Psychophysiological reactivity to stress and aerobic fitness

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ストレス負荷に伴う生理心理学的反応性と有酸素作業能

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Introduction

Stress is one of the most serious problems of society. Although a number of ways to define stress have been undertaken (Apply and Trumbull, Cox, Lasarus, Selye), there is not a clear definition of the word “stress”. The most important reason for this may be the variety of considerations taken when discussing stress: type of stressor (e.g., physical, psychological, and physiological), the direction (e.g., internal and external stimulus), and the source (e.g., death of spouse, change in environment, and overload). Recently, stress has been considered an area of study which includes the dimensions of stimulus, response and intervening variables. Therefore, a multidimensional approach has been needed (Everly and Rosenfeld, Garrison). This approach to stress assumes the interconnectedness of mind and body such that no mental activity occurs without corresponding somatic activity and vice versa. Garrison defined...
stress as a psychophysiological reaction to an internal or external stimulus, determined to be a stressor through cognitive appraisal. It has been shown that psychological stress influences various physiological changes in humans (e.g., Burchfield12)). Therefore, frequent psychologically stressful situations may be subsequently associated with a variety of psychosomatic diseases (Girdano and Everly58)).

To clarify the relationship between psychological and physiological measures, the psychophysiological approach has been at the center of stress study. As a psychophysical approach to stress, the stress profile procedure has been widely adopted since Lacy and Lacy46) found evidence for what they termed response stereotype in the normal population.

These investigations have focused on typical behaviors related to cardiovascular disease, such as Type A behavior (e.g., Jamieson and Lavoie69), the tendency for hypertension (e.g., McGann and Matthews56) and cigarette smoking (e.g., Emmons and Weidner28)). This approach may lead to the development of various diagnostic measures concerning psychological problems. For example, Takenaka et al.78) performed an experiment comparing American and Japanese students at an American university. They measured their physiological reactivity to psychological stress in order to examine the stress in adjustment to a new culture (Takenaka and Zaichkowsky77)). Results revealed that Japanese students showed greater reactivity than Americans to psychosocial stress, especially in English reading tasks and in stressful imagination tasks. They suggest that this procedure would be useful in learning to cope with the stress of acculturation.

The magnitude or pattern of autonomic response has been associated with the adaptiveness of an individual’s coping style (Light50). For example, Schwartz et al.67) reported that affective imagery was an efficient strategy for inducing reliable patterns of systolic and diastolic blood pressure (SBP, DBP) and heart rate (HR) associated with particular emotional states. In their experiment, the imagery of anger produced the greatest cardiovascular response in SBP, DBP and HR, while the relaxation imagery showed the smallest responses. Thus, as a direct coping procedure, relaxation and biofeedback trainings have been used to reduce or stabilize individual physiological reactions to everyday life.

Recently, the relationship between fitness level and reactivity to stress has been investigated (e.g., Holmes and McGilley38), Shulhan et al.71), Sinyor et al.73)). Such investigations have focused on cardiovascular responses, such as HR and blood pressure to psychological stress (Crews and Landers21), DeBenedette23)). It is well known that increasing the aerobic fitness level through endurance training decreases the workload and increases the efficiency of cardiovascular response to physical stressors. This enhanced efficiency includes increases in oxygen uptake, stroke volume and cardiac output, as well as decreases in HR at rest and at any given submaximal level of oxygen uptake (Blomqvist and Saltin48), and rapid HR recovery (Shephard70)). Therefore, it is possible that the aerobic fitness level influences cardiovascular reactivity to psychological as well as physical stressors.

The autonomic nervous system (ANS) consists of the sympathetic (SNS) and parasympathetic (PNS) nervous systems. The systems generally have opposite effects on a particular organ of function (Jone-Witters and Witters43)). For example, PNS slows HR while SNS accelerates it. Although physiological changes in aerobic fitness are produced by a complex set of central and peripheral mechanisms at structural, metabolic, and regulatory levels, it is thought that aerobic fitness enhances PNS drive or decreases SNS drive (Shulhan et al.71)). In terms of this viewpoint, physiological reactivity to psychological stress as a function of the aerobic fitness level may be significant because of its application to coping with stress.

These investigations have dealt with various physiological responses during and following the exposure to stressors in a laboratory. Some investigators have looked at the effect of aerobic fitness on the magnitude of reactivity.
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During exposure to stressors (e.g., Cantor et al., Holmes and Roth, Light et al.), while others have studied the recovery time (e.g., Cox et al., Brooke and Long, Sinyor et al.). For example, Holmes and Roth found that highly fit subjects evoked a smaller HR increase in response to stress (recall of digits backwards) that did unfit subjects. Hull et al. also reported that relative diastolic response to a stressful film and the Stroop task was smaller in fit subjects than in less-fit subjects, with both groups over 40 years old.

