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# Effects of Aerobic Fitness Training on Migraine Headache

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# EFFECTS OF AEROBIC FITNESS TRAINING ON MIGRAINE HEADACHE

by

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This dissertation, submitted by W. Clinton McSherry in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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TABLE OF CONTENTS

LIST OF TABLES

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DEDICATION

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## ABSTRACT

This study investigated the effectiveness of a 12 week aerobic fitness training program at reducing migraine headache symptoms in a sample of formerly sedentary, community-recruited adult chronic migraine sufferers. Seven subjects (5 females, 2 males) monitored their headache symptoms four times daily throughout the five months of the study, which included a one month baseline period, three consecutive months of fitness training, and a one month post-treatment period. During the fitness training phase, subjects' blood pressures and pulse rates were recorded before and after each exercise session, which occurred three times per week. All subjects walked for 30 minutes per exercise session at a rate sufficient to maintain heart rates in their aerobic training range, which was defined as 65 to 80% of their maximum heart rate. Results indicated that the training program was effective at increasing aerobic and cardiovascular fitness. While there was no change in psychological distress (depression, anxiety, anger) as a result of treatment, a significant decrease was observed in headache index from baseline to treatment month 1. Peak headache intensity per week decreased significantly from baseline to treatment months 1, 3, and the posttreatment month. Significant increases were observed for number of headache-free days per week from baseline to treatment months 1 and 2. No changes were observed in medication usage. These results suggest that an aerobic fitness training program may be an effective treatment for certain aspects of migraine

symptomatology for some individuals who suffer from chronic migraine.

EFFECTS OF AEROBIC FITNESS TRAINING ON MIGRAINE HEADACHE

Migraine headache is a temporarily disabling disorder common in virtually all human societies. Migraine prevalence estimates have been obtained from epidemiological studies (Leviton, 1978; Stewart, Lipton, Celentano, & Reed, 1992; Waters, 1971; Waters & O'Connor, 1975), surveys of specific populations (Andrasik, Attanasio, & Blanchard, 1983; Andrasik, Holroyd, & Abell, 1979), and other sources (Andrasik & Kabela, 1988; Bakal, 1975).

In a review of headache prevalence studies, Leviton (1978) cited the following data:

1. Between 1 and 8 percent of medical complaints are primarily for headache symptoms.
2. At the Harvard Street Clinic in Boston, 35% of new patients acknowledged that they had a "headache problem."
3. Community estimates of headache as a "common occurrence" run as high as 89% for women and 75% for men.
4. In a national survey of U.S. citizens, 13.7% of men and 27.8% of women reported having headaches "every few days" or having headaches that bothered them "quite a bit."
5. Fifteen and a half percent of women in one study had headaches "severe enough to affect daily activities."
6. Roughly 38% of men working in a photographic processing firm suffered "severe headaches," while 22% of workers had headaches once per month.

7. In a survey of Danish physicians 14% of the men and 22% of the women reported having migraines; when asked if they "suspected" their headaches were migraine, the estimates rose to 21% and 31%, respectively.
8. In a survey of British physicians, 14% of the males and 25% of the females reported having migraines.

These data clearly indicate that headache is a common disorder and that migraine in particular affects a significant portion of society.

In a recent and rigorously conducted epidemiological study of migraine headache in this country, Stewart, Lipton, Celentano, and Reed (1992) concluded that 18 million females and 5.6 million males currently suffer from severe migraine headaches, with approximately half these numbers (8.7 and 2.6 million, respectively) suffering from "moderate to severe disabling headaches" (p. 69). Interestingly, prevalence of migraine was found to correlate negatively with household income, such that prevalence in households earning less than $10,000 was more than 60% higher than in those with more than $30,000 in annual income. Furthermore, gender ratio was found to vary considerably with age, with females experiencing from 2.0 to 3.3 times the prevalence of migraines as males at different stages of life. Gender ratio increases following the age of menarche, peaks near the age of menopause, and subsequently declines. The authors concluded that these data "suggest that hormonal factors play a role in gender differences in migraine prevalence" (p. 68), although they noted that gender ratio persists at 2.5 even after the age of 70 years. With best estimates being that approximately 23.5 million American men and women currently suffer from migraines, this condition clearly deserves persistent efforts to elucidate and develop a variety of effective treatments.

Classification and Diagnosis of Headache

In 1962 the Ad Hoc Committee on Classification of Headache (Friedman et al., 1962), under the auspices of the National Institute of Neurological Disease and Stroke, provided what came to be the most widely used diagnostic criteria for all forms of headache for the next 25 years. By this classification, migraine headache is a form of vascular headache in which a person suffers from recurrent attacks, usually unilateral in onset, usually associated with anorexia, frequently associated with nausea or vomiting, and some of these attacks may be preceded by or associated with neurologic and/or mood disturbances. Of all of the types of migraine headache included in the 1962 description, by far the most frequent are the "Classic" and "Common" migraine.

Classic migraine is diagnosed if prodromal symptoms are present, such as visual or other sensory or motor disturbances. These may include visual scotoma (blind spots, flashing lights), photophobia, numbing or tingling in an arm or leg, hypersensitivity to noise, dizziness or vertigo, disturbances of sense of smell (hyperosmia), hallucinations, and other symptoms. Taken together, these prodromal symptoms are known as the "aura." Prodromal symptoms are generally rapid in onset, are clearly defined, contralateral to the side of pain, and last from 10 to 30 minutes, followed by the onset of a throbbing, unilateral headache. The headache builds in intensity usually for about an hour, but may last several hours. Friedman (1978) reports that approximately 10% of migraine patients experience classic migraine.

Common migraine is diagnosed if no prodromal symptoms are present, or at least they are less sharply defined. Thus, many common migraine attacks occur with little or no warning. Most individuals who suffer from migraine headache experience common migraine. This syndrome includes some characteristics shared with classic migraine, such as local or generalized edema, irritability, dizziness, and sweating. Also, both types of migraine headache are characterized by severe, throbbing pain often accompanied by nausea, vomiting, tremor, and hypersensitivity to noise and light. Common migraine headache may be bilateral, although it is more usually unilateral, and may last longer than the classic type, perhaps as long as several days. As patients with common migraine get older, symptoms tend to become less intense, and associated symptoms such as vomiting may disappear.

Some investigators have argued for a concise definition of migraine headache, which would be based solely on clinical manifestations of the disorder. Such a definition, they claim, would enhance our understanding of the disorder, thus improving research and clinical efforts. One such definition is provided by Blau (1984):

> Episodic headaches lasting 2 to 72 hours with total freedom between attacks. The headaches must be associated with visual or gastrointestinal disturbances, or both. The visual symptoms occur as an aura before, and/or photophobia during, the headache phase. If there are no visual but only alimentary disturbances, then vomiting must feature in some attacks (p. 445).

As Blau points out, one of the advantages of such a definition is the time limited nature it describes. According to this definition, any headache lasting less than two hours is not a migraine, while one lasting longer than 72 hours would be known as status migrainosus (Couch & Diamond, 1983).

The Headache Classification Committee of the International Headache Society (IHS) (1988) recently drafted and approved the most comprehensive diagnostic criteria available, which includes all types of headache syndromes. As these are the most current and extensive diagnostic criteria yet to be compiled, this dissertation will focus on migraine headache as defined by these criteria. The IHS (1988) classification distinguishes migraine headache without aura and with aura. The following are the IHS descriptions of these two disorders, which represent the vast majority of migraine cases:

> **Migraine without aura:** Idiopathic, recurring disorder manifesting with attacks lasting 4-72 hours. Typical characteristics of headache are unilateral location, pulsating quality, moderate or severe intensity, aggravation by routine physical activity, and association with nausea, photo- and phonophobia.
>
> **Migraine with aura:** Idiopathic, recurring disorder manifesting with attacks of neurological symptoms unequivocally localizable to cerebral cortex or brain stem, usually gradually developed over 5-20 minutes and usually lasting less than 60 minutes. Headache, nausea and/or photophobia usually follow neurological aura symptoms directly or after a free interval of less than an hour. The headache usually lasts 4-72 hours, but may be completely absent (IHS, 1988, pp. 19-20).

Pathophysiology of Migraine

Although the etiology of migraine remains unclear, some promising theories exist. The most widely recognized theory hypothesizes that migraines involve some sort of regulatory dysfunction of the cardiovascular system, particularly vasomotor control of extracranial and intracranial blood vessels. Briefly, this theory suggests that for some time before the onset of headache, cranial arteries constrict, then suddenly dilate causing pain to occur around these heavily innervated arteries.

In an important paper published in 1940, Ray and Wolff outlined their conclusions about the nature of the pain sensitive areas of the skull. These findings resulted from multiple observations of intracranial and extracranial stimulation of various sites of 30 brain surgery patients:

1. Of the tissues covering the cranium, all are more or less sensitive to pain, the arteries being especially so.

2. Of the intracranial structures, the great venous sinuses and their venous tributaries from the surface of the brain, parts of the dura at the base of the dural arteries, and the cerebral arteries at the base of the brain are sensitive to pain.

3. The cranium (including the diploic and emissary veins), the parenchyma of the brain, most of the dura, most of the pia mater and arachnoid, the ependymal lining of the ventricles, and the choroid plexuses are not sensitive to pain.

With the exception of those sensations that resulted from stimulation of the parenchyma and nerves, the only sensation that was experienced on stimulation of

> the intracranial structures was pain (Ray & Wolff, 1940, p. 813).

These findings suggest that the arteries just inside and outside of the cranium are among the most pain sensitive structures of the head. This fact relates to the predominant theory of the pathophysiology of migraine, since distention and dilation of these arteries would therefore likely result in significant head pain. As Appenzeller (1978) explained, "These blood vessels are innervated by the trigeminal and glossopharyngeal cranial nerves and the upper sensory roots of the spinal cord. The sensitivity of large blood vessels and their dense sensory innervation contrasts with the insensitivity of small blood vessels of arteriolar size within the brain which are not innervated (p. 467)."

Among the most influential discoveries in the pathophysiology of migraine is the seminal study by Tunis and Wolff (1953), which initiated investigation into vascular components of migraine. They compared psychophysiological recordings of migraine patients with those of nonheadache controls and found that: a) temporal artery pulse wave amplitudes of migraine patients were significantly larger, b) extracranial vascular activity in migraine patients was significantly more variable, and c) that these two characteristics became more conspicuous during a period two to three days prior to onset of a headache. Since these initial findings, many additional studies have examined the cerebrovascular nature of migraine headache, contributing to our understanding of its pathophysiology.

Some support for Tunis and Wolff's (1953) basic hypothesis of cardiovascular concomitants of migraine can be found in recent psychophysiological research, such as that of Drummond (1982). Drummond monitored physiological activity in migraine and nonheadache controls throughout several laboratory stress tasks. He found differences between groups during a mental arithmetic test, a carbon dioxide rebreathing test, and a head-back tilt test. "Thus, psychological factors, a physiological factor and postural change affected the extracranial vasculature of migrainous and non-migrainous subjects differently. However, there was very little support for the hypothesis that the migraine syndrome is part of a more generalized dysfunction of vasomotor control because blood pressure responses were similar in both groups during every test and heart rate responses differed between groups only during the inter-trial periods of the isometric exercise and mental arithmetic tests (p. 327)." Thus, Drummond's findings suggest that any vascular regulatory dysfunction involved in migraine may not be evident in measures such as peripheral blood pressure and heart rate, but may be confined to extracranial measures. In general, however, Drummond's (1982) research supports the notion of differing extracranial vascular responses in migrainous and nonheadache controls between attacks, particularly during periods of psychological stress.

Appenzeller (1978) has summarized much of what is known about the vascular nature of migraine as it relates to a host of associated disorders. Computerized axial tomography (CAT scan) has provided evidence of ischemia as a result of reduced blood flow in the vasoconstriction phase. Analysis of cerebrospinal fluid, together with the CAT scan evidence, supports the notion of cerebral hypoxia (deficiency of oxygen) during the aura phase experienced by many migraineurs. Furthermore, Appenzeller (1978) points to evidence indicating that changes in arterial carbon dioxide content during the aura contribute to a loss of autoregulatory capacity of cerebral vessels. Thus, cerebral hypoxia, which is associated with, and may contribute to, the symptoms of aura, may be prolonged by vascular dysfunction, contributing to the continuation of pain.

The finding that almost all migraine patients have increased blood flow to the brain and scalp during the headache phase may be related to the hypoxia of aura, and this increase may also be accentuated by metabolites released during ischemia (local anemia caused by mechanical obstruction of blood supply). However, the distribution of the hyperperfusion (increased blood flow as a result of vasodilation) does not correspond well with the location of the headache. That is, the headache may be sharply localized while the increased blood flow may be hemispheric. In fact, many patients with unilateral head pain demonstrate increased blood flow to the entire brain. This absence of a definitive relationship between head pain and vasodilation does raise several questions. For example, Dalessio (1978), while agreeing that vasomotor regulatory dysfunction is at least one of the causes of migraine headache, points out that vasodilation itself is not usually painful. For example, physical exertion, excessive heat, and anoxia (absence of oxygen) all produce vasodilation, yet this effect is rarely uncomfortable. This fact highlights the lack of clarity and explanatory precision surrounding the pathophysiology of migraine.

Several researchers have noted the importance of considering humoral regulatory effects on headache (Dalessio, 1978; Friedman, 1978; & Kudrow, 1983). Friedman (1978) listed several possible factors affecting migraine, including pain sensitizing substances which accumulate around the dilated arteries such as serotonin, catecholamines, histamine, tyramine, bradykinin, prostaglandins, adenosine monophosphate, prolactin, and gamma amino butyric acid (GABA-inhibitory transmitter). Friedman also discussed the possibility that platelet aggregation may play some role in migraine symptoms, since it is known that platelet aggregation increases prior to the onset of headache, and decreases during the headache phase. As "serotonin is excreted or metabolized, blood levels fall rapidly, and the vasodilatation of scalp vessels, constriction of skin capillaries, and headache result from withdrawal of its vasotonic influence (Friedman, 1978, p. 483)." Finally, Friedman acknowledges the theoretical incongruence of the catecholamine-serotonin hypothesis with both the rapid onset and unilaterality of migraine headache. Dalessio (1978) believes that the role of vasoactive substances in migraine is important only to that part of the migraine attack characterized by an increase in vascular permeability. He proposes that histamine, serotonin, the plasma kinins, and possibly other substances participate in a sterile inflammatory reaction (an inflammatory reaction not associated with bacterial or viral causes) surrounding the painfully distended blood vessels.

