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THE EFFECTS OF SYMPATHETIC ACTIVATION ON PHYSIOLOGICAL AND SUBJECTIVE SEXUAL AROUSAL IN WOMEN

CINDY M. MESTON and BORIS B. GORZALKA

Department of Psychology, University of British Columbia, Vancouver, Canada V6T 1Z4

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Summary—This investigation was designed to examine the effects of acute exercise on physiological and subjective sexual arousal in women. In Experiment 1, *S*s participated in two experimental sessions in which they viewed a neutral film followed by an erotic film. In one of these sessions, *S*s were exposed to 20 min of intense exercise prior to viewing the films. Subjective sexual arousal was measured with a self-report rating scale and physiological sexual arousal was measured with a vaginal photoplethysmograph. Acute exercise significantly decreased vaginal pulse amplitude responses to a neutral stimulus and significantly increased vaginal pulse amplitude responses to an erotic stimulus. Exercise marginally increased vaginal blood volume responses to an erotic film but had no significant effect on subjective perceptions of sexual arousal. In Experiment 2, *S*s viewed two consecutive neutral stimuli preceded by 20 min of intense exercise. There were no significant differences in either vaginal blood volume or vaginal pulse amplitude between the two neutral films. Together, the data from Experiments 1 and 2 provide indirect support for a facilitatory role of sympathetic activation in female sexual arousal.

INTRODUCTION

The precise role of sympathetic and parasympathetic nervous system influences on sexual arousal remains a matter of conjecture. For many years, it has been argued that increases in sympathetic activity inhibit sexual arousal in both men and women and parasympathetic influences play a facilitatory role (e.g. Kaplan 1974, 1988; Wolpe, 1958). These assertions are based, in large, on clinical reports which indicate that performance anxiety causes erectile difficulties in men (e.g. Ansari, 1975; Cooper, 1969; Johnson, 1965), and on the well known fact that sympathetic activation inhibits blood flow to specific organ systems (e.g. Carlson, 1994; Weiss, 1972).

In contrast to this view however, recent research on the effects of anxiety on sexual arousal has shown that, in certain situations, sympathetic activation may in fact facilitate or have no effect upon sexual arousal. For example, Lange, Wincze, Zwick, Feldman and Hughes (1981) reported that sympathetic activation, artificially induced by injections of epinephrine hydrochloride, had a significant inhibitory effect on penile tumescence post-stimulus presentation, but had no effect on tumescence during the sexual-stimulus presentation. Other research conducted in men has shown that anxiety induced by shock-threat (Barlow, Sakheim & Beck, 1983), performance demand instructions (Heiman & Rowland, 1983), or exposure to an anxiety-arousing videotape (Wolchik, Beggs, Wincze, Sakheim, Barlow & Mavissakalian, 1980) can heighten physiological sexual arousal. Studies that have been conducted in women reveal similar increases in physiological sexual arousal with exposure to an anxiety-evoking film (e.g., Hoon, Wincze & Hoon, 1977). While some of these studies may suggest a facilitatory influence of sympathetic activation on sexual arousal, it is uncertain to what extent the reported changes in sexual arousal are attributable to changes in nervous system function or, alternatively, to cognitive factors associated with the anxiety stimuli. The untangling of these two potential explanations is impossible given these studies did not directly measure nervous system activity. By examining the effects of acute, intense exercise on sexual arousal in women, the present experiments were designed to provide a more direct examination of the effects of sympathetic activation on subjective and physiological sexual arousal in women.

In the present investigation, exercise was chosen as a means of activating the sympathetic nervous system based on a number of pharmacological and physiological studies which indicate that activation of the sympathetic branch of the nervous system becomes prominent at high intensities

of exercise. For example, an early study on the effects of heart rate response to exercise during pharmacological blockade (Robinson, Epstein, Beiser & Braunwald, 1966) demonstrated that, while the increase in heart rate with exposure to low or moderate intensities of exercise is mediated primarily by parasympathetic nervous system withdrawal, the increase in heart rate at higher levels (e.g. 60% $VO_{2\,max}$) of work is mediated primarily by sympathetic stimulation. Numerous studies that have reported increases in plasma norepinephrine and epinephrine to moderate and heavy exercise also support the idea that intense exercise activates the sympathetic nervous system (e.g. Galbo, Holst & Christensen, 1976; Haggendal, Hartley & Saltin, 1970; Mazzeo & Marshall, 1989). More recently, studies using the technique of spectral analysis of heart rate variability have shown that parasympathetic nervous system withdrawal occurs primarily up to moderate levels of exercise, and sympathetic nervous system activity becomes prominent during moderate to heavy exercise (Nakamura, Yamamoto & Muraoka, 1993; Yamamoto, Hughson & Nakamura, 1992). These sympathetic nervous system effects at high intensities of exercise are thought to remain significantly elevated for between 15–30 min post exercise (e.g. Cleroux, Peronnet & De Champlain, 1985; Kraemer, Patton, Knuttgen, Hannan, Kettler, Gordon, Dziados, Fry, Frykman & Harrian, 1991; Strobel, Hack, Kinscherf & Weicker, 1993). In the present investigation, sympathetic activation was ensured by exercising *S*s at high intensity workloads (70% $VO_{2\,max}$), for sufficient periods of time (20 min), and by measuring sexual arousal following exercise, within a time frame that sympathetic nervous system activation was still present (15 min).

EXPERIMENT 1

The purpose of Experiment 1 was to examine the effects of acute exercise, designed to elicit sympathetic nervous system activity, on physiological and subjective sexual arousal in women. Thirty-five *S*s participated in two experimental sessions in which they were shown a neutral film stimulus followed immediately by an erotic film stimulus. In one of these two sessions, the *S*s were exposed to 20 min of stationary cycling prior to viewing the films. Subjective sexual arousal was measured using a questionnaire. Physiological sexual arousal was measured using both vaginal blood volume and vaginal pulse amplitude as indices. Heart rate was used as an indicator of general autonomic arousal.

Method

Subjects

Thirty-five women participated in the study (M age = 24.6 yr, range = 18–34). The *S*s were recruited through a psychology department undergraduate research participant pool or by personal contact. Nine *S*s were graduate students in psychology, 14 *S*s were first or second year undergraduate students in psychology, and 12 *S*s were undergraduate or graduate students in disciplines other than psychology. Racial background of the *S*s was: Caucasian (32), and Asian (3). All *S*s were currently involved in sexual relationships. Of the 35 *S*s, only one *S* was married. Subjects were given course credit and/or a fitness assessment profile as an incentive for their participation. Initial telephone screening criteria were: between the ages of 18–35 yr, no use of medications known to affect vascular or sexual functioning, no history of treatment for sexual dysfunction, no medical condition that may put the *S* at risk when exercising, and current involvement in a heterosexual relationship. Further inclusion criteria, based on *S* information from the Derogatis Sexual Functioning Inventory (Derogatis, 1978), and the Physical Activity Readiness Questionnaire (developed by the British Columbia Ministry of Health) included: absence of general psychopathology, absence of sexual dysfunction, within the normative range of sexual experience, no history of heart disease or cardiovascular dysfunction, no history of dizzy spells or 'light-headedness', and no bone or joint problem that might be aggravated by 20 min of cycling.

Profile descriptions of all *S*s were obtained via the Derogatis Sexual Functioning Inventory (Derogatis, 1978). The Sexual Functioning Index and the Global Sexual Satisfaction Index of the Derogatis Sexual Functioning Inventory were used to screen for absence of sexual dysfunction. All *S*s employed in the study scored greater than or equal to the 40th percentile on both the Sexual Functioning Index (M = 51.08, range = 40–70) and the Global Sexual Satisfaction Index

($M = 55.11$, range = 40–70). In addition, the Brief Symptom Inventory (Derogatis, 1975) subtest of the Derogatis Sexual Functioning Inventory was used to screen for absence of general psychopathology. All *S*s employed in the study scored greater than or equal to the 30th percentile (i.e. within two SDs of the normative mean) on the Brief Symptom Inventory ($M = 48.03$, range = 30–79). Data from the Experience subtest of the Derogatis Sexual Functioning Inventory was used to ensure that all *S*s were within the normative range of sexual experience (i.e. within two SDs of the normative mean). All *S*s scored above the 30th percentile on the Experience subtest ($M = 51.94$, range = 31–63).

One *S* was eliminated from the study because of breathing difficulties related to asthma. One *S* was eliminated because she scored below the cutoff criterion for general psychopathology. Five *S*s were eliminated from the study because they were considered sexually dysfunctional according to the Derogatis Sexual Functioning Inventory criteria. Data for one *S* was eliminated because of technical difficulties which may have influenced the results. Thirty-five *S*s met all inclusion criteria and served as *S*s in the study.

Design and procedure

The procedure consisted of four sessions: a 1-h orientation screening and questionnaire session; a 20-min bicycle ergometer fitness test; a 45-min No-exercise experimental session; and a 1-h Exercise experimental session. Order of the two experimental conditions, Exercise and No-exercise, was counterbalanced across *S*s. The Exercise session was presented first for 17 *S*s, and the No-exercise session for the remaining 18 *S*s. During each experimental session *S*s viewed one of two 7-min videotaped sequences, referred to here as Sequence A and Sequence B. Each sequence consisted of a 1-min display of the word 'relax' followed by a 3-min neutral travelogue film and then a 3-min erotic film. Nine of the *S*s in each condition viewed Sequence A in the 3rd session and Sequence B in the 4th session, while the reverse was true for the remaining *S*s. Subjects were told that they would be viewing films which may contain erotic scenes.

Sequence A and B differed only in the content of the neutral and erotic films. The neutral film in Sequence A depicted geographic scenes from the Antarctic; Sequence B depicted wildlife scenes from the Antarctic. In both Sequence A and B, the erotic films depicted a nude, heterosexual couple engaging in foreplay and intercourse. The erotic films were accompanied by fast-paced music and included explicit sexual communication by the couple. The two erotic films used in Sequences A and B were matched on the number, order, type, and duration of sexual acts, and included the same actors and settings.

Sessions one and two were conducted during the same week, and preceded the two experimental sessions by two weeks. The two experimental sessions were scheduled at approximately three day intervals and excluded times during which the *S*s were menstruating. Phase of the menstrual cycle was not controlled given that sexaul arousability to erotic stimuli in laboratory situations, measured both subjectively and physiologically, is only minimally, if at all, influenced by the menstrual cycle (Hoon, Bruce & Kinchloe, 1982; Meuwissen & Over, 1992). All *S*s were asked to abstain from psychoactive drugs (including caffeine and alcohol) and to refrain from engaging in any strenuous physical activity for 24 h prior to each experimental session.

Session 1 (orientation/screening). Following an initial telephone screening, *S*s were scheduled for a first session with the female experimenter. During this session, *S*s were shown the laboratory facilities and equipment, were given verbal instructions on the use of the photoplethysmograph, and were encouraged to ask any questions related to the experiment. Subjects were told that they would be participating in an experiment which involved the effects of exercise on female sexual arousal. They were told that they would be viewing brief visual stimuli, some of which may include erotic content. To minimize a possible sense of coercion, *S*s were given the option of either participating in the first session on that day, or telephoning within a week, regarding their decision to participate. One *S* telephoned the following day and withdrew from the study; all other *S*s chose to begin the study that day. Subjects who chose to take part in the study signed the standard consent form and completed the Derogatis Sexual Functioning Inventory in a private room.

