ELSEVIER

Journal of Psychosomatic Research, Vol. 40, No. 2, pp. 123–141, 1996

0022-3999/95 $15.00 + 0.00

0022-3999(95)00554-4

REVIEW

THE ACUTE EFFECTS OF EXERCISE ON MOOD STATE

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Abstract – This paper documents the recent (1976–1995) literature on the acute mood effects associated with participation in single sessions of exercise. Issues regarding experimental design, 'ecological validity' and the operational definition of mood are addressed. Results from these studies suggest that both clinical and nonclinical subjects may benefit acutely from even a single bout of exercise. Finally, possible mechanisms and recommendations for future research are discussed.

Keywords: Acute exercise; Mood; Psychological states.

INTRODUCTION

There has been a tendency in recent years to view exercise as a universal panacea, providing a wide range of both physical and psychological benefits. Indeed, research has supported that participation in habitual physical exercise is inversely related to the incidence of cardiovascular disease, as well as having beneficial effects on conditions such as osteoporosis and diabetes [1]. The psychological benefits of long-term exercise participation in both clinical and community subjects are also well documented [2, 3].

Given the considerable health benefits of physical activity, it is worrying that so few people participate in any regular exercise. A recent study conducted in the United Kingdom established that approximately 70% of men and 80% of women did not engage in the level of exercise recommended for their age group [4]. These alarming statistics are not dissimilar from findings in North America and Australia [5–7]. In addition, approximately 50% of those who begin or renew a program of exercise will drop out within 6 months to a year regardless of the exercise context, for example, whether a community exercise class or a cardiopulmonary rehabilitation program [8]. Given these attrition rates and the fact that people often make repeated attempts to become active and fail, the problem is not one of persuading people to begin exercising, but encouraging participants to adhere once a program has begun. For some time now, exercise scientists have posited that an understanding of the acute psychological effects of single bouts of exercise may be useful in producing exercise protocols that enhance long-term exercise adherence [9].

This article reviews two decades of research on the acute effects of exercise on mood and affective states. Previous reviews have tended to focus on factors concomitant with

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habitual exercise participation or have confounded acute and long-term exercise studies. The present paper addresses not only the alleviation of negative mood states, but also the enhancement of positive mood. The problem of ecological validity is also discussed: that much of the research has employed testing protocols that are unrepresentative of actual exercise experiences has produced results with very limited generalizability. Finally, directions for further research and tentative conclusions are outlined.

EXPERIMENTAL DESIGN

Before examining the research literature, it is useful to review briefly the importance of experimental design. Only the true experiment, with random allocation of subjects to exercise and no-treatment conditions, provides the methodological rigour necessary for strong conclusions [10]. Quasi-experimental designs are characterized by comparisons of experimental versus nonequivalent control groups; subjects have often been allowed to self-select participation in either an exercise or control (e.g., lecture class) condition. In the event that the exercise group does exhibit significant psychological change, it is impossible to exclude the alternative hypothesis that the two groups differed beforehand on some variable such as personality. The absence of a control group in preexperimental designs introduces a host of possible confounds. For example, significant pre- to post-exercise change in mood could possibly be attributed to the passage of time or any other factors, as opposed to exercise *per se*.

A number of these studies are technically defined as experimental, in that subjects were randomly assigned to various treatment conditions. For the purposes of this review, however, studies are defined as experimental only if they included a no-treatment or other control group as well as random assignment. Studies with nonrandom control groups are defined as quasi-experimental herein.

OVERVIEW OF RESEARCH

A search was conducted in February 1995 on the following computer databases: BIDS, MEDLINE, and PSYCLIT. Only papers that were published in full in peer review journals or conference proceedings were accepted. Results from abstracts only were rejected on the basis that they did not provide sufficient information regarding their experimental procedures. It is important to recognize that such a decision might have led to a publication bias. Unpublished studies may, therefore, yield smaller or nonsignificant effects. However, this problem cannot be avoided if only studies with sufficient detail are to be included.

It was the considered opinion of the author not to include effect sizes in either tables or discussion. From a theoretical perspective, many of these studies employed multigroup designs with several exercise and several control conditions. Therefore, it would be difficult to know which are the relevant comparisons to calculate without producing a prodigious amount of data. Such a relatively brief paper can allow the reader to glean no more than a gist of a field of research of this size.