Kudrow (1983) declares that biochemical events should occupy the majority of our research efforts, as he believes that vascular changes are not the primary occurrence in the pathogenesis of migraine. Following a review of the independent roles of several biochemical substances, he summarizes the action of several:

> The current concept regarding pain mechanisms of migraine holds that the site of migraine pain is peripheral. In this scheme, the initial pathways involve some or all of the biochemical changes discussed earlier, causing platelet aggregation and serotonin release, thus inducing cerebral vasoconstriction (the prodromal phase of migraine). The activation of prostaglandin release from the lungs by serotonin, and the subsequent depletion of the latter, causes painful extracranial vasodilatation (the headache phase). Central serotonin depletion may also lead to a reduced pain threshold. Fanchamps (1974) includes a second pathway system that is activated concurrent to platelet release of serotonin. He suggests that mast cells liberate histamine and proteolytic enzymes. The combined effect of histamine and serotonin increases capillary permeability. This facilitates transudation of plasmakinins, formed by the action of proteolytic enzymes on plasmakininogen, into blood vessel walls and perivascular tissue. Thus, painful vasodilatation, a lowered pain threshold, and increased pain sensitivity focally contribute to the migraine pain (p. 47).

As this passage suggests, a clear understanding of the biochemical events associated with migraine is not currently available [*for more serotonin discussion, see Adams, Feuerstein, & Fowler, 1980*]. However, it certainly appears that continued research in this area will provide useful information concerning the etiology of migraine symptoms.

To summarize, there appears to be a strong body of evidence supporting the notion of vascular abnormality in migraine patients, and there also appears to be evidence for vasoactive biochemical effects in migraine. However, much is unknown, or at least unclear, regarding the pathophysiology of migraine. Specifics concerning the relative importance of particular factors and relationships among these factors continue to be shrouded in mystery.

Treatment of Migraine

Treatment for migraine headache has evolved in two separate spheres: pharmacological and psychological, with the recent emphasis in the psychological arena being predominantly behavioral. Pharmacological treatments for migraine are aimed at either preventing attacks (prophylactic treatment), aborting attacks early in their onset, or simply managing the pain. Behavioral treatments for migraine, generally aimed at preventing attacks, include biofeedback, relaxation procedures, autogenic training, and cognitive and stress management techniques.

Prophylactic medications include beta-adrenergic agents such as propranolol, and calcium antagonists (a.k.a. calcium channel blockers). These medications act as chronic vasoconstrictors, thereby preventing the painful distention of intra- and extracranial arteries associated with migraine. Generally, only those patients experiencing at least three migraine headache episodes per month are considered candidates for prophylactic treatment. As with any prophylactic drug therapy, patients must continue drug treatment virtually indefinitely, and these medications have been associated with several bothersome side effects. Ergot compounds such as ergotamine tartrate are the most commonly used abortive agents, and this treatment seems to be most effective in patients with migraine with aura. Timing of drug administration appears to be crucial to their effectiveness, and patients with aura can use their prodromal symptoms as warning signals of an oncoming episode. Behavioral strategies can increase effectiveness of abortive drug therapies by improving patients' adherence to strict administration guidelines (Holroyd et al., 1988). Finally, analgesics (e.g., Tylenol, Advil, aspirin) and some narcotic agents (e.g., codeine, butalbitol, and others) have been prescribed for pain management in migraine. However, analgesics (particularly narcotic analgesics) are often considered inappropriate for recurrent headache sufferers because of the frequency with which they are usually required and the amount often necessary to achieve even minimal pain reduction. In fact, according to some researchers (Adams, Feuerstein, & Fowler, 1980) all pharmacological treatments for migraine are insufficient, since they are directed solely at the management of the disorder.

Of all the behavioral treatments for migraine, skin temperature biofeedback (usually taken from the distal phalanx of the nondominant index finger) and progressive relaxation (e.g., Bernstein & Borkovec, 1973) are the most widely used. In one meta analytic comparison study (Blanchard, Andrasik, Ahles, Teders, & O'Keefe, 1980) of 16 migraine treatment outcome studies using either one of these procedures or a combination of the two, researchers concluded that these behavioral treatments were equally effective and significantly superior to medication placebo. In this meta-analysis, six studies (total N = 234) using drug placebo showed a mean percentage improvement of 16.5%, whereas thermal biofeedback (five studies, N = 41) resulted in 51.8%, relaxation training (six studies, N = 159) achieved 52.7%, and thermal biofeedback combined with autogenic training (seven studies, N = 146) produced a 65.1%

improvement in headache. Although not all 16 behavioral treatment studies provided all measures, these researchers listed the dependent variables, in order of preference, as: headache index, headache frequency, headache intensity, and headache duration.

Of further interest in the Blanchard et al. (1980) review is their omission of studies examining the efficacy of biofeedback of the activity of the temporal artery (Bild & Adams, 1980; Friar & Beatty, 1976), as only two studies were available utilizing this treatment. However, Friar and Beatty (1976) reported a greater improvement in headache from the temporal artery biofeedback than from traditional finger temperature biofeedback. This finding further supports the notion that cephalic vasomotor functioning is a key determinant of migraine headache symptomatology, and suggests that interventions aimed at improving vasomotor functioning may be fruitful areas for future research.

Several investigators (Newton & Barbaree, 1987; Norton & Nielson, 1977) have suggested other possibly important mechanisms of change in headache disorders. Newton and Barbaree (1987), for example, focused on the cognitive appraisal processes associated with treatment outcome. Their study provides evidence of cognitive changes occurring during headache episodes throughout a course of "stress inoculation" (Meichenbaum & Turk, 1976) treatment. Specifically, those subjects who reported the greatest improvement in pain intensity following treatment also demonstrated the greatest positive shift in appraisal during headache attacks. However, this study did not use standard headache classification criteria, so results should be interpreted carefully. This is unfortunate, as this study did employ a novel design feature: subjects wore electronic beepers which signaled them throughout the day, in their natural environment, to record headache activity and related thoughts. Newton and Barbaree (1987) suggested that reductions in negative appraisal may represent a significant change mechanism in chronic headache patients.

The hypothesis that cognitive changes represent significant mediators of treatment effectiveness in chronic headache sufferers was supported by a study investigating change mechanisms in EMG biofeedback treatment of tension headache (Holroyd et al., 1984). Holroyd et al. (1984) assigned tension headache sufferers to one of four EMG biofeedback conditions in a 2 X 2 design (decrease EMG, increase EMG, high success feedback, moderate success feedback), while all subjects were led to believe that they were decreasing frontal EMG activity. Regardless of actual direction of EMG changes, subjects in the high success feedback group showed greater improvement in headache activity than those receiving moderate success feedback. These results suggest that cognitive changes elicited by performance feedback may be more important for treatment effectiveness than actual reduction in EMG activity levels.

In a recent investigation of comparative effectiveness of abortive medication versus a home-based behavioral intervention (Holroyd et al., 1988) it was found that both therapies were approximately equally effective (41% reduction for ergotamine tartrate vs. 52% for combined relaxation training and thermal-biofeedback training). However, several differences in the two treatments were discovered: a) timing of improvement, with drug treatment being effective in the first month of treatment, whereas improvement with relaxation/biofeedback training was not found until the posttreatment period; b) reduction in analgesic medication use, with behavioral treatment resulting in reductions, while drug treatment did not; and c) patterns of nonresponsiveness, with patients with few headache-free days unlikely to respond to behavioral treatment, while those with high trait-anger scores were unlikely to improve with drug treatment.

According to Holroyd et al. (1988), these differences in treatment response may indicate that different treatments should be applied with patients with different characteristics. For example, migraine patients with high pretreatment trait-anger scores (> 25 on the STPI-T, Spielberger, 1979) would not appear to be good candidates for abortive pharmacological therapy. They also found a trend for high depression scores on the BDI (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) to be indicative of poorer response to drug treatment. In contrast to these findings, both of these psychological variables (trait anger and depression) were unrelated to response to relaxation/thermal biofeedback treatment. Holroyd et al. (1988) reported that if patients averaged less than three headache-free days per week they were unlikely to respond to behavioral treatment (14% responded), whereas patients averaging three or more headache-free days per week responded well to behavioral treatment (75% responded). These findings suggest that drug therapy should be the treatment of choice for patients with frequent attacks, while behavioral therapy should be the treatment of choice for patients with relatively higher levels of psychological distress (trait anger or depression, in particular).

Although treatment for migraine has evolved rapidly in the last 20 years, major improvements are still needed. As has been noted, pharmacological interventions are not currently able to "cure" the disorder, but are primarily intended to manage frequency, symptoms, and pain. Psychological treatments, while unaccompanied by the serious side effects of drugs, also have their drawbacks. Symptoms may not be relieved for quite some time after beginning treatment, those who suffer from very frequent attacks may not experience a reduction in headache activity, and adherence to the behavioral prescription may be insufficient to produce positive effects. Furthermore, neither current pharmacological nor psychological treatments appear effective for some migraine sufferers. It seems then that a search for yet other means of treatment appears warranted. One intervention that has been ignored in the headache literature is aerobic exercise or fitness training. Although vascular dysfunction has been implicated in migraine, only one study (Fitterling, Martin, Gramling, & Cole, 1988) has investigated the use of aerobic fitness training as a treatment for migraine, and the primary focus of that study was not headache symptoms but rather was adherence to exercise in a sample of individuals with vascular headache.

Aerobic Exercise and Fitness Training

The purpose of this section will be to provide an overview of some of the short- and long-term physiological effects of aerobic exercise. This discussion will focus on cardiovascular responses to exercise and training, the role of the autonomic nervous system, muscular adaptations, and the development of cardiorespiratory endurance. Finally, I will provide a rationale for prescribing a particular type of fitness training program intended to induce aerobic fitness in a formerly sedentary group of otherwise healthy adults. Much of the description of these physiological phenomena was derived from Wilmore and Costill (1988).

Cardiovascular Responses to Exercise. The primary function of the cardiovascular (CV) system, either at rest or during exercise, is to deliver blood to active tissues. Blood carries oxygen and nutrients throughout the body's organs, and picks up waste materials to be discarded. Another function of the CV system is in regulating body temperature. The specific CV factors that are important in exercise are heart rate (HR), stroke volume (SV), blood flow (BF), blood pressure (BP).

At rest, an average adult heart beats at approximately 60 to 80 beats per minute (bpm). This resting HR is affected by age and environment, generally decreasing with age and increasing with extremes in temperature and altitude. Heart rate increases in a linear manner with increases in intensity of exercise, until near the point of exhaustion. One's maximal heart rate is a reliable value, changing slowly over the course of years. Maximal HR may be estimated by subtracting age from 220. The result reflects an average maximal HR for one's age ($SD$ = 12). At moderate levels of exercise, HR increases fairly rapidly (within one or two minutes) until it reaches a plateau, called the steady state heart rate.

Stroke volume (SV) is the quantity of blood pumped from the left ventricle per heart beat, and is affected both by the quantity of blood available to be pumped, and the contractile force of the ventricle. Stroke volume increases greatly when an individual exercises; in an upright position, SV doubles from resting to maximal values - from 60 to 120 ml in an untrained individual, and from 110 to 200 ml in a well-trained athlete.

While resting, only about 15 to 20% of cardiac output goes to muscle, while in maximal exercise, muscles receive 80 to 85% of cardiac output. This shift in blood flow (BF) from inactive to active tissues during exercise is a result of constriction of blood vessels in the inactive areas and dilation of vessels in the active areas. These changes in vasoconstriction are controlled via the autonomic nervous system (ANS) and through local effects of increased metabolism at the site of muscular activity. Increased metabolism creates an increase in acidity, carbon dioxide ($CO_2$), and temperature of the local tissue, which can have a direct effect on dilating the local arterioles and increasing BF in local capillaries. This local regulation of BF is referred to as autoregulation.

Systolic blood pressure (BP) increases in direct proportion to intensity of exercise, with values ranging from 120 mmHg at rest to 200 mmHg or more at the point of exhaustion. In contrast, diastolic BP does not appear to be affected, or only slightly, regardless of the intensity of exercise.

Various characteristics of the blood itself are also affected by aerobic exercise. The difference in oxygen ($O_2$) content of arterial and venous blood is referred to as the arterial-venous oxygen difference, and reflects the extent to which $O_2$ is removed from the blood as it passes through the body. At rest, the $O_2$ content in arterial blood is approximately 20 ml of $O_2$ for every 100 ml of blood, while the $O_2$ content of venous blood is approximately 14 ml of $O_2$ for every 100 ml of blood, for a difference of 6 ml. With exercise, there is a progressive increase in the arterial-venous oxygen difference, reflecting a decreasing venous $O_2$ content, with the arterial $O_2$ content remaining about the same. The composition of the blood also changes with exercise, with red blood cells experiencing a decrease in size with prolonged exercise, due to losses in body fluid from sweating. Sweating also leads to a reduction in plasma volume, resulting in a hemoconcentration of red blood cells and plasma proteins. Due to the reduction in fluid volume, the cellular and protein portions account for a larger proportion of total blood volume, resulting in a rise of up to 20 or 25% in the red blood cell concentration. This hemoconcentration causes an increase in the viscosity of the blood, which in turn may limit the $O_2$ carrying capability of the blood. Finally, the blood can undergo a significant change in pH with moderate to high intensity exercise, reflecting the increased reliance on anaerobic metabolism and corresponding to increases in blood lactate observed with increases in intensity of exercise.

<u>The Autonomic Nervous System</u>. The autonomic nervous system (ANS) controls many of the internal functions of the body which are not normally subject to voluntary control, such as HR, BP, and respiration. The ANS is divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS), which

originate from different areas of the spinal cord and base of the brain. The effects of the two subsystems are generally antagonistic to each other, and they generally secrete different neurotransmitter substances.

For example, the SNS stimulates the HR to increase, while the PNS decreases HR. The SNS is responsible for constricting most of the blood vessels, thus controlling BP and cardiac output. However, SNS stimulation results in dilation of the coronary blood vessels that supply heart muscle itself. Thus, during exercise, SNS stimulation is extremely important, as it increases HR which increases the work of the heart. It simultaneously causes dilation of coronary blood vessels, providing more blood to reach the heart muscle, allowing it to perform at its increased work load. Finally, SNS stimulation elevates BP in order to allow enough blood to return to the heart to maintain adequate cardiac output. The PNS, on the other hand, plays a minor role in controlling the systemic blood vessels.

Although the nervous and endocrine systems share many similar features in their regulation of the CV system, there are also important differences. The nervous system functions quickly and its effects are relatively short-lived and localized, whereas the endocrine system functions more slowly, and its effects are broader and generally longer lasting.