Session 2 (fitness testing). During the second session, *S*s first completed a Physical Readiness Exam for Fitness Test, adapted from the Physical Activity Readiness Questionnaire, to ensure they

would not be at risk when exercising. Subjects who were not at risk engaged in a submaximal multi-stage bicycle ergometer fitness test. These assessments provided the necessary information to set cycle speed and intensity, during the exercise conditions (sessions 3 or 4), to the same relative work load for all *S*s. The fitness tests were conducted in accordance with the guidelines set forth by The American College of Sports Medicine (Pollock, Wilmore & Fox, 1978). A Monarch 814E bicycle ergometer was used to conduct the fitness tests. The bicycle seat height was adjusted for each individual to ensure a slight bend in the knee joint when the pedal was in its lowest position. The test began with a workload of 150 kg/min. The *S* cycled at a constant 50 rpm while the workload was increased 150 kg/min every 3 min. The test lasted between 9–12 min (i.e. 3–4 workloads) depending on the *S*s' heart rate response. Heart rate was monitored manually from the carotid artery during the final 30 sec of each third min. Using a standard formula (Golding, Meyers & Sinning, 1982),* the *S*'s heart rate over time, in relation to workload, was used to predict each *S*'s maximum volume of oxygen uptake ($VO_{2\,max}$). The second and third workloads (kg/min) were entered into the formula to predict all *S*s' $VO_{2\,max}$ except for *S*s who received 4 workloads, in which case the third and fourth workloads (kg/min) were entered into the formula. Subjects' fitness levels ranged from 'poor' to 'excellent' according to Canadian Fitness Standards (1986) (M $VO_{2\,max} = 26.71$, range = 16–45).

$VO_{2\,max}$ is the maximal volume of oxygen that one can consume during exhausting work; it is the point at which increased workload is no longer associated with increased oxygen uptake. Because heart rate and oxygen uptake increase linearly in response to increased workload, this test allows the prediction of $VO_{2\,max}$ from heart rate response (Pollock *et al.*, 1978). $VO_{2\,max}$ is an established indicator of cardiorespiratory endurance and subsequent physical fitness (Pollock *et al.*, 1978). The submaximal multi-stage ergometer testing and scoring procedures used in this investigation were identical to those suggested for women by the Young Men's Christian Association (YMCA) (Golding *et al.*, 1982).

Sessions 3 and 4 (experimental). The third and fourth sessions were the two experimental sessions: Exercise and No-exercise. The order of these two sessions was counterbalanced across *S*s. Both experimental sessions were conducted inside the Sexual Psychophysiology Laboratory at the University of British Columbia. This laboratory has an adjoining, private, internally-locked subject room. Communication with *S*s is made possible via an intercom system between subject and experimenter rooms. The room is kept at a constant 21.7°C. A 41 cm color television monitor is positioned 205 cm from the *S*, a distance which allows *S*s to sit comfortably in a recliner with a full view of the screen. A bicycle ergometer is positioned to the rear of the room.

During the No-exercise session, *S*s entered the private, internally locked room together with the female experimenter. They were told that, once the experimenter left the room, they were to sit in the chair and insert the photoplethysmograph so as to allow approximately a 2.5 cm distance between the end of the probe and the vaginal opening. They were also asked to remain as still as possible throughout the session in order to minimize potential movement artifacts. When *S*s notified the experimenter, via the intercom system, that they were ready, a 10-min adaptation recording was taken.

Following the adaptation period, *S*s viewed either videotaped sequence A or B. Each sequence consisted of the word 'relax' (1 min), a neutral travelogue (3 min), followed by an erotic film (3 min). Immediately following the erotic film, *S*s were asked to fill out the subjective rating scale.

During the Exercise session *S*s entered the private, internally locked room with the female experimenter and were informed of the experimental procedure as in the No-exercise session. Subjects were then asked to cycle for 20 min on a Get Fit 200-II stationary bicycle. The *S*s' heart rates were monitored continuously using a Heart Speedometer model 8719 (Computer Instruments Corp., Westbury, N.Y.). Based on the *S*s' working heart rate, the workload was adjusted by the experimenter throughout the 20 min by adding or subtracting pressure to the bicycle pedal to ensure that the *S*s cycled at a constant 70% of their estimated $VO_{2\,max}$. By ensuring that all *S*s worked

*The following standardized formula (Golding *et al.*, 1982) was used to predict *S*s' maximum volume of oxygen uptake: $VO_{2\,max} = SM2 + b(\text{max HR1} - \text{HR2})$, where SM1 = Second workload (kg/min), SM2 = Third workload (kg/min), HR1 = Second workload heart rate (bpm), HR2 = Third workload heart rate (bpm), $b = (SM2 - SM1)/(HR2 - HR1)$, max HR = 220 − age in yr.

at equivalent levels of their $VO_{2\,max}$, differences in physiological responses resulting from variations in fitness levels are minimized (Grossman & Moretti, 1986).

When one minute of cycling time remained, the experimenter left the room. Subjects had been instructed to continue cycling until the time signaled 20 min and then to sit in the chair, insert the plethysmograph, and notify the experimenter, via the intercom system, when they were ready. When the experimenter was notified, a 10-min adaptation recording was taken, followed immediately by one of the two videotaped sequences (A or B). The total time from the cessation of exercise to the onset of the erotic stimulus was approximately 15 min (10-min adaptation, 1 min to insert the plethysmograph, 1 min display of the word 'relax', 3-min neutral film). Immediately following the erotic film, *S*s were asked to fill out the subjective rating scale. With the exception of 20 min of cycling, all experimental procedures were identical to those of the No-exercise session.

Subjects who would not be participating in Experiment 2 were thoroughly debriefed, informed about the additional purposes and goals of the study, and given an opportunity to view the records of their vaginal responses. All *S*s were given personal fitness profiles indicating their level of cardiovascular fitness as per Canadian Fitness Standards (1986). Psychology undergraduate students were given credit points for their participation.

Data Sampling and Reduction

Physiological measurements

Physiological measures were obtained using a vaginal photoplethysmograph (Sintchak & Geer, 1975). The photoplethysmograph was washed with Hibitane and sterilized by soaking in Cidex, 2% glutaraldehyde, 98% inert ingredients (long-life activated dialdehyde solution: Surgikose Canada, Peterborough, Ontario) for 10 h between uses.