Several researchers have found a rapid recovery of physiological response following stress exposures. Cox et al., using tonic HR as the criterion variable, found a large negative correlation between recovery HR and aerobic power. Sinyor et al. performed more expanded measurements to examine other physiological reactions to psychological stress. They showed that highly fit subjects had higher levels of norepinephrine and prolactin early in the stress period, more rapid HR recovery following the stressors, and lower levels of anxiety at the conclusion of the session.

It is clear from the literatures that aerobic exercise can be a stress coping method as well as a method for improving overall fitness. In spite of the positive results, there are some questions concerning the findings of these studies. For example, Dorheim et al. were not able to find differences between marathoners and untrained subjects in HR and stroke volume when exposed to psychological stress. Although careful statistical controls were applied to physiological data, there were some negative reports. Plante and Karpowitz failed to find differences among groups when statistically controlling for the baseline/anticipation-of-stressors physiological measures. Furthermore, even though Roth used the analysis of covariance to control for baseline differences, he could not find evidence to obtain that exercise influenced cardiovascular reactivity to mental stressors. The difference in results may be attributed to procedural variations in each experiment.

To help explain reasons for variation in results, the following items, as evidenced from the literature review, are compared in the following sections: experimental design, nature of stressor, physiological measure, and psychological measure. Even though these investigations have focused on reactivity as a function of aerobic fitness itself, there have been several studies directly related to cardiovascular disease in terms of clinical (hypertension) and behavioral (Type A pattern) attitudes. As such, these studies are reviewed separately because of their different purposes in the reactivity study concerning aerobic fitness. Furthermore, although these types of investigations have been performed under laboratory situations, the focus is on whether aerobic exercise training is a practical way to cope with stress in daily life. As such, the relationship between long term life stress and aerobic fitness is briefly discussed.

Review of Literature

Reactivity and aerobic fitness

To date, there have been nineteen published papers that have examined the relationship between aerobic fitness and reactivity to stress. Table 1 summarizes these studies.

1. Experimental design

Essentially three types of experimental designs have been used to address this problem: correlational, cross-sectional, and longitudinal. Cox et al. found a large correlation (-0.54) between aerobic capacity and recovery HR following the exposure to stressors. Furthermore, Hollander and Seraganian also reported large correlations between aerobic capacity and HR (-0.49), and skin conductance level (-0.56) during the recovery period following a cognitive task (word rhyming task). Their results indicate that subjects with a high aerobic capacity can recover more quickly from the effects of psychosocial stressors than subjects with a low aerobic capacity. On the other hand, Sothmann and Ismail failed to show the effects of physical fitness by analyzing urinary samples during resting (after sleep) and occu-
Table 1. Physiological reactivity to psychological stress as a function of aerobic fitness.

<table>
<thead>
<tr>
<th>Study</th>
<th>Subject</th>
<th>Physiological measure</th>
<th>Psychological measure</th>
<th>Stressor</th>
<th>Criteria of fitness level</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantor et al. (1978)</td>
<td>36 female and 36 male undergraduates</td>
<td>SBP, HR, ST</td>
<td>rating forms of</td>
<td>medical and erotic films</td>
<td>low-fit subjects:</td>
<td>low-fit subjects:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>subjective physiological and emotional responses</td>
<td>a median split of physiological response</td>
<td></td>
<td>SBP increases, ST decreases no difference in self-ratings</td>
</tr>
<tr>
<td>Cox et al. (1979)</td>
<td>41 male and 29 female undergraduates</td>
<td>HR</td>
<td>questionnaire</td>
<td>subtests from the WAIS Stroop color-word task</td>
<td>submaximal test</td>
<td>aerobic power × resting HR −0.43 × recovery HR −0.54</td>
</tr>
<tr>
<td>Sinyor et al. (1983)</td>
<td>15 highly trained and 15 untrained subjects from pool of participants</td>
<td>HR, biochemical measures</td>
<td>subjective arousal level, STAI, aerobic points, performance of task</td>
<td>arithmetic, Electrocardiogram Quiz, Stroop color-word task</td>
<td>submaximal test</td>
<td>trained subjects: higher levels of NE and prolactin early in the stress period rapid HR recovery decreased post-STAI</td>
</tr>
<tr>
<td>Hollander &amp; Seraganian (1984)</td>
<td>10 male and 9 female adults</td>
<td>HR, SCL</td>
<td>nothing</td>
<td>word rhyming task</td>
<td>submaximal test</td>
<td>during recovery: aerobic fitness HR × −0.49 × SCL −0.56</td>
</tr>
<tr>
<td>Dorheim et al. (1984)</td>
<td>12 male marathoners and 12 untrained subjects</td>
<td>HR, stroke volume</td>
<td>nothing</td>
<td>tilt test, video game, cold pressor, RT test</td>
<td>marathoner run 40-50 miles/week</td>
<td>no difference</td>
</tr>
<tr>
<td>Hull et al. (1984)</td>
<td>35 male and 20 female adults</td>
<td>HR, SBP, DBP, biochemical changes in blood</td>
<td>film, Stroop color-word task, cold pressor, treadmill run until exhaustion</td>
<td></td>
<td>fit-subjects over 40 yr: smaller DBPs to stress</td>
<td></td>
</tr>
<tr>
<td>Keller &amp; Seraganian (1984)</td>
<td>Exp. I: 45 male adults (still trained, training, and untrained groups for 9 weeks)</td>
<td>EDR, HR recovery time</td>
<td>nothing</td>
<td>bolt head maze, Stroop color-word test</td>
<td>participation in aerobic program HR recovery time following step test</td>
<td>trained subjects: faster EDR recovery</td>
</tr>
<tr>
<td></td>
<td>Exp. II: 30 male and 30 female adults (exercise, music, or meditation groups for 10 weeks)</td>
<td></td>
<td></td>
<td>Raven's progressive matrices, mirror star tracing, block design, digit span, Stroop color-word, bolt head maze</td>
<td></td>
<td>participants in the exercise faster recovery in EDR</td>
</tr>
<tr>
<td>Sothmann &amp; Ima Eli (1984)</td>
<td>34 healthy males</td>
<td>Urinary CA (N M, MHPG)</td>
<td>MPI</td>
<td>occupational situation</td>
<td>submaximal test</td>
<td>no effect of physical fitness in urinary CA metabolities</td>
</tr>
<tr>
<td>Holmes &amp; Roth (1985)</td>
<td>10 high-fit and 10 low-fit subjects from 72 male undergraduates</td>
<td>HR</td>
<td>subjective cognitive and somatic arousal</td>
<td>memory test from the WAIS</td>
<td>submaximal test</td>
<td>high-fit subjects: smaller HR increase in response to stress but not their subjective responses to stress no difference during recovery</td>
</tr>
<tr>
<td>Shulhan et al. (1986)</td>
<td>24 males (high and low fitness groups)</td>
<td>HR, TWA</td>
<td>nothing</td>
<td>mental arithmetic (hard to easy)</td>
<td>submaximal test (CHPT)</td>
<td>no difference of HR low fitness group greater TWA attenuation</td>
</tr>
<tr>
<td>Sinyor et al. (1986)</td>
<td>38 subjects from 43 males (VO2 max &lt;38 ml/kg/min aerobic training 15, anaerobic training 15, walking list control, for 10 weeks)</td>
<td>est. VO2 max body fat, SBP, DBP, HR</td>
<td>subjective arousal level, STAI daily hassles and uplifts scales, Hopkins system checklist, coping resource scale</td>
<td>arithmetic, Electrocardiogram Quiz, Stroop color-word task</td>
<td>submaximal test</td>
<td>aerobic trainers: fitness improvement tended to correlate with faster HR recovery following psychosocial stress</td>
</tr>
<tr>
<td>Homes &amp; McGilley (1987)</td>
<td>34 high-fit and 34 low-fit undergraduates (half of high and low-fit subjects participated in a 13-week aerobic training program)</td>
<td>12 min run, HR</td>
<td>subjective cognitive and somatic arousal assessment</td>
<td>memory subtest from WAIS</td>
<td>questionnaires, 12 min run test</td>
<td>low-fit subjects: greater HR response to stressor in the pretest the training program reduced HR response of low-fit subjects to stressor no differences of arousal assessments</td>
</tr>
</tbody>
</table>
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Sothmann et al. (1987) 10 high-fit and 9 low-fit adults from 65 volunteers (psychological screening: > 34 on STAI physiological screening: high-fit: > 55 ml/kg/min; low-fit: < 50 ml/kg/min) plasma CA, HR RT of the task, cognitive performance (anagrams), POMS, STAI a well-learned Stroop color-word test, anagrams exhaustion test low-fit group: longer to complete the first set of anagrams greater NE but not E response no-difference of self-report, HR and RT

