Affect change with acute exercise: determining an optimal dosage and testing thermogenesis and distraction as plausible mechanisms

A thesis presented for the degree of

Master of Science

By

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March 2002

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Glossary of terms

Acute exercise	short term bout of exercise
Ad ACL	Activation Deacativation Adjective Check List
Affect	broadest measure of feeling states
Chronic exercise	long term exercise training
Cognitive anxiety	psychological tension levels
EFI	Exercise Feeling Inventory
Emotion	brief, but intense response to a specific situation
Exercise	physical activity that is planned, structured, repetitive with a goal of improvement of fitness or health
MAACL	Multiple Affect Adjective Check List
Mood	set of feeling varying in intensity and duration usually involving more than one emotion
Negative affect	High affect indicates anger, contempt, disgust and fear, while low negative affect indicates calmness and serenity.
PANAS	Postive Affect and Negative Affect Schedule
Physical activity	general term describing any bodily movement that results in energy expenditure
POMS-bipolar	Profile of Mood States questionnaire– bipolar version
POMS-unipolar	Profile of Mood States questionnaire-unipolar
Positive affect	High positive affect indicates enthusiasm and alertness, while low indicates depression, lethargy and fatigue.
SEES	Subjective Exercise Experience Scale
Self-esteem	representation of how individuals view themselves, the awareness of good possessed by the self
Somatic anxiety	muscle or body tension
STAI	State-Trait Anxiety Inventory

Acknowledgements

My thanks goes firstly to Professor Nanette Mutrie for allowing me the to undertake the project and for her patience, encouragement and support throughout this study. I was very lucky you were my supervisor. Also thanks to Tom Aitchison for helping me organise the statistics and project design.

I would also like to thank the medical faculty especially Alison Spurway and Alison Neil for allowing me to complete this long period of study. Also thanks to Glasgow University engineering department for designing and mending my temperature probes.

Thanks also to members of staff of the Stevenson building who let me use the fitness-testing suite for 10 weeks and for allowing all my subjects access to the building.

Not forgetting thanks to all my subjects, without their dedication, there would be no study.

Finally thanks to Nikki, Elaine and Mum for your encouragement and belief when it seemed impossible also thanks to Matt and the rest of my friends and family for their support and encouragement.

Abstract

Exercise is associated with an improved affect, whether this is causal has not been confirmed yet. Little research has been carried out to identify optimal duration or environment, but intensity studies tend to favour moderate for producing the best psychological benefits. This thesis comprises three studies. The main study had two aims, to determine an optimal dosage of exercise for affect changes, and to test two causal mechanisms, the thermogenic hypothesis and the distraction hypothesis of exercise and affect change.

Study 1 was developed to determine which temperature site would be used to measure core temperature for the main study. Tympanic, oral and rectal measurement sites were tested, the rectal site provided clear results that were sensitive enough to detect core temperature changes with only a small variation between subjects. Study 2 looked at two mood questionnaires to determine sensitivity in registering small changes in affect. POMS-bipolar (Lorr and McNair, 1984) and PANAS (Watson *et al*, 1988) were selected for testing. The PANAS was chosen for the main study as it measured affect changes on a dimensional scale, took very little time to complete and was sensitive enough to pick up changes in affect with acute exercise.

The main study used 9 exercise conditions made up of short (10 minutes), medium (20 minutes) and long (40 minutes) duration exercise and low (45 - 55% Hrmax), moderate (65 - 75% Hrmax) and high (80 - 89% Hrmax) intensity bouts; and 3 quiet rest conditions of similar short, medium and long duration. PANAS (Watson *et al*, 1988) and core temperature were measured before and after each condition. Moderate intensity exercise consistently produced most of the improvements in affect as research predicted. Intensity significantly influenced negative affect, but not positive affect. The medium and short duration exercise bouts produced more improvements in positive and negative affect than the long duration exercise. There was no evidence to support the thermogenic hypothesis, as core temperature changes did not correlate with affect changes. The quiet rest condition produced significant improvements for medium duration therefore supporting the distraction hypothesis.

Future research could involve looking at delayed improved affect post exercise with particular interest in higher intensity exercise bouts. More research looking at how causal mechanisms may interact to produce an integrative model would be advised.

Chapter 1 Exercise and affect

The relationship between exercise and mental health

The relationship between mind and body has been of interest from the days of Hippocrates, Plato and Aristotle in the 3rd and 4th centuries. More recently there has been a growth in interest in holistic health and psychosomatic medicine, which appears to favour a link between mind and body. Layman (1960) explains that holistic theory maintains that no physical or mental illness may be adequately diagnosed, understood or treated unless it is viewed as both physical and psychological, therefore advocating a mind body link. There are many studies to support the physical benefits of exercise but psychological benefits of exercise are not so clear. In an attempt to clarify the psychological benefits of exercise, the International Society of Sport Psychology (ISSP, 1992) prepared a position statement. The position statement included the following statements:

- Exercise can help reduce state anxiety;
- Exercise can help decrease the level of mild to moderate depression;
- Long term exercise can help reduce neuroticism and anxiety;
- Exercise may be an adjunct to the professional treatment of severe depression;
- Exercise can help reduce various kinds of stress;
- Exercise can have beneficial emotional effects across all ages for both sexes.

This statement was developed ten years ago and research in this field has progressed over the decade. There is no information regarding exercise dosage or modality in the above position statement. The position statement does not include any information on exercise dosage modality. The position statement was based on published studies and does not take into account their methodological shortcomings, lack of control groups, randomisation or affect measurement. Research has been developed in an attempt to learn more about exercise and psychological benefits. These will be discussed next.

Population studies

Population studies look at lifestyles and habits of large populations. Three large population surveys (Steptoe and Butler, 1996, Sports Council and Health Education

Authority, 1992, Stephens 1988) have confirmed the positive relationship between physical activity and mood.

Stephens (1988) looked at four large population studies (concerned with the general, non - institutionalised public) in the U.S. and Canada and found that physical activity was positively associated with general well - being, positive mood and relatively infrequent symptoms of anxiety and depression in all age and gender subgroups measured. He found the relationship to be particularly evident in women and those aged over 40 years. Steptoe and Butler (1996) and the Sports Council and Health Education Authority (1992) both found individuals who were involved in activity had an association with positive emotional well being.

Population studies do not allow us to determine what comes first, inactivity or poor mental health. Although these studies usually benefit from a large sample size they often suffer from being cross sectional studies therefore a causal relationship cannot be assumed. Additionally these studies are not able to determine the effects of an acute (short-term) exercise bout or chronic (long-term) training programmes.

Narrative reviews

Narrative reviews look at all relevant research and produce conclusions based on the majority of research results. Yeung (1996) in an extensive review stated that "85% of studies researched found at the very least there was improved mood with exercise" (page 130). The results were either positive or mixed, despite a diversity of exercise mode, duration and intensity. He also reported that enhanced mood was found in different population types, i.e. females and males, young students and middle aged adults plus older and elderly subjects. The studies that reported worsened mood states had used competitive training intensities of exercise or unusual conditions.

Fox's review (1999) summarised physical activity as a means of "upgrading life quality through enhanced self-esteem, improved mood states, reduced state and trait anxiety, resilience to stress, or improved sleep" (page 414). Consensus from most reviews points towards positive mood changes with exercise (Paluska and Schwenk, 2000, Berger, 1996, Mutrie and Biddle, 1995, McAuley and Rudolph, 1995) although causal links have not been established.

McDonald and Hodgdon (1991) suggest that narrative reviews are a valuable source of information regarding current research tendency and general trends. One problem with narrative reviews is the reported support can be much stronger as the number of studies is often counted up and the most frequent result is cited as the outcome (McDonald and Hodgdon, 1991). One way to overcome this is to use a meta-analysis approach, which is more scientific as statistical analysis is incorporated.

Meta-analysis

A meta-analytic approach has the benefit of using previous research figures and analysing statistically the figures from all relevant studies. This is a far more scientific approach than a narrative review. In their meta-analysis McDonald and Hodgdon (1991) found a clear relationship between exercise and vigour and lack of negative mood. This study examined only aerobic type exercise and added studies that measured psychological states with only the POMS (Profile of Mood States; McNair *et al*, 1971) and the MAACL (Multiple Affect Adjective Check List (MAACL; Zuckerman & Lubin, 1965). In this meta-analysis there was no distinction between acute and chronic exercise. Petruzzello *et al* (1991) found evidence to substantiate the claim that exercise is associated with reductions in anxiety, but only for aerobic forms of exercise. North *et al* (1990) found both acute and chronic exercise was associated with a reduction. Problems for meta-analysis stem as experiments that have appeared in the literature can only be used. It could represent a bias in favour of only those studies that produced positive results; many that produced negative results remain unpublished (McDonald and Hodgdon 1991).

From these studies we could make some additions to the ISSP (1992) position statement:

- Moderate intensity exercise (American College of Sports Medicine guidelines, 1995) most consistently improves psychological well-being;
- Exercise training can reduce trait anxiety and single exercise sessions can result in reductions in state anxiety;

- Physical activity is associated with a decreased risk of developing clinically defined depression;
- Exercise improves increased mental well being for the nonclinical population
- Exercise can improve energy levels and ability to cope.

(Biddle *et al*, 2000, Paluska and Schwenk, 2000).

We are learning more about exercise and psychological changes through the above research methods although a causal link has not yet been established. Research in this area is generally split into two types, acute and chronic. Acute exercise is a short-term exercise bout, while chronic is a longer term training programme. Previously research has concentrated on chronic exercise, research has been looking at acute exercise more recently to try to establish an optimal exercise intensity, duration and modality.

Chronic exercise

Moses *et al* (1989) found tension and anxiety were significantly reduced in previously sedentary adults following a 10-week moderate intensity training programme. No improvements were made for a group that worked at a higher intensity over the 10-week programme. A study involving a 10-week physical conditioning class, which incorporated aerobic and anaerobic exercise, was carried out to test the changes in personality associated with participation in differing forms of physical activity (Jasnoski *et al*, 1988). Significant improvements were seen in coping and mood, happiness and security after the programme. Berger and Owen (1983) found that both male and female recreational exercisers (runners and swimmers) display more positive characteristics than their non-exercising controls. This was a descriptive study therefore it does not provide evidence on causality.

Chronic training studies generally show an improvement in psychological state which is superior to a placebo treatment (Moses *et al*, 1989, Steptoe *et al*, 1989).

Acute exercise

General findings associate an acute exercise bout with improvements in psychological well being. Studies (Barhke & Morgan, 1978, Berger and Owen, 1992, Dunn and

Dishman, 1991, Raglin & Morgan, 1987) found that acute exercise is associated with reductions in anxiety and tension. DeVries (1968) tested gastrocnemius muscles electromyographically after an acute bout of exercise and found that acute exercise produced a significant decrease in muscle tension levels thereby reducing somatic anxiety. The subjects who derived the greatest benefits from the exercise bout were those with the highest levels of muscle tension before exercise. This suggests that individuals with differing levels of anxiety feel better after an acute bout of exercise. This effect has been shown to last for between 1 to 2 hours following the cessation of exercise when it returns to pre-exercise levels (Raglin & Morgan, 1987). As this occurs with anxiety it may be possible that this will take place with other measures of mood. Morgan *et al* (1971) looked at depression levels in subjects with non-clinical depression. After an acute exercise bout all of the exercise groups had mean depression scores that fell below the published norms.

Chronic studies tend to look in more detail at self-esteem, self-image and trait anxiety whereas acute studies concentrate more on somatic anxiety, tension and levels of vigour. Petruzzello *et al* (1991) found that training programmes looking specifically at anxiety produced benefits in trait anxiety. Acute exercise will therefore need to be maintained on a chronic basis for the individual to continue re - experiencing the anxiety reduction effect (Morgan, 1997). Whether these effects from an acute bout of exercise accumulate to improve long term moods and traits is a question still to be answered. Morgan (1997) felt that it's possible that acute physical activity has little or no influence on a specific psychological construct (e.g. self-esteem), but this same variable may improve following chronic physical activity. For these reasons it is important to research both the acute and chronic effects of exercise on all aspects of mood states and traits without the assumption that the build up of acute mood changes will lead to chronic personality trait changes.

Most studies concentrate on specific areas of mood and affect; the following are the most commonly researched:

- Improved self confidence and awareness
- Relief of depression, tension and anxiety
- Increased energy and ability to cope

(Paluska & Schwenk, 2000,Biddle & Mutrie, 1991, Folkins & Sime, 1981).

There is growing interest in more general measures of mood rather than specific aspects that are generally measured such as anxiety or tension (Ekkekakis and Petruzzello, 2000). This will be discussed in more detail in Chapter 4.

Two broad areas of research have developed, psychological changes with exercise for the nonclinical population and the clinical population. Evidence exists for benefits both to the normal population and to those suffering from mental illness (Raglin, 1990). Fox *et al* (2000) commented on the deterioration of mental health of the general public with growing trends of mild depression, low self – esteem, high stress and anxiety and a lack of coping ability. This has produced a greater focus on the effects of exercise on mental health (Fox *et al,* 2000). More studies have been carried out in the past decade than ever before in exercise and mental health (Biddle and Mutrie, 2001).

Mental health isn't an all or none proposition, but really a sliding scale. At points in everyone's life they will suffer moderate depression, stress or anxiety it's just the depth and nature of these experiences which vary and shift. The estimation is that one in seven adults in the United Kingdom at some point in their life will suffer some form of psychiatric morbidity at (Health Survey for England, 1995).

The Department of Health (1996) estimated that in 1992-93, 17% of expenditure in the health services was spent on mental illness and disorders. There are several strategies used to treat mental health disorders i.e. drugs, psychotherapy, but one more recent form is exercise. There are many benefits to using exercise, instead of or in association with traditional methods, as a mechanism for improving mental health. These benefits include no harmful side effects unlike some mood enhancing drugs, it's generally inexpensive as it can be carried out without equipment, easy to administer and it's self-sustaining as it can be maintained by the individual (Fox *et al*, 2000). The many physiological benefits of exercise i.e. reducing the risk of coronary heart disease (CHD), normalising high blood pressure (Powers and Howley 1990), reduced loss of bone density (Fentam *et al*, 1988) and improvement of health related quality of life (Biddle, 2000) are considerable.

Although the psychological benefits of exercise to those suffering from mental health disorders have been documented (Biddle and Mutrie, 1991, 1995, Morgan, 1997, Fox, 1999, Fox *et al* 2000) mental health services in Britain rarely use exercise as a type of therapy. (Fox *et al*, 2000). Evidence from experimental studies shows that both aerobic exercise and resistance training exercise may be used to treat moderate and more severe depression, usually in association with standard treatment (Mutrie, 2000). Scully *et al* (1998) found in a review that both aerobic and anaerobic exercise could be associated with an elevation of mood states, particularly for clinical samples. Faulkner and Biddle (2001) found most clinical specialists had "favourable attitudes regarding exercise" (page 433), but these attitudes were "more related to exercise being seen as a positive lifestyle activity that is worth encouraging, rather than exercise being recommended as an adjunctive treatment for mental health problems" (page 433). As Raglin (1990) found, exercise can improve psychological health for both clinical and nonclinical populations. An acute exercise bout may produce the 'feel better' factor for both groups. Are these benefits produced by all exercise intensities, durations and modalities or is it only specific types and levels of exercise that produces these changes? These issues will be discussed next.

More recently emphasis has been on acute exercise in an attempt to find optimal dosage. Exercise intensity has received the most interest and will be discussed next.

<u>Exercise intensity and psychological benefits</u>

Morgan noted (1973) there was a lack of information concerning intensity and duration at which exercise should be performed for optimal psychological improvements. Dishman (1994) speculated that there is probably not just one exercise intensity, type and volume to improve all aspects of mental health for all people. This relationship of dose response still remains unresolved (Ekkekakis & Petruzzello, 1999) although recently there has been an increase in the number of studies in this area.

Methodological Issues.

Many of the methodological issues which make comparison between studies difficult stems from the different ways intensity is calculated and monitored. The following are widely used:

- Ratings of Perceived Exertion (RPE);
- maximum heart rate;
- heart rate reserve;
- maximum oxygen uptake (VO_2 maximum);
- Watts;
- Kilocalorie usage.

The lack of consistency in quantification of intensity prevents any real comparison of results between studies. To allow comparison between studies there needs to be standardisation of intensity. To attempt to compare studies with exercise bouts at 25watts for 20 minutes to exercise bouts at 50% VO_2 max for 30 minutes would result in misleading information. Using the standardised ACSM protocols (Table 1.1) of intensity that are easy to measure and recognised as guidelines of intensity and a constant duration would allow a thorough comparison of results (ACSM 1995).

Table 1.1 American College of Sports Medicine guidelines (1995) for classification of exercise intensity.

	% Heart rate max	**% VO_2 max**	**RPE**
Light intensity	35 - 59	30 - 49	10 - 11
Moderate intensity	60 - 79	50 - 74	12 - 13
Heavy intensity	80 - 89	75 - 84	14 - 16
Very heavy intensity	>90	>85	>16

For a true comparison a standardised exercise duration, modality and environment would be beneficial. Most studies are carried out in laboratory settings using a cycle ergometer or a treadmill, although swimming and relaxational methods have also been studied.

Exercise intensity research

Earlier investigations indicated that light intensity exercise (power outputs of less than 60% VO_2 max) did not reduce state anxiety or improve psychological status, whereas moderate to high levels of exercise intensity were effective in reducing state anxiety and improving psychological status (Farrell *et al*, 1987, Morgan *et al*, 1971, Sime 1977). This view has now changed and moderate intensity exercise is generally viewed as the most beneficial exercise intensity with doubt cast over whether light and high intensity exercise improves psychological health. (Steptoe & Cox, 1988, Kerr & Svebak, 1994).

Low intensity exercise.

Low or light intensity exercise has been associated with improved mood (Steptoe and Cox, 1988, Steptoe and Bolton, 1988) and no change in mood (Farrell *et al*, 1987, Felts and Vaccaro, 1988). A threshold for exercise intensity and psychological change has been suggested to exist (Ekkekakis and Petruzzello, 1999) although DeVries (1981) has recommended that low intensity exercise, which he stated as 30 – 60% of HRR, was enough to gain psychological benefits. Low intensity exercise (25 watts) and high intensity exercise (100 watts) were associated with similar increases in exhilaration and vigour and decreases in tension (Steptoe and Cox 1988). Steptoe and Bolton (1988) found that low intensity exercise (25Watts) produced modest improvements in mood while the higher intensities (100watts) worsened negative mood. The exercise intensities used in both studies is questionable as 100 watts is probably not high intensity exercise, possibly more like moderate low intensity exercise. Kerr and Sveback (1994) found significant improvements in state anxiety after low intensity jogging in comparison to high intensity rugby. This study may prove unreliable, as the rugby session was a competitive sport, not exercise.

In contrast Farrell *et al* (1987) found no mood change at 40% VO_2 max but mood change was observed at higher intensities. Similar observations were made for exercise at 30% HRR by Felts and Vaccaro (1988) but higher intensities produced more positive changes.

Moderate Intensity exercise.

The relationship between moderate intensity exercise and mood is much clearer. Moderate intensity exercise has consistently been associated with mood benefits. Swimming (Berger and Owen, 1992), jogging (Berger *et al,* 1988, 1998) and cycling (Motl *et al*, 1996) found positive mood changes with moderate intensity exercise. Motl *et al* (1996) studied highly fit cyclists at moderate, high and maximal intensity levels and mood improvements were seen only in the moderate intensity condition. Parfitt *et al* (1994) also found only moderate intensity exercise reduced negative mood states. Subjects that exercised at 75% and 79% of age adjusted maximum heart rate reported that they felt better after exercising (Berger and Owen, 1998).

High intensity exercise.

The effects of high intensity exercise on mood are not so clear. High intensity exercise has been reported to improve mood (Dishman, 1986, Tate and Petruzzello, 1995), have no effect on mood (Berger and Owen, 1992) and worsen mood (Parfitt *et al*, 1994, 1996, Steptoe and Cox, 1988).

Tate and Petruzzello (1995) found significant improvements in state anxiety after a high intensity exercise session (70% VO_2 max), but not for moderate intensity exercise (55% VO_2 max) while the changes for energetic arousal were significant for both conditions. 70% of VO_2 max has been classified as moderate intensity by the ACSM (1995, see table 1.1) therefore these results can be viewed as low and moderate intensity activity if working on the ACSM's guidelines (1995).

There was no evidence that high intensity swimming (81% or 82% Hrmax) was related to mood alteration (Berger and Owen, 1992). The same researchers (1988) again found no mood change for a high intensity (90%Hrmax) conditioning class.

Steptoe and Cox (1988) results suggested an increase in negative mood following higher intensity exercise, but their high intensity exercise was only 100 watts, which may not classify as high intensity. Affect changes became progressively less positive (Parfitt *et al*, 1996) as exercise intensity and RPE increased. The higher intensity exercise made feeling states significantly worse for less active individuals (Parfitt *et al,* 1994).

Some studies (Berger and Owen, 1998, Raglin and Wilson, 1996) have not seen any difference in mood alteration for different exercise intensities. Raglin and Wilson (1996) reported that exercise intensities of 40%, 60%, and 70% of VO_2max were found to be equally effective in reducing post exercise state anxiety although the reduction is delayed somewhat following exercise at a high intensity (i.e., 70% VO_2 max). Using the ACSM guidelines these values fall into low (40%) and moderate (60% and 70%) intensity exercise. Regardless of intensity, participants reported they felt better after a 20-minute exercise bout (Berger and Owen, 1998). This study had hoped to measure low, moderate and high exercise intensity but the actual intensities measured were low intensity and moderate intensity.

Intensity Conclusion

Low intensity is associated with improvements in mood and sometimes no change in mood. The psychological effect of low intensity exercise is important as recent interest in promoting low intensity activities, for example, walking or climbing the stairs, has been developed into a new healthy living message. If mood improves with low intensity exercise then adherence may also improve. Moderate intensity exercise consistently improves psychological mood in numerous studies. The results of high intensity exercise are still to be clarified. Berger & Motl's (2000) review stated " high intensity exercise promotes cardiorespiratory and metabolic training benefits but it has been associated with few desirable changes in mood" (page 81). This suggests that moderate intensity exercise is the only exercise intensity that consistently improves mood.

Maximal exercise studies

Maximal exercise studies constitute a relatively standard exercise load thus facilitating cross study comparisons. These tests also allow us to examine current thinking that highly strenuous exercise has a negative impact on affect (Ekkekakis & Petruzzello, 1999).

Fitness Level.

Fitness level may affect mood alterations to maximal exercise. Steptoe *et al* (1993) tested fit sportsmen and inactive men in exhaustive tests. Exhilaration was increased in both groups, but a decrease in tension was only found for the highly active group.

Ratings of tension-anxiety, vigour and exhilaration were higher prior to maximal exercise as compared to submaximal exercise participation in both groups.

Motl *et al* (1996) compared experienced cyclists with non-experienced students in response to 3 exercise tests to exhaustion, no differences were found between the groups as both experienced a worsening of mood.

It is plausible that individuals who are more accustomed to the sensations of exercise are more able to exercise comfortably at higher intensities. The results tentatively suggest that maximal exercise is more beneficial to those that are highly active.

<u>Post exercise duration</u>

Improvements in mood are not necessarily observed immediately following exercise. Delays of greater than 30-minutes may be required before any improvements in mood are recorded (Raglin & Wilson, 1996, Morgan & Horstman, 1976,O'Connor *et al*, 1993, Raglin *et al*, 1993). This has been noted particularly following bouts of high intensity exercise (Raglin & Wilson, 1996).

Parfitt *et al* (1996) found positive affect was considerably higher 5 minutes after exercise in comparison to the last 20 seconds of the exercise bout for both highly active and low active females. Raglin and Wilson (1996) found state anxiety was significantly reduced in all post-exercise assessments at 40 and 60% VO_2 max conditions. State anxiety was elevated at 5 minutes following exercise of 70% VO_2 max, but decreased below initial levels at 60 and 120 minutes post-exercise.

There have been no specific guidelines as to how long after exercise mood should be measured, especially at different intensities. Further clarification is needed to determine affect changes post exercise with regard to different intensity levels (Biddle, 2001).

<u>Exercise duration and psychological benefits</u>

The standard exercise dose of 20 minutes duration has been the message which has been advocated (ACSM 1995) for a number of years. Dishman (1986) agreed and stated that in order to insure anxiolytic effects the exercise bout must be performed for at least twenty minutes. Twenty to thirty minutes of exercise may be sufficient for reducing stress (Berger, 1986, Berger & Owen, 1983); 60 minutes may provide even more psychological benefit. Berger *et al* (1997) found longer duration training was associated with no mood changes and O'Connor *et al* (1991) found it was associated with mood deterioration.

Ekkekakis *et al* (2000) found that short (10 – 15 minute) bouts of walking were consistently associated with improvements in positive affect. Nabetani and Tokunaga (2001) contrasted the effects of two short-duration exercise sessions on mood changes. Participants ran on a treadmill for 10 or 15 minutes at a self-selected intensity, they were instructed to run at a rate that felt good, not painful. They found that exercise between 10 and 15 minutes resulted in similar psychological benefits. Petruzzello and Landers (1994) found 15 minutes of exercising produced a reduction in state anxiety, but no changes in positive or negative effect were produced. Thayer (1987, 1996) found positive changes in mood when exercising for as little as 5 to 10 minutes.

Petruzzello *et al's* (1991) meta-analysis found an overall effect for duration. The magnitude of anxiety reduction for exercise lasting 1 to 20 minutes (effect size = 0.04) was significantly less than anxiety reduction for durations of 21 to 30 minutes (effect size 0.41). This would support Dishman (1986) although 48% of the effect sizes in the 1 to 20 minute categories were derived from comparisons between exercise and other anxiety reducing treatments. When the effect size was recalculated similar anxiety reductions were found for both durations.

Petruzzello *et al* (1999) found that exercise duration had received little attention and this area needed further clarification. Future research should examine different durations of exercise at set intensities to determine if optimal exercise duration exists or if fitness level or environment affects this.

Exercise modality and psychological benefit

Most exercise psychology research has focused on aerobic exercise although recently there have been more studies looking at tai chi and differing forms of meditation (Jin, 1992). The few studies that have looked at resistance training tend to be chronic studies (Tucker 1982, Jasnoski *et al,* 1988). A previous review (Fox, 1999) suggested that aerobic and resistance exercise consistently enhances mood.

Four aspects of exercise mode (Berger & Motl, 2000) that appeared particularly conducive to mood improvement were identified. These aspects include:

- The inclusion of abdominal and rhythmical breathing;
- The relative absence of interpersonal competition;
- Closed and predictable activities;
- Repetitive and rhythmical movements.

Exercise has helped yoga participants to be less anxious, tense, depressed, angry and confused (Berger & Owen, 1983, 1988, Morgan 1979) while fencing was found to increase vigour. Swimmers have been observed to be significantly less tense, depressed, angry, confused and anxious after one swimming bout. (Berger & Owen, 1983).

Koltyn *et al* (1995) studied students who took part in a weight training exercise session in which they self selected the intensity but no improvement was found in state anxiety after the exercise bout, although it was assessed immediately following the exercise bout. It is possible that anxiolytic effects could be delayed as some investigators have found this result for walking, running etc. (Cox *et al,* 2000, Morgan 1997, Parfitt *et al,* 1996). Raglin *et al* (1993) found that weight training increased state anxiety while the same subjects found decreased state anxiety following cycling. Both conditions worked at a controlled high intensity. Less strenuous weight training exercise bouts may produce decreases in state anxiety.

Raglin's (1993) study used competitive athletes while Koltyn (1995) used relatively inexperienced subjects; the results would appear to be similar across both ability levels.

The majority of studies have looked at aerobic exercise, primarily running, although cycling and swimming have also been researched. Results are mixed and more research would be beneficial investigating different modalities of exercise.

Exercise environment and psychological benefit

The environment in which a subject exercises may be a factor that affects mood. A subject may feel more anxious entering a laboratory as opposed to an exercise environment with which they are familiar. This may produce elevated anxiety levels pre exercise, which in turn may produce a larger anxiolytic effect than would be found in a familiar environment. This may produce more favourable results in terms of exercise and affect. Ceci and Hassmen (1991) compared the speeds of laboratory treadmill and field running, in the field condition subjects ran at a faster pace although their perceived level of exertion was the same as laboratory treadmill running. Laboratory settings may have an important influence on pre and post mood (Kerr and Els Van Den Wollenberg (1997).

The effects of music and television whilst exercising on mood are not clear (Berger & Motl, 2000). A study examined whether lively stimulating music moderated mood changes in high or low intensity aerobic exercise (Steptoe & Cox, 1988). No evidence was produced to say that music was a factor in affecting mood change.

Conclusions

Exercise is consistently associated with improvements in mood. The optimal exercise intensity appears to be moderate although further research investigating intensity and mood would be beneficial. Additionally post exercise duration and mood alteration with different intensities will require clarification. Optimal exercise duration is not yet known at this time although studies have found benefits ranging from 10 minutes to 60 minutes. Fitness level may affect mood states when exercising at different intensities or durations.

The issue of exercise modality and affect has received much less attention. Most studies have concentrated on aerobic type exercise although a number of studies are beginning to look at resistance type exercise; results have been mixed and environmental effects have not been researched in much detail.

The first aim of this thesis is to determine if an optimal intensity and duration for providing psychological improvements exists. Additionally is there an optimal exercise intensity and duration interaction for psychological benefits?

Chapter 2 Investigating the proposed causal mechanisms of improved affect with exercise.

Exercise has been shown to be associated with increasing positive and decreasing negative mood states in males, females, older adults and children (Bahrke & Morgan, 1978, Raglin & Morgan, 1985, 1988, Yeung 1996, Paluska and Schwenk 2000*)*. For these reasons it seems of primary importance to examine the possible mechanisms underlying this association. A number of physiological and psychological mechanisms have been proposed to explain the link between exercise and positive psychological functioning.

Psychological proposals have included the self-esteem hypothesis (Bandura, 1977); mastery hypothesis (Sonstroem, 1982); distraction hypothesis (Bahrke and Morgan, 1978); social interaction and reinforcement hypothesis (Hughes, 1984) and the opponent-process hypothesis (Solomon, 1980). The main physiological proposals include cardiovascular fitness (Morgan, 1969); biofeedback (Hollandsworth, 1979); monoamines (Ransford, 1982); endorphins (Farrell, 1981) and thermogenesis (Von Euler and Soderberg, 1956).

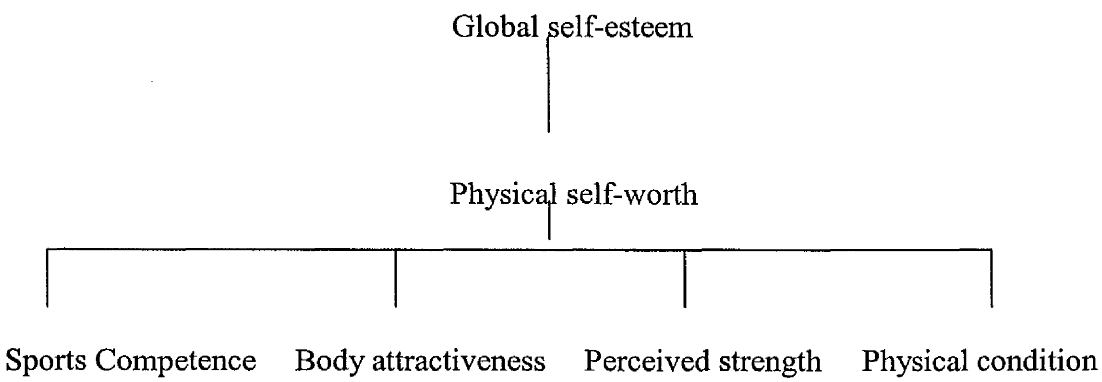
The main principles of each of these proposed mechanisms will now be explained.

Self-Esteem

Self-esteem is the single most important measure of an individual's psychological well being (Biddle and Mutrie, 2001). Harris (1973) suggested that physical activity has great potential to affect self-esteem positively. Self-esteem is made up of different hierarchical levels with a global judgement of self-esteem at the top.

Fox and Corbin (1989) produced a model of self-esteem to explain the relationship between global self-esteem and the sub domains. Self-esteem is made up of a number of domains. For example social and academic domains as well as the physical self worth domain will influence global self-esteem. If one domain is more important than another this will have a larger effect on global self-esteem (Fox, 2000, 1990).

Figure 2.1. Fox and Corbin (1989) Model of physical self-perception



Sonstroem (1984) found that body image and perceptions of physical ability were highly correlated with global measures of self-esteem. Changes in exercise efficacy may change perceptions of competence, strength or condition, physical self-worth and other physical self-perceptions. Participants who had an initial lower self-esteem had greater improvements in self-esteem with exercise. (Sonstoem, 1997).

<u>Does self esteem increase with improved fitness level?</u>

Sonstroem (1984,1997) found that perceived fitness changes were more important than actual fitness increases. Doan and Scherman (1987) found a positive relationship with self-esteem / self-concept and exercise in the majority of studies they reviewed. A small number of studies in that review found no change but not one of the studies found a negative relationship. Fox (2000) agreed with their results in his review and demonstrated that 76% of all randomised controlled studies had shown positive changes in physical perception or global self-esteem with exercise. It can therefore be concluded that exercise is related to positive changes in self-esteem (Biddle and Mutrie, 2001).

<u>Does global self-esteem affect involvement in physical activity?</u>

Marsh and Sonstroem (1995) demonstrated that physical self-concepts for example, sports competence and body attractiveness, rather than global self-esteem, were associated with physical activity involvement. They found little to support the theory that individuals with perceptions of being competent in one sub domain would exercise more than individuals with low perception of competence. Different motivations existed, i.e. those low in body attractiveness exercised to improve while those high in body attractiveness exercised because they felt competent or felt that they looked good.

Conclusion

The bulk of work looking at self-esteem as a mechanism has focused on chronic training programmes (Sonstroem, 1997). The conclusion from Sonstroem's review (1984) highlights this point; "exercise programmes are associated with significant increases in self-esteem scores of participants" (page 151). Can self-esteem changes produce psychological benefits with exercise? As suggested previously, self-esteem is the single most important measure of an individual's psychological well being (Biddle and Mutrie, 2001), therefore improvements in self-esteem will improve psychological well being. Changes in the sub domains of self-esteem will happen over a period of time so does self-esteem explain the mood improvements produced in acute exercise? Research needs to look at the psychological changes in acute exercise to determine if a pattern exists of acute exercise improving sub domains of self-esteem to become global self-esteem changes.

Mastery Hypothesis

This theory was developed by Sonstroem (1982) to explain why participants felt better after they exercise. Exercise provides participants with situations in which they can feel a degree of control, achievement and mastery. This is linked to the concept of Seligman's learned helplessness model (1975) and Abramson *et al's* (1978) research, as both found depression was the result of repeated experiences of having no control over what happens in one's life. When an individual expects to be able to control both the good and bad things that happen in life this expectation should immunise against depression (Abramson *et al*, 1978). Could exercise provide this feeling of control in a person's life? Exercise can be a challenging task for sedentary individuals so successfully adopting regular physical activity may produce an improved mood, increased self-confidence and enhanced ability to handle and control events (Biddle and Mutrie, 1991). Exercise can play a role in helping an individual to gain control in one area of life, namely the physical self. Improvement and progress in physical activity can only really be attributed to self rather than an additional person or factor.

North *et al* (1990) explained that exercisers often experience positive cognitive behaviour changes post exercise and explained this as achievement and increased sense of mastery. Exercise was suggested to release positive thoughts and feelings that could break the downward thought affect spiral that characterises depression.

Successes raise mastery expectations, repeated failures lower them (Bandura, 1977). If an exercise bout is set with individualised and attainable settings that are challenging, then the participant should gain a sense of achievement and eventually mastery (Biddle and Mutrie, 1991)

Exercise and Control

Many people have emotional barriers such as feeling they can't exercise as they aren't the sporty type or that they would not manage to keep it up (Sports Council and Health Education Authority, 1992). The individuals that manage to overcome these barriers will gain a sense of having mastered their fear or barriers to exercise. If they persist in perceived threatening situations that are in fact relatively safe in terms of achievement, they will experience a sense of mastery because they have managed that activity (Bandura, 1977). Physical activity can positively affect cognitive view and perceptions (Bandura, 1977).

Conclusion

This is a tenable hypothesis as individuals tend to feel better once they have gained control of a situation (North *et al*, 1990). Again most studies have looked at chronic exercise patterns and not the effect an acute exercise bout has on feelings of mastery.

Distraction Hypothesis

This theory, proposed in 1978 by Bahrke & Morgan, states that it isn't exercise *per se* that causes a reduction in anxiety and depression, but a simple time-out factor which allows individuals to be distracted from their worries and frustrations. Exercisers tend not to think about problems when exercising because exercise is used as a cognitive diversion (Hughes, 1984). Exercise can be put in the same category of relaxation as fishing or watching a movie (Ransford, 1982). Physical activity has been found to be equally effective in this regard to relaxation techniques, i.e. quiet rest or meditation (Gauvin & Spence, 1996).

These statements have been based on a number of studies (Bahrke & Morgan, 1979, Raglin & Morgan, 1985, Gauvin & Spence, 1996) which have shown no quantitative differences in anxiety and tension reductions after an exercise bout, quiet rest period or a meditation session.

Exercise Vs Quiet Rest or Meditation

Bahrke & Morgan (1979) conducted a study using 75 regularly exercising male volunteers and randomly assigned them to one of three conditions–aerobic exercise, meditation or quiet rest which served as a control group. The exercisers walked for 20 minutes on a treadmill at 70% of their maximum heart rate. The meditation group used Benson's relaxation technique for 20 minutes and the control group rested quietly for 20 minutes, reading a magazine if they desired. A reduction in state anxiety was observed for each of the three conditions. The anxiolytic response of the control subjects was identical with that of the meditation group. These results suggest that simply taking 'time–out' is just as effective as exercise or meditation in reducing anxiety. Time-out therapy may represent the effective ingredient in therapies that are designed to reduce anxiety. In a similar study to Bahrke & Morgan (1978), Suedfeld (1980) used a quiet rest technique termed 'reduced environmental stimulation treatment' (REST) and found a reduction of arousal and blood pressure post treatment.

Michaels *et al* (1976) found that quiet rest was equivalent to transcendental meditation in the reduction of plasma [adrenaline], [noradrenaline] and blood [lactate] that compose the biochemical rationale for reduced anxiety levels. Meditation and quiet rest appeared equivalent in reducing anxiety levels.

Tate and Petruzzello (1995) found no mood changes occurred for the control condition on any variables measured but significant changes were found for the exercise conditions. In this study the control subjects sat on the bike instead of cycling this may have led to some discomfort therefore diminishing any effects of quiet rest or distraction.

Quality and quantity of anxiety

It is possible that while time–out is just as effective as exercise in reducing anxiety, the decrement following exercise may be sustained for a longer period, i.e. the quantity of the shift may be similar, but the quality may differ.

A study conducted by Raglin & Morgan (1985) investigated the qualitative effects of exercise, quiet rest and meditation. They found quiet rest and exercise were associated with quantitatively similar reductions in state anxiety and blood pressure. Higher readings of blood pressure being an indicator of higher levels of stress and anxiety. Post–exercise blood pressure was significantly lower for 2–3 hours after the exercise condition; the decrease in blood pressure in the distraction group did not last after the treatment. Reduction in state anxiety also persisted for longer following the exercise condition. An additional study (Raglin & Morgan, 1988) has shown that blood pressure and state anxiety decrease significantly following a 45-minute quiet rest period or exercise session. In this study participants performed their usual form of aerobic exercise (jogging, swimming or cycling) but no randomisation of participants to conditions took place. They were evaluated for three hours following the exercise and time–out interventions and similar effects to their previous study were noted. These studies suggest that reductions in blood pressure and anxiety do persist for a longer period of time following exercise. Pennebaker and Lightner (1980) used healthy subjects that ran on a treadmill, some listening to 'distracting noises' through headphones, others listening to an amplification of their own breathing, and those remaining had no distracting noises. After the exercise session those subjects listening to distracting noises reported less fatigue and fewer symptoms of depression and anxiety than subjects hearing an amplification of their own breathing. This study indicated that increased attention to internal cues results in greater perception of fatigue and physical symptoms of depression and anxiety. This lends support to the distraction hypothesis, adding more distractions while exercising can help to reduce anxiety and tension levels to a larger extent than just exercise alone.

Distraction and fitness levels

Roth (1991) investigated the effect of fitness levels and distraction. They used 80 subjects, randomly assigned to either an aerobic exercise session for 40 minutes or a waiting period control. Of the 80 subjects 40 were classed as active and the other 40 classed as inactive. The study showed that there were no mood changes related to physical fitness; both active and inactive individuals experienced reductions in anxiety following acute exercise. Anxiety and tension levels were significantly reduced by 40 minutes of aerobic exercise; no significant reductions in anxiety and tension levels were seen in the waiting period control group. This conflicts with results from Raglin and Morgan (1985, 1988) as a difference was seen between the exercise condition and the non-exercise condition, with the former creating a greater mood change in active and inactive subjects. The Raglin and Morgan studies (1985, 1988) reported that a single exercise bout could be useful for elevating and enhancing a sense of stress resistance and improving some cognitive functions to a greater degree than a quiet rest period. The intensity of the exercise condition was not strictly monitored, so whether fitness level and exercise intensity may have an effect on distraction, was not measured.

Conclusion

Exercise and quiet rest have been associated with similar quantitative, but different qualitative effects, exercise causing the more favourable and longer lasting anxiolytic effect. Few studies have looked at distraction in terms of increases in self-esteem and reduction of depression. The studies focus mainly on anxiety and stress. To gain a clearer picture of the distraction hypothesis, broader affective changes that are evident post exercise need to be researched to determine whether a simple 'time-out' is the main mechanism involved.

Social Interaction and Reinforcement

Mental benefits of exercise may be produced from the social interaction that accompanies sport and exercise (Hughes 1984). This hypothesis is based on the fact that often when exercising people receive some form of social group interaction, pleasure, or personal attribution which could account for the antidepressant effect of exercise (Doyne *et al*, 1983, Hughes, 1984). While this may indeed be a benefit subjects who exercise alone have also reported significant positive mental health benefits (Brown, 1988) and so this mechanism may have limited explanatory power. Meta–analysis does not support the social interaction hypothesis as being the sole mediator of the antidepressant effect of exercise (North *et al*, 1991). The available research concludes that there isn't strong support for the social interaction hypothesis as being the sole mediator of mood changes with physical activity.

Hughes (1984) felt that social reinforcement occurred because exercisers were often praised for exercising. Social reinforcement is a major factor in all psychotherapies therefore social reinforcement may be the active ingredient in exercise therapy and not simply exercising in a social environment.

Conclusion

Individual exercise has proven to have psychological benefits (mostly shown in chronic studies (Glenister, 1996) so social reinforcement and interaction cannot alone explain the positive psychological changes associated with exercise.

Opponent-process theory

This theory was based on Solomon's opponent-process theory (1980) of acquired motivation. This has been suggested as a useful framework to examine exercise-related affective change (Petruzzello *et al*, 1997). This theory views emotions as pairs of opposites (for example, fear-relief, pleasure-pain). The opponent –process theory states that when one emotion is experienced, the other is suppressed (Solomen, 1980). For example, if you are frightened by a situation, the emotion of fear is expressed and relief is suppressed. If the fear-causing stimulus continues to be present, after a while the fear decreases and the relief intensifies. For example, if the situation did not change, your fear would decrease and you would feel relief that nothing has happened. If the stimulus is no longer present, then the first emotion disappears and is replaced totally with the second emotion.

The opponent emotion dissipates more slowly than the initial emotion (Solomen, 1980). Thus, when the original emotional stimulus is removed, the initial emotion terminates quickly but the opponent emotion remains in effect; in this way, the original emotion is replaced by its opposite.

Also the opponent emotion strengthens with repetition. As it strengthens, it can effectively reduce the initial emotion to near-zero levels.

Exercise and the opponent process theory

An example of opponent process can be suggested from exercise. When an individual exercises they may feel stress on the body, pain, fatigue, muscle soreness but when the exercise bout stops they feel the opposite set of emotions – exhilaration, euphoria, the negative emotion produced by the exercise is gradually replaced by the opposite positive emotion.

Petruzzello *et al* (1997) tested two groups (active and non-active) for 24 minutes. They found the non-active group had a decrease in affect (a decrease in positive affect and an increase in negative affect) during exercise and an improvement in affect on completion of the exercise bout (an increase in positive affect and as decrease in negative affect). This supports the opponent-process theory, the active group had reduced negative and increased positive during exercise that was sustained post exercise. There were no differences between groups for state anxiety measured by the STAI (Speilberger *et al*, 1991). This study provided mixed results for the opponent process hypothesis.

Petruzzello *et al's* (1991) meta-analysis on exercise and anxiety supported the exercise stimulus mechanism although this review only looked at acute exercise. Boutchers and Landers (1988) tested this theory by comparing self reported state anxiety in trained and untrained runners, the trained runners experienced a significant decline in anxiety post exercise, the trained runners had a greater opponent affective reaction after completing the exercise bout (Boutchers and Landers, 1988). This agrees with this theory as long term exercise training causes a constant state of arousal, while the opponent processes and it's affective state (relaxation) becomes increasingly stronger.

A line of evidence of refutation of the opponent process model lies with the affect changes with high intensity or maximal studies. The higher the exercise intensity then the more stress and strain is put on the body, especially with maximal exercise. These studies have not shown as large a swing of affect as some of the lower intensities of exercise produced (Steptoe & Cox, 1988, Kerr & Svebak, 1994, Motl *et al,* 1996).

Conclusion

This hypothesis has not received as much attention as some of the other psychological models i.e. self-esteem and mastery. The Petruzzello *et al* (1997) study provided mixed support for the opponent –process hypothesis. Additional testing needs to be carried out before drawing conclusions about the role of this proposed mechanism (LaForge, 1995).

Cardiovascular Fitness Hypothesis

This theory, by Morgan (1969), proposes that improved affect is due to an increase in cardiovascular fitness; the fitter a person gets the greater the mood change. This proposition was formed after a negative correlational relationship was found between aerobic fitness level and depression (in a meta-analysis by North *et al*, 1990). This hypothesis has been widely rejected by literature (Scully *et al,* 1998) for three main reasons. Firstly because of the time scale in which a person gains psychological and physiological benefits. Psychological benefits of aerobic exercise can occur after one exercise bout, which is well before a subject will experience a substantial improvement in cardiovascular fitness. Moses *et al* (1989) showed that fitness and psychological benefits don't coincide with each other, i.e. the psychological benefits were witnessed well before any realistic cardiovascular benefits appeared. Cardiovascular fitness enhancement, which is probably the most highly regarded chronic training effect of exercise, appears to be neither necessary nor sufficient for at least some psychological benefits.

Secondly, anaerobic or non-aerobic (such as weight training or yoga) exercise, in which no cardiovascular fitness improvements are seen, can also cause a reduction in depression and anxiety levels. A decrease in depression was observed during a weight training programme that provided minimal aerobic conditioning effects (Doyne, 1987). Similar psychological gains were achieved through aerobic and anaerobic exercise. The psychological gains associated with perceived fitness relative to actual fitness (Plante & Rodin, 1990) suggest that aerobic fitness gains don't necessarily cause an increase in positive psychological mood states. It is possible that many positive affect results may be due to the psychological gains experienced from trying to get fit rather than, or at least in addition to, gains attributable to physical fitness *per se* (Plante & Rodin, 1990). Perceived fitness was more closely associated with improvements in psychological variables among 120 middle age adults following a 6 month exercise programme, than measures of actual fitness (King *et al*, 1989). A better correlation is witnessed between perceived fitness benefits and psychological enhancement.

Finally the higher intensity exercise bouts, which quickly increase cardiovascular fitness, are linked with reductions in the quantity of affect improvements. Studies have shown that high intensity aerobic exercise does not produce the largest psychological benefits (Berger & Owen, 1988, Steptoe and Cox 1988, Parfitt *et al,* 1994, 1996). An exercise bout of 5 minutes in duration can provide an anxiolytic effect (Landers & Petruzzello, 1995) although this will provide limited cardiovascular fitness benefits (ACSM 1995). Dunn *et al* (2001) concluded, the relation of exercise dose to changes in cardiorespiratory fitness is equivocal with some studies showing that fitness is associated with reduction of symptoms and others that have demonstrated reduction in symptoms without increases in fitness.

Conclusion

The cardiovascular hypothesis struggles to explain the psychological benefits of acute exercise and does not always provide a direct correlation with actual fitness increases and therefore this theory has generally been rejected. Evidence suggests that changes in self-ratings of self-esteem and depression following exercise training occur independently of increases in aerobic capacity (Dishman, 1995). The evidence exists to agree that as a person increases their perception of fitness they will undergo an improvement in psychological well being (Morgan, 1985, Dishman, 1995, Paluska & Schwenk, 2000) but the literature suggests that is not the only mechanism for the improved mood states associated with exercise.

Biofeedback

Hollandsworth (1979) proposed this as a mechanism for the "feel-good factor". Biofeedback is a mechanism using electronic instruments or other techniques to monitor and change subconscious activities, many of which are regulated by the Autonomic

Nervous System (ANS). By monitoring the changes for skin temperature and heart rate for example, using biofeedback techniques, a person can learn how consciously to reduce heart rate and blood pressure, how to regulate blood flow through muscle blood vessels. It has been claimed that people can learn how to prevent the onset of migraines or reduce the intensity of migraines by learning to dilate blood vessels in the skin of their arms and hands. Increased blood vessel dilation increases skin temperature, which is correlated with a decrease in the severity of a migraine.

Some people use biofeedback methods to relax by learning to reduce the heart rate or change the pattern of brain waves. Using such techniques may reduce blood pressure, anxiety and depression (Hollandsworth, 1979). Biofeedback techniques can be used to reduce symptoms that are frequently associated with stress.

Exercise and biofeedback

Exercise may improve the accuracy of perception of somatic signals; i.e. exercise may be a biofeedback process (Hollandsworth, 1979). Improved accuracy of perception of bodily states appears to not only decrease anxiety but also to increase ability to discriminate stress–producing situations. Tests of whether exercise improves perception of somatic signals, such as heart rate, have been inconclusive (Hughes, 1984).

Schwartz *et al* (1989) found that subjects who exercised reported a decrease in somatic anxiety (muscle tension levels), but not in cognitive anxiety (psychological tension levels). Exercise may interact with somatic signals in a way that only affects somatic sensation and not cognition. Subjects, when exercising, experience symptoms normally associated with anxiety such as sweating, hyperventilation and fatigue but don't experience the subjective state of anxiety, therefore the repeated pairing of these symptoms without the anxiety would eventually cause subjects to report less anxiety as in classical conditioning. These processes include reattribution of symptoms, cognitive dissonance, counter–conditioning and extinction. Unfortunately this area has received little research (Hughes, 1984).

Conclusion

This hypothesis has received little attention in the area of causal mechanisms. Biofeedback may be an important system in the reduction of anxiety and stress, but this hypothesis struggles to explain all the changes in psychological well being i.e. Increased energy and ability to cope (Folkins and Sime, 1981), happiness and security (Jasnoski *et al*, 1988). Additional research is needed to determine if biofeedback plays any part in improved affect with exercise.

Monoamine Hypothesis

Monoamines are localised in the limbic system of the brain and regulate the forebrain circuits mediating mood and arousal (neurons secrete monoamines, which transmit information to neighbouring neurons, Vander *et al*, 1994). The function of monoamines is to modulate the overall tone of neural activity in selected brain regions. They are critical in the role of regulating psychological mood. The monoamine hypothesis attempts to explain improved mood with exercise by changes in concentration of one or all of the following monoamines: dopamine; serotonin and noradrenaline. Each one will now be explained

Serotonin - regulates calmness, mood stability, sleepiness, appetite and pain control,
Dopamine - regulates energy, concentration, alertness and blood pressure,
Noradrenaline - regulates alertness, fight or flight pathway. Increased sympathetic activation.
(Friedhoff, 1975, Vander *et al,* 1994).

Morgan (1985, 1997) warned that singling out noradrenaline, dopamine and serotonin as the only or crucial amines might be premature. Most research has only looked at these three amines as possibilities in changing affect.

Measurement of monoamines

Measuring the levels of monoamines in the brain is understandably difficult so measuring the level of monoamine fluctuations has been carried out in a number of ways. The main methods are:

- testing plasma or urine levels of amines
- testing lumbar cerebrospinal fluid (CSF) metabolites.
- using animal models generally rodents

There are definite problems with each of these methods; plasma or urine amine measurements can be affected by the increase in circulating amines during exercise. The lumbar canal is a cul-de-sac and many amines are found in the spinal cord and these will contribute to cerebrospinal fluid values. Additionally rodents can't complete mood scale questionnaires (Chaouloff, 1989). They can be observed for changes in mood, depression causes withdrawn behaviour, but whether any of this parallels the human condition is less certain

Monoamines and Mood

Weiss (1981) reported that disturbance of [noradrenaline] and [serotonin], or both, takes place in human depression in its symptomology and response to treatment. Central monoamine metabolism can be disturbed in clinical depression and, in general, a sub–group of patients exist with decreased metabolism of either the noradrenaline or serotonin systems. There is evidence that neurotransmitters such as noradrenaline and serotonin are implicated in depression and schizophrenia (Morgan, 1985). Various antidepressant drugs (Selective serotonin reuptake inhibitors, monoamine oxidase inhibitors, tricyclic antidepressants) and electroconvulsive shock treatment are known to elevate brain [serotonin] and [noradrenaline] in humans and animals (Schildkraut *et al*, 1983). Restoration of depleted [noradrenaline] results in a reduction of depression (Weiss, 1981). Ransford (1992) suggested that restoration of brain levels of monoamines via drug therapy eliminate depression in animals and suggests this would be similar in humans.

Acute changes in lumbar CSF monoamines with exercise have been demonstrated in depressed patients by Post (1973). