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The effects of biofeedback in diabetes and essential hypertension

ABSTRACT

The metabolic syndrome is likely to develop in patients in whom genetic predisposition, chronic stress, negative emotion, and unhealthy lifestyle habits converge. In light of the psychophysiologic aspect of most of these factors, biofeedback, relaxation, and other psychophysiologic interventions have been studied and used in patients with elements of the metabolic syndrome, particularly diabetes and hypertension. This article reviews the rationale and evidence for biofeedback for the treatment of diabetes and hypertension, which has been shown to effectively lower blood glucose and blood pressure in numerous studies. Patients with prehypertension may be a particularly appropriate target population for biofeedback for blood pressure reduction. Further research is needed to guide identification of the best candidates for psychophysiologic intervention for these conditions, although patient readiness for change is a clear prerequisite.

Type 2 diabetes, essential hypertension, obesity, and hyperlipidemia are the major components of the metabolic syndrome. Understanding the psychophysiologic basis of the metabolic syndrome is important since its prevalence has been increasing dramatically over the last decade. In the past, type 2 diabetes was diagnosed almost exclusively in persons in their 40s or older. Health care providers are now reporting emergence of type 2 diabetes and the metabolic syndrome in individuals in their 30s and even their late 20s.[1,2]

This article outlines the psychophysiologic bases for components of the metabolic syndrome and reviews the application of biofeedback and other psychophysiologic interventions on the two components for which such interventions have been most studied—diabetes and essential hypertension.

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ETIOLOGY OF METABOLIC SYNDROME: THE INTERSECTION OF BIOLOGY, LIFESTYLE, STRESS

The disorders that constitute the metabolic syndrome share several etiologic factors. First, genetic predisposition increases the risk for diabetes, hypertension, hyperlipidemia, and obesity.[3,4] Second, patients' own behaviors—their choice of activity or inactivity, their food preferences, and their appetite—lead to gradual loss of control over body weight, blood glucose, blood pressure, and lipid levels. Third, chronic stress and its coincident psychological burden contribute to the etiology of various components of the metabolic syndrome.[5] As life events accumulate and individuals lose their ability to cope, the stress response system maintains a higher than optimal level of activation.[5–8]

Chronic stress affects multiple organ systems, including the two master systems—nervous and endocrine. The biologic effects of stress include disordered breathing, increased activation of the renin-angiotension system, vascular constriction, tachycardia, decreased heart rate variability, inflammation, and sleep disruption.[9] The mechanisms involved in acute stress responses are purpose-driven and adaptive. In contrast, chronically activated stress response systems involving increased sympathetic activity, decreased parasympathetic activity, and release of stress hormones have serious deleterious effects.[10] Psychobiologic systems fail to adapt, delay recovery, or become exhausted.[11]

Role of psychological factors

As summarized in a review by Goldbacher and Matthews,[12] psychological factors have been related to increased risk for the metabolic syndrome. Depression has probably been most studied in the settings of cardiovascular disease and diabetes, whereas the psychological states of anger, hostility, and anxiety have been identified as salient etiologic factors in hypertension. In particular, depressed mood has been linked to decreased heart rate variability during the stress response.[13] Anxiety affects blood pressure and blood glucose in normal individuals as part of the adaptive stress response, and the effects of anxiety are exacerbated in persons with the metabolic syndrome.[14]

Importance of sleep

Sleep disruption is often ignored in discussions of the mind-body interface in hypertension and diabetes. However, Knutson and Van Cauter[15] suggested that sleep quality and sleep length have important effects on leptin levels and risk for diabetes. Very short sleepers have stronger appetites, as a result of lower leptin concentrations, and are much more likely to be obese compared with long sleepers (≥ 10 hours). This indicates that sleep length and quality affect metabolism. With regard to hypertension, a very important reduction of blood pressure occurs during the night, and a lack of nighttime blood pressure "dipping" is one of the markers for sustained blood pressure elevation.[16]

Factors overlap and begin to affect self-care

In addition to the effects of stress on mood and anxiety, repeated necessary demands for adaptation have marked effects on self-care behavior. Patients who suffer from anxiety are less efficient in managing their time and may be distracted from monitoring blood glucose and blood pressure. Anxious people often turn to the use of high-calorie comfort foods to soothe themselves during stressful times. Alcohol may be chosen as a means of reducing worry and tension. Depressed people lack the energy needed to maintain medical regimens and tend to be poor adherents to treatment recommendations. They also may choose comfort foods and addictive substances instead of nutritious, high-quality food and drink.[17]