Table I summarizes findings from pre-experimental studies on the effects of single bouts of exercise on mood in adult samples [9, 11–48]. Table II concerns quasi-experimental research [49–66], and Table III examines true experiments only [67–89]. For the quasi-experimental and experimental studies, subject numbers are listed for all exercise as well as control groups. In a number of articles, the gender or status (student versus

Table I.—Summary of acute exercise studies: Pre-experimental designs

Researchers	Subjects	Activity	Psychological Instruments	Outcome
Berger and Owen [11]	42 M and F students	swimming	Profile of Mood States	5/6 improved
Bozoian et al. [12]	36 F students	cycling 70%HRR	Exercise Feelings Inventory	1/3 improved
Cameron and Hudson [13]	66 M and F anxious patients	mixed exercises	unvalidated scale	worsened in some subjects only
Choi et al. [14]	97 F students and adults	aerobics	in-study (by principal components analysis)	3/3 improved
Douchamps-Riboux et al. [15]	11 M adults	competitive rowing	unvalidated ratings	2/5 worsened
Farrell et al. [16]	7 M adults	running (40%, 60% or 80%VO_{2max}	State Anxiety Inventory	60% and 80% only: improved
Felts [17]	24 F	cycling (30% or 60%HRR)	State Anxiety Inventory	improved
Fillingim et al. [18]	60 F students	cycling	Profile of Mood States	1/6 worsened following high distraction; 1/6 improved following low or no distraction
Goode and Roth [19]	150 M and F students and adults	running	Profile of Mood States	5/6 improved
Grossman et al. [20]	6 M adults	cycling (40% or 80%VO_{2max}	visual analogue scale	no change
Hatfield et al. [21]	9 M adults and 7 M elderly	maximal cycling test	Multiple Affect Adjective Checklist	no change
Janal et al. [22]	12 M adults	running 85%VO_{2max}	visual analogue scales	2/3 improved
Kraemer et al. [23]	23 M and F adults	running 85%MHR	Profile of Mood States	4/6 improved
Markoff et al. [24]	15 M and F adults	running	Profile of Mood States	3/6 improved
McAuley and Courneya [25] (study 2)	100 M and F adults	cycling	Subjective Exercise Experiences Scale	2/3 improved
McAuley and Courneya [25] (study 3)	51 M and F adults	1-mile walk	Positive Affect and Negative Affect Schedule, Feeling Inventory, Subjective Exercise Experiences Scale	2/2, 1/1, 1/1, 2/3 improved
McIntyre et al. [26]	18 students	mixed exercises	Positive Affect and Negative Affect Schedule	1/2 improved

Continued

Table I. — *Continued*

Researchers	Subjects	Activity	Psychological Instruments	Outcome
McMurray et al. [27]	11 M adults	running 70%VO_{2max}	General Affect Scale	improved
McMurray et al. [28]	8 M adults	running 70%VO_{2max}	General Affect Scale	improved
Nowlis and Greenberg [29]	18 adults	running	State-Trait Anxiety Inventory, Nowlis Mood Adjective Checklist	0/1, 1/14 improved
O'Connor et al. [30]	17 M and F adults	running 84%VO_{2max}	State Anxiety Inventory, Bodily Awareness Scale	1/1, 1/1 improved
O'Connor and Davis [13]	12 M adults	running 70%VO_{2max}	State Anxiety Inventory, State-Trait Anger Expression Inventory	1/1, 1/2 improved
Parfitt et al. [32]	71 M and F students	cycling	Feeling Inventory	improved
Petruzzello and Landers [33]	19 M adults	running 75%VO_{2max}	State Anxiety Inventory	improved
Petruzzello et al. [34]	20 M students	running 75%VO_{2max} (normal, warmer, or cooler conditions)	State Anxiety Inventory	all groups: improved
Pierce and Pate [35]	16 elderly F	aerobic line dancing	Profile of Mood States	5/6 improved
Pronk et al. [36]	11 premenopausal and 11 postmenopausal F	walking (50% or 70%VO_{2max}	Profile of Mood States (modified)	1/7 improved
Pronk et al. [37]	22 F adults	maximal walk test	Profile of Mood States (modified)	2/7 improved
Raglin et al. [38]	26 M and F students	cycling 70%MHR or weight training	State Anxiety Inventory	cycling only: improved