Changes in vaginal blood volume, vaginal pulse amplitude, and heart rate were monitored simultaneously during all experimental sessions. Vaginal blood volume, the dc signal, reflects slow changes in the pooling of blood in the vaginal tissue (Hatch, 1979). Vaginal pulse amplitude, the ac signal, reflects short-term changes in engorgement (Rosen & Beck, 1988). Several investigators have found pulse amplitude to be a more sensitive measure of sexual arousal (e.g. Geer, Morokoff & Greenwood, 1974; Heiman, 1977; Osborn & Pollack, 1977) and to be less influenced by temperature changes (Beck, Sakheim & Barlow, 1983).

Light and heating effects were minimized by allowing the photoplethysmograph a 45-min warm-up period prior to insertion, followed by a 10-min recorded adaptation period before the experiment began. The signal from the Geer gauge and module (Farrall Instruments, Grand Island, NE) was channeled through an optical isolator-power supply. Vaginal blood volume was transduced using a Beckman Type 9806AB coupler and amplified to yield 0.1 V/mm with the high frequency response filter set at 22 Hz and the time constant set to dc. Pulse amplitude was transduced using a Sensormedics Type 9853A coupler and amplified to yield 10 mV/mm with the low frequency response filter set at 5.3 Hz. The blood volume signal was recorded at a sampling rate of 5 times/sec with a Data Translation (Marlborough, MA) analog-digital converter and Labtech Acquire Program (Laboratory Technologies Corp., 1986) installed on a Samtron SC-386 microcomputer. The vaginal pulse amplitude and vaginal blood volume signals were channeled and recorded on a Beckman model R612 dynagraph (Scheller Park, IL) with a rectilinear pen system, and chart speed set at 2.5 mm/sec. Heart rate was extracted from the pulse amplitude recordings. The software program timed the administration of the stimuli and used an audio trigger signal to mark all stimulus changeovers.

Vaginal pulse amplitude. Vaginal pulse amplitude was recorded throughout the entire 180 sec of neutral film and 180 sec of erotic film. The data were hand scored from the polygraph recordings by a research assistant who was kept blind to the experimental manipulations. For each experimental condition, an average peak to peak amplitude was computed for both the neutral and erotic films by summing the amplitudes of each peak during the middle 20 sec of the neutral or erotic film stimulus and dividing by the number of peaks per interval. Difference scores were computed for each experimental condition by subtracting the average pulse amplitude score during the neutral film from the average pulse amplitude score during the erotic film.

Vaginal blood volume. Vaginal blood volume was sampled during the last 80 sec of neutral film,

and during the entire 180 sec of erotic stimuli. Because there is no absolute method of calibrating vaginal blood volume and, hence, no zero point, the data were scored as 0.0001 mV units of blood volume deviation from a baseline reference level defined as the mean of the last 80 sec of the neutral stimulus.

Heart rate. Heart rate was scored from the pulse amplitude polygraph records by counting the number of beats per 20 sec interval. To ensure that heart rate did not significantly change with time post exercise, the entire 180 sec of neutral and 180 sec of erotic film were scored to yield 18 measures (bpm) for each *S* per experimental condition (nine measures during each of the neutral and erotic films).

Subjective measurements

A self-report rating scale, adapted from Heiman and Rowland (1983), was used as a subjective measure of sexual arousal. This scale has been shown to be a sensitive indicator of emotional reactions to erotic stimuli (Heiman, 1980; Heiman & Hatch, 1980; Heiman & Rowland, 1983; Morokoff & Heiman, 1980). Research indicates that there are no significant differences in subjective reports of sexual arousal obtained by methods of discrete vs continuous subjective measurement (Steinman, Wincze, Sakheim, Barlow & Mavissakalian, 1981). The scale consists of 32 items: sexual arousal (1 item), perceptions of physical sexual change (4 items), autonomic arousal (5 items), positive affect (11 items) and negative affect (11 items). Subjects rated each of these items, depending on the degree to which they experienced the sensations, on a 7-point Likert Scale, from *not at all* (1) to *intensely* (7). Subjective sexual arousal was defined by the first 5 items on the scale: Sexually aroused, warmth in genitals, genital wetness or lubrication, genital pulsing or throbbing, and any genital feelings. Subjective autonomic arousal was defined by the next 5 items on the scale: Faster breathing, faster heart beat, perspiration, feelings of warmth, and any physical reaction at all.

Results

Analyses of the effects of fitness levels

In order to verify that variations in individual fitness levels did not influence levels of physiological sexual responding during the Exercise conditions, Pearson product-moment correlational analyses were calculated between fitness levels (as indicated by $VO_{2\,max}$ scores) and vaginal blood volume deviation scores, and between fitness levels and pulse amplitude difference scores. There were no significant correlations between fitness levels and pulse amplitude responses, $r(35) = 0.022$, $P = 0.45$, or between fitness levels and blood volume responses, $r(35) = 0.211$, $P = 0.112$.

Analyses of physiological sexual arousal

Vaginal pulse amplitude. A Condition (Exercise vs No-exercise) × Order (Exercise condition session 1 vs No-exercise condition session 1) analysis of variance was conducted on vaginal pulse amplitude difference scores. Mean difference scores for the No-exercise and Exercise sessions were 4.75 and 9.54, respectively. Results revealed a significantly greater increase in pulse amplitude during the Exercise condition, $F(1,33) = 23.47$, $P < 0.001$. There was no significant order effect, and the interaction between order and condition was not significant (all Fs < 1).

In order to determine whether the increase in pulse amplitude difference scores with exposure to exercise was attributable to decreases in vaginal pulse amplitude responses to neutral stimuli, and/or to increases in vaginal pulse amplitude responses to erotic stimuli, and to verify that the erotic films facilitated sexual arousal, a 2 × 2 (Condition by Film) repeated-measures analysis of variance was conducted. There was no significant main effect of exercise on vaginal pulse amplitude responses $F(1,34) < 1$. There was, however, a significant main effect for film, $F(1,34) = 71.32$, $P < 0.001$, and a significant interaction between film and condition, $F(1,34) = 24.23$, $P < 0.001$. Post hoc comparisons showed a significant decrease in vaginal pulse amplitude responses to neutral stimuli with exposure to exercise, $t(35) = 2.21$, $P = 0.034$, and a significant increase in vaginal pulse

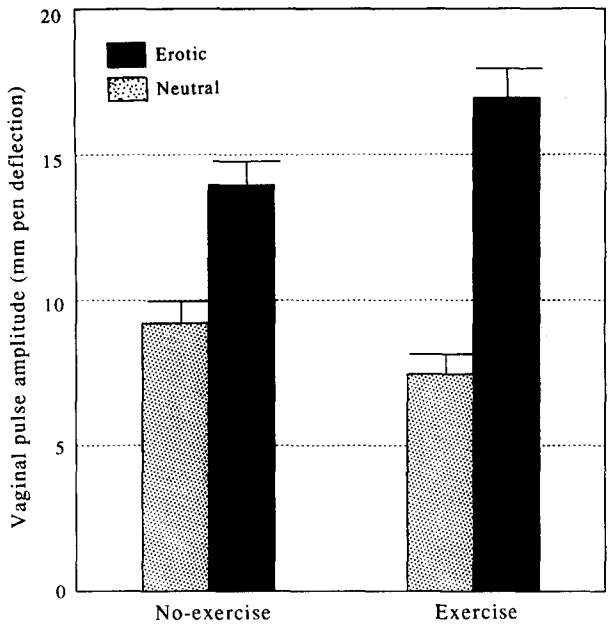

Fig. 1. Mean vaginal pulse amplitude (mm of pen deflection) ± SEM between neutral and erotic stimulus presentations during the No-exercise and Exercise conditions.

amplitude responses to erotic stimuli with exposure to exercise, $t(35) = 2.91$, $P = 0.006$. Mean vaginal pulse amplitude scores are presented in Fig. 1.

Vaginal blood volume. Deviation scores in blood volume between neutral and erotic stimuli were compared between the No-exercise and Exercise conditions using a Condition (Exercise vs No-exercise) × Order of analysis of variance. Mean vaginal blood volume deviation scores during the Exercise and No-exercise conditions were 0.75 and 1.93, respectively. Results showed a nonsignificant trend toward greater increases in blood volume during the Exercise condition, $F(1,33) = 3.59$, $P = 0.067$. Neither the order of condition presentation nor the order by condition interaction were significant (all Fs < 1).

In order to determine whether the erotic films caused a significant increase in vaginal blood volume responding, blood volume responses averaged across the last 80 sec of neutral stimuli (No-exercise, $M = -0.479$; Exercise $M = 0.391$) were compared to blood volume levels averaged across the entire 180 sec of erotic stimuli (No-exercise, $M = 0.273$; Exercise, $M = 2.319$). Analyses revealed a significant increase in blood volume in both the No-exercise, $t(34) = 2.64$, $P = 0.012$, and Exercise conditions, $t(34) = 3.60$, $P = 0.001$, with the presentation of an erotic film.

Heart rate. A repeated-measures Condition (Exercise vs No-exercise) × Film (neutral vs erotic) × Time (nine 20-sec time block means) analysis of variance of heart rate revealed a significant increase in heart rate during the Exercise condition, $F(1,34) = 108.15$, $P < 0.001$. No difference in heart rate was found between neutral and erotic films, $F(1,34) < 1$, or across 18 time periods (nine heart rate measures during each of the neutral and erotic films), $F(8,272) < 1$. The condition by time interaction was marginally significant, $F(8,272) = 1.84$, $P = 0.07$, but all other interactions between condition, time, and film were not significant (all Fs < 1). Mean heart rate during the No-exercise neutral and erotic films was 70.9 and 70.6, respectively, whereas heart rate was much higher after exercise for both films, producing rates of 91.1 and 90.0 for neutal and erotic films, respectively.

Analyses of the Relationship Between Vaginal Blood Volume and Vaginal Pulse Amplitude responses

In order to determine the relationship between blood volume and pulse amplitude responses, Pearson product-moment correlation coefficients were calculated between the mean vaginal pulse amplitude score of the middle 20 sec of the neutral or erotic film stimulus and the mean vaginal

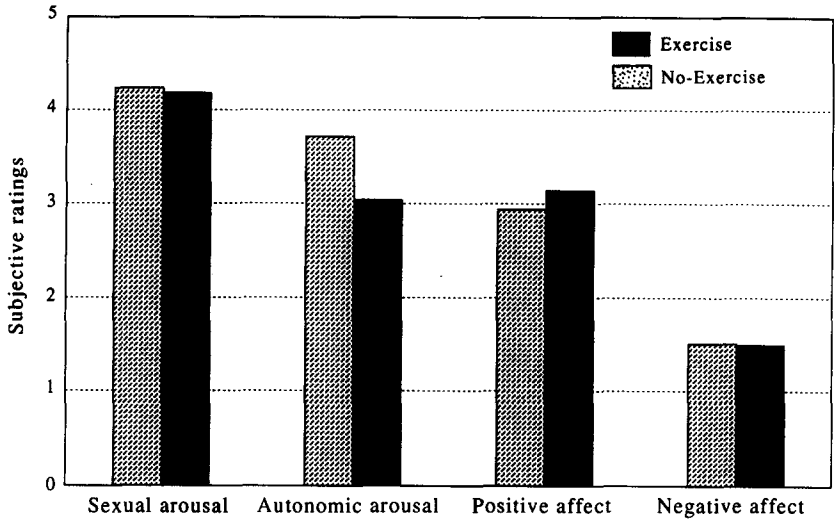

Fig. 2. Mean subjective ratings of sexual arousal, autonomic arousal, positive affect, and negative affect in response to erotic stimuli during the No-exercise and Exercise conditions.

blood volume score of the middle 20 sec of the neutral or erotic film stimulus for both the Exercise and No-exercise conditions. Analyses revealed a significant correlation between blood volume and pulse amplitude during the No-exercise neutral film, $r(35) = 0.508$, $P = 0.001$, and the No-exercise erotic film, $r(35) = 0.429$, $P = 0.005$, but no significant correlation between blood volume and pulse amplitude during the Exercise neutral film, $r(35) = 0.109$, $P = 0.266$, or the Exercise erotic film, $r(35) = 0.203$, $P = 0.121$.