Both anxiety and depression affect sleep routines and efficiency. Anxious people have trouble getting to sleep and may wake up often during the night, while depressed individuals frequently wake up early and cannot get back to sleep. Additionally, psychological distress influences social behaviors. Overt depressive and anxious symptoms tend not to foster social interactions with family and friends. Lack of social support and a scarcity of personal resources eventually contribute to the risk for diabetes and hypertension.[18,19]

In short, the metabolic syndrome is most likely to emerge when there is a combination of genetic factors, chronic stress, negative emotion, and unhealthy habits. The application of psychophysiologic interventions to diabetes and hypertension is based on our understanding of the etiology of these disorders, particularly the roles of psychological distress and behavior on blood glucose and blood pressure.

BIOFEEDBACK IN TYPE 2 DIABETES

Diabetes is characterized by elevated blood glucose and resistance of cell membranes to insulin, such that glucose is impeded from crossing from the blood into the cells. Standard treatment consists of oral antihyperglycemic agents, exogenous insulin, diet, and exercise.[20] Type 2 diabetes may be the most behaviorally demanding of all chronic illnesses because patients must take an active role in daily management. Typical requirements are to measure blood glucose and take oral medicine, perhaps along with insulin, as well as to exercise, monitor diet, and adjust calories depending on activity level.

Therapy goals and a sampling of evidence

The goal of psychophysiologic therapy is not to replace standard treatment with relaxation training or biofeedback but rather to use biofeedback-assisted relaxation therapy to improve control of blood glucose. For example, McGinnis and colleagues compared the effects of 10 sessions of biofeedback (both surface electromyography and thermal feedback) and relaxation therapy versus three sessions of education in a sample of 30 patients with type 2 diabetes.[21] No medicines were changed unless medically necessary. Patients kept daily logs of blood glucose, and had their hemoglobin A_{1c} measured before and after treatment. Significant between-group differences in hemoglobin A_{1c} and average blood glucose emerged in favor of the biofeedback group.[21] However, patients with high scores on the Beck Depression Inventory[22] (indicating more severe depressive symptoms) tended to drop out of the study or did not do as well as patients who were not symptomatic.

Another application of biofeedback in type 2 diabetes has been demonstrated by Rice and Schindler[23] and Fiero et al.[24] These investigators showed that patients with peripheral neuropathy, a common long-term complication of diabetes, were able to warm their hands and feet with the use of thermal biofeedback. Increased peripheral blood flow mediated the decrease in neuropathic pain.

Possible mechanisms of biofeedback in diabetes

Several explanations can be suggested to account for the results of biofeedback on blood glucose levels. Forehead muscle tension feedback (surface electromyography) helps patients to reduce facial tension and relax skeletal muscles, while increased finger temperature is an indicator of general relaxation. In the patients who completed the above study by McGinnis et al,[21] both depression and anxiety scores decreased, which suggests a psychological mechanism for blood glucose reduction. Patients also reported improved sleep duration and quality with the use of relaxation therapy at bedtime.

BIOFEEDBACK IN ESSENTIAL HYPERTENSION

Biofeedback-assisted relaxation therapy has also been applied to control essential hypertension. The definition of hypertension, according to the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7),[25] is systolic blood pressure greater than 139 mm Hg and diastolic blood pressure greater than 90 mm Hg. Prehypertension refers to systolic blood pressures between 130 and 139 mm Hg and diastolic pressures between 80 and 89 mm Hg. Standard treatment for established hypertension is antihypertensive medications, diet, and exercise. For patients in the prehypertensive blood pressure range, lifestyle changes are the primary intervention, unless the patient has multiple risk factors.[25]

Representative clinical evidence

Linden et al reported on the effects of 10 weeks of individualized psychophysiologic treatment on ambulatory blood pressure in patients with essential hypertension.[26] Patients were initially screened for anxiety, depression, and anger, after which a program was designed for each patient based on his or her psychological risk factors. All patients received some form of relaxation therapy, and some received biofeedback. Over time significant reductions in ambulatory systolic and diastolic blood pressure were observed.[26] In a separate study, Yucha et al provided a multimodal training program to hypertensive individuals and also reported significant decreases in blood pressure.[27]

