources of variance increases the likelihood of detecting relationships with other variables.

coefficients were examined to determine if post hoc changes improve the strength of the original proposed relationships.

For the post hoc test of Model 2 an acceptable fit of the data is indicated (Chi-square = 10.48, df = 14, p > .05). Comparing this to the original Model 2, Chi-square difference = 4.53 (df = 7, p > .05), indicating that the new model provides a better overall fit to the data. However, as shown in Figure 6, the addition of post hoc relationships does not change the magnitude of the paths in the model. Therefore, these modifications do not provide support for the existence of the proposed model relationships.

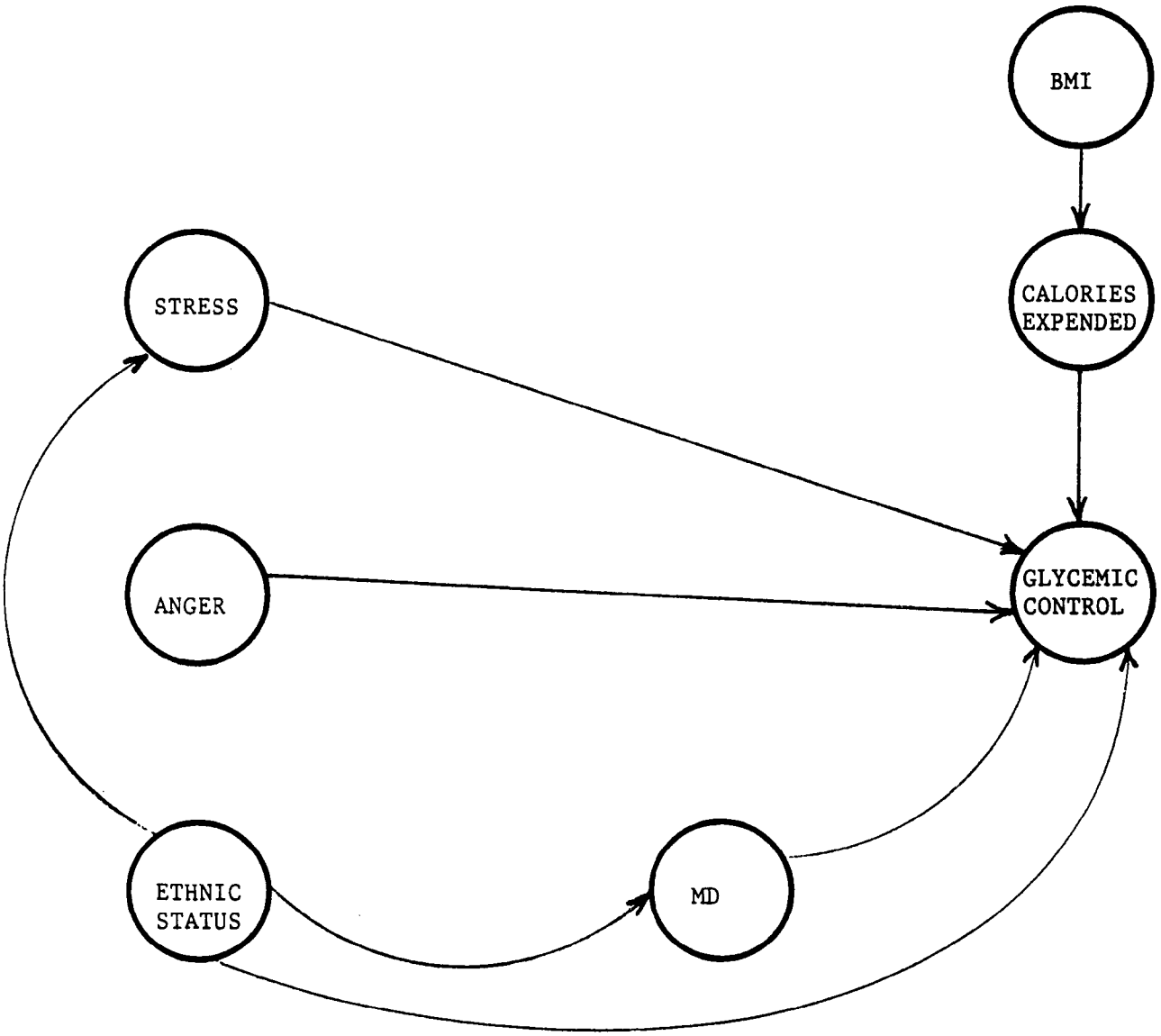

Figure 6. Model with Post-Hoc Revisions.

DISCUSSION

This study investigated the relationship between subjective minor stress and glycemic control in older Type II diabetics. This relationship was evaluated by comparing three nested causal models that included effects of mood and energy balance changes, with pathways corresponding to direct, mood-mediated, and fully mediated effects of stress.

This study did not find support for relationships of subjective minor stress and mood with health outcomes in this patient population. Neither health behaviors (eating and activity patterns contributing to energy balance) nor glycemic control measured by the fructosamine and glycated hemoglobin assays were related to stress ratings. No relationship with glycemic control was found in the pathways from energy balance or any of the three mood variables considered herein (depression, anxiety, and anger).

A positive relationship was found between subjective minor stress and mood, indicating that negative moods tended to be reported on days that stress also occurred. However, the lack of a relationship of either of these variables with other variables in the model makes interpretation of this relationship difficult. The hypothesized pathway proposes a causal sequence emanating from stress; however, this study does not support a unidirectional interpretation in favor of either stress or mood, particularly as the two variables were measured at a single time point. In addition, the possibility of a measurement bias should be considered, as both concepts were operationalized as summaries of self-ratings. Discriminant validity is also a viable issue, as both stress and negative mood may be conceptualized as

aspects of a more general "distress" variable (cf. Dohrenwend et al., 1984).