Analyses of subjective measures

Subjective ratings of sexual arousal, autonomic arousal, positive and negative affect, in response to erotic stimuli, were analyzed using 2 × 2 (Condition × Order) analyses of variance. Mean subjective ratings are presented in Fig. 2. There were no significant differences between the No-exercise and Exercise conditions, on measures of subjective sexual arousal, $F(1,33) < 1$, subjective autonomic arousal, $F(1,33) < 1$, positive affect, $F(1,33) = 1.23$, $P = 0.275$, or negative affect $F(1,33) < 1$. There were no significant main effects of order for any of the subjective measures, (all Fs < 1), but there were, however, significant interactions between condition and order for subjective ratings of sexual arousal $F(1,33) = 4.19$, $P = 0.049$, and negative affect $F(1,33) = 10.30$, $P = 0.003$. Follow-up analyses on the effects of order on subjective sexual arousal during the Exercise and No-exercise conditions, and negative affect during the Exercise and No-exercise conditions were $t(33) = -0.49$, $P = 0.628$, $t(33) = 0.82$, $P = 0.416$, $t(33) = -0.72$, $P = 0.479$, and $t(33) = 1.56$, $P = 0.128$, respectively. There were no significant interactions between condition and order for the remaining subjective variables, autonomic arousal and positive affect (all Fs < 1).

Analyses of the relationship between physiological and subjective responses

Pearson product-moment correlation coefficients were calculated separately for each experimental condition in order to investigate the degree of association between physiological and subjective ratings of sexual arousal. There were no significant correlations between pulse amplitude and subjective ratings during the No-exercise, $r(35) = -0.188$, $P = 0.140$, or Exercise conditions, $r(35) = -0.076$, $P = 0.332$, or between blood volume and subjective ratings during the No-exercise, $r(35) = -0.232$, $P = 0.09$, or Exercise conditions, $r(35) = -0.066$, $P = 0.353$.

Discussion

The results reveal significant increases in both vaginal pulse amplitude and vaginal blood volume with the presentation of erotic stimuli indicating that the experimental stimuli were successful in altering physiological sexual arousal. Analyses of heart rate showed significantly higher heart rate levels throughout the film presentations during the Exercise condition. This suggests that cycling

for 20 min at 70% of $VO_{2\,max}$ was sufficient to elicit significant sympathetic activity. The absence of a correlation between fitness levels and physiological measures of sexual arousal indicates that exercising *S*s at relative, as opposed to absolute, work loads eliminated any potential confounds relating to variations in fitness levels. Analyses of order effects revealed that the order of presentation of experimental conditions did not influence subjective or physiological measures of sexual arousal. That is, familiarity with the experimental procedures and/or with viewing an erotic film did not influence *S*s' responses. These findings indicate that the experimental manipulations and controls were effective.

The finding that differences in pulse amplitude during viewing of neutral and erotic films were significantly higher during the Exercise condition, and the finding that blood volume deviation scores between neutral and erotic films were marginally higher during the Exercise condition provides support for a facilitatory effect of acute exercise on sexual arousal in women. With respect to vaginal pulse amplitude, it is important to note that the increase in difference scores with exposure to exercise is attributable to both a decrease in vaginal pulse amplitude with exposure to a neutral film, and an increase in vaginal pulse amplitude with exposure to an erotic film. The fact that exercise reliably decreased vaginal pulse amplitude responses to a neutral film demonstrates that certain physiological measures of the sexual response may be influenced by the cardiovascular and/or hormonal responses of exercise independently of sexual cues. This finding has not previously been reported and may be worthy of further investigation. Taken together, the changes in pulse amplitude reported in the present study, suggest that exercise reliably influences vaginal pulse amplitude, and the direction of this influence is dependent upon the presence or absence of an erotic stimulus. While it would be interesting to know whether exercise also caused a significant decrease in vaginal blood volume responses to a neutral film, there is no absolute calibration method for the measurement of vaginal blood volume and, hence, direct comparisons between neutral films cannot be made.

Despite the changes in physiological sexual arousal with exposure to exercise, there were no significant differences in self-reported levels of arousal between the Exercise and No-exercise conditions. Furthermore, there was a lack of correlation between *S*s' physiological and subjective ratings of sexual arousal. This is consistent with other research that has demonstrated desynchrony between subjective and physiological components of the female sexual response (Heiman, Rowland, Hatch & Gladue, 1991; Morokoff and Heiman, 1980; Steinman *et al.*, 1981; Wincze, Hoon & Hoon, 1976).

The significant correlations between vaginal pulse amplitude and vaginal blood volume responses during both the neutral and erotic films in the No-exercise condition is consistent with previous research conducted by Heiman (1976) in sexually functional women. Interestingly, despite these correlations during the No-exercise condition, there were no significant correlations between vaginal pulse amplitude and vaginal blood volume responses during either the neutral or erotic films in the Exercise condition. The reason for this lack of correlation remains open to speculation. One possibility is that blood volume, but not pulse amplitude, was influenced by fluctuations in body temperature resulting from exercise. This assertion is supported by research which indicates that the dc signal, used in the measurement of blood volume, is more likely affected by temperature confounds than the ac signal used in the measurement of pulse amplitude (Beck *et al.*, 1983). One must keep in mind, however, that it is questionable whether pulse amplitude and blood volume responses can be meaningfully compared, given that they reflect different aspects of the vasocongestive response and are sampled and analyzed differently.