Elliott et al trained hypertensive patients to use the RESPeRATE™ device to achieve the slow, deep breathing associated with the "relaxation response" sought in relaxation training.[28] After initial training, patients were instructed to practice this device-guided breathing technique at home. Significant reductions in systolic blood pressure were observed over 8 weeks in the patients who used the device compared with controls who simply monitored their blood pressure at home. A maximum mean systolic blood pressure reduction of 15 mm Hg was achieved in the group of patients who practiced device-guided breathing for the greatest number of minutes during the 8-week study. Similar results with device-guided breathing using this device have been reported in two separate studies.[29,30]

More general stress reduction programs have also achieved success when offered to patients with essential hypertension in the clinic or the workplace. Studies of programs focusing on meditation and repeated practicing of centered breathing and relaxation responses, without use of biofeedback, have reported reductions of approximately 10.7 mm Hg in systolic pressure and 6.4 mm Hg in diastolic pressure.[31,32] McCraty and colleagues provided a stress management program to hypertensive individuals at their place of work,[33] based on the premise that individuals' work demands are a source of chronic stress and thus create an ideal setting for the application of new coping skills. In this study, stress reduction training was associated with significant reductions both in blood pressure and in global measures of distress.[33]

Prehypertensive patients: An ideal target population

Although meta-analyses demonstrate that there is support for the efficacy of biofeedback in patients with essential hypertension,[34,35] the field has been handicapped by the reality that most patients with hypertension are already being treated pharmacologically, which means that their blood pressure levels when starting biofeedback treatment are often low,[36] limiting the potential effects of the intervention. The new category of patients with prehypertension may thus be the ideal population for stress management therapies, since their blood pressure is elevated, but not elevated enough to have prompted medication prescriptions in most cases. Lifestyle modifications, which could certainly include stress management, are the recommended first-line therapies for these prehypertensive patients.[25]

Possible mechanisms of biofeedback in hypertension

One can hypothesize on the mechanisms of action of relaxation-based therapies in hypertension. Relaxing the muscles of the face via electromyography biofeedback and increasing finger temperature facilitates whole-body relaxation and decreased sympathetic adrenergic activity. Parasympathetic dominance is facilitated by the use of breathing techniques to increase heart rate variability.[37,38] The improved deep sleep that results from relaxation may also reduce blood pressure by restoration of nighttime blood pressure dipping.[16]

IDENTIFYING THE BEST CANDIDATES IS NOT EASY

Some individuals are excellent candidates for biofeedback, while others do not benefit despite their best efforts.[39,40] The likelihood of response is generally associated with adherence to medical recommendations and willingness and ability to follow instructions for home practice of relaxation. Nevertheless, some patients who attend sessions and practice still do not succeed, perhaps because they have few signs of overarousal in the system, such as a high degree of sympathetic activation, muscle tension, or low heart rate variability. Further, patients must be able to demonstrate that they learned the skill that was trained, such as consistent warming of the hands. If the training was for heart rate variability, the patient should be in the optimal range of heart rate variability and be able to demonstrate high-frequency waves.[34] Patients with specific characteristics, such as stress sensitivity, may benefit more than those whose blood pressure and blood glucose are chronically elevated with few fluctuations.

CONCLUSIONS

The etiology of the metabolic syndrome is complex and multifactorial. Psychophysiologic interventions such as biofeedback and relaxation training are sometimes warranted for multiple aspects of metabolic syndrome, and they target several specific associated disruptions, particularly chronic stress, negative mood, and behavior. Initial patient evaluation should aim to assess the patient's readiness for change, which must be present to a sufficient degree before continuing with biofeedback or relaxation techniques. Use of motivational interviewing techniques is recommended to increase patients' preparedness for change.[41] Understanding patients' characteristic responses to stress will guide decisions on the type of biofeedback and relaxation therapies to use and whether or not psychotherapy will be necessary. Specific modalities of biofeedback or particular types of relaxation do not appear to be as critical as the total package of individualized psychophysiologic therapy.

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