Reeves et al. [39]	20 M students	calisthenics (normal or hot conditions)	Multiple Adjective Checklist	normal: 1/3 improved hot: 2/3 worsened
Rejeski et al. [40]	30 M students	cycling 70%HRR	State Anxiety Inventory, Activation-Deactivation Adjective Checklist	1/1, 2/2 improved
Slaven and Lee [41]	15 premenopausal and 17 postmenopausal F	aerobics	Profile of Mood States	6/6 improved
Steptoe and Bolton [9]	40 F students	cycling (25W or 100W)	Profile of Mood States (modified)	25W: 3/7 improved 100W: 2/7 worsened, 1/7 improved
Steptoe and Cox [42]	32 F students	cycling (25W or 100W)	Profile of Mood States (modified)	25W: 2/7 improved 100W: 2/7 worsened
Thayer [43]	9 M and F students	walking	Activation-Deactivation Adjective Checklist	2/2 improved
Thayer et al. [44]	34 M and F students	walking	Activation-Deactivation Adjective Checklist	2/2 improved
Thomas et al. [45]	4 M adults	level or downhill running or cycling 60%VO_{2max}	Profile of Mood States	downhill run and cycling: 2/6 worsened
Williams et al. [46]	10 pregnant F and 6 nonpregnant F adults	step test	Profile of Mood States	pregnant: 5/6 worsened nonpregnant: 5/6 improved
Wood [47]	106 M and F students	running	State Anxiety Inventory	high anxious: improved low anxious: worsened
Wormington et al. [48]	21 students and adults	running	Profile of Mood States	4/6 improved

Table II. – Summary of acute exercise studies: Quasi-experimental designs

Researchers	Subjects	Activity	Control Instruments	Psychological Outcome	Outcome
Barabasz [49]	36 students	aerobics	quiet rest	Profile of Mood States	1/6 improved
Berger and Owen [50]	100 M and F students	swimming	lecture	Profile of Mood States	5/6 improved
Berger and Owen [51]	170 M and F students	swimming or fencing	yoga or lecture	Profile of Mood States, State Anxiety Inventory	swim: 2/6 improved fencing: 1/6 improved yoga: 5/6, 1/1 improved
Berger and Owen [52]	74 M and F students	swimming training >80%MHR	lecture	Profile of Mood States, State Anxiety Inventory	1/6 worsened
Berger and Owen [53]	87 M and F students	swimming	yoga or lecture	Profile of Mood States	swim and yoga: 4/6 improved
Berger et al. [54]	78 F students	swimming	lecture	Profile of Mood States	5/6 improved
Dyer and Crouch [55]	59 M and F students	running	lecture	Profile of Mood States	run: 4/6 improved
Dyer and Crouch [56]	70 M and F students	running or aerobics or weight training	lecture	Profile of Mood States	run and aerobics: 1/6 improved weights: 2/6 improved
Ekkekakis and Zervas [57]	84 F adults	aerobics	lecture	Profile of Mood States, State Anxiety Inventory	aerobics: 5/6, 1/1 improved lecture: 1/6 improved
Gurley et al. [58]	88 students	sports	lecture	semantic scales	sports: 2/15 improved lecture: 3/15 improved

Lichtman and Poser [59]	64 adults	aerobics	lecture	Profile of Mood States, Nowlis Adjective Checklist	aerobics: 4/6, 4/14 improved lecture: 2/6 improved
Maroulakis and Zervas [60]	99 F adults	aerobics 60–80%HRR	clerical work	Profile of Mood States	5/6 improved
McGowan et al. [61]	72 students	running or weight lifting or karate	lecture	Profile of Mood States	run: 2/6 improved weights: 2/6 improved karate: no change
McInman and Berger [62]	117 F students	aerobics	lecture	Profile of Mood States	5/6 improved
Thayer [63]	18 M and F students	walking	sugar snack	Activation-Deactivation Adjective Checklist	2/2 improved
Weinberg et al. [64]	279 M and F students	running or swimming or racquetball or tennis	massage or quiet rest	Profile of Mood States, State Anxiety Inventory	run: 5/6 improved swim and racquetball: no change tennis: 1/6 improved massage: 6/6, 1/1 improved
Wilson et al. [65]	42 M and F adults	running or aerobics	eating lunch	State Anxiety Inventory	all groups: improved
Zervas et al. [66]	123 F students	aerobics (40%, 60% or 80%MHR or self-selected)	lecture	Profile of Mood States, State Anxiety Inventory	40% and 80%: 2/6 improved 60%: 4/6 improved lecture: 1/6 improved self-selected: 5/6 improved