Muscular Adaptations. The effect of chronic exercise is adaptation within and around muscle fibers that make them more tolerant of strenuous effort. Muscles adapt to stress by increasing their capacity for energy production and metabolic waste removal. In general, then, physical training stimulates growth and improves performance. Most of the changes require several weeks or months, and the amount of change is somewhat proportional to the amount of exercise performed during training. One of the key concepts for training is that muscles will adapt optimally to exercise that moderately exceeds their capacity, necessitating a gradual progression in training load in order to maximize performance.

Improvements in aerobic endurance are the result of changes in both central and peripheral circulation (e.g., cardiac output, muscle blood flow) and muscle metabolism. One of the most important changes produced by training appears to be the increase in the number of capillaries surrounding each muscle fiber. For example, with eight weeks of conditioning, the number of capillaries increases approximately 15%. This increase allows greater exchange of gases, heat, and nutrients between blood and muscle fibers, thus permitting prolonged energy production and muscle contraction.

Within the muscle fiber, other improvements occur as a result of training. Myoglobin, a compound similar to hemoglobin, carries $O_2$ from the cell membrane to the mitochondria, the energy producing system within the cell. Aerobic training increases the myoglobin content of muscle fibers to the same extent as other biochemical adaptations. Training also improves the capacity of the mitochondria to produce ATP, as well as producing an increase in the number and size of mitochondria.

The chemical reactions of the mitochondria that produce ATP are governed by several key protein molecules, or enzymes. As a result of aerobic training, there is a dramatic increase in the amount of these enzymes, particularly succinate dehydrogenase (SDH), hexokinase (HK), and malate dehydrogenase (MDH). It has been demonstrated that even moderate amounts of aerobic activity will increase the activity of these enzymes, thereby enhancing the number, size, and efficiency of muscle mitochondria in ATP production.

An endurance-trained muscle also burns fat more effectively, resulting in a lowered demand on that muscle's limited supply of glycogen. Training also increases the release of free fatty acids from the fat cells during exercise, making them available for the muscle's use in energy production. Thus, improvements in the muscle's aerobic energy system increase that muscle's energy producing capacity, and also effect a shift toward a greater use of stored fat for ATP production.

It is important to note that one does not need to perform exercise at an intense level in order to achieve an increase in aerobic capacity, as described above. Improvements in aerobic capacity appear to be determined at least partly by the number of calories expended during each exercise session and the total amount of work performed each week. For peak athletic performance, fairly intense exercise seems to be required; however, if the goal is increased aerobic endurance, then low intensity training appears equally appropriate.

Development of Cardiorespiratory Endurance. Cardiorespiratory endurance refers to the body's ability to maintain prolonged exercise without experiencing fatigue or exhaustion, and has become synonymous with the term physical fitness. Although cardiorespiratory endurance (max $O_2$ uptake or $VO_2$ max) can be assessed either in the field or in the laboratory, laboratory max tests are the most acceptable measure of cardiorespiratory endurance. In a laboratory setting, an individual needs to be exercising up to the point of exhaustion. At the point of exhaustion, the amount of oxygen consumed ceases to increase, signaling that the $VO_2$ max has been reached. Thus, $VO_2$ max is defined as the highest attainable oxygen uptake value during maximal exercise. However, as will be discussed later in the section on methods, $VO_2$ max can be accurately estimated without expensive equipment or the requirement that individuals exercise to the point of exhaustion.

Resting heart rate will decrease as a result of endurance training. While a typical HR for a sedentary adult is about 80 bpm, this will decrease by approximately one beat per minute for each week of training for the first several weeks. After about ten weeks of training, for example, the typical resting HR should drop to about 70 bpm. Also as a result of conditioning, one's HR during exercise becomes less, for the same amount of work done. It is not considered unusual to observe decreases of 20 to 40 bpm during moderate exercise following a six-month training program. Finally, HR recovers from exercise at a much faster rate following a period of endurance training. This phenomenon has led to the use of pulse rate recovery as an index of cardiorespiratory fitness, as the more fit individual recovers faster from a given level of exercise. However, since this varies greatly among individuals, it is best to use it as a means of quantifying a single person's improvement, rather than as a comparison tool.

Stroke volume also improves with fitness training, both at rest and at maximal performance. For untrained individuals, resting SV is generally at about 70 ml, while for a moderately trained individual, resting SV improves to about 90 ml. Maximal SV for untrained individuals approaches 125 ml, while for moderately trained individuals it advances to around 150 ml. Likewise, the weight of the heart, heart volume, and the size of the heart chambers all appear to increase as a result of endurance training.

Due to an increase in the number of capillaries passing through muscle tissue as a result of fitness training, blood flow is increased through the muscles. Muscle fibers also become larger as a result of training. Interestingly, arterial BP during work does not appear to be changed as a result of training, but resting BP is generally reduced for individuals with borderline or moderate hypertension.

One of the most significant changes to occur as a result of aerobic training is an increase in blood plasma volume which is greater than the increase in red blood cell volumes. This increase causes a lowering of blood viscosity, allowing the blood to move more efficiently through the blood vessels, particularly the capillaries, thus enhancing the delivery of $O_2$ to active muscles and facilitating removal of waste products. Although the $O_2$ content of arterial blood changes very little with training, the arterial-venous oxygen difference is increased, which is caused by a greater extraction of available $O_2$ at the tissue level. Also, lactate threshold is increased with cardiorespiratory training, resulting in lower blood lactate at each level of exercise.

Pulmonary ventilation at rest does not improve as a result of training, but it is slightly reduced during exercise. Maximal pulmonary ventilation does improve with training, increasing from approximately 120 liters per minute (L•m) to around 150 L•m following training. Blood flow to the lungs is enhanced by training, particularly to the upper regions of the lungs while the individual is either sitting or standing.

Oxygen consumption at rest does not appear to be dramatically altered by training, while at moderate levels of exercise it appears to be slightly reduced, although conclusive evidence is still needed. If $O_2$ consumption were found to be reduced as a result of training, this would indicate an increase in metabolic and/or mechanical efficiency as a result of training. What is known is that $VO_2$ max is substantially increased with even moderate training. For example, if a formerly sedentary individual trains at 75% of his or her maximum HR three times per week for 30 min. each time, over a period of six months an increase of 15 to 20% in $VO_2$ max can be expected. These increases appear to be attributable to increased muscle blood flow and increased muscle capillary density.

A Fitness Program for Sedentary Adults. Several factors should be considered when designing a cardiorespiratory fitness training program. These are progressive overload, duration of each session, frequency of sessions, intensity of exercise, ratio of intense work to rest intervals, and the purpose of the program. Progressive overload implies that the rate of work should be slightly greater than that which can be comfortably performed on a continuous basis. Beyond the minimum required to achieve training effect, the duration of each session will depend largely on one's goals and time constraints, as does the frequency of sessions. Intensity of exercise must be determined not only by one's goals, but also by age, level of prior fitness, medical status, and personal preference. In general, the ratio of intense work to rest intervals is a function of the type of training program. A high intensity program necessitates frequent rest intervals, while a low intensity program can be continuous, and does not require rest intervals. Finally, the purpose of the program needs to be considered when setting all of the above parameters.

Two basic types of training programs are interval training and continuous training. In interval training, periods of usually moderate to intense work are alternated with shorter periods of rest or reduced activity. Continuous training involves continuous activity without rest intervals. One variation of continuous training has been called LSD training, for "long, slow distance," and this implies low intensity exercise for an extended period. With LSD training, one's HR is kept between 60 to 80% of HR max. For example, for a 35 year old exercising at 70% of HR max, the training HR (THR) would be 130 [(220-35) X 70%], while for a 45 year old, the THR is 123. It has been demonstrated that the concept of training heart rate (THR) is an extremely useful one, since a high correlation exists between HR and amount of work done by the heart. When using THR in an extended training program, an individual's heart will perform at the same level of work even though other factors may vary significantly. This means that the use of an individual THR automatically offers a "built-in" safety mechanism which regulates the amount of work done by the heart, even though other factors may change (temperature, humidity, altitude, level of fitness, etc.).

Long, slow distance (LSD) training has been recommended as the treatment of choice for formerly sedentary adults, due to benefits such as the relatively low heart rates required to achieve fitness improvements and the low risk of joint or muscle damage. As Wilmore and Costill (1988) state, "For the middle-aged, or older, individual who is attempting to attain or maintain an acceptable level of physical fitness, from a medical viewpoint this is also the most judicious way to train" (p. 172). While both interval training and continuous training have been shown to be equally effective in producing gains in cardiorespiratory endurance, it appears that continuous training, specifically LSD training, offers the advantage of being minimally hazardous and easier to perform for the formerly sedentary adult. It is noteworthy that aging appears to have little effect on the ability of skeletal muscle to adapt to endurance training.

It also appears that the same fitness training program is suitable for both men and women, since the sexes respond to acute and chronic exercise in much the same manner. Wilmore and Costill (1988) state that, "Major cardiovascular and respiratory adaptations accompany cardiorespiratory endurance training; these adaptations do not appear to be sex-specific" (p. 329).

Finally, a warm-up period before the training portion of a fitness program serves to increase HR and respiration from resting rates, as well as providing for the safe functioning of blood vessels, muscles, and joints in the exercise to follow. A warm-up also reduces muscle and joint soreness following exercise in early stages of a training program. Although it was once believed that flexibility exercise should be done prior to endurance exercises, it is now recommended that these exercises be performed after endurance exercises, since muscles, tendons, ligaments, and joints are more responsive to flexibility exercises at this time. Following the training portion of the program a cool-down period of five to ten min., involving a slow, easy walking pace, keeps the blood from pooling in the legs, and reduces the chances for developing muscle soreness.

Aerobic Fitness Training as Treatment for Migraine

In this section I will a) review the current use of exercise as treatment for various psychological conditions, b) outline existing knowledge about the use of exercise as treatment for migraine headache, and c) describe a number of measures that are known to increase adherence to exercise programs, specifically with migraine sufferers.

Uses of Exercise as Treatment for Psychological Conditions. Several researchers have reported that exercise can be an effective treatment for mild to moderate depression (Doyne, Bowman, Ossip-Klein, Osbam, McDougal-Wilson, & Neimeyer, 1983; Simons, Epstein, McGowan, Kupfer, & Robertson, 1985). However, the precise agent of change is not well understood. Simons et al. (1985) point to the lack of differential effectiveness between aerobic and nonaerobic exercise in treating depression, and suggest that self-efficacy (Bandura, 1977) may provide a framework for assessing treatment outcome. Simons et al. (1985) also recommend greater recognition of the need to operationalize and monitor treatment and outcome variables, including exercise routine, physiological measures, and type and degree of improvement.

Judging from results of the Doyne et al. (1983) study, it appears that the effects of exercise on depression are not a result of aerobic conditioning. In that study, subjects in both an aerobic (running) and a nonaerobic (weight training) group showed equal rates of improvement in depression scores. At least one other study (Fremont & Craighead, 1984) reported no correlation between changes in Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) scores and percent of decrease in exercise recovery HR (an index of fitness improvement). These findings further suggest that a purely physiological mechanism alone is not responsible for the effectiveness of exercise as a treatment for depression. Further evidence for a nonphysiologic pathway comes from the timing of improvement in depression. Although eight to ten weeks of exercise are generally required to achieve a fitness effect, in both Fremont and Craighead's (1984) and Doyne et al.'s (1983) studies, the antidepressant effect occurred in the early weeks of treatment.

According to Bandura's (1977) self-efficacy theory, various treatments are all equally effective in reducing psychological distress mainly because they all enhance patients' sense of self-efficacy by establishing a series of mastery experiences. This may account for the equal effectiveness already mentioned for aerobic and nonaerobic exercise in treating depression. However, other research (Golden, Sinyor, Steinert, & Seraganian, 1983) has revealed that, at least for nonclinical populations, aerobic exercise results in increased self-efficacy, whereas nonaerobic exercise does not. This latter finding indicates that self-efficacy may not be the primary agent in reductions of depression with exercise.

Essential hypertension is a condition of chronically increased blood pressure with no known organic basis (such as renal, endocrine, or other disorders). In spite of the absence of any identifiable organic cause, aerobic exercise has recently been shown (Martin, Dubbert, & Cushman, 1990) to be an effective treatment for reducing BP in mildly hypertensive adults. This study is noteworthy due to its crossover design, which included an "exercise placebo" group to control for any nonspecific treatment effects, such as continued monitoring of BP, repeated contact with experimenters, and psychological effects, such as increased self-efficacy as a result of exercising over a 10-week training program. The exercise placebo control group was restricted from exercising at a HR above 60% of their maximal HR, to ensure that no aerobic fitness training occurred. Following a statistically significant between-groups comparison on BP measures that confirmed effectiveness of treatment, seven of the nine men from the exercise placebo group completed the aerobic regimen, and they also subsequently experienced statistically significant reductions in blood pressure.

Primary fibromyalgia is a common pain disorder with no known organic cause. It is generally considered a disorder of pain regulating mechanisms, and recently (McCain, Bell, Mai, & Halliday, 1988), CV fitness training was shown to be effective in reducing pain symptoms. Of particular interest in McCain et al.'s (1988) study is the fact that although significant differences in pain threshold were found between aerobic and nonaerobic groups, no differences were found in changes in psychological symptomatology. This indicates that any improvements in pain symptoms experienced by members of the CV group were not likely a result of psychological change, but appear to be related primarily to the type of exercise program engaged in by these individuals.

Over the last 20 years, the syndrome known as Type A Behavior Pattern (TABP) has been investigated as a possible contributor to increased risk of CV disease. Briefly, TABP includes a chronic sense of time urgency, high levels of competitiveness, hostility, and need for achievement. In the past, psychotherapy and stress management techniques have been employed to reduce Type A behaviors, in an attempt to avert increased risk of coronary heart disease. Recently, exercise has been used as an effective treatment for TABP (Blumenthal et al., 1988).

As with other studies reviewed here, Blumenthal et al.'s (1988) design included an aerobic exercise training group and a nonaerobic exercise control group. These researchers were specifically interested in change over time in patterns of CV responses between the two groups. As expected, after 12 weeks of training, the aerobic exercise group demonstrated significant improvements in SBP, DBP, HR, and estimated (HR X SBP) myocardial oxygen consumption ($MVO_2$), while the nonaerobic exercise group did not. These investigators concluded that a moderate aerobic fitness training program may help to reduce the risk of CHD among Type A males. It should be noted that posttreatment responses to psychosocial stressors, as well as physical stressors, were included as part of this study.