Light et al. (1987) 174 male undergraduates (low exercise: 0-19 points, 56; moderate exercise: 20-63 points, 59; high exercise: > 83 points, 59 by using Cooper’s aerobic points) HR, SBP, DBP, pre-ejection period parental health questionnaire RT task involving the threat of shock, foot immersion cold pressor test, mild exercise Cooper’s aerobic points low-exercise subjects greater myocardial responses to the mild exercise and RT tasks

Brooke & Long (1987) 9 high-fit and 9 low-fit males HR, catecholamines, cortisol mood checklist, perceived efficacy rappelling task exhaustion test a median split of 52 ml/kg/min of VO2 max high-fit group: faster recovery from subjective anxiety more efficient recovery for relative plasma E when statistically controlling for the baseline/anticipation of-stressors, no difference in physiological measures among groups

Plante & Karpowitz (1987) 107 males (intense exercisers, 35; moderate exercisers, 36; nonexercisers, 36) from 509 undergraduates pulse rate, pulse volume, SRA personal measures, life stress measures, hobby hours, aerobic points electric shock, intelligence questionnaire no mood effect no difference in physiological measures between activity status groups

Roth (1989) 40 female and 40 male college students HR, SBP, DBP POMS digits backward test, arithmetic Exercise Participation Questionnaire no mood effect no difference in physiological measures among groups when statistically controlling for the baseline, lower HR during for the athlete group no difference in EMG between groups

Takenaka (1990) 18 aerobically trained athlete and 18 sedentary subjects HR, trapezius EMG arithmetic, start-trace task training self-report when statistically controlling for the baseline, lower HR during for the athlete group no difference in EMG between groups

Takenaka & Zaichkowsky (1992) 24 females (jogging: 8, biofeedback: 8, control: 8, for 4 weeks) HR, SCL, ST subjective estimation of stress, STAI arithmetic all of novices jogging group: lower HR during recovery period following stress exposure than other groups

pational periods. They found no significant correlations between physical fitness and the urinary concentrations of 3-methoxy-4-hydroxyphenylglycol, normetanephrine, and metanephrine.

The cross-sectional design compares high- with low-fit subjects in physiological responses. Most studies have been of this type. Generally, suitable subject groups that have low and high aerobic capacities have been chosen from recruited participants according to maximum oxygen uptake (VO2 max) by using a submaximal or an exhaustion test. For example, Sothmann et al.79 used an exhaustion test and chose ten high-fit and nine low-fit subjects from 65 volunteers. The high-fit subjects had a mean VO2 max of 65.4 ml/kg/min, while the low-fit subjects had a mean VO2 max of 44.6 ml/kg/min. In the report of Sinyor et al.72, there is a large difference of VO2 max between high- and low-fit groups (high: 69/1 ml/kg/min; low: 32.8 ml/kg/min). Besides VO2 max, some researchers used other physiological measures. Keller and Seraganian40 used HR recovery time following a step test, and Holmes and McGilley38 adopted the 12-minute run test as their physiological aerobic fitness index.

Another method of selecting subjects was to divide the participants at the median split from the results of physiological response testing (Brooke and Long77; Cantor et al.13; Shulhan et al.71). Unfortunately, there is a small difference of VO2 max between high- and low-fit groups in these experiments (Brooke and Long77, high:
58.0 ml/kg/min; low: 48.0 ml/kg/min; Shulhan et al.71, high: 54.6 ml/kg/min; low: 44.0 ml/kg/min). Therefore, this method of choosing subject groups may not be suitable for defining high- or low-fit subjects because of the small difference of VO₂ max between the two fitness groups.

The final selective method was the use of a questionnaire. Light et al.51 and Plante and Karpowitz58 chose subjects by using Cooper's aerobic points (Cooper17,18). As a different questionnaire, Roth67 had his subjects complete the Exercise Participation Questionnaire (by Roth and Fillingim64) to obtain a measure of current exercise activity. Although each of the experimental groups consisted of a large number of subjects, physiological confirmation of the aerobic fitness level was not performed. Thus, this may not prove to show accurate effects of the difference in aerobic fitness.

Finally, there are some reports that high-fit subjects are selected from athletes. For example, Dorheim et al.26 used marathoners as the high-fit subjects. Takenaka80 also compared aerobically trained athletes with sedentary subjects in reactivity to laboratory stressors. As a result, he suggests that athletes may be inappropriate subjects to examine physiological reactivity as a function of aerobic fitness, in spite of their superiority, because of the inconsistency of reactivity and anxiety level. It may be different for the norms to choose appropriate subjects in terms of definition of high-fit.

Designs other than correlational ones have also been used. Holmes and McGilley38 examined the difference between their high- and low-fit subject groups on HR and subjective responses to a psychological stressor (recall of digits backwards test). Half of each subject group underwent a 13-week aerobic exercise program. Although the low-fit subjects showed a greater HR response to the stressor than the high-fit subjects in the pretest, the low-fit subjects who participated in the training program could reduce their HR responses to the stressor after the 13-week period.

In relation to the nature of exercise, Sinyor et al.73 compared the effect of HR and subjective response to psychological stress exposure in the laboratory. They made assessments prior to and following 10 weeks of training with aerobic, anaerobic (weight-lifting) and control groups. They found that fitness improvement tended to correlate with faster HR recovery following psychological stress only for aerobically trained subjects. Keller and Saragianian44 also found that participants in a 10-week aerobic exercise showed faster recovery in electrodermal response (EDR) to stress compared to participants in a 10-week music appreciation and meditation course. In addition, Takenaka and Zaichkowsky79 reported that aerobic training group more improved HR, skin conductance level, and skin temperature (ST) reactivities during recovery period following the stress exposure after only 4-week jogging program, compared to biofeedback assisted relaxation and control groups.

2. Nature of stressor

In this section, the word “stressor” will be used as a stimulus which leads to physiological reactivity in laboratory-related settings. Thus, the nature of stressor is essentially different from daily life stress for individuals.

A variety of different stressors have been used in reactivity studies. Although common stressors such as the Stroop color-work, memory, and arithmetic tasks have been used, most stressors depend on each experiment’s procedure. Therefore, the intensity of the stressor may be attributed to the content. For example, a reaction task involving the threat of shock (Light et al.51) and electric shock (Plante and Karpowitz58) may give subjects tremendous psychological stress. Outside the laboratory, occupational situations (Sothmann and Ismail74) and rappelling tasks (Brooke and Long75) were used as psychosocial stressors. Sinyor et al.73 noted that since subjects may be responding maximally to highly stressful psychological laboratory tasks, exercise training related differences may be obscured. When the stressor task is very weak, the magnitude of the reactivity may be masked and is not related to the fitness level. In the experiment of Soth-
mann et al., a well-learned vigilance task (Stroop color-word task) was used to minimize the novelty of the conflict stress. Despite the reduction of plasma norepinephrine, the fitness groups did not differ on HR reactivity. Thus, failure to find the difference of HR may be due to the stressor being too weak. Holmes and Roth also assumed the influence of stress level; with high stress the response will occur during recovery and with low stress it will occur during the stress itself. However, since it is quite difficult to quantify each stressor in reactivity studies, the results in reactivity cannot be compared each other. To define stress level, more direct empirical stress tests may be required.

3. Physiological measure

Much of the literature has demonstrated that autonomic responses are influenced by psychological stress (e.g., Williams), Typical indices of sympathetic activation have been elevations in HR, SBP and DBP and decreases in ST as an index of vasoconstriction. Thus, most investigations concerning physical fitness levels and reactivity to stress have focused on the same indices because aerobic fitness can improve the efficiency of cardiovascular response to physical stressors.

Regarding HR and blood pressure, some researchers reported that low-fit subjects had greater HR and blood pressure in response to stress (Cantor et al., Holmes and Roth, Holmes and McGilley, Light et al.). Others found that high-fit subjects had faster HR recovery following stress than did low-fit subjects (Cox et al., Hollander and Seraganian, Sinyor et al., Takenaka).

As another cardiovascular measure, Shulhan et al. measured the T-wave amplitude in addition to HR. According to their report, analysis of HR data revealed no aerobic fitness level effect. However, they found greater T-wave amplitude attenuation in the low-fit compared to the high-fit group on hard mental tasks. Dorheim et al. tried to examine the effects of long distance running on mental stress in marathoners. They studied various cardiovascular responses (total systemic resistance values, stroke volume index, and HR), but failed to find a difference between marathoners and the control group.

Biochemical response to stress has also been investigated. Plasma catecholamine (CA) responses to stress include heightened secretion during such conditions as public speaking, complex mental discrimination tasks and physical activity (Cleroux et al., Dimsdale and Moss, Forsman and Lindblad, Frankenhaeuser, Ward et al.). Frankenhaeuser suggests that epinephrine level increases under psychological stress in situations of novelty, anticipation, unpredictability, and general emotional arousal, while the level of norepinephrine rises during increased physical activity. Dimsdale and Moss also found that during public speaking epinephrine levels increase twofold, whereas during physical exercise norepinephrine levels increase threefold. In animal experiments, Brown et al. reported that in most rat brain areas, norepinephrine and serotonin levels were significantly greater among eight-week exercise groups than in to sedentary groups. Recently, CA response to psychosocial stimuli has been proved to be significant relation to aerobic fitness levels (Brooke and Long, Cleroux et al., Hull et al., Sinyor et al., Sothmann et al.).

