THE ACUTE EFFECTS OF AEROBIC EXERCISE ON CIGARETTE SMOKING

by

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86

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ABSTRACT

The effects of two intensities of exercise and a no-exercise control condition on cigarette smoking were investigated in 18 men, aged 20 to 30 years. Each subject, who was blind to the purpose of the study, came to the laboratory at the same time on three consecutive days to pedal a stationary bicycle at a work-load sufficient to maintain a heart rate between 130-135 b.p.m. or 160-165 b.p.m. or to be monitored while seated in a chair, for 10 minutes. Each subject was then ushered into a waiting room where he remained for one hour while indices of smoking behavior including number and weight of cigarettes consumed, cigarette duration (time elapsed from the instance the cigarette was lit to the instance it was extinguished) and number of puffs taken for the first cigarette post-exercise were surreptitiously observed by a confederate. Subjects also self-monitored cigarette intake during the three days of the study. Urine samples were collected pre- and 15 and 64 minutes following exercise. The only smoking measure found to be significantly affected by exercise was cigarette duration, which was inversely related to exercise intensity. Additional analyses revealed that high-intensity exercise significantly acidified the urine, and that a significant inverse correlation existed

between urinary pH change and cigarette duration for this condition. The implications of this finding are discussed in regard to Schachter's hypothesis of nicotine addiction.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

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INTRODUCTION

Cigarette smoking is an addictive behavior with staggering medical and economic consequences. It has been linked to lung cancer, cancer of the mouth and throat, cardiovascular disease, and pulmonary disease including bronchitis and emphysema (Shillington, 1977). The U.S. Surgeon General (1979) estimated that approximately $27 billion is spent each year in medical expenses, decreased work productivity and work absenteeism, and accidents attributed to smoking. In view of the adverse effects of this behavior it is not surprising that the majority of smokers not only express a desire to quit but also have initiated at least one serious attempt to do so (USPHS, 1976).

Given the magnitude of the problems caused by smoking a number of techniques have been developed in an attempt to discover an effective treatment for smoking. Yet despite the vast amount of research in this area, the effectiveness of smoking cessation methods is unimpressive. Reviews of the literature on smoking indicate that although initial success rates are high, abstinence rates are much lower. McFall and Hammen (1971) summarized the results of eight prominent studies on smoking cessation. They found a post-treatment reduction in cigarette consumption to 30-40% of baseline frequency, returning to 75% of baseline frequency at a 4 to 6 month follow-up. Hunt and Bespalec (1974) summarized data from 80 studies on smoking cessation and found that less than one-third of subjects who are able to quit smoking at the end of treatment maintain nonsmoking over the following six to twelve months. It seems, therefore, that one problem with present smoking cessation techniques lies in their relatively poor long-term effects (Bernstein and Glasgow, 1979).

Another concern with methods for eliminating smoking stems from the fact that although nonaversive strategies are available, aversive techniques are more popular (Lichtenstein and Brown, 1980). Rapid smoking is the most common aversion technique, wherein subjects are required to puff rapidly on a cigarette every five to six seconds, inhaling normally, until they can tolerate no more. While this method yields favorable results (Lando, 1976; Best, Owen, and Trentadue, 1978) it is rather unpleasant to the smoker. Furthermore, it induces in subjects a number of potentially harmful physiological changes which have been of concern to several researchers (Lichtenstein and Glasgow, 1977; Miller, Schilling, Logan, and Johnson, 1977). The use of rapid smoking, therefore, seems to be limited by a careful preselection of clients in view of its physiological effects and unpleasant nature.

From the above discussion it can be concluded that two current issues pertaining to smoking cessation techniques are that: 1) although initial smoking reduction rates are impressive, rates for maintenance of nonsmoking are relatively disappointing, and 2) most strategies have implemented aversive techniques which are unpleasant and not without potential undesirable consequences. These two concerns have led numerous researchers to suggest that smoking cessation programs incorporate techniques which facilitate maintenance of nonsmoking and which are nonaversive (Bernstein, 1969; Hunt and Matarazzo, 1973; Lichtenstein and Brown, 1980).

It is partly in response to these suggestions that psychologists have recommended the use of exercise in treatment for smoking. Lichtenstein and Brown (1980) and Engs and Mulhall (1982) discuss "lifestyle balancing" in smoking relapse prevention, wherein a "positively addicting" activity such as physical exercise replaces smoking. Hunt and Matarazzo (1973) suggest the use of exercise in an approach where supportive techniques are incorporated into individually-tailored programs for non-smoking. These suggestions have rested on the assumption that an inverse relationship exists between smoking and exercise. However, research on the effects of exercise on cigarette smoking has been limited to date, with no single adequately controlled study demonstrating that the former inhibits the latter. The purpose of this thesis, therefore, is to investigate the effects of exercise on cigarette smoking.

A review of the research suggesting an inverse relationship between aerobic exercise and cigarette smoking is presented below. It is followed by an examination of a current theory of smoking which could predict an increase rather than decrease in smoking following exercise. Finally, a statement of purpose for the present study and experimental hypotheses are presented.

Literature Review on Exercise and Smoking

Evidence suggesting an inverse relationship between exercise and smoking stems from anecdotal reports as well as correlational and experimental research. Various studies also suggest a physiological incompatibility between these two behaviors. Finally, research exists which suggests that smoking and exercise are both linked to psychological variables which may mediate an effect of the former on the latter. These studies are presented below.

Anecdotal Reports and Correlational Studies

Morgan, Gildiner and Wright (1976) conducted a mail survey to determine the exercise performance and smoking behavior of members of a running club, who averaged 35 miles per week. Of the 141 members, 35 had been smokers, of whom all but three abandoned smoking after joining the club. In a similar anecdotal report on exercise and smoking, Hickey, Mulcahy, Bourke, Graham and Wilson-Davis (1975) questioned men about their work and leisure activity over the previous six months. They found a significant inverse correlation between heavy leisure activity, including running, squash, tennis and swimming, and smoking in men 25 to 60 years old. Although this finding was based exclusively on retrospective self-report of change in smoking, it suggests that exercise reduces smoking.

In an aerobic exercise program for 237 NASA employees (Durbeck, Heinzelmann, Schacter, Haskell, Payne, Moxley, Nemiroff, Limoncelli, Arnoldi, and Fox, 1972) 35 to 55 year old men exercised for 30 minutes, three times per week. At the conclusion of the 12-month program approximately 15 percent of "good adherers" reported a decrease in smoking, compared to 10 and 5 percent for equally large groups of "fair" and "poor" exercise adherers, respectively.

Two correlational studies failed to find an effect of exercise on smoking. Bonanno and Lies (1974) engaged 19 middle-aged coronary-prone male smokers in a 12-week supervised aerobic exercise program of walking and jogging. Neither subjects in the experimental group nor those in a matched no-exercise control group discontinued or substantially decreased smoking during the program. Engs and Mulhall (1982) investigated the smoking habits of university undergraduates before and after 15-week courses requiring either strenuous activity such as jogging and conditioning exercises, or leisure activity such as billiards and riflery. No pre- to post-program changes in smoking behavior were found for subjects in either group.

Interpretation of data in the above studies is difficult for a number of reasons. The researchers, with the exception of Engs and Mulhall, did not design their studies to examine specifically the relationship between these two variables and therefore they lacked control procedures. The smokers were not representative of the general population as three of these programs were designed for those at risk for coronary heart disease. Consequently, most subjects were middle-aged coronary-prone men who may have been changing other lifestyle behaviors in addition to physical activity. Another difficulty with interpretation is that although the frequency, intensity and duration of exercise were reported in most studies exercise adherence was not always monitored. Finally, the assessment of smoking behavior was retrospective for the most part and based solely on self-report. One aspect of the Engs and Mulhall (1982) study which may mask an effect of smoking is the fact that most students in the group (85 of 100 in the strenuous activity group and 72 of 100 in the leisure activity group) did not smoke, and only a very small percentage of subjects (2 percent in the former and 12 percent in the latter group) initially smoked at least one package of cigarettes daily.

Experimental Studies on Exercise and Smoking

The relationship between exercise and smoking has been investigated incidentally in studies on the relationship between physical activity and coronary risk factors. Mann, Garrett, Farhi, Murray, Billings, Shute, and Schwarten (1969) trained 106 men, aged 25 to 60 years, in a strenuous program of supervised exercise, including calisthenics, walking, jogging and running in an attempt to reduce the risk of coronary heart disease. Each subject was exercised at one of three intensities according to his fitness level, for five days per week for six months. At the end of the program, 22% reported a decrease in smoking, versus 7% for a no-exercise control group. One difficulty with data interpretation in this study arises from the fact that no mention is made of the proportion of subjects who initially smoked. If it is assumed that smokers were proportionally represented in both groups, as subjects were randomly assigned to the groups, then the data suggest that exercise is inversely related to smoking.

