Br J Sports Med 2000;**34**:268–272

Stress reactivity to and recovery from a standardised exercise bout: a study of 31 runners practising relaxation techniques

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Abstract

***Objective*—To compare the efficacy in runners of two relaxation techniques with regard to exercise reactivity and recovery after exercise.**

***Methods*—Thirty one adult male runners were studied prospectively for six months in three groups practising either meditation (n = 11) or autogenic training (n = 11) or serving as controls (n = 10). Before and after the six months relaxation intervention, indicators of reactivity to exercise and metabolism after exercise (blood lactate concentration, heart rate (HR), and oxygen consumption (Vo_2)), were tested immediately after and 10 minutes after exercise. Resting HR was also assessed weekly at home during the trial. State anxiety was measured before and after the intervention.**

***Results*—After the relaxation training, blood lactate concentration after exercise was significantly ($p<0.01$) decreased in the meditation group compared with the control group. No difference was observed in lactate responses between the autogenic training group and the control group. There were no significant differences among the groups with regard to HR, Vo_2, or levels of anxiety.**

***Conclusion*—Meditation training may reduce the lactate response to a standardised exercise bout.**

(*Br J Sports Med* 2000;**34**:268–272)

Keywords: autogenic training; lactate; meditation; recovery; relaxation; psychology

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Accepted for publication 24 February 2000

Relaxation techniques have been used in sport primarily to enhance recovery from training and competition, manage anxiety, and improve performance.[1] They have been suggested to increase concentration, enhance motor skills, and improve ability to handle arousal and stress.[2] However, there has not been much research to support the application of relaxation methods for these purposes in sport. Some of the research is also unsatisfactory and suffers from flaws that preclude conclusions, including the lack of manipulation checks, appropriate controls, and clearly described interventions.[1 3 4] Reviews of the literature have found that more than 85% of studies showed significant improvements in performance after mental training.[1 3 4] On the other hand, the validity of these studies has been questioned, and causality between the psychological intervention and the performance could be inferred in few of them.[1 3]

There is also debate and disagreement over the relative efficacy of particular techniques. The effectiveness of different relaxation techniques has not been compared in sports settings.[1]

A generally used technique is autogenic training,[5 6] which is a directive specific technique working on relaxing and sensitising psychophysiological variables such as heart rate, respiration, and muscle tone. Its efficacy, however, has not been scientifically documented in sport,[1 3 7 8] but may be expected given its uses in other areas.

Meditation is probably the most commonly used relaxation technique for stress management and personal growth. In contrast with autogenic training, meditation is more general and usually based on stimulation of free floating awareness, a perspective different from goal orientation in competitive sports. Investigations indicate that reactivity and recovery variables relevant to sports, such as blood lactate concentration, heart rate (HR), and oxygen uptake (Vo_2), are decreased following meditation.[9 10] HR at rest has been found to be reduced (mean 7 beats/min, range 2–15) after meditation.[10] Several studies,[11–17] have shown a reduction in Vo_2 at rest in non-athletes. Several studies have shown significant reduction in blood lactate after meditation.[10] The lowered levels lasted for some time after meditation,[17] indicating that the relaxing effect persisted beyond the meditation period.

It is commonly accepted that lactate is an important indicator of recovery from exercise. High concentrations of lactate in the muscles (>8–10 mmol/l) are regarded as a limiting factor for physiological performance capacity.[18] Lactate in the blood has also been correlated with emotional states, and several researchers[19 20] have observed a relation between intravenous administration of lactate and anxiety attacks. Excessive lactate production after standard exercise has been shown in patients with anxiety neurosis.[20] Because anxiety is reduced by meditation,[9 10] it is possible that meditation, or other similar interventions, may also affect lactate levels.

Although meditation and other relaxation techniques are widely used in sport to enhance performance, it is unclear whether they can be beneficial in assisting athletes to recover from high intensity training. A modulating effect of meditation on immune response to strenuous physical exercise, however, has been reported.[21]

The aim of this study was to investigate whether stress reactivity and recovery was changed in runners after six month programmes of either autogenic training or meditation, each compared with a placebo control condition. Vo_2, HR, and lactate concentration were chosen as reactivity and recovery variables. As lactate is a measure of exercise stress and also has been implicated in anxiety states, the relation between lactate and anxiety after meditation was explored.