Table III. – Summary of acute exercise studies: Experimental design

Researchers	Subjects	Activity	Control Activity	Psychological Instruments	Outcome
Bahrke and Morgan [67]	75 M adults	running 70%VO_{2max}	relaxation or quiet rest	State Anxiety Inventory	all groups: improved
Berger et al. [68]	280 M and F students	running 65–80%MHR	relaxation or discussion group	Profile of Mood States	run and relaxation: 3/6 improved
Boutcher and Landers [69]	30 M students and adults	running 80–85%MHR	reading	State Anxiety Inventory, Profile of Mood States	1/1 improved only for runners
Brown et al. [70]	10 M and F disabled students	cycling or running	quiet rest	State Anxiety Inventory	both groups: improved
Crocker and Grozelle [71]	85 M and F students	aerobics	relaxation or no-exercise	State Anxiety Inventory	aerobics and relax: improved (following an anxiety-inducing procedure)
Ewing et al. [72]	52 M and F students and adults	running 65–70%MHR	quiet rest	Profile of Mood Stress (modified)	1/2 improved
Farrell et al. [73]	6 M and F adults	running (60% or 80%VO_{2max} or self-selected)	quiet rest	Profile of Mood States	no change
Felts and Vaccaro [74]	24 F students	cycling (30% or 60%HRR)	quiet rest	State Anxiety Inventory	60%HRR only: improved
Flory and Holmes [75]	18 F students	aerobics 60–80%MHR	no-exercise	Multiple Affect Adjective Checklist, Profile of Mood States	1/3 improved
Girodo and Pellegrini [76]	40 F students	cycling	no-exercise	unvalidated scale	improved (following anxiety-inducing procedure)

Glazer and O'Connor [77]	9 F bulimics and 9 F adults	walking 70%VO_{2max}	quiet rest	Profile of Mood States, State Anxiety Inventory	5/6, 1/1 improved
Hobson and Rejeski [78]	80 F students	cycling 70%HRR	quiet rest	Positive Affect and Negative Affect Schedule	no change
McGowan et al. [79]	12 M adults	cycling (45%, 55% or 70%VO_{2max})	cognitive task	Addiction Research Centre Inventory	no change
Molloy et al. [80]	15 M and F elderly	aerobics	quiet rest	Geriatric Depression Scale	no change
O'Connor et al. [81]	14 F students	weight training	no-exercise	State Anxiety Inventory	improved
O'Connor and Petruzzello [82]	16 M students	running 75%VO_{2max}	quiet rest	State Anxiety Inventory	both groups: improved
Raglin and Morgan [83] (study 1)	15 M adults	mixed exercises	quiet rest	State Anxiety Inventory	improved
Raglin and Morgan [84]	15 normotensive and 15 hypertensive M adults	mixed exercises	quiet rest	State Anxiety Inventory	all subjects: improved
Rejeski et al. [85]	12 M adults	cycling (50% or 80%VO_{2max}	quiete rest	Profile of Mood States	no change
Rejeski et al. [86]	48 F adults	cycling 70%HRR	quiet rest	Multiple Affect Adjective Checklist	no change
Roth [87]	80 M and F students	cycling 57%-67%MHR	quiet rest	Profile of Mood States	2/6 improved
Saklofske et al. [88]	93 students	walking	relaxation	Activation-Deactivation Adjective Checklist	walk: 2/2 improved relaxation: 1/2 improved
Steptoe et al. [89]	72 M adults	cycling (50% or 70%VO_{2max}	cycling (10W)	Profile of Mood States (modified)	50% and 70%: 2/7 improved

adult) of subjects was not reported. Otherwise, gender, status and any other distinguishing characteristics of subjects are included. Regarding outcomes, where the psychological instrument included two or more subscales (or more than one instrument was used), a fraction is given denoting the proportion of subscales that evinced significant change. Unless otherwise indicated, change in mood for the exercise group is significantly greater than for the control group(s) at the 0.05 level. Where significant changes occur in more than one group, these are reported individually.