Heinzelmann and Bagley (1970) exercised 239 initially sedentary men, 45 to 59 years old, for one hour, three times per week for 18 months. The study does not mention the nature of exercise performed; however, it was most likely aerobic as it was designed to improve cardio-pulmonary function of men at risk for coronary heart disease. A randomly assigned control group of 142 men did not exercise, but filled out questionnaires on health attitudes and beliefs, and received medical evaluations at standard three- to four-month intervals. Twenty percent of men in both the experimental and control groups reported smoking less at the end of 18 months. It may be that filling out the health questionnaires and possible exposure to the experimental subjects, who were recruited from the same university setting, may have spurred the control subjects to initiate their own exercise program during the course of the study. The experimenters would have been uninformed of this as change in exercise habits of control subjects was not assessed at the end of the study.

Two unpublished studies were designed specifically to assess the effects of exercise in treatment for smoking. Johnson, Rosenbaum, Framer and Wildman (1979) assessed the influence of an 8-week exercise program on cigarette consumption and physical fitness. The study compared the effects on smoking of two exercise programs the first involving 30 minutes of walking per day, the second consisting of an incremental program of walking and a weekly exercise session which began at the same level as the first. Subjects in both groups received, in addition to exercise, instruction in self-monitoring, relaxation training, cigarette refusal training and behavioral analysis of smoking. Results indicate no difference in smoking behavior between the groups either post-treatment or at a one year follow-up. Subjects in both programs significantly decreased smoking, returning to 67% of baseline frequency at a one-year follow-up. The lack of a no-exercise control group and the use of a multi-component treatment package for smoking cessation precludes any assessment of the effects of exercise on smoking. An important finding, however, is that post-treatment cigarette smoking was significantly inversely related to pre- and post-treatment aerobic capacity ($r = -0.64$ and $r = -0.86$, respectively) as determined by a step test, suggesting that smoking is related to initial level of physical fitness and physical improvement following exercise.

In a study by Howley, Callahan and Yaeter (1980), a 2 X 2 factorial design was implemented to determine the separate and combined effects of exercise and self-management strategies on smoking. Subjects in an exercise group followed an individualized exercise plan including walking and running, which was gradually increased during the study. Smokers in a self-management group learned self-control procedures for dealing with smoking situations. In both groups self-monitoring, contracting, and social facilitation were used for treatment adherence. A third group received both exercise and self-management training components, while a final group served as a delayed treatment control. Results indicate that all three treatment groups significantly reduced their smoking rate and that there was no difference among these groups post-treatment nor at six-week and six-month follow-ups.

In both the Howley *et al.* and Johnson *et al.* studies, physiological indices of recovery were used to assess exercise adherence. However, changes in these measures cannot be attributed solely to exercise participation, as smoking cessation alone is sufficient to improve aerobic capacity (Rode, Ross and Shepard, 1972). It may be, therefore, that in these studies physiological indices of recovery did not reflect exercise adherence accurately. Another difficulty with data interpretation in these studies stems from the fact that no controls were made for subject expectancies and beliefs that the treatment would reduce smoking. As programs in both studies were presented as anti-smoking treatments, subjects volunteering for the studies may have reduced smoking partly or wholly as a result of these nonspecific treatment factors (McFall and Hammen, 1971). Finally, conclusive interpretation of an effect of exercise in the Howley et al. study is hampered by the fact that seven of the 36 subjects in the three treatment groups dropped out of the study (no drop-out data are presented for the exercise group alone), while four of the nine subjects in the exercise group failed to adhere to the exercise regimen.

Physiological Incompatibility between Aerobic Exercise and Smoking

There exists evidence suggesting that aerobic exercise is incompatible with smoking. While aerobic exercise increases cardio-pulmonary function, cigarette smoking produces physiological changes in an opposite direction (Cooper, Gey, and Bottenberg,1969). Studies confirming this finding indicate that: 1) smokers perform worse than nonsmokers on cardiovascular and pulmonary tests, 2) smokers' exercise performance decreases following cigarette consumption, and 3) nonsmokers respond more favorably than smokers to physical training programs. A review of these studies is presented below.

In a comparison of smokers' and nonsmokers' cardio-pulmonary performance, Cunningham, Montoye, Higgins, and Keller (1972) engaged male and female smokers in a bench stepping test and found they had significantly higher heart rates than nonsmokers pre- and three minutes post-exercise. Shaver (1973) found differences in exercise performance between female smokers and nonsmokers on three measures of cardiovascular and pulmonary efficiency: a bench step test, a 60 yard run-walk test and a repetitive treadmill test. Furthermore, Franks (1970) noted that when smokers abstain from their usual pattern of smoking for one day, they experience an improvement in three cardiac measures: diastolic blood pressure, stroke volume and cardiac sympatho-adrenergic activity, in response to exercise.

Krone, Goldbarg, Balkoura, Schuessler and Resnekov (1972) determined smokers' exercise performance both before and after cigarette smoking. In the first session nine male smokers aged 21 to 27 years pedaled a bicycle ergometer for 18 minutes at a heart rate elevation of up to 150 beats per minute, rested for 30 minutes, and repeated the exercise. This sequence was later repeated for a second session, except that the subject smoked a single cigarette during the 30-minute rest period. The authors found an increase in heart rate and a decrease in stroke volume during exercise after smoking a cigarette. The same results were found by Goldbarg, Krone and Resnekov (1971) using a similar methodology with nine male habitual smokers, aged 22 to 26 years.

Further support for the physiological incompatibility between aerobic exercise and smoking is provided by studies comparing the response of smokers and nonsmokers to physical training programs. Cooper, Gey, and Bottenberg (1969) tested endurance performance using a running test in 419 young airmen (mean age 19.1 years) before and after six weeks of basic training. They found that smokers had lower respiratory minute volume and oxygen consumption at equivalent heart rates compared to nonsmokers both before and after training. This impairment was significant in subjects who had smoked for over six months, and performance was inversely related to daily cigarette consumption. Similarly, Peterson and Kelly (1969) conditioned 60 men in an eight-week running program and found that smokers increased their maximal oxygen uptake (MVO2) levels at a lower rate than nonsmokers.

The above findings of an incompatibility between exercise and smoking are consistent with the fact that two compounds in cigarettes, carbon monoxide (CO) and nicotine, have been linked to decreased cardio-pulmonary efficiency. Carbon monoxide in cigarette smoke binds to hemoglobin thus leaving less available for oxygen transport in the blood (Montoye, Gayle and Higgins, 1980). A smoker may have approximately 5 percent or more of his blood cells blocked by CO, making oxygen transport more difficult (Astrand and Rodahl, 1970). Body tissues also receive less oxygen because CO reduces peripheral blood flow, pulmonary diffusion capacity and vital capacity (Montoye et al., 1980). Furthermore, CO increases airway resistance, which interferes with oxygen-carrying capacity and causes vast constriction of blood vessels, resulting in increased heart rate (Rode and Shepard, 1971). Carbon monoxide, therefore, is at least partially responsible for smokers' reduced cardiopulmonary function. A second harmful agent in tobacco, nicotine, decreases cardiac output and stroke volume (Astrand and Rodahl, 1970). It also stimulates the release of catecholamines, which raise heart rate and therefore increase the heart's work-load (Astrand and Rodahl, 1970).

Collectively, the above findings indicate that smoking induces numerous physiological changes opposite to those produced by aerobic exercise. It is possible, therefore, that smokers exposed to aerobic exercise may be encouraged to decrease their smoking in order to participate more effectively in physical activity. Conversely, if they were to smoke less they would become aware of the improved quality of their exercise performance. This positive feedback regarding physical fitness may, in turn, provide further motivation for smoking abstinence. Consistent with this hypothesis, Paxton and Scott (1981) found that improvement in lung function following smoking cessation was inversely correlated with relapse, and suggested that positive feedback regarding physiological change resulted in greater maintenance of treatment success.

Psychological Factors Related to Exercise and Smoking

A number of psychological factors have been linked to either an increase or decrease in cigarette smoking (Lichtenstein and Brown, 1980). Research suggests that these same variables may be affected by physical activity (Martin and Dubbert, 1982). To the extent that exercise may reduce psychological states related to increased smoking or increase mental states known to reduce smoking, it may modify smoking through these mediating variables.