Materials and methods

SUBJECTS

Subjects were recruited from the running community in Oslo by an invitation letter distributed at the Oslo marathon and by an advertisement in a local paper. Regular physical exercise, participation in at least one long distance race (⩾10 000 m), and no prior familiarity with relaxation techniques were inclusion criteria. The responding runners were randomly assigned to one of three groups; to practise either autogenic training or meditation, or to be a placebo control. In the invitation letter, the participants were informed about random assignment to the groups and assumed practice of the techniques at home during the intervention period. The sample was limited to men ranging in age from 29 to 49 to delimit the variability in physiological responses that could result from including women or younger and older men. Accordingly, only consenting male runners within the prescribed age range were invited to take part in the present reactivity and recovery substudy. Six runners declined to participate for personal reasons. The results of two participants were excluded from analysis because of a testing error, leaving a total of 31 subjects (meditation group = 11, autogenic training group = 10, control group = 10). The mean (SD) age was 39 (7) (range 36–42) years, and there were no significant age differences among the groups.

THE RELAXATION PROGRAMMES

Autogenic training[5 6] and a meditation technique referred to as ACEM meditation[22 23] were used as relaxation techniques. Autogenic training was chosen because it has been commonly used in sport,[24] and ACEM meditation because it is widely used in Scandinavia (further details of the latter are available at ACEM International home page http://www.acem.com/). The technique involves a non-directed repetition of a sound designed for meditation practised in sequences of 30 minutes. The practice is fairly similar to transcendental meditation,[17] but has a different background and is explained in western non-culture psychophysiological terms. Both relaxation techniques are based on well established programmes, an advantage for research purposes because the teaching is easier to reproduce.

Both groups had weekly meetings for seven consecutive weeks combined with regular practice at home throughout the trial. For the meditation group, each session lasted two and a half hours, and for the autogenic training group each session lasted one and a half hours, according to standard teaching procedures. The home programme was 30 minutes each time for meditation, and sessions of 5–10 minutes repeated three times for autogenic training. The autogenic training group was instructed by a physiotherapist experienced in the technique.[5] The meditation group learned the technique from experienced instructors trained at the ACEM School of Meditation. Written material and tapes on meditation practice were provided as an option to the members of the meditation group.

THE CONTROL GROUP

The control group had weekly meetings for one and a half hours. The participants were involved in group processes focusing on general and their own sports psychology problems. The group was scheduled as a "placebo" group, designed to include an assumed positive social group factor, but to exclude the relaxation technique. They had no home training scheduled and were aware that the other runners received relaxation training. The attendance was comparable with that of the experimental groups. After the initial programme, all three groups had follow up meetings together once a month until the end of the study.

MANIPULATION CHECK

Both experimental groups completed a questionnaire after three and six months, reporting compliance with regard to the practice of the techniques. They were also asked if they had experienced specific signs of relaxation ("muscles are getting heavy and warm?") during the practice. The latter was performed as an additional compliance control. The reasons for the questions about signs of relaxation were deliberately not explained to the participants to minimise demand characteristics. During the intervention, the participants in the autogenic training and meditation groups had practised their relaxation technique respectively 21 and 30 times a month on average. More than 85% of the participants in both groups reported signs of relaxation. Attendance was noted at every meeting. The leaders of the groups confirmed that the participants had completed the courses satisfactorily. None of the subjects who met the initial criteria were dropped because of inadequate participation in the training.

In an effort to control for the potential influence of extraneous factors on the results, smoking (registered by a simple questionnaire) and alcohol consumption (registered by the short Michigan alcoholism screening test[25]) were assessed. Misuse of both cigarettes and alcohol may influence performance and the result in the exercise tests. Smoking is a sympathetic stimulating agent and affects oxygen consumption and thus aerobic metabolism. Alcohol may decrease performance and also affect metabolism. Stress was investigated (by a shortened 60 question version[26] of Life event stress[27]), as a possible factor that could affect performance and metabolism. Injuries that limited training capacity for more than two weeks were assessed with a questionnaire. Only two of the subjects were smokers, and one had had a previous problem with alcohol. None of the factors significantly affected the results.