Three investigations comparing fitness groups failed to find a difference in the magnitude of plasma CA response (Cleroux et al., Hull et al., Sinyor et al.). However, Sinyor et al. unexpectedly found that trained subjects showed higher levels of norepinephrine and prolaction early in the stress period. Furthermore, Sothmann et al. examined whether or not high-fit subjects manifest different plasma CA response profiles to a well-learned vigilance task. As a result, they found that only plasma norepinephrine response as greater in the low-fit group than in the high-fit counterparts. Contrary to their results, Brooke and Long reported that aerobic power was associated with a more efficient recovery for relative plasma epinephrine measures. In their experiment, the stressor was rappelling and most of the high-fit subjects had experienced...
high risk sports (scuba diving, hand gliding, hiking, and canoeing) rather than aerobic sports. Thus, the definition of aerobic fitness level may be unclear in their study. Although the relationship between urinary CA metabolites and physical fitness has been examined, no significant correlation was revealed (Sothmann and Ismail74). Concerning CA response to psychosocial stimuli as a function of the aerobic fitness level, more careful investigations considering withdrawal periods are necessary because ambiguous results still remain.

Finally, regarding EDR, two investigations showed that high-fit subjects had faster recovery from stress than did low-fit subjects (Keller and Seregian441, Sinyor et al.72). Since EDR has a time delay to stress, it may not be clear whether this response was during or following the exposure to stress.

4. Psychological measure

Some investigations contained physiological as well as psychological outcome measures in laboratory stress situations. Regarding anxiety level, Sinyor et al.72 found that high-fit subjects reported significantly lower post-scores than did low-fit subjects on the Spielberger State Anxiety Inventory (STAI)76. Furthermore, Brooke and Long7 found that high-fit subjects recovered faster than low-fit subjects in subjective anxiety following stress. However, Takenaka80 was not able to find a difference in STAI between aerobically trained athlete and sedentary groups. Also, Takenaka and Zaichkowsky76 reported, by their longitudinal study, no difference in STAI between pre- and post-training for 4-week aerobic training group. In mood states, Hull et al.40 showed an industrial accident film to their subjects and found that both scores of depression and anger were lower in high-fit subjects.

Regarding subjective estimation, Cantor et al.131 reported that their subjects were not accurate in their self-reports of physiological responses and that their reports did not reflect the difference which existed between the two fitness levels in actual physiological assessment. Other investigators also failed to find differences in subjective responses to stress between high- and low-fit subjects (Holmes and Roth39, Holmes and McGilley38, Sinyor et al.73, Sothmann et al.75). Therefore, there are still controversy about psychological results in reactivity.

Type A behavior and aerobic fitness

There are experiments which have clinical or behavioral goals in relation to coronary heart disease. These researchers may be interested in the effect of behavioral change rather than physiological reactivity change to stress through aerobic exercise training. Thus, although their experiments involve the research classification as described in the previous section, they are discussed from a different perspective.

Type A behavior, hypertension, and smoking have been discussed as major independent risk factors for coronary heart disease (e.g., Review Panel on Coronary-Prone Behavior and Coronary Heart Disease60). It has been suggested that Type A persons tend to show greater increases in cardiovascular responses, such as HR and blood pressure, when facing challenging behavioral situations (Dembroski et al.44, Krantz and Manuck43, Manuck et al.53, Matthews et al.55). Therefore, the effect of long term aerobic conditioning has been expected to improve exaggerated physiological reactivity to psychosocial stress for Type A persons (Blumenthal et al.6, Lake et al.47, Roskies et al.61). Their subjects exhibited Type A behavior patterns, as measured by a direct behavioral assessment (the Type A Structured Interview: SI; Lake et al.47, Roskies et al.61). Further Type A assessments were both direct and self-reported (SI and the Jenkins Activity Survey: JAS; Blumenthal et al.6).