One variable which is negatively related to smoking is health awareness. Research suggests that smokers are less likely to guard their health than are nonsmokers. Eiser, Sutton, and Wober (1979) found that smokers were less likely to believe that smoking was 'really dangerous', were less prone to wearing seat belts, and were more likely to believe that individuals have a right to risk their own health rather than a moral responsibility to protect themselves from health risks. To the extent that exercise improves one's attitude towards health and well-being, it may mediate a reduction in smoking. Two studies attest to the improvement in health attitude following participation in exercise programs. Heinzelmann and Bagley (1970) found more positive feelings regarding health habits and behavior, while Durbeck et al. (1972) reported increased positive feelings about health status. Smoking presumably would be antithetical to an increased concern over one's health patterns and a smoker might, therefore, abandon his smoking to maintain consistency with his newly acquired beliefs regarding his health lifestyle. Gottlieb, Freidman, Cooney, Gordon and Marlatt (1981) did, in fact, find that health was by far the most common reason cited by smokers to attempt smoking cessation. Further support for health as a mediating variable in smoking cessation is provided by Shipley (1981) who found that ex-smokers with an internal health locus of control (HLC - the belief that one controls his/her health) remained abstinent longer than those with an external HLC.

Various studies have indicated that exercise decreases feelings of stress, tension and anxiety (McCrae, Costa and Bosse, 1978; Lichtenstein and Brown, 1980). Moreover, these factors are known to be associated with smoking. Subjects participating in a NASA-US Public Health Service Health Education and Enhancement program (Durbeck et al. 1972) reported decreased feelings of stress and tension after exercising, as did those in exercise programs for men at risk for coronary heart disease (Heinzelmann and Bagley, 1970; Folkins, 1976). Cooper (1977) reported a "greater ability to resist all types of stress" following physical fitness training, and Cureton (1963) reported tension reduction in adults participating in a physical conditioning program. Morgan (1979) reviewed seven studies in which the effects of acute aerobic activity are investigated. Of these, two failed to demonstrate a decrement in perceived anxiety following exercise. In both studies, however, the exercise consisted simply of walking, suggesting that physical activity may need to be more vigorous to achieve a significant reduction in anxiety. Of the five remaining studies, four consisted of investigations where subjects ran and one entailed participation in racquetball. All five studies demonstrated a reduction in anxiety through self-report. Folkins and Sime (1981) reviewed six studies investigating the effect of physical fitness training on anxiety, tension and/or well-being, of which all show an improvement in affect (obtained by self-report) in response to exercise. They note that the decrement in negative emotions is particularly evident with subjects who are either initially less physically fit or more psychologically distressed.

Ikard and Tompkins (1973) provide evidence that people smoke for two major reasons: to increase positive affect and to decrease negative affect. Furthermore, smokers maintain smoking when they realize that it is a source of reward and/or a means of controlling negative affect. If exercise has a similar effect on mental state, it may decrease the need for smoking. Numerous studies report that subjects "feel better" after exercise (Morgan, Roberts, Brand and Feinerman, 1970). Folkins and Sime (1981) reviewed seven studies assessing the effect of exercise on depression, mood and well-being. Of these, six demonstrated a significant post-exercise improvement in affect, as determined by questionnaire, while the seventh found this in depressed, but not in normal subjects.

Further support for increased positive affect following exercise stems from research indicating that physical activity releases beta-endorphins, substances in the brain known to act as opiates, inhibiting pain and improving mood states (Appenzeller, 1981; Appenzeller, Standefer, Appenzeller and Atkinson, 1980). Physical exercise also activates the sympathetic nervous system, resulting in positive emotional states (Dimsdale and Moss, 1980). Furthermore, exercise reduces feelings of chronic fatigue, known to be associated with depression (Dimsdale and Moss, 1980).

In addition to health awareness and negative affect, other variables may also mediate an effect of exercise on smoking. Some people smoke for social approval (Lichtenstein and Brown, 1980). A smoker might also cultivate social approval by engaging in regular exercise and becoming more physically fit. Exercise enhances self-image and confidence (Heinzelmann and Bagley, 1970; Collingwood and Willett, 1971; Cooper, 1977) and therefore might actually decrease one's initial need for social approval. Other factors linked to cigarette smoking include boredom (Lichtenstein and Brown, 1980) and a need for sensorimotor stimulation (Flaxman, 1979), both of which may be combatted using exercise.

In conclusion, the above studies confirm that a number of psychological factors may be responsible for smoking.

Furthermore, exercise has been demonstrated to be related to many of these variables. If smoking and exercise are related to psychological states in an opposite direction, exercise participation may induce a decrement in smoking.

Summary of Research on Exercise and Smoking

Although the above studies indicate that exercise and smoking may be inversely related, firm conclusions regarding the effects of exercise on smoking cannot be made on the basis of evidence provided. Of the studies reviewed, only four were concerned specifically with an examination of the relationship between these two variables. Of these four, the results of two (Johnson et al., 1979; Howley et al., 1980) suggest that exercise may lead to a decrement in smoking, but exercise is not manipulated to the exclusion of other treatment factors. While Morgan et al. (1976) found a reduction in smoking following participation in an exercise program, the study was retrospective, and information on smoking was provided solely by self-report. Finally, the correlational study by Engs and Mulhall (1982) failed to find a decrease in smoking following enrolment in physical education courses, but only a small percentage of subjects were regular smokers who consumed at least one package of cigarettes per day.

The remaining research on the effects of aerobic exercise on smoking is often retrospective and anecdotal, with studies assessing the relationship between these two variables only as part of a larger project. In conclusion, there is a need for well-controlled empirical research exploring the effects of aerobic exercise on smoking before a decision regarding its clinical utility can be made.

<u>Schachter's Model of Smoking: Implications for Exercise</u>

Schachter (1977) proposed a model of smoking which would predict a change in smoking following exercise in a direction opposite to that suggested by research on exercise and smoking reviewed above; i.e., it would predict a post-exercise increase rather than decrease in smoking. He suggested that people smoke to regulate nicotine, and that an internal homeostatic mechanism is responsible for monitoring nicotine levels in the body. According to Schachter, when a smoker's nicotine reserves are depleted he will compensate for this loss by increasing his cigarette consumption. Furthermore, Schachter explains that when urinary pH decreases, i.e., when urine becomes more acidic, as it does when subjects are stressed, the rate of nicotine excretion increases (Wesson, 1969). This would result in increased rates of smoking in order to compensate for nicotine loss.

Schachter (1977) presented a series of five studies to verify that smokers regulate nicotine. In the first (Schachter, 1977) he demonstrated that heavy smokers consistently consume more low- than high-nicotine cigarettes when these are alternated on a weekly basis. In a second study, an increase in smoking was found following urine acidification by vitamin C intake, but smoking did not increase when urine was alkalized using sodium bicarbonate or was unchanged using a placebo (Schachter, Kozlowski and Silverstein, 1977). Next, Silverstein, Kozlowski and Schachter (1977) determined the effects of party going on urinary pH and smoking, and found that smokers have lower bedtime urinary pH and report smoking more cigarettes on days in which they attend parties than on 'nonparty' days. In a parallel manner, Schachter, Silverstein, Kozlowski, Herman, and Liebling (1977) found lower urinary pH levels and a greater increase in smoking rate and number of puffs taken per cigarette following electric shock. Finally, Schachter, Silverstein and Perlick (1977) separated the effects of psychological stress from those of urinary acidification on cigarette smoking. In a 2 X 2 factorial design, subjects were given either sodium bicarbonate or a placebo and were placed in a high or low stress condition. Subjects were then escorted to a waiting room where smoking rate and number of puffs taken for each cigarette were unobtrusively observed. In the high-stress placebo condition urine was significantly acidified, whereas the high-stress bicarbonate condition did not acidify the urine. Results indicate that the manipulations increased smoking only when pH was decreased, suggesting that smoking was influenced by pharmacological rather than psychological manipulations.

The relationship between urinary pH and smoking as predicted by Schachter was also verified by Dobbs, Strickler and Maxwell (1981). These investigators placed undergraduates under stress by leading them to believe they would be asked to speak in front of graduate students and faculty. Subjects were then exposed to either a relaxation tape (S-R), a stress-provoking tape (S-S), or a neutral tape (S-N). Subjects in a control group (N-N) did not anticipate having to give a speech and listened to a neutral tape. Urinary pH measures were obtained during baseline, and 10 and 35 minutes post-treatment. In addition, measures of puff rate and centimeters of cigarette smoked were obtained before, and for 35 minutes following treatment. Analyses revealed significantly greater urine acidification during treatment for the S-S group than for the N-N and S-R groups and a significant decrease in puff rate and amount smoked for the S-R group than for the other two stress groups. In addition, changes in amount of cigarette smoked during a 35-minute post-treatment session were negatively correlated with treatment pH levels, suggesting that the increase in smoking under stressful conditions was related to urine acidification.