TEST PROCEDURES

VO_2MAX, oxygen consumption after exercise, $VO_2SUBMAX$, lactate, and HR measurements were used as test variables. All tests were performed before and after the six month intervention period. The subjects were asked not to exercise, smoke, or use alcohol on the day of the assessment, nor to drink coffee for two hours before the assessment.

OXYGEN UPTAKE TESTS (VO_2MAX AND $VO_2SUBMAX$)

A four minute standard submaximal workload at a speed corresponding to the point of levelling off of the VO_2 (100% of VO_2MAX) was chosen as a stress reactivity and recovery model. This protocol was chosen because it is known to increase and sustain lactate concentration in blood at suitable levels for our measurements. Assessments of oxygen uptake were made continuously during the first five minutes after exercise.

Several days before these tests, the aerobic power of the subjects was assessed by the protocol described by Åstrand and Rodahl,[18] which involved running on a motor driven treadmill at 3° uphill inclination. To determine VO_2MAX,VO_2 was measured while the subjects ran on the treadmill for five minutes at four different speeds ranging form 60 to 90% of VO_2MAX. VO_2 was measured for a period lasting from the second to the fourth minute of each load. The values from these four submaximal workloads and the measurement of VO_2MAX were used to identify the speed corresponding to the point of levelling off of the VO_2 (100% of VO_2MAX). This speed was then applied when the subjects performed the four minute standard work protocol.

The technicians who conducted the exercise tests were unaware of whether the subjects were in an experimental or control group.

DEPENDENT VARIABLES

Lactate measurements

To investigate stress reactivity, we examined blood lactate immediately and 10 minutes after the standard submaximal work. A 50 µl sample of capillary blood was taken from a fingertip of the subject for lactate analysis. At 10 minutes after the exercise, a second 50 µl blood sample was taken with the subject now sitting relaxed in a comfortable chair. Blood lactate was measured with a YSI model 23L lactate analyser (Yellow Springs, Ohio, USA). Haemolysed blood was used in all lactate measurements. Rate of recovery was determined as the decline in blood lactate measured immediately after to 10 minutes after exercise.

HR and VO_2

Recovery was also measured as VO_2 after exercise and HR accumulated in the first five minutes after exercise, to provide an indication of how these variables responded to the recovery period.

The VO_2 data are presented as cumulative VO_2 during this period. HR is presented as mean beats/min of the cumulative HR during the five minute period, and telemetric equipment (Danica, Rødovre, Denmark) or a Sport Tester with a memory (PE 3000 Polar Electro, Oy, Finland) was used for the recording.

HR at home

Resting HR was self assessed weekly at home to determine the effectiveness of the relaxation procedures in a non-exercise setting. The subjects were instructed how to measure resting HR by palpation of the radial artery a few minutes after awakening. They were given written instructions to assess resting HR two mornings each week during the six month treatment. Twenty three of the subjects completed the resting HR scheme at home. The mean number of weekly assessments was 20 (range 8–25).

Anxiety

A validated Norwegian version of Spielberger's State-Trait-Anxiety-Inventory (STAI),[28] a 12 item questionnaire, was completed at the group meetings to test levels of anxiety. The STAI assesses state and trait aspects of anxiety, and the instrument is commonly used in anxiety research.

STATISTICAL ANALYSIS

Parametric tests (analysis of variance) were used to determine the statistical significance of observed differences between groups and within subjects. In the case of home assessment of resting HR, the Kruskal-Wallis test was used. When correlation between changes in lactate concentration and adherence to the relaxation programmes was calculated, Spearman's two tailed correlation coefficient was used.

Results

BASELINE DATA

No significant baseline physiological differences were found between the groups except for one lactate value immediately after exercise, which was significantly higher ($p = 0.05$) in the meditation group than in the control group. The lactate concentrations of the meditation group and the autogenic training group did not differ, nor were lactate concentrations measured 10 minutes after exercise significantly different across the groups (fig 1). The mean VO_2MAX values (ranging from 57 to 60 ml O_2/min/kg in the groups) and the runners' mean age (39 years) indicated that the participants were representative of an average recreational marathon runner.