In a study designed to assess the CV and psychological effects of exercise training in 70- to 79-year-old men and women (Norvell et al., 1989), researchers found no differences between an aerobic, a nonaerobic, and a control group in overall psychological benefits. However, the aerobic group evidenced some improvement in depression scores. Subjects in this study were nonpathological elderly adults, so any psychological benefits of fitness training may not be apparent in this population, due to floor effects. However, this study demonstrates that elderly adults can experience significant improvements in CV fitness as a result of moderate exercise over a 26-week program. In addition, no differences in psychological benefits were found between aerobic and nonaerobic exercise groups.

Exercise and Migraine. In one of the few controlled studies investigating exercise as a treatment for migraine (Fitterling et al., 1988), four out of five women who completed a 12-week aerobic exercise program experienced significant reductions in headache activity. Fitterling et al. (1988) used a six-point Likert rating scale (Blanchard & Andrasik, 1985) for their measure of migraine headache activity. The mean rating of the six-week baseline monitoring period for all five of Fitterling et al.'s (1988) subjects was .84, which corresponds to their rating scale's behavioral descriptor of 1.00 which states, "Very mild headache, aware of it only when attending to it." One issue which evolves from this relatively low baseline level of headache activity is whether these subjects represent a chronic migraine sample. Nevertheless, of the four women who showed improvement, one stopped exercising after the study was completed, and her headaches quickly returned to approximately pretreatment levels. The other three women all continued exercising and showed no signs of migraine headache activity at a six month follow-up. Fitterling et al. (1988) note that headache activity served as a deterrent to exercise early in the training program, yet adherence measures (such as a group/social setting for exercise; flexible goal setting; individualized feedback and praise during exercise; training in, and use of, distraction-based cognitive strategies; and active spouse support for the exercise program) appeared to have overcome this problem.

In a recent study examining effects of exercise on migraine (Lockett & Campbell, 1992), 11 subjects classified as classic migraineurs completed a six-week aerobic exercise program. The authors reported that the exercise program was successful in reducing perceived pain severity (as measured by the West Haven-Yale Multidimensional Pain Inventory; Kerns, Turk, & Rudy, 1985), but not affective distress or any of the other, more direct, measures of headache symptomatology (frequency, intensity, and duration), although there were trends toward significance in these measures. In Lockett and Campbell's (1992) study, 26 of 33 women who responded to advertisements were classified as classical migraineurs, or approximately 79% of their sample population. This extraordinarily high percentage calls into question the classification method used in the Lockett and Campbell (1992) study, as the percentage of migraineurs classified as classical (or migraine with aura by IHS criteria) is typically around 10% (Stewart et al., 1992).

There have been few other reports of exercise as treatment for migraine. A neurologist (Van Gijn, 1987) reported that a 44-year-old male physician found relief from "attacks of a dull, boring headache in the left temple" that had occurred for six years by either strenuous cycling or running. However, as pointed out by Ferrari (1987), this single case study may not have been a case of true migraine, therefore questioning whether exercise is appropriate for migraine sufferers. In a more recent report (Kumar, 1988), a physician who had suffered from common migraines since childhood, and who successfully used beta-blocking medications (atenolol, 50 mg/day) for prophylactic prevention of migraines for six years, began walking for 30-45 min. per day. The result of his exercise routine was that in four months he was both drug-free and headache-free, which continued for six months prior to the time of the report. He also mentioned that previous attempts to discontinue medication use without exercise had been unsuccessful. Although anecdotal, these reports suggest that the possibility of a migraine-preventing use of moderate aerobic exercise deserves further attention.

Finally, one recent review of the possible relationships between exercise and migraine (Darling, 1991) offered several avenues by which aerobic fitness training might theoretically affect migraine headache symptoms. However, while Darling (1991) posits that fitness training is effective in reducing migraine symptomatology, she admits that "Due to the paucity of empirical investigations, the bulk of supportive evidence for exercise as a method of migraine management must be gleaned from related areas of research" (p.295).

Adherence to Exercise. In spite of the fact that exercise can have numerous positive effects on both physical and mental health, a large percentage of people who begin exercise programs quit exercising, often within the first few months (Martin et al., 1984). In order to achieve any positive effects from exercise, individuals need to adhere to a program for several months; after such an extended time period, many people cannot stop the exercise habit. Although many research studies have suggested numerous ways to promote exercise adherence, Martin et al. (1984) is particularly relevant for purposes of this study. Over the course of three and a half years, these researchers compiled an adherence package designed specifically for formerly sedentary adults in a community-based moderate aerobic exercise program. As will be discussed in my section on methods, these subject characteristics are similar to those targeted by the present study.

Each of six studies reported in Martin et al. (1984) was conducted as part of a community enrichment program at a small private college using formerly sedentary adults who enrolled in a noncredit exercise course. The first study (4 males, 29 females, M age = 34 years) addressed the issues of type of feedback volunteers received while exercising (personalized vs. group-oriented) and ty e of goal exercisers set (distance goal vs. time spent exercising). Results indicated that personalized feedback (e.g., "You're pace is perfect now--you're doing really well!") and time goals were more effective in promoting adherence to the exercise program.

The second study (6 males, 28 females, M age = 29 years) sought to discover a) whether a weekly lottery for attendance would improve adherence, and b) whether increasing subjects' input into goal-setting procedures would improve adherence. While there were no significant differences between the lottery vs. no lottery conditions, results did indicate that flexible goal-setting (allowing subjects to modify their daily distance goals based on how they felt that day) had a positive impact on adherence. The flexible goals groups also experienced the lowest overall dropout rates. The third study (2 males, 13 females, M age = 28 years) was designed to test for order effects of flexible vs. fixed goals, as the experimenters hypothesized that flexible goal-setting was so important that it would be associated with superior adherence regardless of when it was introduced. Results of this study indicate that fixed goals are decidedly inferior to flexible goals, and that if subjects are first given fixed goals then allowed to use flexible goals, adherence is far less than the reverse condition, throughout a 12-week program. At this point, then, we can conclude that at least for females (who constituted the majority of those in Martin et al.'s [1984] studies), personalized feedback, time goals, and flexible goals are all beneficial in improving formerly sedentary subjects' exercise adherence.

Study number four (4 males, 20 females, M age = 30 years) focused on the frequency of goal setting, specifically whether distal goals (five week periods) or proximal goals (new goals each week) would result in greater exercise adherence. Contrary to Martin et al.'s (1984) expectations, there were no significant differences, but the distal goal group appeared to have slightly greater adherence overall. Martin et al. theorized that the distal goal setting may have permitted greater flexibility in daily and weekly performance, or that less frequent goals helped avoid constant reminders of failure (i.e., abstinence violation effect).

Interactions of associative vs. distraction-based cognitive strategies with exercise adherence was the issue explored by the fifth study in the series (5 males, 12 females, M age = 33 years). It was believed that for untrained, formerly sedentary adults, distraction-based cognitive strategies would produce greater adherence. As expected, subjects in the dissociative (distraction-based) group showed greater adherence, both during the 12-week course, and at three- and six-month follow-ups. Study number six was intended to assess relapse prevention measures, but several events served to confound the results (e.g., attrition was higher than in previous studies, one group leader for the control group continued to arrange exercise meeting times after the course ended, and members in one of the relapse prevention groups had formed a social network and continued to run with each other). Martin et al. included this study in their report because they believed that it highlights the powerful effect of social support. To summarize the six studies, it is clear that personalized feedback, time goals, flexible goals, dissociative cognitive strategies, and social support all served to improve these individuals' adherence to an exercise program.

Martin et al. (1984) stress the importance of having enthusiastic participant exercise coordinators to implement the above adherence measures. They also suggest that if these measures are properly enacted, adherence levels around 80% can be expected, with a minimum of dropouts over a 12-week treatment program. Martin et al. (1984) used several measures of adherence in their estimate, including attendance at sessions, required out-of-class exercise, and ideal adherence (in-class combined with out-of-class rates). Several other studies, which will be discussed in this section, support and expand the Martin et al. (1984) recommendations.

In a study designed to assess the differential effectiveness of attendance/participation-oriented vs. goal-oriented exercise strategies in young (M age = 21) and elderly (M age = 68) adults, Ferretti and Hollandsworth (1987) discovered that, while attendance overall was significantly greater in the participation-oriented group, individuals in the goal-oriented group achieved significantly higher levels of physical fitness. This suggests that until attendance is established, perhaps the appropriate adherence strategy is one which emphasizes attendance and participation. Then, after the exercise habit is somewhat established, specific goals, such as distance walked, may help exercisers achieve maximum fitness levels. Thus, timing of particular adherence measures appears to be a relevant aspect of interventions aimed at both attendance and improved fitness. One other finding of the Ferretti and Hollandsworth (1987) study was that there were no improvements in the goal-oriented group in terms of psychological measures such as mood and subjective well-being, contrary to the literature.

King, Taylor, and Haskell (1989) compared group-based vs. home-based exercise programs, as well as higher (65-80% maximum

HR) vs. lower (50-60% Max HR) intensity exercise, in a sample of formerly sedentary middle-aged adults (50-65 year olds). They found that, throughout a six-month program, the low-intensity home-based group had greater adherence to their program than the high-intensity group-based group. The high-intensity home-based group showed the greatest adherence for the first two months, after which it was equivalent to the low-intensity home-based group. Unfortunately for the purposes of this study, the high-intensity group-based group had adherence rates that were significantly lower than the other two groups almost throughout the six-month program. However, King et al. (1989) did not employ any adherence intervention techniques. This fact highlights the need for effective adherence intervention in this study. Finally, King et al. (1989) also concluded that across all three exercise conditions, correlations between adherence measures and physiological improvement were all statistically significant, indicating a positive relationship between amount of exercise and improvement in CV fitness.

Since the vast majority of people who present themselves for professional care for migraine headache are women, information concerning women's exercise adherence characteristics appears warranted. Although not specifically addressing migraine sufferers, a study by Selby, DiLorenzo, and Steinkamp (1987) investigated differences between women who completed an eight-week exercise program, dropouts from the program, and those who never enrolled in the program, but had that opportunity. These researchers found that women who were slightly dissatisfied with their fitness level were more likely to begin and complete the program, whereas those who were satisfied with their fitness level did not begin, and those who were extremely dissatisfied tended to begin but drop out. Selby et al. (1987) suggest that women's adherence may be assisted by encouraging them to set short-term realistic goals and providing them with occasional feedback and praise regarding progress in various areas. It should be noted that the vast majority of Martin et al.'s (1984) subjects were women, so their adherence techniques should be particularly suitable for a predominantly female population.

Rationale for the Current Study

The current study was designed to address the effectiveness of aerobic fitness training in reducing symptoms of migraine headache. Adherence measures were used in an effort to maximize subjects' adherence to the exercise program, and to try to minimize dropouts. Based largely on the Martin et al. (1984) findings, these adherence efforts included the following:

1. A group/social setting for exercise
2. Flexible goal setting (e.g., more or less distance walked) at each session (within agreed upon HR parameters)
3. Individualized feedback and praise during exercise (from experimenter during each session, while walking alongside)
4. Training in, and use of, distraction-based cognitive strategies (e.g., think of something pleasant, not current discomforts).

While the main dependent variable of interest was headache activity (headache index, headache intensity, and number of headache-free days), analyses were also performed on psychological variables in order to assess any potential psychological benefits of the training programs. Furthermore, analyses were conducted to determine the nature of any physiological (blood pressure and heart rate) benefits of the training programs.

Community volunteers were screened for eligibility based on the most recent and accepted headache diagnostic criteria (International Headache Society, 1988). Subjects exercised three times per week for 12 weeks, and monitored and recorded headache activity for one month prior to exercising, throughout the 12 week exercise treatment program, and for one month after exercising. Subjects were also assessed for fitness status prior to beginning the exercise program and at the end of the exercise program. The initial fitness assessment was used as an individual baseline, as well as to determine each individual's maximal heart rate for subsequent exercise sessions. All subjects turned in to experimenters their weekly headache monitoring sheets, which were used to derive the primary dependent measures regarding the previous week's headache activity.

All experimenters who supervised exercise sessions were trained by a Red Cross certified trainer in cardiopulmonary resuscitation (CPR), and were further trained in the rationale behind, and the implementation of, the exercise intervention. Every effort was made to ensure the safety of all volunteers in the exercise program, and all participants were treated in accord with the spirit and content of the American Psychological Association's Ethical Principles in the Conduct of Research with Human Participants (APA, 1982).

Although only two controlled studies are known to exist regarding the effects of exercise on migraine headache (Fitterling et al., 1988; Lockett & Campbell, 1992), those studies provide evidence that exercise may prove to be useful in the treatment of migraine headache. Other anecdotal reports (Kumar, 1988; Van Gijn, 1987) support this notion, and further indicate that there may be positive benefits on headache activity to be derived from an effective fitness training program. Furthermore, both the Fitterling et al. (1988) study and physiological evidence (Wilmore & Costill, 1988) suggest that aerobic exercise (as compared to nonaerobic and/or anaerobic exercise) may provide the greatest degree of relief from migraine headache symptoms. It was my hope that this controlled treatment outcome study would add to our knowledge about the use of exercise as a treatment for migraine headache.

# METHOD

## Subjects

Approximately 300 self-identified chronic headache sufferers responded to newspaper advertisements, television public service announcements, in-store flyers, and physician referrals that solicited volunteers for a chronic headache treatment study in Grand Forks, North Dakota. Volunteers were continuously sought over a 14-month period. From this original pool of 300, approximately 75 individuals (25%) agreed to complete an in-depth assessment procedure that consisted of 10 psychological questionnaires, general headache and medical information, and a structured headache interview that was designed to complement a computer-assisted classification program (Penzien, et al., 1991). This rather extensive headache assessment lasted approximately two and one-half hours. Clinical psychology graduate students interviewed each volunteer in order to establish eligibility for inclusion in the study.

During the initial telephone contact, each respondent learned the nature of the study, the time they would be expected to participate in the study, and other eligibility criteria. Of the 75 individuals who completed the headache assessment, only about half (37) were subsequently classified as migraine sufferers. Each of these 37 potential research participants was invited to take part in the treatment outcome study, but only 12 (less than one-third of those eligible) actually enrolled in the treatment program. Of these

12, one dropped out due to pregnancy complications, one broke her leg, one was admitted as a psychiatric inpatient, one moved out of state, and one never completed the required number of exercise sessions, leaving seven subjects with sufficient data for analyses. All subjects were treated in concordance with the Ethical Principles In the Conduct of Research with Human Participants (APA, 1982).