In cross-sectional research, Lake et al.47 found that sedentary Type A subjects exhibited greater blood pressure increases than either fit A, fit B, or sedentary B subjects. However, their criteria of fitness level was subjective (i.e., their fit subjects were all athletes who were involved mostly in anaerobic sports). Their stressors were also questionable. For instance, a snake was presented to the subjects and the experimenter himself tried to harass
the subjects during card games. Thus, the results could present only limited support for the relationship between reactivity and fitness level in the laboratory setting.

Roskies et al.\(^6\) performed a comparison of three 10-week treatments (aerobic exercise, cognitive-behavioral stress management, and weight training) to modify behavioral and cardiovascular reactivity to laboratory psychosocial stressors in healthy Type A men. Results from the aerobic training group failed to show any reduction in overt Type A behaviors, or physiological reactivity to stressors (a mental arithmetic task and Raven’s Progressive Matrices). Unfortunately, their method of measuring aerobic fitness was based upon estimated submaximal exercise testing. Therefore, the effect of aerobic exercise training for 10 weeks may not be of sufficient length to affect physiological reactivity to stress.

Blumenthal et al.\(^6\) improved upon the methodological limitations of previous research by using a randomized longitudinal design, and measured changes in aerobic fitness by an exhaustion test. In their experiment, thirty-six Type A men were randomly assigned to either an aerobic exercise training group or a strength and flexibility training group for 12 weeks. Subjects completed a comprehensive psychological assessment battery consisting of behavioral (SI), psychometric (JAS and Type A Self Rating Inventory), and psychophysiological tests (HR and blood pressure measurement to a mental arithmetic task) before and after the exercise programs. Results showed that the aerobic exercise group had an attenuation of HR, SBP, and DBP during the task and had a lower blood pressure and HR during recovery. These findings support the notion that aerobic exercise is an effective method of reducing cardiovascular risk among healthy Type A men.

In a very practical clinical study, Cleroux et al.\(^4\) observed eight labile hypertensive men respond to mild psychological stress (playing a video game) and mild physical stimuli (sitting and standing). They performed the examination prior to and following a 20-week aerobic exercise program and found that physical training was associated with smaller increases in SBP during psychological stress and with a lower HR at rest. This investigation suggests that cardiovascular disease patients may be treated with aerobic exercise programs. However, there are questions concerning aerobic exercise training for the treatment of coronary heart disease. Blumenthal and McCubbin\(^5\) propose that the effects of exercise training in patients with coronary heart disease appear to be different from “normal” individuals. Although their VO\(_2\) max can be increased by exercise training, it effects mostly peripheral function (skeletal muscles), but not central (cardiac) function (Cobb et al.\(^15\)). Thus, the benefits of aerobic exercise training for cardiovascular disease patients is still uncertain.

**Life stress and aerobic fitness**

It has been shown that increments in aerobic fitness level are related to improvement in psychological dimensions such as self-concept, emotional stability, self-confidence, and personal adjustment (e.g., Collingwood and Willet\(^6\), Folkins\(^3\), Hilyer and Mitchell\(^3\)). Although this literature has been criticized because of poor experimental design (Folkins and Sime\(^3\)), recent well-designed studies have shown the positive effects of aerobic exercise training on the reduction of anxiety and depression in normal subjects as well as mental patients (Buffone\(^1\), Doyne and Chambless\(^2\), Ledwidge\(^4\), Sachs and Buffone\(^5\), Schwartz and Kaloupek\(^6\)). Furthermore, the effects of aerobic fitness on life stress have been also investigated (Long\(^6\), Roth and Holmes\(^6,63\)). For example, Roth and Holmes\(^6\) had 112 undergraduates report their stressful life changes for the preceding year and assessed their fitness with a submaximal test. They found that by using multiple regression analyses, a high level of life stress during the preceding year was related to poorer subsequent physical health for subjects with a low level of fitness. Furthermore, Roth and Holmes\(^6\) performed an expanded study to determine whether aerobic exercise training would be effective for reducing the deleterious
effects of life stress. First after surveying over 1000 students, they chose 55 subjects who reported experiencing a high number of negative life events over the preceding year. The subjects were then assigned to an aerobic exercise program, a relaxation program, or a no treatment control group, all for an 11-week period. After treatment, the aerobic exercise training group showed more effective reduction of depression than did other groups. However, it was proposed that physical exercise would result in reductions primary in somatic anxiety with less effect on cognitive anxiety, both depending on the individual (Schwartz et al. 66).

**Theoretical explanation**

It might be necessary for future studies to ask why aerobic exercise copes with stress.