In contrast to the above findings, Schachter's suggestion that urinary pH may mediate changes in smoking behavior was not borne out by Marshall, Green, Epstein, Rogers and McCoy (1980) who examined the effect of coffee drinking and urinary pH on cigarette smoking. In a within-subjects design smokers were given water, coffee, coffee and sodium bicarbonate or coffee and ascorbic acid, and were subsequently asked to remain in a waiting room for one hour. Pre- to post-session urine analyses indicated that coffee did not acidify the urine; yet subjects smoked more cigarettes in sessions following coffee consumption, suggesting that smoking behavior was altered in response to coffee drinking rather than to urinary pH changes. One difficulty with interpretation of these results, however, is that the manipulations failed to acidify the urine. This is important, as increasing the alkalinity of the urine does not alter appreciably nicotine excretion (Schachter, 1980), and therefore no consequent change in smoking should have occurred.

The above studies indicate that Schachter's theory of nicotine addiction has some empirical support. The theory points to the importance of urinary pH as a mediating variable in the determination of smoking. This has important implications for the present study, since one factor known to decrease urinary pH is exercise, which acidifies urine for approximately one hour after acute strenuous activity (Wesson, 1969). As urine acidification stimulates nicotine excretion, smokers would be expected to increase their cigarette consumption following exercise.

Statement of Purpose and Hypotheses

The present study was designed to examine the acute effects of two intensities of exercise and a no-exercise control on smoking rate and topography.

It was predicted that cigarette smoking would be inversely related to exercise intensity, being lowest following high-intensity exercise, intermediate following low-intensity exercise, and greatest following no exercise. This would apply for all the smoking indices assessed, including the number and weight of cigarettes smoked, puff frequency per cigarette and cigarette duration. Furthermore, latency to smoke was expected to be directly related to exercise intensity.

A second purpose of the study was to examine the relationship between urinary pH, exercise and cigarette smoking according to Schachter's hypothesis. If Schachter's hypothesis holds then, contrary to the above prediction, strenuous exercise would be expected to lead to a decrease in urinary pH and therefore to a subsequent increase in smoking.

METHOD

Subjects

Eighteen male subjects between the ages of 20 and 30 (mean age = 25.5), who had smoked for an average of 10.3 years (range = 3 to 17 years) were recruited through advertisements posted at the University of British Columbia campus and at various public locations in West Point Grey and Kitsilano. Criteria for inclusion in the experiment were:

1. The subject had to be 20 to 30 years old. It was necessary to select a homogeneous group of subjects with respect to age in order to minimize extraneous factors which may have influenced exercise.
2. The subject had to be screened by a PARQ (Physical Activity Readiness Questionnaire), which was completed to determine that he had no medical condition which precluded his participation in the study.
3. Subjects could not be on any medication which altered their cardiopulmonary function or smoking rate during, or for one day before the study.
4. The subject had to be in poor to average physical condition as determined by his report of weekly physical activity on a screening questionnaire. Weekly activities were transformed into aerobic points (Cooper, 1977), and only subjects with accumulated points placing them in a below-average fitness

category were selected for the study.

5. The subjects had to have smoked at least one package of cigarettes daily for the last three years. If there had been a gap in the subject's smoking history, the three-year period was lengthened by that amount. Volunteers participating in smoking cessation programs or implementing smoking reduction strategies, as well as those who attempted to quit smoking within 30 days of the study were screened out.

Apparatus

Urine samples were collected in 150ml plastic specimen containers and analyzed using an Orion Research Model 701A Digital Ionalyzer pH meter.

Subjects were exercised on a Monark stationary bicycle. Heart rate was recorded using a Grass polygraph D.C. driver amplifier, model 7DAB and a Grass preamplifier, model 7P4 A, and Beckman one centimeter silver silver-chloride electrodes. Blood pressure was measured with an Accoson sphygmomanometer and blood pressure cuff, and a Dittman stethoscope.

Cigarette butts were weighed on a Canlab Sartorius model 2603 analytic balance. Other equipment included a Wittner Super Mini Taktell metronome, a scale for measuring subjects' body weight, and two stopwatches.

Procedure

The study was conducted in two classrooms, one designated the exercise laboratory and the other a waiting room, in the Chemical Engineering Building at The University of British Columbia. Each subject participated in four sessions, three experimental sessions and a debriefing session, on four consecutive days at the same time each day. Exercise monitoring and fitness testing were performed by an experimenter trained in cardio-pulmonary resuscitation. As a safety precaution an assistant was present at all sessions.

During initial telephone contact, the experimenter explained the study to interested potential subjects and screened them to ensure they fit the specified criteria. At the first session subjects were required to sign a consent form which stated that the purpose of the study was to examine the physiological effects of three different intensities of exercise on cigarette smokers. It included information on the procedure of the study, i.e., exercise sessions and self-monitoring of cigarette intake. Misinforming subjects of the purpose of the study was intended to minimize demand characteristics and expectancies of change in smoking behavior.

Prior to participation in the study subjects also completed the PAR-Q and a questionnaire about their smoking and exercise histories. Questions assessed past and current attempts at reducing or quitting smoking and the present rate of smoking as well as the frequency and intensity of exercise in which the subjects had previously engaged and in which they were presently engaged.

Subjects were asked to abstain from smoking for one-half hour, from eating, and from drinking beverages containing caffeine and alcohol for two hours before each session, as these would affect their heart rate. Subjects were asked if they had abstained from these upon their arrival at the laboratory, and those not having done so were to have been rescheduled.

Subjects provided urine samples before and at 15 and 64 minutes following exercise and at equivalent intervals in the no-exercise condition. These were collected in sampling containers and analyzed within four hours on a Digital Ionalyzer pH meter. Sampling containers were reused after being washed and rinsed with distilled water.

The design of the study consisted of a repeated measures design in which each subject participated in three sessions, each one at a different exercise intensity. Prior to each session measures of body weight and blood pressure were taken.

During two of the first three sessions of the study each subject was required to exercise for 10 minutes on a stationary bicycle at one of two different intensities, one resulting in a heart rate of 130-135 bpm (66% to 69% of maximal heart rate) and the other a heart rate of 160-165 bpm (82% to 85% of maximal heart rate). Subjects' heart rates were monitored via a Grass Polygraph ECG machine. A metronome was set at 100 beats per minute, pacing subjects' pedaling at 50 rpms. Subjects started pedaling and within 5 seconds a work-load of two or three kiloponds for a low or high intensity workout, respectively, was added. After 55 seconds to one minute a recording was made of the heart rate and if necessary, the work-load was increased until the target heart rate was achieved. After ten minutes of exercise, the workload was reduced to near zero resistance and subjects continued to pedal for an additional two-minute recovery period. Immediately afterward and at 30-second intervals thereafter subjects rated their respiration rates on a seven point scale until they indicated that they were breathing normally. Blood pressure was taken 3 1/2 minutes following exercise.

Maximal oxygen uptake (MVO2) was predicted for each subject on the basis of his heart rate and the corresponding work-load during the fourth to sixth minute of low exercise intensity and the subject's weight using a nomograph (Astrand and Rodahl, 1970).

In the no-exercise condition subjects' heart rates were monitored for 10 minutes while they remained seated in a chair. All other procedures were the same as those of the exercise conditions, with the exception of the self-rating of respiration rate which was deleted in this condition for the last eight subjects, as the first ten volunteers had consistently rated their breathing as being 'completely normal' following heart rate monitoring.

When heart rate monitoring was completed and blood pressure measurements were repeated, subjects were ushered into the waiting room where they remained for one hour. They were advised that smoking was permitted during this period. To standardize activity during the waiting period, reading material, including a daily newspaper, Time, Macleans, and People was provided. Subjects were also asked to remain in their gym clothing until the last urine sample of each session was obtained. They were provided with a schedule so that they would know in advance of all sessions exactly when they would be asked to give urine samples. In order to standardize cigarette smoking in the waiting room, if a subject was smoking when it was time to provide a urine specimen, either at 15 or 64 minutes following exercise, the observer was instructed to wait until the subject had finished his cigarette before asking him to provide a urine sample. The number and weight of cigarettes were prorated if the subject extended his time in the waiting room beyond 64 minutes.