It should be immediately apparent that a substantial number of these studies used student samples, and students tend to differ from the general population in terms of both fitness and cognitive factors, thereby limiting the generalizability of the results. A further limitation is that the quasi- and pre-experimental designs have been favoured by the greater proportion of researchers. Many of the control conditions have also been of dubious relevance. It is difficult to see how a comparison of exercise with, for example, lecture class or lunch eating groups can provide a stringent test of whether exercise has acute psychological benefits per se. That many studies used small sample sizes also leads to some question over the reliability of their results. One of the most troublesome problems relates to the demand characteristics of exercise testing. It is universally agreed that a double-blind trial provides the best test of the effects of any treatment, such as a drug, on psychological states. In exercise situations, it would be reasonable to employ persons who are blind to the hypotheses under test to provide the treatments. It is virtually impossible, however, to give self-report mood questionnaires to subjects who are unaware of the purported effects of exercise.

Table IV presents a summary of results from the reviewed studies, comparing outcome by design. Positive outcomes are defined as those that produced enhanced mood for at least some of the exercise conditions, with no detrimental effects for any subjects; the converse is true for those defined as negative outcomes. Notwithstanding the aforementioned methodological problems, the research literature does generally support the widespread belief that there are acute effects of exercise on mood. Over 85% of these studies found at least some degree of improved mood, that is, the results were either positive or mixed, on a wide variety of measures following exercise, despite a diversity of exercise modes, durations and intensities. Exercise is also more effective than no-treatment for the reduction of elevated anxiety induced by laboratory-based procedures [71, 76]. Exercise may therefore be a useful short-term strategy for alleviating psychological distress. In general, the mood effects of exercise occur irrespective of either gender or age. Reports of enhanced mood were found for both men and women; young students and middle-aged adults as well as older and elderly subjects benefitted as well. Neither does physical disability preclude the experience of mood enhancement following exercise [70]. One group that may experience mood disturbances following exercise deserves mention: in pregnant women, exercise becomes increasingly less tolerable as pregnancy advances [46]. Several of the studies reporting worsened mood states (negative or mixed results) employed either competitive or training intensities of exercise [15, 52] or unusual conditions such as cognitive tasks or a heated environment during exercise [18, 39].

Reduction of negative mood states seems to accompany most forms of aerobic exercise as well as anaerobic exercise such as weight lifting and yoga. However, few studies have evaluated the two modalities under carefully controlled conditions. The only study to randomly assign subjects to cycle ergometry or weight training conditions found a reduction in state anxiety only for the cycling group [38].

Table IV.—Summary of results: Outcome by design

	Total Number of Studies	Results by Study			
		Positive	Negative	Mixed	No change
Pre-experimental	40	29	3	6	2
Quasi-experimental	18	15	1	2	0
Experimental	23	17	0	0	6

The research has not systematically investigated the impact of different exercise durations. One of the few studies to do so that included a random assignment protocol found no effects at all after 10, 25 or 40 minutes of exercise [78]. Less strictly controlled studies by Thayer and associates, however, have indicated that brisk walks of only 10 minutes in duration are sufficient to enhance energy and reduce tension [43, 44, 63]; exercise durations in excess of an hour can also produce mood benefits [24]. Due to the lack of evidence from adequately controlled research, however, it is currently premature to stipulate an optimal or even minimal duration for the accrual of psychological benefits from exercise.

The literature is also unresolved as to the impact of intensity on mood states. Steptoe and associates found that low intensity exercise (25W) produced modest improvements in mood as measured by the Profile of Mood States (POMS), while high intensity exercise (100W) actually increased negative mood states [9, 42]. Other work has observed that only moderate and high intensity exercise (60% and 80%VO_{2max}) reduced anxiety, with no effect at 40%VO_{2max} [16]. Similarly, Felts and Vaccaro observed a significant decrease in state anxiety only after cycling at an intensity of 60% of heart rate reserve (HRR), but not following 30%HRR or a period of quiet rest [74]. Yet other researchers have not found any effect of intensity on mood states [17, 36, 89]. Despite the use of properly controlled designs in all of these studies, there can be no resolution as to the effects of intensity. The problem may lie in the various definitions of intensity that have been used, including power wattages, and percentages of maximal heart rate (MHR), heart rate reserve, or maximal aerobic capacity (VO_{2max}). Exercise physiologists acknowledge that the correspondence between, for example, 70%MHR and 70%VO_{2max} may be poor [90]. The lack of consistency in quantification of intensity prevents any real comparison of results between studies. From the disparate studies, however, one might tentatively suggest that neither very high nor very low intensities of exercise seem optimal for the accrual of psychological benefits. It is also interesting to note that when Zervas et al. [66] compared low, moderate and high exercise intensities with a group that were allowed to exercise at an intensity of their own choosing, the greatest number of improvements across POMS subscales occurred in the self-selecting group. This result is reminiscent of flow theory, which states that "flow"—a pleasurable state of consciousness—can only be achieved when an individual's competencies are realistically matched against the challenges of the task at hand [91, 92]. When demand is perceived to exceed ability, anxiety and frustration are likely outcomes; on the other hand, boredom may result when the task is not demanding enough. One might speculate that a similar state of affairs is necessary for optimal exercise-induced mood benefits [92]. While some subjects may find the physical discomfort of high intensity exercise distressing, other subjects may enjoy the feeling of tiredness from a 'good workout'. In support of this notion, several studies