STRESS REACTIVITY

Lactate response

Significant differences between groups were observed in the lactate response to exercise after the relaxation training period. The reductions in immediate and 10 minute post-exercise lactate responses after the intervention period

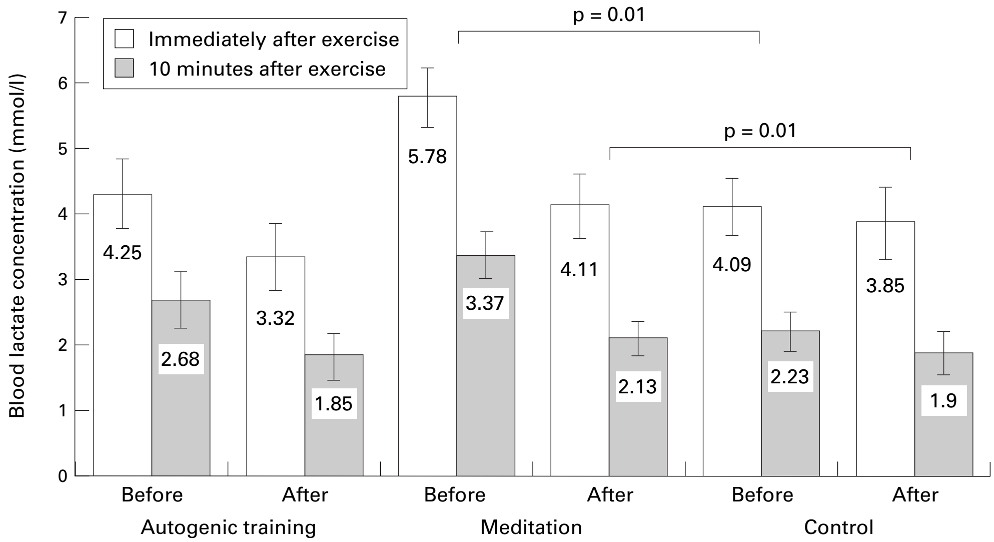

Figure 1 Blood lactate concentrations in the autogenic training group, meditation group, and control group immediately after and 10 minutes after exercise measured before and after the relaxation intervention.

were greater for the meditation group ($p<0.01$) than the control group (fig 1). The difference in lactate reduction between the meditation group and the autogenic training group, however, was not significant.

RECOVERY
The rate of decrease in lactate from immediately after to 10 minutes after exercise was measured before and after the intervention, and no significant differences or trends were observed among the three groups.

ANXIETY
No significant differences across the groups were found in state anxiety levels before and after the intervention (table 1). The level of anxiety for all three groups was lower than the published population norm.[29] The significantly smaller decrease in lactate in the meditation group after the intervention did not correlate with a similar change in anxiety in the same period.

HR AND VO_2
No significant differences in VO_2 and HR were observed after exercise among the groups (table 1). Resting HR values taken at home were also the same in the three groups.

Table 1 Measurements of VO_2MAX (ml/min/kg), heart rate (mean beats/min for five minutes after submax), VO_2 after exercise (ml/min/kg for five minutes after submax), and anxiety before (baseline) and after relaxation intervention

Variable	*Autogenic training (n=11)*	*Meditation (n=11)*	*Control (n=10)*
VO_2MAX			
Baseline	56.9 (1.9)	57 (2.5)	59.7 (2.9)
After	58.9 (1.5)	60.1 (1.8)	61.6 (2.9)
Heart rate			
Baseline	97 (8)	99 (13)	100 (18)
After	92 (10)	96 (11)	93 (16)
VO_2 after exercise			
Baseline	62.1 (8.2)	69.7 (10.7)	69.9 (13.6)
After	62.1 (11.8)	64.9 (9.5)	62.1 (12.1)
Anxiety			
Baseline	3.26 (0.32)	3.05 (0.21)	3.15 (0.23)
After	3.41 (0.46)	3.06 (0.27)	3.21 (0.23)

Values are mean (SD). The values after the relaxation intervention were not significantly different from before for any of the variables.