Several other limitations of this study should be noted. First, the sample size was relatively small for the application of structural modeling techniques. While several authors have suggested the acceptability of smaller sample sizes (e.g., Bentler & Chou, 1987), the increased power provided by a larger sample may be necessary to detect the relatively small effects that may have occurred in the hypothesized models.

The failure of energy balance to predict metabolic control raises several issues. First, the concept of combining caloric intake and output into a single variable is based on the clinical goal of weight-loss in this patient population. Patients are advised by their physicians to increase activity and restrict their diet. This study shows no relationship to glycemic control in a population reporting a consistently negative balance of caloric intake. One explanation for this may be that the majority of subjects were taking medications to control glycemic fluctuations, thus weakening any potential relationship with caloric intake. The dependence on self-report as a data source in this study is also an important consideration, as the subjects are well aware of clinical warnings against overeating. Consequently, they may have underreported their intake. The use of time-cues in addition to the standard 24-hour recall should have contributed to more accurate self-report (Barinowski, 1988), but the validity of dietary assessment methods remains elusive (Block, 1982).

The results for the caloric variables indicate that relationships of eating and activity behaviors with glycemic control may be complex, so that use of a single energy balance variable is not supported. Other aspects of eating and activity behaviors were not measured in this study, and should be considered in planning future research (see Willett & Stampfer, 1986 for a review of factors contributing to energy

intake). In addition to caloric content, patterns of eating, types of calories consumed, and knowledge of dietary guidelines, all are potential variables of interest.

The method of activity measurement utilized in this study is limited by the use of self-report, reliance on subjective estimates of intensity and duration, and the use of tables of standard energy cost that are based on younger adult research. Calculations of energy cost in this method is also largely dependent upon weight, and may be of questionable validity when applied to a sample that is relatively overweight. Accurate measurement of activity in younger adults has long been a target of epidemiological research (e.g., Caspersen, Powell, & Christenson, 1985), while guidelines for assessing this variable in the elderly population are sorely needed (see recommendations in Abdellah & Moore, 1988).

Further study of activity is also needed to establish whether level and types of activity are relevant to clinical outcome in diabetes. Examination of descriptive data for the caloric variables indicates that caloric expenditure in this study was below established norms, raising the question of whether the sedentary nature of this sample was below an as yet unestablished criterion of activity level for this patient group. The investigation of this variable and its relationship to life stress is important, as a paradoxical effect may be possible, in that more stress may actually be activating for certain groups in the population. The study of patients with a wider range of activity and daily stress events would allow examination of potential relationships between these variables. In addition, the study of multiple levels of activity of varying intensity and duration should be extended to include other patient groups in the older population in order to more fully understand relationships to health and disease (Abdellah & Moore, 1988).

In this study, subjects were studied in a period between physician visits, so that changes in medication prescription was not a consideration. However, it is possible that subjects made changes in their medication regimens without consultation with their physician. Unfortunately, subjects were consistently averse to providing reports of non-adherance to medication regimens. Closer monitoring of prescribed regimens, through family and medical staff reports, may provide more accurate assessment of this important variable.

Ideally, future studies should separate subjects who are medication-free from those prescribed insulin or oral agents. The use of medications, especially insulin, may reduce variability in glycemic control to the extent that detection of relationships with other factors is not possible (as noted above). One problem with the study of patient groups who are being treated is that the sub-group of patients whose disorder is most severe will be most likely to receive medications. Therefore, subjects with poorest glycemic control and greater potential variability in glucose levels may display less glycemic variability due to the effects of medications. Longitudinal studies, and studies of newly diagnosed patients may provide valuable information on potential differential effects of stress on the glycemic control of patients treated with behavioral versus medication regimens.

The lack of support for a stress-glycemic control relationship in this study is consistent with the current body of research indicating no effect of naturally occurring stress on metabolic control in Type II diabetes (Glasgow & Toobert, 1988; Wilson et al., 1986). It may be that stress does not have a significant role in glycemic control in this type of diabetes, in contrast to the findings with Type I diabetes (e.g., Aikens, Wallander, Bell, & Cole, 1992; Bradley, 1979; Cox et al., 1984). One explanation for this discrepancy may be the typically wider range and sensitivity of glycemic control in some patients with Type I diabetes, that may allow a greater influence of external factors

on the disorder. However, the possibility of a stress-glycemic control relationship cannot be ruled out by the present study, as other methods of conceptualizing and measuring stress may be more successful in capturing this relationship. The use of spousal ratings (e.g., Stone & Neale, 1984) and employment of scales that are more age-specific (e.g., Aldwin, 1990) may have provided greater validity in stress-measurement in this study, thus increasing the possibility of detecting effects.

In summary, future research would benefit from greater specificity in defining and measuring independent variables. To this end, pilot work establishing a measurement model that accurately represents the predictors of interest would greatly facilitate the use of structural equations in modelling relationships between psychosocial factors and health outcomes. The present study indicates the need to more clearly delineate conceptual and methodological differences in the measurement of daily minor stress and mood. In addition, a more detailed measurement of factors contributing to energy balance is required to establish the role of activity and caloric restriction in any potential relationship of psychological stress and glycemic control. Future studies should also attempt to employ larger samples that are representative of patient subgroups with and without medication regimens. Finally, the use of a prospective approach with multiple time points (e.g., Aikens et al., 1992) for the measurement of both predictor and critierion variables will contribute to both conceptual and measurement validity.

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