EXPERIMENT 2

Experiment 1 demonstrated that exercise influences physiological measures of sexual arousal and, with respect to vaginal pulse amplitude, the direction of this influence depends on the presence or absence of an erotic stimulus. Because the erotic films consistently followed the presentation of the neutral films in Experiment 1, it is possible that the reported difference between the neutral and erotic films was attributable to the presentation of films at different time intervals. In Experiment 2, *S*s were presented with two consecutive neutral stimuli preceded by 20 min of intense exercise. The purpose was to determine whether the increases in sexual arousal with exposure to an erotic

stimulus reported in the Exercise condition of Experiment 1 were attributable to the content of the erotic film, or merely to the passage of time following exercise.

Method

Ten of the 35 women who participated in Experiment 1 took part in Experiment 2 (M age = 25 yr, range = 19–34). Five of the Ss were from the Exercise first session in Experiment 1 and 5 were from the No-exercise first session. Five of the Ss were graduate students in psychology, 2 were first or second year undergraduate psychology students, and 3 were graduate or undergraduate students in disciplines other than psychology. Racial background of the Ss was Caucasian (8), and Asian (2). Participation was strictly voluntary; no incentives were offered.

A within S repeated-measures design was used in which each S viewed two consecutive, neutral travelogue films in one session. The Ss were told that they would be viewing films that may include erotic scenes. The procedure was identical to that used in the Exercise condition in Experiment 1 with the exception of the film stimulus which consisted of a 1-min display of the word 'relax', followed by two consecutive 3-min neutral travelogue sequences.

Data sampling and reduction procedures were identical to those used in Experiment 1. Subjective and physiological data from the 10 Ss who participated in both experiments were used to make comparisons between the findings of Experiment 2 and the findings from the Exercise condition in Experiment 1.

Results

Analyses of physiological sexual arousal

T tests were conducted on vaginal pulse amplitude and vaginal blood volume scores between the two neutral films in Experiment 2. There were no significant differences in pulse amplitude scores between the first and second neutral films in Experiment 2, $t(9) = 0.22$, $P = 0.829$, and no significant difference in blood volume responses between neutral stimuli in Experiment 2, $t(9) = 0.28$, $P = 0.788$. Mean vaginal pulse amplitude scores are presented in Fig. 3.

A one-way, repeated-measures analysis of variance was computed to investigate the effects of film (first neutral film vs second neutral film) and time (nine heart rate measures during each of the two neutral films) on heart rate. Results indicated no difference in heart rate with the presentation of the second neutral film or across time, and the film by time interaction was not significant (all Fs < 1). Mean heart rates during the first and second neutral films were 87.7 and 87.5, respectively.

Comparisons of physiological findings between Experiments 1 and 2 were made in order to examine whether the findings reported in Experiment 1 were due to arousal, as opposed to the passage of time. A Condition (Exercise condition Experiment 1 vs Experiment 2) × Film (neutral film Experiment 1, first neutral film Experiment 2 vs erotic film Experiment 1, second neutral film Experiment 2) repeated-measures analysis of variance of pulse amplitude revealed a significant main effect for film, $F(1,9) = 30.40$, $P < 0.001$, and a significant interaction between film and condition, $F(1,9) = 37.81$, $P < 0.001$. There was a slight but nonsignificant main effect of condition on pulse amplitude scores, $F(1,9) = 4.02$, $P = 0.076$. Post hoc comparisons revealed a significant increase in pulse amplitude between neutral and erotic films in the Exercise condition in Experiment 1 ($n = 10$), $t(9) = 5.96$, $P < 0.001$, and significantly greater pulse amplitude scores with exposure to the erotic film in Experiment 1 than with exposure to the second neutral film in Experiment 2, $t(9) = 3.72$, $P = 0.005$. There was no significant difference between the neutral film in Experiment 1 and the first neutral film in Experiment 2, $t(9) = 1.62$, $P = 0.140$.

T tests were conducted on blood volume deviation scores between the Exercise condition in Experiment 1 ($n = 10$) and Experiment 2. Analyses revealed significantly higher deviation scores in the Exercise condition in Experiment 1 vs Experiment 2, $t(9) = 2.31$, $P = 0.046$. Blood volume deviation scores during the Exercise condition in Experiment 1 ($n = 10$) and Experiment 2 were 3.376 and 0.095, respectively.

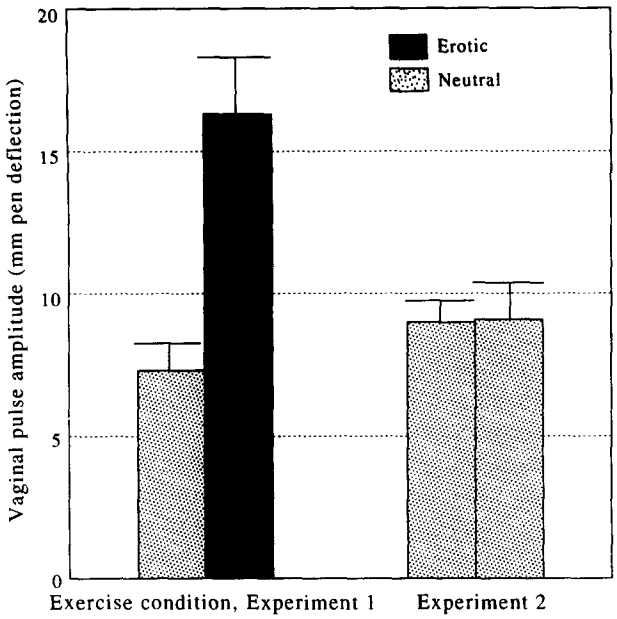

Fig. 3. Mean vaginal pulse amplitude (mm of pen deflection) ± SEM between the neutral and erotic films during the Exercise condition in Experiment 1 and between the first and second neutral films in Experiment 2.

Analyses of subjective measures

Ratings of sexual arousal, autonomic arousal, positive and negative affect were compared between the Exercise condition in Experiment 1 (in response to an erotic stimulus) and Experiment 2 (in response to the second neutral stimulus). Mean subjective ratings for sexual arousal, autonomic arousal, positive and negative affect were, 1.44, 1.50, 1.65 and 1.10, respectively. Analyses revealed significantly greater levels of subjective sexual arousal, $t(9) = 4.20$, $P = 0.002$, subjective autonomic arousal, $t(9) = 3.48$, $P = 0.007$, and positive affect, $t(9) = 3.24$, $P = 0.01$ in response to the erotic stimulus in Experiment 1 than in response to the neutral stimulus in Experiment 2. There was no significant difference in ratings of negative affect with the presentation of the erotic stimulus in the Exercise condition in Experiment 1 vs the presentation of the neutral stimulus in Experiment 2, $t(9) = 0.77$, $P = 0.46$.