observed greater mood effects only for fitter or more active subjects [55, 69], and one study found greater mood enhancement for subjects who categorized themselves as active [32]. It is plausible that individuals who are more accustomed to the sensations of exercise will be more readily able to exercise comfortably at higher intensities. However, the greater proportion have failed to find differences between more or less fit or active volunteers [23, 42, 74, 87, 89].

Only a minority of studies have assessed mood at multiple time points after exercise. Exercise-enhanced mood generally persists for 3 to 4 hours post-exercise [55, 84], although certain effects may persist for as long as 24 hours after a single bout of exercise. Maroulakis and Zervas [60] administered the Profile of Mood States to a group of exercising females 10 minutes before, immediately after, and 24 hours after a single aerobics class; a convenient group of nonexercising women acted as a control. Immediately post-exercise, the exercise group reported highly significant improvements on all six subscales of the POMS (p values were less than 0.001). The control group reported basically unaltered mood states. One day later, the aerobics group exhibited scores for anger and total mood disturbance that were still significantly lower than at pre-exercise. However, it is important to recall that this was a quasi-experimental study; the effects on mood over time may not be so readily apparent when persons not predisposed in such a way to exercise are examined.

There has been a dearth of studies on the effects of acute exercise in clinical samples. This is perhaps surprising, given the efficacy of exercise for mood enhancement in nonclinical subjects. It is also unfortunate that the few clinical studies have tended to be quasi- or pre-experimental in nature. Nonetheless, these preliminary findings are, in the main, encouraging. For example, both hypertensive and normotensive subjects experience exercise mood effects [83]. There has been some debate as to the suitability of exercise for patients with anxiety disorders. Cameron and Hudson ascertained that 31% of patients with diagnosed panic disorder retrospectively reported experiencing increased anxiety during exercise [13]. Another study observed that students scoring high on state anxiety prior to exercise became less anxious, whereas those scoring below the mean actually became more anxious [47]. An experimental trial is needed to elucidate the impact of exercise on anxious subjects. Anecdotal experience has led certain researchers to suggest that patients with bulimia nervosa may be using exercise as another means of weight control, along with vomiting and the use of laxatives [94]. On the other hand, bulimics might be using exercise as a strategy for reducing the distress associated with their disorder [95]. The acute exercise study by Glazer and O'Connor found that bulimics experienced greater improvements in POMS mood states than did a group of nonbulimic controls [77]. Exercise may therefore be a useful adjunct in the treatment of bulimia nervosa.

METHODOLOGICAL CONSIDERATIONS

In addition to the problems that have already been discussed—poor experimental design and an over-reliance on student samples—there are several more concerns that require comment.

A number of the investigations that failed to find acute mood benefits did not consider mood as their primary outcome variable. Many of these were directed at the examination of the psychophysiological response to cognitive stressors following exer-

cise [78, 79, 85, 86]. In the typical psychophysiological stressor paradigm, subjects are asked to complete a mood questionnaire following exercise, but prior to a stressor such as a Stroop or public-speaking task. In the real world, exercisers are unlikely to have to contend with a stressful task immediately after their usual exercise routines. Therefore, the 'ecologically invalid' nature of the testing situation is unlikely to engender psychological changes that are representative of the norm. It is encouraging, however, that researchers are beginning to study exercise-induced mood changes in more naturalistic settings. For example, subjects are increasingly being studied in environments outside of the exercise laboratory [43, 44, 82]. Considering only the true experiments, it is notable that the studies employing stressor paradigms account for 4 of the 6 results that exhibited no change post-exercise. In other words, 17 of 19 ecologically valid, experimental studies supported some degree of affective change following exercise.