Depression and anxiety may be addressed as typical psychological attitudes which are elicited by psychological stress (Berger9). Depression is characterized by generalized feelings of hopelessness, despair, sadness, self-hate, and pessimism. Less severe behavioral manifestations include irritability, social withdrawal, indecisiveness, self-disturbance, loss of appetite, and fatigue (Penfold). Anxiety is characterized by high levels of activation and somatic complaints such as nausea, tiredness, and headaches. Furthermore, these psychological problems may be associated with drug and alcohol uses.

Aerobic exercise has been considered a unique approach to treat depression and anxiety. The most important reason for this may be the different response pattern to stress. According to Davidson and Schwartz (22), there are two types of anxiety: cognitive and somatic. While symptoms of cognitive anxiety include worry, inability to concentrate, and insomnia, those of somatic anxiety regularly cause nausea, headaches, and rapid pulse (Berger9). Schwartz et al. 66 observed the influence of two types of anxiety reduction by using meditation as a cognitive technique and exercise as a somatic technique. Although the two modes of treating anxiety were equally effective, significant interaction between the two components (cognitive and somatic) and anxiety reduction were observed by meaning them separately. That is, the exercisers had significantly less somatic anxiety than cognitive anxiety. Therefore, physical exercise such as running would result in a great reduction in somatic anxiety and have a lesser effect on cognitive anxiety.

After studying the literature, Ranford9 presented two hypotheses as physiological explanations of the antidepressant effect of exercise. One is that exercise may indirectly result in the release of enkephalins (endorphin), which in turn results in a feeling of euphoria. However, Markoff et al. 54 experimented with the narcotic antagonist naloxone which competes with opiates for receptor sites and reverses opiate and endorphin effects. They found it failed to reverse the mood-changes associated with running. Consequently, they suggest that endorphins are not involved. The other hypothesis of Ranford is that exercise may improve the body’s adaptation to emotional stress by increasing the efficiency of adrenal glands and the autonomic nervous system. The adrenal medulla and the autonomic nervous system release the amines epinephrine and norepinephrine. As described in the previous section, many researchers have paid close attention to catecholamine (CA) responses. Since norepinephrine is known to be low in many depressed persons (Buffone11), CA responses may become one of the important physiological indices in this area. Many more psychological and physiological studies must be performed in relation to CA responses since so much controversy still exists.

Brown9 assumed stress-buffering hypothesis (three dimensional model) from his results of the hierarchical multiple regression analysis. He assessed self-reports of physical exercise, self-reports of illness, life stress, and psychological distress for 37 male and 73 female undergraduates. As a result, under the high level of stress, high-fit students keep few frequency of illness, while low-fit students have many health center visits. On the other hand, under the low level of stress, both high- and low-fit students remain at the low level of illness frequency. That is, there is the stress X
fitness interaction in prediction of illness (health center visits). Exercise has a role of buffering the negative effects of life stress. As the reasons, he suggests that feelings of perceived control and mastery increase after regular physical exercise and that physical fitness training typically turns people's attention away from the stressful circumstances in their life.

As a final examination of this paper, Blumenthal and McCubbin present mechanisms for the use of exercise as stress management. They explained the mechanisms from two models: physiological, and behavioral and cognitive processes. According to their physiological model, the anti-anxiety and anti-depressant properties of exercise may be the results of improvements in physiological and biochemical responses to stress. Even though they also suggest the role of beta-endorphins in their physiological explanation, it seems ambiguous because of the controversy concerning the quantitative measure of beta-endorphins during exercise (e.g., Iwane). According to Blumenthal and McCubbin's behavioral and cognitive process, the following items are described as behavioral and cognitive mechanisms: cognitive diversion, social reinforcement, increased feelings of self-efficacy, and attenuation of somatic signals of anxiety.

In reality, if low-fit persons have a greater response to the stressor and thus may be at greater risk for stressor-related disorders than high-fit persons, aerobic exercise training would appear to be an appropriate prescription for low-fit persons who deal with stressors. Furthermore, aerobic exercise training may be applied to various psychological problems because exaggerated physiological reactivity to stress has been reported. For example, a socially anxious person showed a higher SBP during an impromptu speech compared to a non-socially anxious person (Beidel et al., Turner and Beidel, Turner et al.). However, theoretical explanations as mentioned above may not be still sufficient to prove the mechanisms, especially such as the improvement of physiological reactivity to stress as a function of aerobic fitness. It would be expected that more careful and substantial examination will develop the unqualified superiority of aerobic exercise training as a useful stress coping method.

References


38) Holmes, D.S. and McGilley, B.M. (1987) Influ-
ence of a brief aerobic training program on heart rate and subjective response to a psychologic stressor. Psychosomatic Medicine 49: 366-374.