Screening. Initially, subjects were interviewed by a clinical psychology graduate student trained in headache assessment. To be eligible for participation, vascular headache subjects had to meet the diagnostic criteria for either migraine with aura or migraine without aura (International Headache Society, 1988). The following are the IHS descriptions and classification criteria:

> **Migraine with aura** (aura as herein used does not necessarily imply that it precedes the headache)
>
> *Description:* Idiopathic, recurring disorder manifesting with attacks of neurological symptoms unequivocally localizable to cerebral cortex or brain stem, usually gradually developed over 5-20 minutes and usually lasting less than 60 minutes. Headache, nausea and/or photophobia usually follow neurological aura symptoms directly or after a free interval of less than an hour. The headache usually lasts 4-72 hours, but may be completely absent.
>
> *Diagnostic criteria:*
> A. At least 2 attacks fulfilling B.
> B. At least 3 of the following 4 characteristics:
> 1. One or more fully reversible aura symptoms indicating focal cerebral cortical and/or brain stem dysfunction.
> 2. At least one aura symptom develops gradually over more than 3 minutes or, 2 or more symptoms occur in succession.

3. No aura symptom lasts more than 60 minutes. If more than one aura symptom is present, accepted duration is proportionally increased.
4. Headache follows aura with a free interval of less than 60 minutes. (It may also begin before or simultaneously with the aura).

C. At least one of the following:

1. History, physical and neurological examinations do not suggest one of the disorders listed in groups 5-11.
2. History and/or physical and/or neurological examinations do suggest such disorder, but it is ruled out by appropriate investigations.
3. Such disorder is present, but migraine attacks do not occur for the first time in close temporal relation to the disorder.

**Migraine without aura**

*Description:* Idiopathic, recurring disorder manifesting with attacks lasting 4 - 72 hours. Typical characteristics of headache are unilateral location, pulsating quality, moderate or severe intensity, aggravation by routine physical activity, and association with nausea, photo- and phonophobia.

*Diagnostic criteria:*

A. At least 5 attacks fulfilling B-D.

B. Headache attacks lasting 4 - 72 hours (untreated or unsuccessfully treated).

C. Headache has at least two of the following characteristics:

1. Unilateral location
2. Pulsating quality
3. Moderate or severe intensity (inhibits or prohibits daily activities).
4. Aggravation by walking stairs or similar routine physical activity.

D. During headache at least one of the following:

1. Nausea and/or vomiting
2. Photophobia and phonophobia

E. At least one of the following:

1. History, physical and neurological examinations do not suggest one of the disorders listed in groups 5-11.
2. History, physical and neurological examinations do suggest such disorder, but it is ruled out by appropriate investigations.
3. Such disorder is present, but migraine attacks do not occur for the first time in close temporal relation to the disorder (pp. 19-21).

To control other sources of variability, subjects were excluded if they met either of the following exclusion criteria: a) any evidence of possible neurological impairment (e.g., recent onset of headaches, dramatic shifts in symptom patterns, headache as a result of head trauma, etc.); or b) recent participation in a regular (at least three times a week for 20-30 min. each time) aerobic exercise program. Two subjects reported current use of a vasoactive medication such as a beta-adrenergic blocking agent for prophylaxis of their headaches (viz, propranolol) . Such medications have been demonstrated to inhibit sympathetic stimulation of heart rate (Gordon & Duncan, 1991), and while it would have been preferable to exclude individuals using these medications, it became clear that every subject would add valuable data, regardless of ongoing use of vasoactive medications. Individuals using abortive (e.g., ergotamine) and/or analgesic medications were also allowed to participate in this study, as these medications are not associated with the cardiovascular consequences of beta blocking agents.

After completing the initial interview phase, those subjects interested and eligible to participate were required to obtain subsequent medical clearance stating that it was permissible for them to engage in an aerobic exercise program [defined as exercise performed at 65-80% of maximal heart rate for 20-30 min. for 2 to 4 days per week (American College of Sports Medicine [ACSM], 1991)]. Subjects who were ultimately entered into the study were considered characteristic of migraine sufferers for whom medication and other traditional treatments had proven relatively ineffective. Therefore, any reduction in headache activity in the sample could be considered as evidence for the applicability of this exercise treatment to migraine sufferers in the general population for whom traditional treatments had been unsuccessful.

Materials

Headache Index. The primary dependent variable of interest was headache activity. Subjects recorded their headache activity four times daily (e.g., breakfast, lunch, dinner, and bedtime) on forms provided for that purpose and turned their records into the experimenters weekly. An 11-point Likert scale that has been frequently used and validated in headache treatment outcome studies (Blanchard & Andrasik, 1985; Holroyd et al., 1988) was used to assess headache activity. Subjects rated headache intensity four times daily, and also drew the curve between successive data points to represent the pattern of headache activity since their last monitoring. From these ratings the following headache data were obtained for each subject: a) average weekly headache rating (calculated by dividing the sum of each week's headache ratings by 28, the number of total observations per week), b) highest headache intensity rating per week, and c) number of headache-free days per week. Subjects also recorded headache-related medication use.

Orientation to Life Questionnaire. The Orientation to Life Questionnaire (OLQ) (Antonovsky, 1987) is a 29-item scale designed to measure the degree of an individual's "Sense of Coherence," or SOC. Antonovsky hypothesizes three components of one's SOC: comprehensibility, manageability, and meaningfulness. According to Antonovsky, the comprehensibility subscale of the OLQ assesses the degree to which an individual perceives stimuli in their environment to be orderly, predictable, and understandable. The manageability subscale assesses the degree to which an individual believes that he or she, or others who exert influence on his or her behalf, can manage or cope with events in his or her world. Finally, the subscale measuring meaningfulness refers to how emotionally invested or committed an individual is to events in his or her world. Antonovsky proposes that an individual with a strong SOC views the world as comprehensible, manageable, and meaningful, while an individual with a weak SOC views the world as incomprehensible, unmanageable, and not meaningful. Obviously, a strong SOC is preferred over a weak SOC when one is confronted with challenging or stressful situations.

A consistently high level of internal consistency and reliability is reported by Antonovsky (1987), with Cronbach's alpha for the three subscales ranging from .84 to .93. Antonovsky (1987) reports a measure of concurrent validity in which a correlation of .639 was found between the OLQ and an independently developed 22 item SOC scale suggesting that both scales were measuring a similar construct. Finally, Antonovsky (1987) reports that the OLQ has shown adequate convergent validity (correlation of .385 with Rotter's Internal-

External Locus of Control scale [Rotter, 1966]) and discriminant validity (correlation of -.21 with the Sarason Test Anxiety Scale [Sarason, 1978]).

Beck Depression Inventory. The Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) is a 21-item inventory developed and widely used for the assessment of depressive symptoms. The 21 items include the affective, cognitive, motivational, and physiological areas of depressive symptomatology. Beck et al. (1961) demonstrated that individuals' scores on each of the 21 questions are significantly related to their total score on the inventory, indicating internal consistency of the scale. Early validation studies (e.g., Beck et al., 1961) in psychiatric populations demonstrated high split-half reliability (Pearson $r = .86$) and substantial agreement between BDI scores and clinical ratings (Pearson biserial $r = .65$ and 0.67).

State-Trait Personality Inventory-Trait Scale. The State-Trait Personality Inventory-Trait Scale (STPI-T) (Spielberger, 1979) is a 30-item scale designed as a measure of trait anxiety, anger, and curiosity. (Only the anxiety and anger subscales were used in this study.) The means, standard deviations, and alpha coefficients for working adults 33-years-old or older are reported in Spielberger (1979).

Following are the psychometric data pertaining to the anxiety subscale of the STPI-T: The mean for females is 17.98 with a standard deviation of 5.45 and an alpha coefficient of .92; the mean for males is 16.27 with a standard deviation of 4.70 and an alpha coefficient of .88. The anger subscale has the following psychometric properties: the mean for females is 18.13 with a standard deviation of 4.82 and an alpha coefficient of .90; the mean for males is 17.41 with a standard deviation of 5.19 and an alpha coefficient of .88. Lastly, the curiosity subscale of the STPI-T has the following psychometric properties: The mean for females is 28.86 with a standard deviation of 5.73 and an alpha coefficient of .95; the mean for males is 30.45 with a standard deviation of 5.64 and an alpha coefficient of .93. These data indicate that the STPI-T possesses adequate internal consistency.

Headache Locus of Control Scale - Revised. The Headache Locus of Control Scale-Revised (HLOC-R) (Penzien, Holm, Holroyd, Tobin, Hursey, & Brown,1988) is a 15-item scale designed to assess subjects' locus of control beliefs about their headaches. Three dimensions of locus of control beliefs are assessed by the HLOC-R, including: a) internality, b) health care professionals externality, and c) chance externality. Preliminary psychometric analyses of the HLOC-R revealed that the one internal and two external scales are not correlated, while the two external scales are significantly correlated ($r = .32$). The HLOC-R scales are not correlated with measures of headache activity or physical symptoms, and the HLOC-R scale scores did not differentiate among the different headache diagnostic groups (i.e., migraine, tension, etc.). In addition, HLOC-R scale scores changed in the predicted direction following behavioral treatment of headache (e.g., increased externality, decreased health care professionals externality).

Coping Strategy Questionnaire. The Coping Strategy Questionnaire (CSQ) (Rosenstiel & Keefe, 1983) is a 50-item scale comprised of eight subscales (six cognitive coping strategy subscales and two behavioral coping strategy subscales) that each utilizes six items per scale, and two single-item effectiveness ratings. All six of the cognitive coping strategies subscales and one of the behavioral coping strategies subscales were found to be internally reliable, with alpha coefficients ranging from .71 to .85 (only the "increasing pain behavior" subscale was not found to be internally consistent, with a nonsignificant $r = .28$). These seven subscales accounted for statistically significant proportions of variance related to several measures of adjustment to chronic pain beyond that already accounted for by patient history variables and somaticization.

Thoughts at Headache Onset Questionnaire. The Thoughts at Headache Onset Questionnaire (TAHO) (Brown, Penzien, Holm, Ray, & Johnson, 1989) is a 52-item self-report measure of the frequency of self-statements related to headache symptoms. The full-scale TAHO was found to possess adequate internal reliability (Cronbach's alpha = .91), and 8-week test-retest reliability ($r = .83$, $p < .01$). Using a principal components extraction with varimax rotation, eight interpretable factors were found with eigenvalues greater than 1.0, with the total variance accounted for by the factor solution equal to 60.5%. These eight factors comprise the subscales that were analyzed in the present study.

Apparatus

Subjects' blood pressures and heart rates were measured at the beginning and end of each exercise session with a Marshall model 85 oscillometric sphygmomanometer. Subjects also monitored their own heart rates at least every 10 min. during each exercise session in order to ensure that heart rates were maintained within the predetermined parameters assigned to each subject. Subjects monitored their own heart rate by counting their radial or carotid pulse rate for 20 seconds, and calculating their beats per minute (bpm). This information was then used by the subject to adjust the pace of his or her exercise to match his or her own individualized target heart rate.

Procedure

Baseline. Clinical psychology graduate students interviewed all subjects at the Psychological Services Center, University of North Dakota, in order to provide a headache assessment. At these interviews, experimenters provided volunteers with a description of the study, volunteers provided informed consent if they so chose, completed all of the psychological questionnaires, and learned to record headache activity and to monitor their own heart rate. Experimenters explained that subjects were to record their headache activity and medication use for four weeks prior to beginning any treatment as a part of the study. Experimenters instructed subjects to abstain from any additional exercise outside of the supervised treatment program, as this could possibly be detrimental to the purpose of the study. In order to control for diet as a possible contributor to any changes in headache activity, subjects were asked to maintain their same diet throughout the five months of the study.

Treatment Protocol. The current consensus among researchers is that aerobic exercise performed at 65-85% of maximal heart rate for 20-30 min. on three to four days per week is optimal (ACSM, 1991). The aerobic exercise treatment protocol utilized in this study was designed to accommodate these guidelines.

Subjects attended an initial educational and fitness evaluation session in which the treatment coordinator explained principles of aerobic exercise and fitness training. At this meeting subjects were evaluated for their current levels of cardiovascular fitness using the Rockport Fitness Walking Test (RFWT), in which subjects simply walk one mile as fast as they can. At the end of each quarter mile, subjects rated their perceived level of exertion, and at the end of the mile, counted their heart rate for an entire minute. Finally, the pulse rate information was combined with the subject's time to completion of the one-mile walk, gender, age, and weight, and entered into a formula that was validated as an estimate of $VO_{2max}$ (Kline et al., 1987). Finally, at this initial session, experimenters calculated each subject's maximal heart rate using ACSM (1991) guidelines, which incorporate resting pulse rate, age, sex, weight, and approximate current level of fitness; a method of estimating max HR which is more accurate than the 220-age formula used in field settings.

All exercise sessions throughout the study were supervised by experimenters who were trained and certified by the American Red Cross in Cardiopulmonary Resuscitation (CPR). Subjects attended three exercise sessions per week for 12 consecutive weeks. Subjects began their sessions with an 8- to 10-min. warm-up period consisting of a brief walk, and stretching and flexibility exercises, followed by 30 min. of fast walking at an intensity level sufficient to maintain their heart rate between 65% and 80% of maximal throughout the 30 min. During this aerobic training phase of each exercise session, subjects calculated their pulse rate at least every 10 min., and adjusted their pace to stay within their own target heart rate ranges. Each session ended with an 8- to 10-min. cool-down period, consisting of slow walking, and stretching and flexibility exercises. As training progressed through the 12-week treatment program, subjects systematically increased their walking speed and distance to maintain their heart rate within the training range for the duration of the 30-min. training session. Experimenters recorded the distance that subjects walked at the end of each session. Subjects were frequently reminded to refrain from participating in any exercise outside of the supervised sessions.

Experimenters employed a variety of techniques designed to increase the likelihood that subjects would adhere to their exercise programs (Martin et al., 1984). For example, experimenters routinely provided positive feedback during exercise, subjects were encouraged to exercise together in order to maximize effects of social support, experimenters encouraged subjects to set their own goals for each daily exercise session (within the parameters of their individual exercise goals [THR]), and subjects were provided with training in the use of distraction-based cognitive strategies.

To ensure subjects' safety during exercise, the following precautions were strictly enforced: a) as stated in the Subjects section, a physician's release was required of each subject prior to beginning exercise treatment, b) all experimenters were trained and certified by Red Cross Cardiopulmonary Resuscitation (CPR) techniques, c) all exercise sessions were supervised by experimenters, and d) the exercise protocol was designed in accordance with ACSM (1991) guidelines.