Subjects were unobtrusively observed by a male assistant whose presence in the waiting room was ostensibly for the purpose of prompting the subjects at times when urine specimens were to be collected. In order to standardize and minimize any interaction between the subject and the observer, subjects were briefly introduced by first name and were told that the observer would be working in the waiting room. The observer was also instructed to be reading or writing, to look up for a moment and to say "Hi" when introduced. In addition, he was coached on politely terminating any conversation initiated by the subject with, "I would like to chat with you now, but I've got to get this finished for my next class". The observer did not smoke, but had on his desk in clear view of the subject a package of cigarettes, matches and an empty ashtray.

Measurement of smoking latency began four minutes after the subject dismounted from the bicycle ergometer when he entered the waiting room. At that time the observer activated a stopwatch and when the subject took his first inhalation while lighting his first cigarette, the observer recorded the time. The observer also recorded the number of puffs taken from the first cigarette (a puff defined as an instance where the cigarette is in contact with a smoker's lips and flaring) and the time at which it was extinguished (defined as the time when the cigarette came into initial contact with the ashtray while being extinguished).

As an additional measure of smoking rate, one hour after exercise, cigarette butts discarded in an ashtray after the subjects' stay in the waiting room were counted. Furthermore, the weight of cigarette smoked in the waiting room was calculated. This was done by deducting the combined weight in grams (to four decimal places) of the ashtray and its contents after the session from the combined weight of the ashtray and as many unused cigarettes of the subject's brand smoked during the waiting period.

A pitcher of water and glasses were available for subjects in the waiting room to eliminate the possibility that they would decrease their smoking in response to dehydration induced by exercise. Records were kept of the amount of water drunk at each session for each subject. The amount of water consumed was taken as the difference in milliliters between the water pitcher contents at the beginning and at the end of the session, with any water remaining in the subject's glass returned to the pitcher before the final measurement was made.

Subjects monitored their daily cigarette consumption using small tally cards and a pencil which fit conveniently into their cigarette packages. The tally cards were divided into sections corresponding to an hourly sequence beginning with the observation period. Subjects were asked to place a tally mark in the appropriate time segment each time they had a cigarette to permit a calculation of daily smoking rate. Subjects were also asked to record to the nearest hour the time at which they retired and awoke each day. The rationale provided for this was that it was necessary to know how long they slept in order to evaluate accurately their exercise performance. Subjects handed in a tally card at the beginning of each experimental session and were provided with a new card for the following day.

During the fourth session subjects handed in their last tally card and completed a post-study questionnaire which assessed their beliefs and expectations regarding the study. The questionnaire asked for their perceptions of the purpose of the study in order to assess the credibility of the rationale provided during initial contact. In addition, subjects were questioned as to whether they believed exercise would affect their smoking behavior. Subjects were debriefed as to the actual purpose of the study, and were given time to ask questions. They were paid $25 and were offered information regarding their physical fitness (aerobic capacity) which was derived from their exercise performance.

Dependent Variables

Smoking behavior was assessed using measures of smoking rate and direct and indirect measures of smoking topography for each subject. Smoking rate was determined by subjects' self-monitoring of cigarettes consumed for one hour and 23 hours post-exercise, and by a count of cigarette butts discarded in an ashtray during their stay in the waiting room.

Topographical measures of smoking included latency to smoke and puff frequency for the first cigarette consumed following exercise, and weight of cigarette(s) smoked one hour post-exercise. In addition, cigarette duration was calculated by subtracting extinction time from the time the cigarette was lit, for the first cigarette following exercise.

RESULTS

Eighteen volunteers participated in the entire study. One additional subject dropped out after the first session, and his data are not included in the analyses.

Post study questionnaires administered to subjects during the debriefing session revealed that they were unaware of the actual purpose of the study. Furthermore, subjects did not realize that their cigarette or water consumption was being monitored in the waiting room.

Subjects' reports of weekly physical activity on a screening questionnaire were analyzed and it was found that subjects accumulated a weekly average of 19.2 aerobic points (range = 5 to 30), which, according to Cooper (1977) is insufficient for maintaining one's aerobic fitness level. Consistent with these self-report data, maximal oxygen uptake (MVO2) levels, predicted for each subject on the basis of exercise performance during low-intensity exercise, ranged from 36 to 55 ml/kg/min (mean of 45.3 ml/kg/min), placing most volunteers in the low-average range for aerobic fitness.

Data Analyses

Hartley F-max tests conducted on all the data before analyses of variance (ANOVAs) were conducted indicated that in every case the variances across the conditions were homogeneous. For measures of urinary pH, the variances were homogeneous across both conditions and time periods in which the samples were taken.

Manipulation Checks

Measures of urinary pH, taken before and at 15 and 64 minutes following exercise, averaged 6.28 (SD = .81), 5.94 (SD = .80) and 6.34 (SD = .80) for the high-intensity exercise condition, 6.23 (SD = .70), 5.98 (SD = .84) and 6.60 (SD = .80) for the low-intensity exercise condition, and 5.95 (SD = .81), 5.94 (SD = .88) and 6.20 (SD = .87) for the no-exercise condition, respectively. A two-way (condition X time in which the urine sample was obtained) repeated measures ANOVA was calculated on measures of urinary pH, and the results are tabulated in Table 1. There was a significant main effect for time ($\underline{F}(2,34) = 17.15$, $\underline{p} < .01$) and a significant effect for samples obtained 15 minutes following exercise versus those obtained 64 minutes following exercise ($\underline{F}(1,17) = 59.04$, $\underline{p} < .01$). A significant interaction effect was found for condition by time in which the urine sample was obtained ($\underline{F}(4,68) = 2.87$, $\underline{p} < .05$) with a significant effect in the interaction between the no-exercise condition versus exercise conditions and both overall time as well as 15 minutes versus 64 minutes following exercise (i.e., $C_3 - C_1C_2 \times T$, $\underline{F}(2,34) = 4.14$, $\underline{p} < .05$; $C_3 - C_1C_2 \times T_2 - T_3$, $\underline{F}(1,17) = 4.63$, $\underline{p} < .05$). A

Table 1

Summary ANOVA Table for Urinary pH Measures

	error term	SS	df	MS	F
C	C x S	1.602	2	.801	.978
$C_3 - C_1C_2$	$(C_3 - C_1C_2) \times S$	1.401	1	1.401	1.319
$C_1 - C_2$	$(C_1 - C_2) \times S$	.200	1	.200	.347
T	T x S	4.929	2	2.465	17.147**
$T_1 - T_2T_3$	$(T_1 - T_2T_3) \times S$	.006	1	.006	.028
$T_2 - T_3$	$(T_2 - T_3) \times S$	4.924	1	4.924	59.041**
C x T	C x T x S	1.093	4	.273	2.872*
$(C_3 - C_1C_2) \times (T_1 - T_2T_3)$	$(C_3 - C_1C_2) \times (T_1 - T_2T_3) \times S$	.206	1	.206	3.441
$(C_3 - C_1C_2) \times (T_2 - T_3)$	$(C_3 - C_1C_2) \times (T_2 - T_3) \times S$	.392	1	.392	4.633*
$(C_1 - C_2) \times (T_1 - T_2T_3)$	$(C_1 - C_2) \times (T_1 - T_2T_3) \times S$	.269	1	.269	2.459
$(C_1 - C_2) \times (T_2 - T_3)$	$(C_1 - C_1) \times (T_2 - T_3) \times S$	.227	1	.227	1.907
$(C_3 - C_1C_2) \times T$	$(C_3 - C_1C_2) \times T \times S$	.598	2	.299	4.139*
T/C_1	T x S	1.698	2	.849	5.909*
T/C_2	T x S	3.560	2	1.780	12.388**
T/C_3	T x S	0.764	2	0.382	2.659
S		62.152	17	3.656	
S x C		27.848	34	.819	
S x T		4.887	34	.144	
S x C x T		6.470	68	.095	

C_1 high-intensity exercise condition

C_2 low-intensity exercise condition

C_3 no-exercise condition

* $p < .05$

** $p < .01$

significant effect was also found for time within the high-intensity exercise condition ($F(2,34) = 5.91$, $p < .05$) and the low-intensity exercise condition ($F(2,34) = 2.39$, $p < .01$), but there was no time effect for the no-exercise condition. A two-tailed Dunnett's test revealed significant pre- to 15-minute post-exercise urine acidification for the high-intensity exercise condition ($t(17) = 3.51$, $p < .01$) and a significant pre- to 64-minute post-exercise increase in urine alkalinity for the low-intensity exercise condition ($t(17) = 2.57$, $p < .05$).