A further concern relates to the instruments used to tap mood. The Profile of Mood States and the state anxiety scale of the State-Trait Anxiety Inventory have been adopted in the majority of studies. The original POMS comprises 6 subscales: tension, confusion, anger, depression, vigour and fatigue [96]. State anxiety is defined as an undesirable mood state [97]. Thus, the POMS is heavily skewed towards the assessment of negative mood states, with only one positive as opposed to five negative subscales; the STAI measures negative mood only. In contrast, recent conceptualizations of mood place equal emphasis on both the positive and negative dimensions of affect [98, 99]. Stated otherwise, psychological well-being is characterized by more than simply the absence of distress. In practical terms, the POMS and STAI may be prone to floor effects in normal populations. More theoretically, these arguments imply that the POMS and STAI do not adequately sample the full range of affective experience. Due to such concerns, researchers have begun to develop inventories specifically designed to measure the affective changes that may occur during exercise [12, 25].

MECHANISMS

Both physiological and psychological explanations have been suggested to account for the mood enhancing effects of exercise. Of the biological theories, the most attention has been given to the action of endorphins within the central nervous system [100, 101]. Numerous studies have shown that plasma levels of endorphins are elevated following exercise [20, 24, 27, 102], but attempts to correlate endorphin levels with changes in mood by these researchers have generally failed. In addition, administration of the endorphin antagonist naloxone does not completely reverse the mood-enhancing effects of exercise [22]. While the endorphin hypothesis has an intuitive appeal, the evidence does not support it. On the other hand, Thoren et al. [101] warn that methodological problems may account for the lack of significant results. For instance, plasma endorphin levels may not correlate well with concentrations in the central nervous system (CNS). Unfortunately, assessment of endorphin levels in the human CNS is a highly invasive procedure and would in itself cause affective and biological changes.

The thermogenic hypothesis of exercise proposed that an elevation of body temperature is responsible for subjectively increased mood following exercise [83, 103]. Two studies have directly tested the hypothesis. The first, by Reeves et al. [39] measured body temperature in exercising subjects wearing either insulating or noninsulating cloth-

ing (the experimental and control groups, respectively). Subjects in the control group experienced no change in either core body temperature or anxiety. Body temperature in the experimental group rose significantly, which was accompanied by a significant increase in anxiety. Similarly, Petruzzello et al. [34] compared subjects running on a treadmill in Warmer, Cooler, and Normal temperature conditions, finding that increases in temperature were highly correlated with increases in anxiety; the anxiolytic effects of exercise became apparent only when body temperature cooled. While these certainly seem to refute the thermogenic hypothesis, Petruzzello et al. caution that post-exercise anxiety reduction could possibly be linked to brain, rather than core body, temperature. If so, it may not be feasible to test the thermogenic hypothesis.

The distraction hypothesis maintains that it is not a specific action of exercise as such that enhances mood, but rather the respite or 'time out' that it provides from worrisome thoughts and daily stressors [67, 83]. Bahrke and Morgan [67] randomly assigned 75 adult men to exercise, meditation, and no-treatment control conditions. The exercise group walked at 70%MHR, the meditation group practised Benson's relaxation procedure, and the control group rested quietly in a reclining chair. After 20 minutes of each treatment, all three groups evinced significant and equal reductions in state anxiety. A number of experimental studies have also supported the distraction hypothesis in that exercise was no more effective than an equivalent period of quiet rest or relaxation in reducing anxiety and tension [68, 70, 74, 77]. Goode and Roth [19] examined the pattern of cognitions characteristic of runners' thoughts during exercise, finding small but significant correlations between a tendency to engage in nonassociative thoughts, for example, about the external surroundings, and enhanced vigour post-exercise. This certainly indicates that cognitive factors are important during exercise. A study by Fillingim et al. [18], however, provides evidence that distraction alone is insufficient for mood benefits from exercise. Subjects were randomly assigned to exercise under one of three distraction conditions. One group performed a highly demanding cognitive task, while another performed a less demanding task. A third group exercised without additional intervention as a control. While both the low demand and control groups experienced reduced POMS tension, the high demand group reported increased tension, contrary to the distraction hypothesis. The earlier discussion regarding the assessment of both positive and negative aspects of mood may also clarify the distraction hypothesis. Using the Activation–Deactivation Adjective Checklist, Saklofske et al. [88] compared the effects of walking and relaxation. Both treatments resulted in reduced perceptions of tension, but the walking group also expressed an increase in subjective energy. Thus, although exercise may be only equivalent to relaxation for the reduction of negative mood states, it may be superior for the enhancement of positive mood.