RESULTS

Overview of Analyses

Although all participants agreed to exercise under supervision of experimenters three times per week, this was not always accomplished, for various reasons. However, the average compliance rate was 84.86% (SD = 18.14) for those subjects who completed the 12-week fitness training program. While data on sessions missed due to headaches were not formally kept, this was not a particularly problematic issue; perhaps three or four total exercise sessions (out of 252 total) were missed due to headache. Whenever an individual missed an exercise session, their weekly physiological data was obtained by averaging data from the two remaining sessions that week, where possible. In a few instances, only one exercise session was available for a particular week; in those cases, the weekly data were represented by that single session. When travel or other unavoidable circumstances precluded subjects from exercising under experimenters' supervision, subjects were encouraged to exercise on their own in the same manner as they would have if they had been supervised. Therefore, most subjects completed all 36 exercise sessions, plus the two fitness evaluations pre- and posttreatment.

Analyses were subdivided into the following categories: a) fitness data obtained from the two (pre- and posttreatment) fitness assessments; b) physiological data (blood pressure and pulse rate) obtained before and after exercise sessions; c) psychological distress measures (pre- and posttreatment); d) stress and coping measures (pre- and posttreatment); and e) headache-related data from all phases of the experiment.

The rationale and hypotheses for this study concerned only possible improvements in headache symptoms as a result of treatment, and both pathophysiological theory and prior research suggested that worsening of symptoms was not likely. Since this study was viewed as an attempt to further explore the nature of any beneficial treatment effects such as those reported by Fitterling et al. (1988), repeated measures one-tailed t-tests were used with all but one of the classes (stress and coping measures) of variables in order to investigate any within-subject improvements. Since prior research did not address similar constructs, two-tailed t-tests were used with stress and coping measures.

Although the risk of Type I error is increased with one-tailed tests, the small sample size and the exploratory nature of this study increased relative concerns of Type II error. Finally, while some statistical correction to protect against Type I error when conducting numerous t-tests (e.g., Bonferroni's) is typically advised, none was used in this study, as my primary concern was with Type II error, as already noted. To summarize, the liberal application of inferential statistics seemed justified, given the exploratory nature of the study, and the small sample size.

Fitness Data

Variables in this phase of the analysis included estimated maximal oxygen uptake ($VO_{2max}$ [$l*min^{-1}$]), time to complete the one mile walk, heart rate immediately at the end of the mile, and ratings of perceived exertion (RPE) (Table 1). As expected, there was a significant pre-post increase in $VO_{2max}$, with means increasing from 2.535 (l*min$^{-1}$) to 2.[illegible]4 (l*min$^{-1}$), t(6) = 2.24, $p < .05$. Six of the seven subjects experienced increases in $VO_2$, with increases ranging from 0.0810 (l*min$^{-1}$) to 0.7524 (l*min$^{-1}$). Also, as expected, there was a significant pre-post decrease in the time required to walk one mile as fast as possible, with the mean time decreasing from 16.75 minutes to 14.76 minutes (an average of nearly two minutes less), t(6) = 2.86, $p < .05$. Changes in time required to walk one mile ranged from an increase of 0.47 minute to a decrease of 5.50 minutes (see Table 1). Six of the seven subjects showed decreases in time required to walk one mile "as fast as you can," and of these six, only one (subject 001) experienced a decrease of less than one minute. The mean decrease of the remaining five subjects was a substantial decrease of 2.73 minutes. However, none of the other fitness variables showed mean significant changes.

Physiological Data

Measures included in these analyses were monthly averages of data obtained from blood pressure and pulse rate measurements taken before and after each exercise session. These were pre-exercise systolic blood pressure (BSYS), post-exercise systolic blood pressure (ASYS), pre-exercise diastolic blood pressure (BDIA), post-exercise diastolic blood pressure (ADIA), pre-exercise pulse rate (BHR), and post-exercise pulse rate (AHR). For each of these variables, repeated measures one-tailed t-tests were performed comparing each of the three months of treatment.

Table 1

1-mile walk fitness test data pre- and posttreatment

| | Variable | | | |
|---|---|---|---|---|
| Subject (descriptors) | $VO_{2max}$[a] | Time[b] | HR[c] | RPE[d] |
| 01 (33 y.o. female, 180 lbs.) | | | | |
| Pre | 2.0812 | 18.50 | 133 | 8.75 |
| Post | 2.1622 | 17.58 | 136 | 11.00 |
| 02 (38 y.o. female, 135 lbs.) | | | | |
| Pre | 2.6456 | 15.26 | 97 | 14.25 |
| Post | 2.9486 | 13.00 | 118 | 12.00 |
| 03 (38 y.o. female, 205 lbs., daily usage of narcotic analgesics) | | | | |
| Pre | 2.2012 | 17.55 | 152 | 13.00 |
| Post | 2.7116 | 16.08 | 134 | 12.00 |
| 04 (55 y.o. female, 129 lbs.) | | | | |
| Pre | 0.8976 | 21.50 | 88 | 11.00 |
| Post | 1.6236 | 16.00 | 132 | 13.75 |
| 05 (30 y.o. male, 235 lbs., prior ankle surgery) | | | | |
| Pre | 4.3986 | 13.65 | 128 | 12.25 |
| Post | 3.9483 | 14.12 | 158 | 15.50 |
| 06 (23 y.o. male, 153 lbs., daily propranolol use) | | | | |
| Pre | 3.8196 | 13.00 | 144 | 12.00 |
| Post | 4.4812 | 11.75 | 107 | 13.00 |
| 07 (41 y.o. female, 152 lbs.) | | | | |
| Pre | 1.7021 | 17.77 | 144 | 14.25 |
| Post | 2.4545 | 14.78 | 133 | 13.25 |

Note. [a]Values represent estimates of $VO_{2max}$ expressed in $L{*}min^{-1}$.
[b]Values represent minutes required to walk 1 mile.
[c]Values represent beats per minute at the end of the 1 mile walk.
[d]Values represent subjects' mean rating of perceived exertion.

As expected, significant decreases were observed for systolic blood pressure measured before each exercise session [$t(6) = 2.81$, $p < .05$,] from treatment month 1 to 3, with six of seven subjects experiencing decreases averaging 6.38 (SD = 3.92) mmHg, while one subject showed an increase of 2.25 mmHg (see Table 2 for means and standard deviations for all physiological measures). Also as expected, systolic blood pressure measured after each exercise session resulted in significant decreases for all seven subjects from month 1 to month 3, [$t(6) = 4.40$, $p < .05$,] and from month 2 to month 3, $t(6) = 3.52$, $p < .05$. The mean decrease in post-exercise systolic blood pressure for all subjects from month 1 to month 3 was 8.07 mmHg (SD = 4.86).

Similarly, diastolic blood pressure monitored prior to each exercise session showed a significant decrease from month 1 to month 3, $t(6) = 2.83$, $p < .05$, with six of seven subjects showing decreases across this time span (M = 6.25, SD = 3.76), while one subject showed an increase of 2.25 mmHg. Furthermore, diastolic blood pressure measured after exercise decreased significantly from month 1 to month 2, with six of seven subjects experiencing decreases, $t(6) = 2.22$, $p < .05$, M decrease = 3.58, SD = 2.49, and from month 1 to month 3, $t(6) = 3.73$, $p < .05$, when all seven subjects experienced decreases (M = 9.89, SD = 7.01). There was also a significant decrease in ADIA from month 2 to month 3, $t(6) = 3.01$, $p < .05$, when one subject experienced an increase of 0.75 mmHg, while all six others experienced decreases (M = 8.46, SD = 5.76).

Finally, pulse rate measured after exercise decreased significantly from month 1 to month 3, $t(6) = 2.80$, $p < .05$, with six of

Table 2

Physiological measures averaged by treatment month

| Measure | Treatment month: Month 1 | Month 2 | Month 3 |
|---|---|---|---|
| BSYS (systolic BP prior to exercise) | $132.14_{a}$ (13.77) | $127.61_{a,c}$ (15.01) | $127.00_{c}$ (15.67) |
| ASYS (systolic BP after exercise) | $139.54_{a}$ (9.00) | $138.61_{a}$ (13.57) | $131.57_{c}$ (10.83) |
| BDIA (diastolic BP prior to exercise) | $90.18_{a}$ (11.92) | $86.04_{a,c}$ (11.92) | $85.14_{c}$ (10.27) |
| ADIA (diastolic BP after exercise) | $95.25_{a}$ (15.16) | $92.54_{b}$ (13.62) | $85.36_{c}$ (11.64) |
| BHR (heart rate prior to exercise) | $82.43_{a}$ (7.39) | $81.00_{a}$ (10.18) | $77.71_{a}$ (15.36) |
| AHR (heart rate after exercise) | $102.32_{a}$ (10.25) | $100.29_{a}$ (11.44) | $93.93_{c}$ (14.22) |

Note. Means with different subscripts differ significantly at $p < .05$. Figures in parentheses indicate standard deviations.

seven subjects experiencing decreases ($M$ = 10.00, $SD$ = 7.32), and one subject experiencing an increase of 1.25 bpm. AHR also decreased significantly from month 2 to month 3, $t(6) = 2.17$, $p < .05$, with five of seven subjects experiencing decreases ($M$ = 9.65, $SD$ = 6.51), while the other two subjects showed increases of 1.50 and 2.25 bpm, respectively.

As can be seen from the pattern of results described above, almost all of the significant changes in physiological measures occurred between months 2 and 3 of the fitness training program; that is, none of the measures showed improvement from month 1 to month 2, with the exception of diastolic blood pressure measured after exercise (ADIA). This pattern of cardiovascular fitness improvements coincides substantially with the recommendations of the American College of Sports Medicine (ACSM, 1991). As will be noted later in the section on headache-related measures, this finding is particularly noteworthy in regards to the timing of any improvements, especially in light of the generally accepted hypotheses regarding physiological etiology and course of migraine headache.

Psychological Distress Data

The three measures of general psychological distress administered before and after the 12-week fitness program were the BDI, and the trait anxiety and trait anger subscales of the STPI (Appendix A). Interestingly (as decreases in psychological distress were expected as a result of treatment), each of these measures showed slight increases, although none of the increases would be considered significant increases from a clinical standpoint. Also, a floor effect may have minimized chances of observing a decrease, since these measures are generally used with clinical samples, and subjects in the present sample did not report elevated symptoms of psychological distress at the pretreatment evaluation.

Stress and Coping Data

Stress and coping measures included all subscales from the SOC, CSQ, HLOC-R, and TAHO questionnaires, each of which was administered both pre- and posttreatment (Appendix B). Of all these subscales, the following significant pre-post differences were observed: a) from the TAHO questionnaire, the subscale "constructive coping" increased from 18.29 to 20.71, $t(6) = 2.56$, $p < .05$, with six of seven subjects increasing, while the remaining subject showed a decrease of 2.00; and b) also from the TAHO, the subscale "social discord/irritation" increased from 9.71 to 12.43, $t(6) = 3.14$, $p < .05$, with six of seven subjects showing increases, while the other subject showed no change. In summary, it appears that over the course of the three-month-long aerobic fitness training, this group of chronic migraine sufferers experienced a tendency to increase two coping strategies/behaviors, namely constructive coping and social irritability.

Headache-Related Data

The most reliable and inclusive measure of headache activity is headache index, which incorporates frequency, intensity, and duration of all headache activity experienced on a weekly basis (Table 3). For these analyses, headache index (HINX) was averaged for each of the five months of the experiment, as follows: a month of baseline recording (BASHINX), the first month of exercise treatment

Table 3

Headache index means by month

| | Treatment month | | | | |
|---|---|---|---|---|---|
| Subject | Baseline | Mo. 1 | Mo. 2 | Mo. 3 | Post-tx |
| 01 | 2.83 | 2.95 | 2.37 | 2.69 | 4.17 |
| 02 | 1.02 | 0.35 | 1.48 | 1.37 | 0.50 |
| 03 | 5.39 | 3.97 | 4.61 | 5.27 | 5.74 |
| 04 | 3.49 | 0.96 | 2.30 | 3.05 | 0.44 |
| 05 | 0.12 | 0.19 | 0.05 | 0.00 | 0.11 |
| 06 | 2.55 | 1.20 | 1.58 | 2.49 | 2.95 |
| 07 | 0.50 | 0.12 | 0.59 | 0.20 | 0.14 |
| M | 2.27 | 1.39 | 1.85 | 2.15 | 2.01 |
| SD | 1.87 | 1.50 | 1.48 | 1.83 | 2.28 |

(TXHINX1), the second month of treatment (TXHINX2), the third month of treatment (TXHINX3), and a month of posttreatment recording (POHINX). In chronological order, the headache index means for each month of the experiment were 2.27, 1.39, 1.85, 2.15, and 2.00. Repeated measures t-tests performed on these month-by-month averages revealed the following differences.

There was a significant decrease from BASHINX ($M = 2.27$) to TXHINX1 ($M = 1.39$), $t(6) = 2.45$, $p < .05$, but not from baseline to any other month, indicating that all improvement in headache index came during the first month of exercise treatment. As mentioned above in the section on physiological data, there were no significant fitness improvements that occurred during the first month of treatment that could reasonably account for this observed decrease in headache index. This pattern of results represents a finding which may not be consistent with the currently accepted physiological theories of migraine, as the majority of physiological improvements (blood pressure and pulse rate) occurred during the second and third months of fitness training, as already noted. This somewhat puzzling finding will be further explored in the discussion section.

On an individual basis (Table 3), six of seven subjects experienced decreases in headache index from baseline to the third treatment month. In terms of percent decrease from baseline, these decreases were 5%, (34% increase), 2%, 12.6%, 100%, 2%, and 60%, respectively. However, from baseline to posttreatment, only four subjects experienced a decrease (47% increase, 51%, 6% increase, 87%, 8%, 16% increase, and 72%, respectively). The changes in headache index from treatment month 3 to the posttreatment month may have been due to the fact that only one subject continued to exercise on a regular basis following the three-month fitness training program.

The second headache-related variable is the peak intensity of headache pain experienced during each week (PEK; Table 4). Following the previously introduced naming convention, sequential months of PEK data are indicated by BAPEK (a month of baseline recording, $M = 6.84$), TXPEK1 (first month of fitness training, $M = 5.55$), TXPEK2 (second month of treatment, $M = 6.37$), TXPEK3 (third month of treatment, $M = 5.51$), and POPEK (a month of posttreatment recording, $M = 4.99$). A significant decrease, $t(6) = 2.90$, $p < .05$, was revealed from BAPEK to TXPEK1; from BAPEK to TXPEK3, $t(6) = 2.07$, $p < .05$, and from BAPEK to POPEK, $t(6) = 2.38$, $p < .05$. The only month that did not show a significant decrease from BAPEK was TXPEK2. Finally, none of the treatment months were significantly different from each other or from the month of posttreatment measurements (POPEK).