GENERAL DISCUSSION

Together, the results from Experiments 1 and 2 indicate that, in the presence of an erotic stimulus, intense, acute exercise facilitates physiological sexual arousal in women. This effect includes a significant increase in vaginal pulse amplitude, and a marginal increase in vaginal blood volume. Exercise in the present study involved cycling for 20 min at 70% of the *S*s' maximum volume of oxygen uptake ($VO_{2\,max}$). Results from a number of pharmacological and physiological studies suggest that exercise at this intensity is accompanied by prominent sympathetic nervous system activity (e.g. Galbo *et al.*, 1976; Haggendal *et al.*, 1970; Hartley, Mason, Hogan, Jones, Kotchen, Mougey, Wherry, Pennington & Ricketts, 1972; Nakamura *et al.*, 1993; Yamamoto *et al.*, 1992). Thus, the increases in vaginal pulse amplitude and vaginal blood volume with exposure to exercise reported in the present study provide indirect support for a facilitatory influence of sympathetic activation on physiological sexual arousal in women.

Vaginal pulse amplitude and vaginal blood volume responses remained unchanged with the presentation of the second neutral film in Experiment 2. This finding supports the notion that the increases in pulse amplitude and blood volume following erotic stimuli in Experiment 1 are attributable to the sexual content of the film. If, instead, the increases were simply a result of the passage of time following exercise, one would expect a change in blood volume and pulse amplitude during presentation of the second neutral stimulus in Experiment 2.

The finding that *S*s reported higher levels of sexual arousal with exposure to exercise in Experiment 1 than in Experiment 2 indicates that *S*s were able to detect and/or willing to report increases in sexual arousal with exposure to erotic vs neutral stimuli. The finding that, in the Exercise condition in Experiment 1 vs Experiment 2, *S*s reported higher levels of positive affect but no difference in levels of negative affect, suggests that the erotic film may have had a more positive influence on *S*s' mood than the neutral film. Finally, the fact that *S*s reported higher levels of subjective autonomic arousal in the Exercise condition in Experiment 1 (erotic film) than with exposure to exercise in Experiment 2 (neutral film), despite the fact that there were no significant differences in physiological measures of autonomic arousal between these conditions, suggests that *S*s may have labeled changes in sexual arousal as changes in general autonomic arousal.

As is the case with most studies involving autonomic nervous system function, several considerations must be made in interpreting the present results. First, because nervous system activity was measured only indirectly using heart rate, the relative contribution of sympathetic and parasympathetic influences remain somewhat speculative. Future studies on the effects of exercise on female sexual arousal which measure sympathetic activation more directly by either examining blood levels of catecholamines, or by administering drugs prior to exercise which cause specific sympathetic or parasympathetic blockade, would provide further insight into the role of the autonomic nervous system on female sexual arousal. Second, given the impracticality of measuring physiological sexual arousal *during* exercise, the present study focused on the residual effects of exercise on sexual arousal. This design was based on a number of studies which show that increases in sympathetic activation following high intensity, acute exercise remain significantly elevated 15 min post exercise (e.g. Cleroux *et al.*, 1985; Kraemer *et al.*, 1991; Strobel *et al.*, 1993). However, it is likely that sympathetic activation when measured 15 min post exercise is in a declining state. It would, therefore, be interesting to note whether increasing sympathetic activation (e.g. during exercise) vs decreasing sympathetic activation (e.g. following exercise) have the same influence on physiological sexual arousal. It may be the case that, in the presence of an erotic cue, accelerating levels of sympathetic activity would provide an even greater 'boost' to physiological levels of sexual arousal than decelerating levels of sympathetic activity. In addition to comparisons of the relative effects of increasing vs decreasing sympathetic activation on sexual arousal, future research is needed to examine whether the findings of increased sexual arousal reported in the present study would differ if one examined sexual arousal immediately following exercise, when levels of sympathetic activation would be most intense, and 30 min following exercise when most of the cardiovascular and hormonal effects of acute exercise have diminished (Fraioli, Moretti, Paolucci, Alicicco, Crescenzi & Fortunio, 1980). An investigation of this nature would help determine some of the boundary conditions under which acute exercise influences sexual arousal.

In contrast to the reported increases in physiological sexual arousal, exercise in the present study had no significant influence on subjective measures of sexual arousal. In other words, the significant changes in physiological measures were not cognitively interpreted as changes in sexual arousal. Given that *S*s reported differences in sexual arousal between the erotic film in Experiment 1 and the neutral film in Experiment 2, it is unlikely that reporting biases or conservative social norms can explain this finding. One possible explanation for the lack of change in subjective sexual arousal in the presence of increased physiological arousal, is that *S*s attributed their aroused state to having just exercised. This assertion is consistent with the excitation-transfer theory (Zillman, 1983) which posits that undecayed excitation from prior stimulation produces an intensified response to later stimuli, but only when cues from the previous stimuli are not present. In other words, if it is obvious to individuals that the source of their arousal is their prior vs present activity, excitation transfer will not occur. Because *S*s had significantly higher heart rates with exposure to exercise immediately prior to viewing the erotic film (i.e. during the neutral film), residual cues of the source of their arousal, such as heavy breathing and heart pounding, may have led *S*s to attribute any further physiological changes to the residue of exercise. Future studies in women which examine the effects of immediate vs delayed exercise on sexual arousal will help determine whether the residual 'non sexual' effects of exercise influence subjective reporting of the 'sexual' effects of exercise, and will better elucidate the role of acute exercise and sympathetic activation on subjective sexual arousal in women.

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