The mastery hypothesis states that the completion of an important and effortful task brings about a sense of mastery or achievement, thereby improving mood [104]. This bears a striking similarity to Bandura's theory of self-efficacy [105]. Bozoian et al. [12] demonstrated that more efficacious females, that is, those who perceived themselves as being more capable of exercising for a specified duration, experienced a greater sense of revitalization post-exercise than did the less efficacious subjects. However, researchers have yet to examine whether subjects experience an immediate increase in self-efficacy itself.

It has been suggested that subjects report elevated mood following exercise only because they have been influenced by expectancies or demand characteristics of the experimental situation. Certainly, it would be impossible to discount this theory in the majority of this field of research. However, Steptoe and associates conducted two studies in which a cover story was used to conceal the true aim of the experiments [9, 42]. Debriefing verified that subjects had been completely deceived by the cover story, but in both cases, significant mood benefits were still observed.

RECOMMENDATIONS FOR FUTURE RESEARCH

Study of the acute mood benefits of exercise may aid the development of exercise routines designed to improve adherence. It is thus surprising that no attempts have been made to establish a relationship between the acute mood benefits of exercise and subsequent exercise adherence. Research in this direction is strongly advocated.

Replication of several key findings is also necessary. Only one study to date has found elevated mood for more than several hours after exercise [60]. Direct comparisons of aerobic and anaerobic modalities under experimental conditions would also be advantageous; the inclusion of instruments other than the STAI in such a test would also be of benefit. Clinically, the impact of exercise on anxiety levels in patients with diagnosed anxiety disorders merits further investigation. The only studies to be conducted in this population have been either retrospective in nature or used subjects without diagnosed disorders [13, 47].

As already mentioned, there may be no duration and intensity of exercise that is optimal for all exercisers—they may interact to produce acute mood benefits. There may be other important factors such as the fitness level of the exerciser, as well as his or her body mass index. For example, more overweight subjects perspire more heavily during exercise, which may cause greater discomfort for them than for their leaner counterparts. Dispositional factors are known to influence the extent to which individuals experience positive and negative moods [106, 107]. However, the role of personality traits in the determination of acute responses to exercise have been neglected. Clearly, future research should examine these factors in relation to the preferences of individuals.

A related topic of interest is the determination of a critical threshold for the accrual of psychological benefits. This is an important consideration for the prescription of exercise in populations who may be restricted with regard to the intensity or duration at which they are able to exercise. For instance, cardiopulmonary rehabilitation patients and the elderly may initially be unable to engage in more than short bursts of low intensity exercise. It is currently unknown whether such exercise would lead to appreciable mood effects. Meta-analytic results have not indicated a minimum duration or intensity for the anxiolytic effects of exercise to occur [108].

The mechanisms through which exercise influences psychological states need clarification. While the evidence reviewed suggests that exercise may be as effective as relaxation or quiet rest for the alleviation of negative mood states, further research using controlled experimental protocols is needed to determine whether exercise is more effective for the promotion of positive moods. Regarding the mastery hypothesis, it would be of interest to see whether post-exercise enhancement of self-efficacy correlates with the degree of affective change.

CONCLUSIONS

Overall, the findings must be tempered by an awareness of the methodological limitations inherent in the acute exercise literature. Nevertheless, there is strong support for the existence of acute mood benefits derived from a single bout of exercise. This suggests that exercise may be a valuable short-term strategy for the self-regulation of mood in both distressed and normal subjects.

Little is known about the specific factors that may contribute to these mood effects. Parameters such as duration, intensity and mode of exercise have not been investigated systematically. With regard to the mechanisms proposed to mediate these effects, the role of endorphins, distraction and self-efficacy cannot be discounted. In all likelihood, both physiological and psychological factors are implicated.

Acknowledgements—This manuscript was prepared while the author was funded by a Medical Research Council of Great Britain Studentship. The support of Russell Athletic is also gratefully acknowledged.

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