The above findings regarding peak headache intensity were somewhat more consistent both with predominant theory and among subjects than the headache index data, as indicated by the following: a) from baseline to the first month of treatment, six out of seven subjects experienced an average decrease of 1.50 in peak headache intensity, while the remaining subject showed no change; b) from baseline to the third month of treatment, six of seven subjects showed an average decrease of 2.20, while the seventh subject increased 0.25 to the maximum 10.00; and c) from baseline to posttreatment, six of seven showed an average decrease of 2.54,

Table 4

Peak weekly headache ratings by month

| | Treatment month | | | | |
|---|---|---|---|---|---|
| Subject | Baseline | Mo. 1 | Mo. 2 | Mo. 3 | Post-tx |
| 01 | 7.25 | 7.00 | 7.00 | 7.00 | 7.00 |
| 02 | 5.00 | 1.75 | 5.50 | 3.50 | 1.50 |
| 03 | 9.75 | 9.00 | 9.50 | 10.00 | 10.00 |
| 04 | 7.25 | 6.00 | 5.25 | 2.00 | 2.00 |
| 05 | 4.25 | 4.25 | 1.25 | 2.00 | 2.00 |
| 06 | 9.25 | 8.25 | 8.25 | 9.00 | 9.00 |
| 07 | 5.25 | 2.75 | 8.00 | 1.50 | 1.50 |
| M | 6.86 | 5.57 | 6.39 | 5.00 | 4.71 |
| SD | 2.13 | 2.75 | 2.73 | 3.59 | 3.81 |

while the seventh remained at 10.00. It appears that the aerobic fitness training was associated with a gradual and fairly consistent reduction in peak headache intensity experienced by six of seven subjects. It should also be noted that the subject who experienced an increase from baseline (9.75) to treatment month 3 (10.00) and the follow-up month (10.00) was a daily and chronic user of narcotic analgesics, among other headache-related medications. This issue will be further explored in the discussion section.

The final headache-related data concern the number of headache-free days per week (HFRE; Table 5). A significant increase in the number of headache-free days was observed between BAHFRE and TXHFRE1, $t(6) = 3.15$, $p < .05$, and between BAHFRE and TXHFRE2, $t(6) = 4.07$, $p < .05$. None of the other comparisons were significant. However, while the number of subjects experiencing an increase in the number of headache-free days dropped from six in the first two treatment months to five in the third treatment month and, finally, to four in the posttreatment month, those subjects who did show an increase experienced a gradual increase throughout the study. For these "successful" subjects, the average increase in headache-free days per week (again, from baseline) was 1.04 for the first month, 0.96 for the second month, 1.30 (NS) for the third month, and 2.00 (NS) for the posttreatment month. While POHFRE showed the greatest number of headache-free days ($M = 3.29$, $SD = 2.90$) of any of the five months during the study, excessive variability precluded statistical significance.

The last group of relevant symptom variables is reflected by weekly medication usage, including numbers of nonnarcotic

Table 5

Mean number of headache-free days by month

| | Treatment month | | | | |
|---|---|---|---|---|---|
| Subject | Baseline | Mo. 1 | Mo. 2 | Mo. 3 | Post-tx |
| 01 | 1.00 | 0.75 | 2.50 | 2.00 | 0.00 |
| 02 | 2.75 | 3.25 | 3.50 | 1.75 | 3.50 |
| 03 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 |
| 04 | 0.00 | 1.75 | 0.75 | 2.50 | 5.25 |
| 05 | 6.00 | 6.25 | 6.75 | 7.00 | 6.50 |
| 06 | 1.75 | 2.75 | 3.25 | 2.25 | 1.25 |
| 07 | 5.00 | 6.25 | 5.50 | 6.50 | 6.50 |
| M | 2.36 | 3.21 | 3.18 | 3.14 | 3.29 |
| SD | 2.37 | 2.29 | 2.41 | 2.60 | 2.90 |

analgesics (e.g., Tylenol, Advil, Motrin, etc.), narcotic analgesics (e.g., Fiorinal, Tylenol with codeine, etc.), and abortive medications (such as Cafergot) (see Table 6 for summary of medication data). No significant changes were found for any of these variables, perhaps reflecting the habitual nature of subjects' reliance on medication to manage their headaches.

However, a visual inspection of each subject's medication data revealed that for the one user of beta-adrenergic blockers (propranolol), his use of abortive medication decreased over the five months of the study, from an average of 5.75 pills per week during baseline to an average of 0.50 per week during the posttreatment month. His monthly intake averages for abortive medication (Cafergot) were, respectively, 5.75, 3.50, 3.50, 0.75, and 0.50.

Table 6

Medication intake across 5 study months

| Month of study | | Type of medication | | |
|---|---|---|---|---|
| | | Analgesics (N = 7) | Narcotic Analgesics (N = 7) | Abortives (N = 7) |
| Baseline | | | | |
| | Range | 0-22.00 | 0-13.75 | 0-5.75 |
| | Median | 7.00 | 0.25 | 0.00 |
| | Mean | 6.89 | 2.61 | 0.93 |
| | SD | 7.83 | 5.01 | 2.14 |
| Treatment Month 1 | | | | |
| | Range | 0-16.50 | 0-7.25 | 0-3.50 |
| | Median | 4.50 | 0.50 | 0.00 |
| | Mean | 6.79 | 1.39 | 0.96 |
| | SD | 7.10 | 2.64 | 1.65 |
| Treatment Month 2 | | | | |
| | Range | 0-15.00 | 0-10.25 | 0-3.50 |
| | Median | 10.50 | 0.00 | 0.00 |
| | Mean | 7.82 | 1.79 | 0.71 |
| | SD | 7.31 | 3.78 | 1.35 |
| Treatment Month 3 | | | | |
| | Range | 0-16.50 | 0-11.00 | 0-.75 |
| | Median | 10.00 | 0.00 | 0.00 |
| | Mean | 8.14 | 1.79 | 0.11 |
| | SD | 6.76 | 4.09 | 0.28 |
| Posttreatment | | | | |
| | Range | .25-20.75 | 0-16.50 | 0-1.50 |
| | Median | 3.25 | 0.00 | 0.00 |
| | Mean | 6.68 | 2.61 | 0.29 |
| | SD | 7.45 | 6.16 | 0.57 |

Note. There were no significant differences for any of the medication measures across study months.

## DISCUSSION

This study was designed as an initial attempt to investigate the effects of a systematic program of aerobic exercise on migraine headache symptoms in a formerly sedentary community sample of chronic migraine sufferers. Since the predominant theory of migraine etiology postulates the dysfunction of the cardiovascular vasomotor regulatory system, it was hypothesized that improvements in cardiovascular functioning (e.g., lower resting and post-exercise blood pressure and pulse rate) would be reflected in improvements in migraine symptoms, including both physical manifestations of the disorder (frequency, intensity, etc.) as well as psychological processes (distress, coping, etc.). It was hoped that if this program of aerobic fitness training was shown to coincide with improvements in migraine symptoms, then an additional modality would be available for treatment of this costly and debilitating disorder.

Prior to the current study, only one other controlled study had attempted to examine the relationship between aerobic fitness training and vascular headache symptoms (Fitterling et al., 1988), and that study was primarily designed to address the effectiveness of an exercise adherence treatment package with headache patients, while headache activity was analyzed as a secondary dependent variable. Other potential problems with the Fitterling et al. (1988) study include possible headache diagnosis inaccuracies, no ongoing physiological indicators of cardiovascular improvements, no assurances that subjects were exercising in their aerobic ranges, and a general lack of control over the nature and extent of subjects' exercise prior to and during treatment. The present study attempted to address each of these problems.

First, subjects were classified into headache types by clinical psychology graduate students trained in headache assessment, using strict IHS criteria, as described in the methods section. This classification was further corroborated by means of a computer program incorporating IHS criteria which has recently been developed by Penzien et al. (1991). Second, subjects in this study were not allowed to perform any exercise during the baseline phase, which removed the possibility that any treatment effects may have been due to benefits derived from exercise during that period. Third, subjects were required to complete all three of their weekly exercise sessions under the direct supervision of either the principal investigator or trained research assistants, thereby assuring greater confidence that the treatment under investigation was actually taking place, and was being performed in the proper manner. Fourth, physiological recording of blood pressure and heart rate was conducted before and after each exercise session, thus providing an ongoing direct measurement of physiological improvements as a result of fitness training. Finally, subjects were required to monitor their own pulse rate at least every 10 minutes during the aerobic phase of their exercise sessions, thereby ensuring that they were, in fact, exercising within their own aerobic range. Due to these various design improvements, it was anticipated that the present study would provide additional information concerning possible effects of aerobic fitness training on migraine headache.

Five separate categories of outcome measures were collected, each of which will be discussed separately: fitness test data, physiological measures, psychological distress measures, stress and coping measures, and headache measures. In essence, the first two categories represent manipulation checks, while the remaining three categories (in particular, headache measures) constitute the dependent measures of interest.

Fitness Data

Of the four measures included in the pre- and posttreatment fitness assessments, the estimate of maximal $VO_2$ increased significantly, while the time required to walk one mile "as fast as you can" showed a significant decrease. The average increase in $VO_2$ was 14.57% from pre- to posttreatment, with six out of seven subjects experiencing an increase (the remaining subject experienced a decrease of 10.24%). Since the equation used to calculate $VO_2$ estimates in this study was carefully derived and found to be highly correlated with actual oxygen consumption on a treadmill test (Kline et al., 1987), the significant $VO_2$ increase found in subjects in this study clearly indicates that the fitness training program was successful at altering subjects' cardiorespiratory fitness.

On the "time required to walk one mile" measure, the seven subjects demonstrated an average decrease of nearly two minutes, also clearly indicating that the exercise program improved physical fitness. An alternative interpretation of this finding, however, is that subjects gained substantial confidence in their ability to walk one mile at a rapid pace as a result of the three months of aerobic walking. Six out of seven subjects showed reduced times, including all five of the female subjects, whose mean age was 41 (SD = 8.34), with a mean weight of 160 lb (SD = 31.92). At the initial fitness assessment, many of the female subjects expressed at least some doubt regarding their ability to complete the one-mile walk test (neither of the two male subjects expressed similar doubts). At the posttreatment fitness assessment, on the other hand, all of the subjects appeared eager to demonstrate their improvement, and did not express any reservations regarding their ability to complete the one mile walk test.

Physiological Data

The most critical evidence demonstrating beneficial cardiovascular effects of the aerobic fitness training program was obtained from the three physiological measures (systolic and diastolic blood pressure, and heart rate) taken before and immediately following each exercise session throughout the 12 weeks of training. As expected, all six variables demonstrated substantial decreases, with five of the six reaching statistical significance (only heart rate prior to exercise did not reach significance). These significant decreases clearly demonstrate that the aerobic fitness training program was successful at inducing physiological improvements in subjects' cardiovascular performance. In fact, a close inspection of mean blood pressure figures in Table 2 reveals that subjects' third treatment month average systolic and diastolic blood pressures *after* exercise were lower than their respective blood pressures *prior* to exercise in the first month of fitness training. Clearly, the fitness training program utilized in this study produced the desired cardiovascular improvements sufficient to impact upon other related physiological mechanisms outlined in the introduction.

Psychological Distress Data

Analyses revealed that the aerobic exercise intervention was not effective at reducing psychological distress as it was measured in this study. This may have been because of the relatively small changes in headache activity following treatment. I am not aware of any studies showing decreases in psychological distress in the absence of associated decreases in headache activity. An alternative explanation is that since the aerobic exercise treatment did not specifically include components addressing subjects' stress management skills, no subsequent changes were noted in anger, depression, or anxiety.

In fact, this fitness program was possibly the most demanding treatment for their headache problem that each of these individuals had ever attempted or completed. In terms of effort expended, perhaps these subjects expected substantial improvements, and when none were immediately apparent, subjects may have felt some level of disappointment and/or frustration. This hypothesis may explain why the means for all three of these psychological distress measures were slightly higher following treatment than they were before treatment.

Stress and Coping Data

In general, findings from stress and coping data support the hypothesis offered in the previous section. Three of the four significant changes indicated increases in dysfunctional or negative coping techniques. These findings may, at least partly, be an artifact of the study's design. The initial psychological assessment was taken prior to the baseline recording month, before subjects focused increased attention on their headaches for the five months duration of the study. It seems possible that the mere acts of monitoring one's headaches and medication intake four times daily would serve to increase awareness of the negative impact of the condition on one's life. Furthermore, subjects may have experienced substantial conflicts in their normal daily routine as a result of having to exercise under the supervision of experimenters three times each week. This artificially high level of inconvenience, together with the daily self-monitoring, may have been at least partially responsible for the observed increases in catastrophizing, self-pity, and social discord. In other words, perhaps features of this experimental treatment program caused increases in a variety of coping processes, both "negative" and "positive."

On the other hand, the overall significant increase in constructive coping may be more strongly associated with some other aspects of the treatment. For example, perhaps subjects experienced a related increase in their level of self-efficacy (Bandura, 1977) regarding their ability to affect their headache symptoms as a result of treatment, which appeared on the coping measures as an increase in constructive coping. Another possibility is that the observed increase in cardiovascular fitness was somehow related to the observed increase in constructive coping.

Headache-Related Data

Within this final category of dependent variables were the three measures of headache symptoms (headache index, peak intensity, and number of headache-free days per week) and the average intake of headache medications. Data concerning peak intensity and number of headache-free days were generally supportive of the main hypothesis that improvements in cardiovascular fitness would be associated with reductions in headache symptoms. However, the headache index and medication data did not provide similar support for this hypothesis.

Overall, subjects experienced a general decrease in the peak intensity of headache pain over the course of the study. For the six out of seven subjects who reported lower peak intensity scores, the average decrease from the month of baseline to the month of posttreatment was 2.55, or approximately a 40% decrease. Furthermore, reductions in peak headache intensity occurred in a manner that was substantially congruent with the fitness improvement hypothesis. That is, except for the second month of fitness training, peak intensity scores demonstrated a steady decrease over the course of the study, as cardiovascular fitness improvements accrued.

However, even though posttreatment ratings continued to decrease, all but one subject discontinued exercise following the three months of supervised exercise sessions. In fact, only one subject (not the one who continued exercising) reported any change whatsoever in peak intensity ratings from the final treatment month to the posttreatment month, with a reduction from 3.50 to 1.50. In spite of these inconsistencies, in general it appears that adhering to an aerobic fitness training program for three months resulted in significant reductions in peak headache intensity ratings in this sample of chronic migraine sufferers.

Data concerning the number of headache-free days per week also offered support for the cardiovascular fitness hypothesis, but these data appeared to split the sample more noticeably than the peak intensity data. In other words, while those four subjects who continued to respond on this symptom dimension through the posttreatment month demonstrated a fairly steady increase in the number of headache-free days throughout the study (increase of two days), three other subjects experienced fewer headache-free days (decrease of 0.5 days). It appears that a majority of subjects experienced a substantial increase in the number of headache-free days as a result of treatment, while others either experienced no increase or a slight decrease.