Repeated ratings of breathlessness were taken for the first ten subjects immediately after the two exercise sessions and at the corresponding intervals in the control condition. Ratings of breathlessness in the no-exercise condition were subsequently discontinued as all volunteers had consistently indicated their breathing was "completely normal" on a seven-point scale. For the remaining eight subjects breathlessness ratings were completed only after exercising. The first ten subjects rated themselves as breathing normally after an average of 2.75 (SD = 1.31) and 1.95 (SD = 1.44) minutes for the high, and low, intensity exercise conditions respectively (mean = 2.56 and 1.81 for all 18 subjects). There was a significant difference in ratings of breathlessness among the three conditions as determined by a repeated measures ANOVA, for the first ten subjects ($F(2,18) = 21.85$, $p < .001$). Results of a Tukey's Honestly Significant Difference test conducted on all possible pairwise comparisons indicated a significant difference in breathlessness ratings between the no-exercise and high-exercise groups ($\overline{X}_3 - \overline{X}_1 = 2.75$) and between the no-exercise and low-exercise groups ($\overline{X}_3 - \overline{X}_2 = 1.95$) (CV = 1.09, $p < .05$, k = 3, r = 18). A Scheffé test conducted on comparisons of each condition with the other two (i.e., $C_1 - C_2C_3$, $C_2 - C_1C_3$, $C_3 - C_1C_2$) indicated a significant difference between the high-exercise versus the no- and low-exercise conditions ($F = 22.38$, $p < .01$) and between the no-exercise versus the hi- and low-exercise conditions ($F = 39.78$, $p < .01$).

Pulse rates, taken immediately after the two-minute recovery period, were highest for the high intensity exercise condition (mean = 120.3, SD = 9.34), intermediate in the low intensity exercise condition (mean = 104.2, SD = 5.46) and lowest in the control condition (mean = 69.6, SD = 9.34). A repeated measures ANOVA showed a significant difference among the three conditions ($F(2,34) = 353.93$, $p < .001$) and planned orthogonal contrasts revealed a significant difference between the experimental and control conditions ($t(1,17) = 20.6$, $p < .001$) and between the high and low intensity exercise conditions ($t(1,17) = 11.87$, $p < .001$).

Reliability Checks

Reliability checks were made by an independent observer on 26 percent of the observations, including latency to smoke, time extinguished and number of puffs, all taken for the first cigarette smoked in the waiting room. There was a perfect correlation between the two observers for the latency measure and a near perfect correlation for measures of cigarette extinction time ($\underline{r} = .99$, $\underline{p} < .001$) and number of puffs per cigarette ($\underline{r} = .98$, $\underline{p} < .001$).

Pearson correlations were calculated for the observer's record of the number of cigarettes smoked by the subject in the waiting room and subjects' self-report via tally cards of the number of cigarettes smoked during the same period. The correlation was .76 ($\underline{p} < .001$), indicating that subjects' self-report is a fairly reliable indicant of smoking behavior within the experimental session.

Dependent Variables

Two way (order x condition) repeated measures ANOVAs were conducted on measures of smoking rate and topography, with order effects counterbalanced. Analyses revealed no main effect for order and no order by condition interaction on any measures. The cells were, therefore, collapsed across order and one-way repeated measures ANOVAs were computed for each of the smoking variables.

Scores for the number of cigarettes consumed 23 hours post-exercise were adjusted by dividing these scores by the number of waking hours (calculated from the subject's report on the tally card of the time he retired and awoke each day). There was no difference in the ANOVA results of these scores and the unadjusted scores; the latter were, therefore, used in subsequent analyses.

The only smoking measure for which a significant overall finding was obtained was cigarette duration ($F(2,34) = 3.31$, $p < .05$), which was longest following the control condition and shortest after high-intensity exercise. Planned orthogonal contrasts indicated a significant difference in this smoking variable between the exercise conditions and control condition ($t(1,17) = -2.45$, $p < .05$), but not between the high- versus low-intensity exercise conditions. Means and standard deviations for all the smoking measures are presented in Table 2.

Correlational Statistics

Pearson correlations were calculated between cigarette duration and pre- to 15 minute post-exercise urinary pH change for the high-intensity exercise condition, for which urine acidified significantly. A significant inverse relationship was found between cigarette duration and change in urinary pH following high-intensity exercise ($r = -.41$, $p < .05$). Pearson correlations were calculated between cigarette duration and the remaining physiological measures across conditions in order to explore any potential relationships among these variables. A Bonferroni correction for alpha level was calculated by dividing the level of significance by seven comparisons in each exercise condition and by six comparisons in

Table 2

Means and Standard Deviations of Smoking Measures in the Three Experimental Conditions

Smoking Measures	High Intensity Exercise Condition		Low Intensity Exercise Condition		Control Condition	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
CIG 1	1.72	0.58	2.00	0.69	1.78	0.81
CIG 23	25.28	17.87	25.78	10.83	25.06	10.97
WTCIG	0.93	0.38	1.10	0.44	1.00	0.47
LAT	10.73	12.05	7.67	6.88	10.86	12.64
PUFF	7.17	2.50	7.94	3.28	7.33	2.06
DUR*	7.49	1.76	7.70	1.59	8.51	1.79

CIG 1 number of cigarettes smoked in waiting room 1 hour post-exercise
CIG 23 number of cigarettes smoked 23 hours post-exercise
WTCIG weight of cigarette(s) smoked in waiting room
LAT latency to smoke in waiting room post-exercise
PUFF number of puffs for first cigarette smoked in waiting room
DUR duration of first cigarette smoked in waiting room
* a significant difference ($p < .05$) across the three conditions

the control condition, for which ratings of breathlessness were omitted (Kirk, 1968). An initial alpha level was set at .10 due to the exploratory nature of the analyses. This resulted in the adoption of alpha levels of .014 and .017 for correlations in the experimental and control conditions, respectively. None of these correlations attained this level of significance, suggesting that these physiological variables did not mediate the effect of exercise on cigarette duration.

Pearson correlations were also calculated among the smoking measures to determine any interrelations between them. These correlations are presented for the two exercise and the control conditions in Tables 3, 4 and 5, respectively. A Bonferroni correction for level of significance, using .10 for an overall alpha level, resulted in an alpha level of .007 for the matrix in each condition. One consistent finding is that the weight and number of cigarettes consumed in the waiting room were significantly correlated in all the conditions, indicating that their relationship is not influenced by exercise. Additionally, three significant correlations, those between weight of cigarette(s) consumed during the first hour and both latency to smoke (negative correlation) and number of puffs for the first cigarette, and between number of puffs for the first cigarette and number of cigarettes smoked in the waiting room, are significant only in the no-exercise condition. That these relationships were significant in the control condition but in neither of the exercise

Table 3

Correlation Matrix for Smoking Measures following No-Exercise Condition

		cig1	cig23	wtcig	lat	puff
cig23	r =	.52				
wtcig	r =	.85**	.43			
lat	r =	-.54	-.32	-.63*		
puff	r =	.65*	.52	.64*	-.29	
dur	r =	-.28	-.03	.09	.02	-.004

cig1 = number of cigarettes smoked 1 hour post-exercise
cig23 = number of cigarettes smoked 23 hours post-exercise
wtcig = weight of cigarette(s) smoked 1 hour post-exercise
lat = latency to smoke post-exercise
puff = number of puffs for first cigarette post-exercise
dur = duration of first cigarette post-exercise

* $p < .005$
** $p < .001$

Table 4

Correlation Matrix for Smoking Measures following Low-Intensity Exercise

		cig1	cig23	wtcig	lat	puff
cig23	r =	.55				
wtcig	r =	.84**	.49			
lat	r =	-.10	-.43	-.25		
puff	r =	.39	.19	.46	-.25	
dur	r =	.02	.24	.16	.03	.47

cig1 = number of cigarettes smoked 1 hour post-exercise
cig23 = number of cigarettes smoked 23 hours post-exercise
wtcig = weight of cigarette(s) smoked 1 hour post-exercise
lat = latency to smoke post-exercise
puff = number of puffs for first cigarette post-exercise
dur = duration of first cigarette post-exercise

* $p < .005$
** $p < .001$

Table 5

Correlation Matrix for Smoking Measures following High-Intensity Exercise

		cig1	cig23	wtcig	lat	puff
cig23	r =	.41				
wtcig	r =	.96**	.36			
lat	r =	-.41	-.18	-.32		
puff	r =	.36	.19	.28	-.15	
dur	r =	.27	.35	.37	-.18	-.14

cig1 = number of cigarettes smoked 1 hour post-exercise
cig23 = number of cigarettes smoked 23 hours post-exercise
wtcig = weight of cigarette(s) smoked 1 hour post-exercise
lat = latency to smoke post-exercise
puff = number of puffs for first exercise cigarette post-exercise
dur = duration of first cigarette post-exercise

* $p < .005$
** $p < .001$

conditions suggests that the variables are differentially affected by exercise. Finally, it is interesting that a topographical measure of the first cigarette smoked, puff rate, was significantly correlated with a behavioral by-product of smoking, cigarette weight, and a measure of smoking rate, number of cigarettes consumed, both of which were obtained during the first hour following exercise.