Discussion

The study attempted to compare the influence of two relaxation techniques on stress reactivity and recovery. To some extent the meditation group benefited from the relaxation training. Lactate concentrations after exercise were significantly reduced in the subjects practising meditation, but not autogenic training, compared with the controls. However, the two other recovery indicators, HR and VO_2, did not differ across the groups, suggesting that the relaxation conditions did not influence exercise reactivity. There is evidence, however, that lactate is a more sensitive indicator than HR of relaxation effects.[30]

This reduction in lactate after exercise is consistent with previous research showing a decrease in lactate measured at rest shortly after meditation.[10 11 17] Thus the observed effects of meditation on lactate during rest may also apply during conditions related to running. The lower blood lactate observed after meditation may be due to reduced noradrenaline (norepinephrine), reduction of anxiety caused by relaxation training, or redistribution of blood flow to a more aerobic skeletal muscle metabolism.[14 17] The hypothesis that the lowering of the lactate level can be explained by a fall in the level of anxiety[13 16 17] was not supported by the results of this study. State anxiety did not differ significantly across conditions before and after the intervention. Other research has also found lactate concentrations to be unrelated to anxiety.[31] The reported increase in the rate of lactate elimination during and after meditation[17] may indicate that meditation alters the rate of recovery after exercise. In the present study, the rate of decline in lactate after exercise was no different after the intervention period in any of the groups. Thus these findings do not support the suggestion that meditation is of help in enhancing recovery responses immediately after exercise. A reduction in lactate production during exercise, however, may explain changes in lactate concentration observed in the meditation group. Other researchers[32] report that red cell glycolysis decreased during meditation. Further research will be needed to test this hypothesis more fully.

The autogenic training group displayed a tendency towards reduced blood lactate levels after the relaxation training, but this finding did not reach statistical significance. V_{O_2} after exercise, and HR measured both after exercise and at home, did not show any significant differences. To summarise, the findings indicate that meditation was more effective than autogenic training, but further research is necessary to confirm this and identify underlying mechanisms responsible for the effect.

Caution is warranted in the interpretation of these data. To our knowledge no long term studies on stress recovery variables have been conducted with athletes practising relaxation techniques. The compliance data showed that the meditation group had more exposure to relaxation than the autogenic training group, which may have contributed to the findings. Anxiety was tested in a non-exercise setting, and the values attained were consistently low. This floor effect could have acted to prevent significant reductions from occurring.

On the other hand, self reported compliance with regard to the practice of the relaxation techniques was satisfactory in the two intervention groups. Nearly all the participants experienced signs of relaxation, another indicator of satisfactory practice. An initial questionnaire did not show that the runners participated in the study because they felt stressed.

The concept of stress modulation is important in sports medicine. With higher training doses, increased focus on recovery processes is needed.[33] The present effect of meditation training on lactate reactivity in a small sample of runners may be of clinical importance. A natural follow up study would be to test whether meditation can reduce stress reactivity, as measured by a broader set of variables, including immunological factors. Further scientific focusing on stress management techniques used in sport is proposed with the ultimate aim of preventing overtraining, balancing stress reactivity, and facilitating recovery.

We are indebted to Mitch Loeb for excellent help with the statistics. Also we want to thank the Norwegian Association for Sports for generous financial support. The testing and blood sampling were conducted at the University of Sport and Physical Education in Oslo. Teachers from the ACEM School of Meditation instructed the meditation group, and physiotherapist Anine Woodhouse instructed the autogenic training group.

Contributors: E S initiated and coordinated the study, designed core ideas, participated in data collection and analysis, and was the main author. He acts as a guarantor for the publication. F I was responsible for the oxygen uptake and lactate tests. He also contributed to the writing and to the design of the protocol. A H discussed core ideas and study hypothesis and contributed to the writing and editing of the article. J Sundgot-Borgen conducted the control group meetings and discussed the planning of the study. S N discussed core ideas of the study and contributed to the writing and the protocol. I H and his assistant Mitch Loeb performed most of the statistical analysis and contributed to the protocol.

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Take home message

Meditation training may reduce stress reactivity as measured by lactate response to a standardised exercise bout.