The two headache-related measures discussed above represent clinically important dimensions for chronic headache sufferers, as reductions in peak headache intensity of 25% and/or a gain of two headache-free days per week both represent extremely desirable lifestyle improvements. These changes are particularly noteworthy in light of the fact that four out of seven subjects experienced both of these improvements. For these four subjects, their average reduction in peak headache intensity from baseline to posttreatment was 3.69 ($\underline{SD}$ = 1.23), while their average increase in headache-free days was 2.00 ($\underline{SD}$ = 2.21).

The one subject who benefitted the most overall from this treatment was a 55-year-old female who experienced both a reduction in peak intensity of 5.25 and a simultaneous increase in headache-free days of 5.25. Clearly, for this individual, the aerobic fitness training program resulted in extremely desirable changes in the topography of her migraine symptoms. Although much research will be needed to further clarify the nature of benefits derived from this type of treatment, this woman's remarkable improvements suggest that aerobic fitness training may prove to be an important alternative and/or adjunct treatment for certain individuals.

In general, headache index is regarded as the most reliable measure of headache activity, as this measure incorporates several characteristics (frequency, intensity, and duration) of an individual's weekly headache symptoms. Although the average headache index was lower than baseline levels during each month of treatment and posttreatment, only the first treatment month was significantly lower than baseline. As noted in the results section, this significant decrease in headache index noted in the first month of fitness training cannot be wholly accounted for by improvements in cardiovascular fitness, since subjects had just begun aerobic training. However, this negative finding regarding headache index should not obscure the observed improvements mentioned above concerning peak intensity and number of headache-free days. It appears that in this sample of migraine sufferers, although headache index did not show improvements that coincided with cardiovascular improvements, two other clinically important measures did show improvement subsequent to physiological fitness training effects. It seems possible, if not likely, that the initial reduction in headache index was due to subjects' expectation that their efforts were resulting in some overall improvements. Timing of the significant decrease in headache index (during the first treatment month only) parallels that found in at least two studies (Doyne et al., 1983; Fremont & Craighead, 1984) investigating effects of exercise on depression.

The final group of outcome measures includes the three categories of headache-related medications: non-narcotic analgesics, narcotic analgesics, and abortive medications. There were no statistically significant differences observed for any of these three variables, suggesting that the fitness training had no effect on medication usage. This finding is particularly interesting in light of the significant improvements found for two out of three headache symptom measures (peak intensity and number of headache-free days). In spite of these symptom improvements, subjects in this sample continued to consume virtually the same amounts of headache medications. Together, these findings tend to confirm the habit strength of medication consumption. Although subjects may have perceived the medication as contributing to their improvements, most research (Baumgartner, Wessely, Bingol, Maly, & Holzner, 1989; Diener, et al., 1989) suggests that chronic analgesic intake is not only ineffective in reducing migraine symptoms, but may actually exacerbate symptoms. Furthermore, it may be that subjects' continued daily (or near daily) consumption of either nonnarcotic or narcotic analgesics may have suppressed additional effects of the fitness treatment. Four of the seven subjects in this study consumed nonnarcotic analgesics throughout the study in quantities sufficient to meet criteria for IHS 8.2.2 "analgesics abuse headache," while one of these four subjects also ingested between one and two narcotic analgesics per day, on average, throughout the study ($\underline{M}$ = 11.75 per week). It should be noted, however, th[illegible]s headache classification can only be confirmed if, upon cessat[illegible] all analgesics, the headache disorder substantially improves. It is certainly possible that cessation of these medications prior to participating in an aerobic training program may result in significant reductions in headache index in addition to the other headache symptom improvements already noted in this study.

Summary of Findings

In spite of the prevalence of migraine headaches in our society (10%; Stewart et al., 1992), and a vigorous campaign designed to attract research participants, this study experienced a surprisingly low rate of response to advertisements for a free chronic headache treatment. In a city of 45,000 people, roughly 4,500 could be expected to suffer from migraine, yet only 300 individuals responded to a variety of announcements. Furthermore, after being told the nature of the treatment being offered, only a fraction (25%) of the original 300 agreed to come to the clinic for the headache assessment. Finally, of the 37 individuals who completed the headache assessment and were subsequently classified as migraine sufferers, only 12 began treatment. Therefore, of 4,500 potential participants, only 12 (.27%) actually initiated treatment, with seven going on to complete treatment (.16%). This extremely low participation rate should serve as a caution to those who would proclaim the potential benefits of exercise as a treatment for chronic migraine sufferers (e.g., Diamond, 1992). Anecdotally, our efforts to recruit participants in this study seemed to encounter markedly increased resistance as soon as potential participants learned that the treatment was a 12 week program of aerobic exercise. A large body of research exists concerning the difficulty of increasing exercise activity in the general population (Dishman, 1990, 1991; King et al., 1992). It is possible that increasing physical activity may be even more problematic with chronic migraine sufferers than in the general population.

For this group of seven chronic migraine sufferers, the 12-week aerobic fitness training program succeeded in producing the desired cardiovascular benefits, as evidenced by significant changes in blood pressure and heart rate from the beginning to the end of treatment. These physiological benefits were also evident on the pre- and posttreatment fitness tests, as both $VO_2$ and time to complete a one-mile walk showed significant improvement. Therefore, the physiological changes observed verified that fitness training was effective in altering subjects' cardiovascular response to exercise.

The treatment used in this study did not affect levels of psychological distress (depression and anxiety), which is not surprising, given that the associated changes in headache activity were relatively small and that no distinctly psychological treatment component was included. However, there were significant increases in several coping subscales, one of which is generally considered dysfunctional (social discord/irritation), and one which is a more positive coping strategy (constructive coping). As already mentioned, it seems possible that the treatment itself was stressful and somewhat aversive, resulting in the observed increase in negative coping (social discord/irritation). It also seems possible that the increase in "constructive coping" was a result of the ineffectiveness of other strategies to resolve ongoing stressful demands. Another possible explanation is that the treatment simply increased all forms of coping.

For the seven subjects in this study, there was a significant decrease in peak headache intensity experienced, as well as a significant increase in number of headache-free days per week, as a result of treatment. These findings indicate that a program of moderate aerobic exercise, by itself, can significantly improve headache symptoms for at least some chronic migraine sufferers. However, the negative findings concerning headache index do not support the overall utility of aerobic fitness training as a treatment for migraine headache. Further research is needed before definitive statements can be made concerning whether this treatment is effective, for whom it is most likely to be effective, what dosage is required, etc.

Weaknesses of Present Study

One apparent weakness of the present study is its lack of a control group. However, a recent meta-analytic review (Holroyd & Penzien, 1990) of clinical trials of pharmacological and non-pharmacological prophylaxis for recurrent migraine revealed that groups that received no treatment or placebo treatment experienced no significant improvements (average untreated groups' percentage improvement ranged from 0.2 [N = 15 groups] to 1.1 [N = 17], while placebo groups' improvement ranged from 11.9% [N = 15] to 12.2% [N = 20]). Therefore, the effective control group for the present study is comprised of all those subjects in previous studies that received no treatment and showed no improvement. Others (Parloff, 1986) have argued that in experimental designs where effects of no treatment are well established (as is apparent in the case of migraine headache), placebo control groups are not only not necessary, but may even be irrelevant, unethical, inefficient, and may preclude more useful and veridical findings from emerging from experiments.

This study attempted to rigorously control several research variables in order to provide a more definitive examination of the effects of aerobic fitness training on migraine headache symptoms. Perhaps partially as a result of this experimental rigor, relatively few potential participants (25% of respondents) agreed to enter the study, even for an initial assessment, still fewer decided to begin the fitness training, and only seven completed the full three months of training. It seems probable that these seven subjects represent a select group of migraine sufferers who, compared to the population of chronic migraine sufferers, were either a) more committed to finding ways to manage their disorder, b) more desperate for symptom relief, c) more receptive to exercise, or d) possessed some combination of these and/or other characteristics that differentiated them from the general population of migraine sufferers. In order to make more reliable inferences to the general population of migraine sufferers, more subjects are needed to complete a program of aerobic fitness training, and these subjects will need to be more representative of the general population of chronic migraine sufferers.

Another weakness of the present study is the liberal interpretation of inferential statistics. Because of my use of one-tailed t-tests, lack of statistical correction (such as Bonferroni's) for use of a large number of statistical tests, and the aforementioned probability of self-selection bias of the relatively small sample, I strongly advise that the results of this study be interpreted with caution. Specifically, I would advise against extrapolating these findings as a means to guide treatment recommendations for the general population of migraine sufferers. Any such use of these findings would be at least premature, and possibly wholly inaccurate.

This study is also unable to address the issue of whether self-efficacy, or some other psychological construct, contributed to any of the observed treatment gains. Of particular interest would be additional information that might offer some clues as to why the observed decrease in headache index occurred during the first month of treatment. If this phenomenon is a reliable one, then research should be designed in such a way as to try to explain what processes are responsible for this apparently nonphysiological improvement.

Although the physiological data indicate that the fitness training was successful in increasing cardiovascular fitness, the process by which subjects were determined to be exercising in their aerobic range was not precise. Occasionally, both subjects and research assistants forgot that subjects were supposed to measure pulse rate every ten minutes. It would have been preferable if some sort of ambulatory monitoring device had been available to ensure that subjects were walking at an aerobic pace at all times in their exercise sessions, thus ensuring that the target of treatment was, in fact, being accomplished.

Future Directions

Similar studies ought to include some sort of additional, tangible incentive to encourage potential participants to agree to initiate and complete the required 12 weeks of fitness training. Such incentives might include a cash bonus at the conclusion of training, several smaller prizes at predetermined intervals during training, or some other means of enticing individuals to participate. If future studies are to be able to satisfactorily answer the question of the efficacy of exercise in chronic headache treatment, then sufficient power will need to be attained, and since treatment effects appear to be moderate and variable across individuals and studies, substantially more subjects will be required to complete an adequate fitness training treatment program.

The timing of the observed decrease in headache index in the present study highlights the need for between groups research, similar to the design employed by Martin et al. (1990). Other non-exercise variables, such as self-efficacy, should be repeatedly monitored to establish the role, if any, of those variables in headache improvements that cannot logically be attributed to fitness improvements. The scope of such a design requires significant resources in terms of experimenters' time, equipment, and subject availability.

Another issue to be addressed in future research is the task of determining if fitness training is appropriate as a headache treatment for some individuals, but not others. If it were shown that only a subset of migraine sufferers improve as a result of training (as occurred in the present study), then researchers would need to determine what, if any, individual characteristics predict treatment response.

While many questions concerning the efficacy of exercise as a treatment for migraine remain unanswered, the present study offers support for the hypothesis that improvements in cardiorespiratory functioning have beneficial effects on various aspects of individual's headache symptom patterns. However, due to a relatively small sample size and other design characteristics, it represents a mere beginning in our quest for definitive knowledge about exercise as a treatment for migraine headache. Much more research is needed if we are to gain a fuller understanding of how exercise can be best utilized, who is likely to benefit from exercise, when to introduce treatment and when to expect improvements as a result of treatment, what are the essential components of treatment efficacy, what type of exercise program is maximally effective, and many other remaining issues.

APPENDIX A

MEANS AND STANDARD DEVIATIONS OF

PSYCHOLOGICAL DISTRESS DATA

| | Treatment phase | |
|---|---|---|
| Construct | Baseline | Posttreatment |
| Depression[a] | 6.71 (5.62) | 8.29 (6.75) |
| Trait Anxiety[b] | 15.29 (7.68) | 18.86 (6.04) |
| Trait Anger[b] | 12.00 (4.76) | 15.71 (3.45) |

Note. Figures in parentheses indicate standard deviations.

[a]Measured by BDI

[b]Measured by STPI

# APPENDIX B
## MEANS AND STANDARD DEVIATIONS OF STRESS AND COPING DATA

| | Treatment phase | |
|---|---|---|
| Variable (Instrument) | Baseline | Posttreatment |
| Daily Stress-total (DSI) | 29.71 (17.12) | 49.57 (35.55) |
| Sense of coherence-total (SOC) | 134.71 (49.80) | 133.29 (21.31) |
| Diverting Attention (CSQ) | 13.43 (5.77) | 13.29 (6.85) |
| Reinterpreting Pain Sensations (CSQ) | 6.29 (7.65) | 10.43 (12.14) |
| Catastrophizing (CSQ) | 8.71 (6.55) | 12.29 (8.06) |
| Ignoring Sensations (CSQ) | 14.29 (7.85) | 15.57 (6.32) |
| Praying or Hoping (CSQ) | 14.00 (6.19) | 14.71 (8.20) |
| Coping Self-Statements (CSQ) | 17.00 (5.63) | 17.43 (6.60) |
| Increased Behavioral Activity (CSQ) | 11.43 (3.91) | 12.00 (6.43) |
| Control Over Pain (CSQ) | 2.29 (0.95) | 2.29 (0.76) |
| Ability to Decrease Pain (CSQ) | 2.71 (0.95) | 3.29 (1.50) |
| Internal Locus of Control (HLOC-R) | 2.60 (0.69) | 2.26 (0.89) |
| External-Chance (HLOC-R) | 2.91 (1.23) | 2.40 (0.97) |
| External-Professional (HLOC-R) | 1.66 (0.75) | 1.74 (0.53) |
| Environmental Withdrawal (TAHO) | 18.71 (3.55) | 19.57 (3.31) |
| Catastrophizing (TAHO) | 17.86 (5.27) | 17.00 (3.00) |
| Self-Denigration (TAHO) | 6.00 (2.58) | 6.00 (2.52) |
| Helplessness/Self-Efficacy (TAHO) | 19.86 (2.67) | 19.29 (3.45) |
| Fear of Social Consequences (TAHO) | 14.71 (7.87) | 17.14 (4.71) |
| Constructive Coping (TAHO)* | 18.29 (6.08) | 20.71 (6.78) |
| Why Me? (TAHO) | 7.86 (3.98) | 9.86 (4.14) |
| Pain Approach/Avoidance (TAHO) | 15.71 (7.06) | 14.14 (1.35) |
| Social Discord/Irritation (TAHO)* | 9.71 (3.73) | 12.43 (3.95) |
| Anger Over Headache (TAHO) | 11.57 (5.47) | 12.00 (4.32) |
| Wishful Thinking (TAHO) | 12.29 (2.43) | 12.29 (2.87) |

Note. * indicates that means differ significantly at $p < .05$.
Figures in parentheses indicate standard deviations.

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