DISCUSSION

A significant inverse relationship was found in this study between exercise intensity and cigarette duration. This would appear to be the first controlled demonstration of an effect of exercise on cigarette smoking, since there was no mention in a recent exhaustive review of the literature (Martin and Dubbert, 1982) of studies showing this effect. An additional finding is that while weight and number of cigarettes were significantly correlated across conditions, correlations between puff frequency and both weight and number of cigarettes were significant only in the control condition, suggesting that these variables are differentially affected by exercise. Finally, high-intensity exercise significantly reduced urine pH at 15 minutes post-exercise and there was a significant inverse relationship between this change in pH level and cigarette duration. No other significant correlations were found between cigarette duration and any other physiological measure.

Why did exercise reduce cigarette duration and yet fail to suppress any other smoking measure? One possible reason is that cigarette duration is closely related to the smoker's exposure to sidestream smoke, which is released directly into the air. The remaining measures, except for weight of cigarette consumed, primarily reflect exposure to mainstream smoke, which is inhaled directly by the smoker (Frederiksen and Martin, 1980). As sidestream smoke is unfiltered, it contains higher concentrations of both nicotine and CO (USPHS, 1977). It may be that exercise reduces one's tolerance for these harmful smoke elements and, to the extent that cigarette duration is one of the smoking measures most directly related to sidestream smoke exposure, it would more likely be suppressed following exercise.

This study is the first to indicate that multiple topographical measures are affected differentially in response to exercise or urinary pH change. In one other study assessing smoking following urinary pH change (Dobbs, et al., 1981), the dependent variables included puff rate and length of cigarette smoked. In that study, stressing subjects by leading them to believe they would be required to give a speech significantly acidified the urine and had an inhibitory effect on both smoking measures. Two of the Schachter studies (Schachter, Silverstein, Kozlowski, Herman, and Liebling, 1977; Schachter, Silverstein, and Perlick, 1977) found a decrease in urinary pH and in both number of cigarettes smoked and number of puffs per cigarette in a one hour waiting period following electric shock. Neither the remaining Schachter study (Schachter, Kozlowski, and Silverstein, 1977) nor the Marshall et al. (1980) study, both of which assessed the influence of urinary pH on smoking, used topographical aspects of smoking in their analyses, nor did the four studies directly examining the influence of exercise on smoking (Engs and Mulhall, 1982; Howley et al., 1980; Johnson et al., 1979; Morgan et al., 1976). As suggested by Foy, Rychtank and Prue (1981) there is a need, therefore, for further research to examine the relationships among topographical measures during changing patterns of cigarette smoking.

Although this study found an effect of exercise on smoking, the exercise manipulation was apparently weak as it affected only one of six smoking measures. Furthermore, the presence of an effect on only one of six variables raises the possibility of a significant finding due to chance alone. Clearly, the need exists for replication of the present finding. To maximize the effect of exercise on smoking, consideration should be given in future research to providing exercise of longer duration and to scheduling repeated exercise sessions over a longer period of time. In addition, future studies assessing directly the effects of aerobic exercise on smoking should continue to include assessment of topographical aspects of smoking. Indeed, no effect of exercise on smoking would have been found in the present study were it not for assessment of these smoking measures.

If the finding of an effect of exercise on smoking is replicated, both theoretical and clinical implications would ensue. At a theoretical level, repeated demonstrations of a decrease in both urinary pH and smoking following exercise would suggest the need for re-examination of Schachter's hypothesis. According to Schachter (1977), a reduction in urinary pH would result in a greater rate of depletion of nicotine, leading to increased smoking in order to restore nicotine homeostasis. This has been replicated by research examining the effect of decreases in urinary pH on smoking. The Schachter studies demonstrated that stress manipulations resulted in a decrease in urinary pH and a concomitant increase in smoking rate. These findings were verified by Dobbs and his colleagues (1981). In their study, subjects who were psychologically stressed and listened to a neutral tape experienced an average urinary pH decrease of slightly over 0.2 pH (as indicated by a graph). Results demonstrate that these subjects significantly increased their puff rate and amount smoked. In the present study, a mean pH decrease of 0.248 and 0.347 was found for subjects in the low- and high-intensity exercise conditions, respectively. Since the pH changes in the present study were of a greater magnitude than those in the Dobbs study, correspondingly greater increases in smoking would be expected. Instead, results of the present study indicate a significant decrease in cigarette duration and no change in the other smoking measures, in response to urine acidification. Moreover, there was a significant inverse relationship between cigarette duration and urinary pH.

What factors might account for the contradictory results between the present study and the Schachter and Dobbs studies? One major difference between the studies is that the present study involved physical rather than psychological stress. Therefore, even though urinary pH levels were low due to physical stress, subjects may have experienced a decrease in tension and anxiety in response to exercise. This in turn may have curtailed rather than increased smoking. There is suggestive evidence that subjects in the present study reduced smoking following exercise due to these factors. In a post-experimental questionnaire the most frequently selected item to account for reductions in smoking following exercise (selected by 6 of 11 subjects) was that biking in the study reduced feelings of tension and anxiety. These results suggest that psychological factors may be either more influential than urinary pH in determining post-exercise smoking, or it may be that pH changes are merely correlated and not causally related to smoking. Further research examining post-exercise change in both urinary pH and psychological state is necessary to evaluate the effects of these two variables on smoking.

In addition to providing an impetus for a re-examination of Schachter's nicotine addiction hypothesis, replication of an effect of exercise on smoking would have clinical implications.

If future research confirms that exercise reduces smoking, then exercise could be used in a DRO (Differential Reinforcement of Other Behavior) strategy for smoking cessation, where undesirable behavior is eliminated by encouraging the development of incompatible responses (Homer and Peterson, 1980). Behavior modifiers prefer the use of this approach over the use of aversive response elimination procedures as it is more ethically acceptable, has fewer side effects, and results in a more durable and generalizable response reduction (Homer and Peterson, 1980).

Despite the above advantages of DRO, there exists only one mention in the literature of the use of this procedure for eliminating smoking (Barton and Barton, 1978). One reason why this approach has not been used more regularly in smoking treatment is that very few behaviors have been demonstrated to be incompatible with smoking. If further research indicates that smoking and exercise are incompatible, the use of this strategy may be applied to smoking intervention.

In conclusion, while the present study demonstrated a suppressive effect of exercise on smoking, replication of this finding is necessary before definitive conclusions regarding the relationship between these two variables can be made. Implications for further research are twofold. First, demonstration of smoking reduction following post-exercise urine acidification would lead to a re-examination of the role of nicotine and urinary pH in smoking. Secondly, exercise could be used therapeutically in a DRO strategy for smoking cessation.

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APPENDIX A

INFORMATION FOR PHONE CONTACT

This study investigates the physiological effects of different intensities of exercise on cigarette smokers. We will ask you to come to the lab in the Chemical Engineering building at the same time on 4 consecutive days to pedal on a stationary bicycle for 10 minutes. During one of these sessions, you will just be sitting on the bike without doing any exercise.

We will be taking various physiological measures before, during, and after you exercise on the bicycle. These measures include blood pressure, ECG, a urine sample, and weight. At the first session we will ask you to complete a questionnaire on your smoking and exercise history.

After each exercise session, we require that you wait in an adjacent room for 1 hour until we have obtained the last urine sample. However during this time you are free to work quietly on whatever you like (reading, writing, homework, etc.) so be sure to bring something to work on.

You will be required to abstain from eating, or drinking caffeinated or alcoholic beverages for 2 hours before each session, and from smoking for 1/2 hour before each session. Immediately after exercise you will be permitted to smoke, and a pitcher of water will be available in case you are thirsty. After the first session, we will give you a tally card to keep track of the number of cigarettes you smoke each day between the exercise sessions, i.e., for three days. This information will assist us in interpreting the differences among participants in terms of physiological effects to be observed following exercise sessions.

At the last session, you will receive $25 for your participation in the study and we will give you personal feedback on the measures that we have taken. Do you have any questions?

(Get name, phone number, times available, and schedule sessions).

APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

A Self-administered Questionnaire for Adults

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check ( ) YES opposite the question if it applies to you.

YES

( ) 1. Has your doctor ever said you have heart trouble?

( ) 2. Do you frequently have pains in your heart and chest?

( ) 3. Do you often feel faint or have spells of severe dizziness?

( ) 4. Has a doctor ever said your blood pressure was too high?

( ) 5. Has a doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

( ) 6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

( ) 7. Are you over age 65 and not accustomed to vigorous exercise?

APPENDIX C

Physiological Responses to Exercise Among Smokers

Outline of Study

Throughout the 4 days of the study - Refrain as much as possible from taking any drugs, medications and alcohol since these substances may effect your physiological responses to exercise. From your first session to your last, record the time at which you smoke every cigarette including those smoked during, and between sessions.

2 hours prior to each session - abstain from eating, and from drinking alcohol and caffeinated beverages.

1/2 hour prior to each session - abstain from smoking.

Sessions A. In the lab

1. pre-exercise measures of pulse and blood pressure will be taken and samples of urine will be collected. (5 min.)
2. ECG monitoring while pedaling an exercise bicycle. (10 min.)
3. post-exercise measure of blood pressure. (5 min.)

Total time in the lab: 20 min.

B. In the waiting area

Urine specimens collected after 15, and 60 minutes.

Note: During the hours you spend in the waiting room, you may work at the desk on any reading or studying you bring with you. Although you may smoke during this time and drink water which will be provided, you may not eat until the final measures are taken.

APPENDIX D

Consent Form

The purpose of this study is to examine the physiological response to exercise among cigarette smokers. Four 1 1/2 hour sessions will be scheduled on consecutive weekdays during which you will pedal a stationary exercise bicycle for approximately 10 minutes. The resistance or the drag against which you will pedal, however, will vary from one session to the next. While you are pedaling, changes in your heart rate will be monitored by an instrument (ECG) via electrodes attached to your chest by sticky tape. There will also be a session where your heart rate will be monitored while you are seated and engaging in no exercise. To ensure that your heart rate is unaffected by factors other than exercise, it is essential that you: (1) refrain from engaging in other vigorous physical activity during the four days of the study; (2) refrain from smoking, eating, and drinking coffee, tea, or cola beverages within two hours of each session, and (3) refrain from consuming alcoholic beverages each day before each session.

In addition to heart rate changes, we are also interested in changes that occur in the urine as a result of exercise. Accordingly, we will ask that you provide a urine specimen before exercising and that you remain in the laboratory waiting room for one hour afterward. The second and third urine specimens will be collected 15 and 60 minutes after completing the exercise.

Since your physiological response to exercise may vary according to the amount you smoke, it is also important that you keep a tally on the card provided of the number of cigarettes you smoke during the study and the times at which you smoke them. This information will assist us in accounting for any difference among the participants in terms of their physiological response to the exercise in which they engage during the sessions.

After the fourth session, you will be paid $25 for participating in the study and given feedback if you would like it regarding your level of aerobic fitness. You may, of course, withdraw from the study at any time.

I have read the description above, had all my questions answered to my satisfaction, and do hereby consent to participate in this study.

Date: ____________________

Participant's
Signature: ________________

Witness: __________________

APPENDIX E

SUBJECTIVE RATINGS OF BREATHLESSNESS FORM

Subject no. ____ Session no. ____ Condition no. ____

Please circle the number which represents how you feel right now.

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

1.	2.	3.	4.	5.	6.	7.
As out of breath as I've ever been						breathing completely normal

APPENDIX F

Experimental Script: Waiting Room

At first session

E1: (working at the table, in view of where subject will sit) -- knock on the door - (E1 starts stopwatch)

E2: (S's name, "You can sit, (E2 gestures towards a seat), relax and work quietly on whatever you have brought, or look through the magazines if you like. This is (E1's name)"

E1: (looks up) "Hi" (Then resumes work)

E2: "He will be working here while you are waiting and will let you know when it's time to take samples. We'd like you to wait in your gym strip and change after all the sampels have been taken. Any questions?" (allow time for S to respond).

E1: (after 11 minutes) "Okay (S's name), time for the urine specimen just like before" (Hand S the container and thank him when he returns).

E1: (after 60 minutes "The hour's over (S's name). After you do the urine sample that will be it for today". (Hand S the container and thank him when he returns).

Subsequent sessions:

Follow basically the same script with some modification considering that S has been through the procedure already.

Deviations from Script:

Any conversation with S should be minimized since interaction with subject may influence their smoking behavior. This can be accomplished by: 1) answering questions pertaining to the experiment as briefly as possible from the information on their schedule and returning back to work or 2) politely terminating any additional conversation: "I'd like to chat but I've got to get this finished for my next class" (or something similar). Remember, S does not know that his smoking behavior is being observed so try and be as unobtrusive as possible in noting the time. Also, do not acknowledge at any time that the study is in any way connected with Psychology. Finally, during the session S may ask for a light, or for a cigarette. Acknowledge the request, give them a cigarette or light, then return back to work (make sure both are available at each session).

APPENDIX G

EXERCISE AND SMOKING QUESTIONNAIRE

Name:________________________ Age:________ Sex:_________

Address:____

____

Phone Number:______________ Best time to call:______________

Occupation:____

Do you exercise regularly?________ If yes, describe your exercise habits____

____

____

Please circle all of the physical activities in the following list in which you have engaged during the past four weeks: aerial tennis, badminton, basketball, boxing, calisthenics, curling, bicycling, stationary cycling, dancing (please specify step below), fencing, football, golf, handball, hockey, karate, kung-fu, lacrosse, racquetball, rope-skipping, rowing, running (stationary), running/jogging, skating, skiing, squash, swimming, tennis, volleyball, walking, wrestling, other sports not mentioned above.

Enter the activity(ies) you have circled in the appropriate space(s) below and provide as accurate an estimate as you can of each of the following: quantity or distance travelled on each occasion (e.g., miles, yards, sets), time in minutes to complete the activity, and average number of times you engaged in the activity each week.

Activity	Quantity/Distance	Time	Average Weekly Frequency
____________	____________________	__________	__________________
____________	____________________	__________	__________________
____________	____________________	__________	__________________
____________	____________________	__________	__________________

Circle a number below to indicate:

1. How physically active you consider yourself to be now.

1	2	3	4	5
very active	active	average	inactive	very inactive

2. Your current level of physical fitness.

1	2	3	4	5
very fit	fit	average	unfit	very unfit

What brand of cigarette do you smoke? ______________________

How many cigarettes per day do you smoke on the average on a weekday? ______________

on weekends? ______________

How long have you been smoking? ______________years

Have you made any attempts to quit smoking in the last 6 months?

Yes______No________

If so, when and for how long? _________________________

Are you presently attempting to cut down or stop smoking?

Yes_____No_______Are you presently on any medication? If so, please specify the type, dosage, and frequency:_____________

____

Thank you for your cooperation in filling out this questionnaire.

APPENDIX H

Post-Study Questionnaire

1. What was the purpose of the study?

____

____

____

____

2. Did you make any deliberate attempt during the study to alter your smoking behavior? Yes_____No______If so, please specify what you did and whether you believe it did in fact affect your smoking.

____

____

____

____

3. Did you expect at any time that participation in the study would affect your smoking?

Yes_____ No_____ If yes, what aspect of the procedure did you believe would affect your smoking? _____________________

____

How did you expect your smoking would be effected?

Increased______ Decreased______

When did you expect your smoking would be effected?

_____prior to first session

_____between 1st & 2nd session

_____between 2nd & 3rd session

_____between 3rd & 4th session

_____following fourth

4. Do you think that the exercise you engaged in during any of the sessions affected your smoking? Yes_____No______If yes, how was your smoking affected? Increased_______Decreased_____

Why do you think it was affected in this way?

____

____

____

____

5. Check any of the following explanations you believe account for the changes in your smoking behavior:

Explanations for increased smoking:

_____ felt more tense and anxious due to the evaluative nature of the study or exposure to a health-promoting environment.

_____ you were bored in the waiting room.

_____ you always smoke in waiting rooms and/or when you read.

_____ you wanted to reward yourself for having engaged in exercise.

_____ you felt uncomfortable smoking in front of the other person in the waiting room.

Explanations for decreased smoking:

If you feel you decreased you smoking behavior after exercise was it for any of the following reasons? (please check):

_____ you were trying to recover from the exercise, i.e., "catch your breath" and smoking hindered this.

_____ participating in exercise made you more aware of your health habits and thus motivated you to decrease your smoking.

_____ exercising reduced feelings of tension and anxiety; therefore, you needed to smoke less.

Thank you for filling out this questionnaire.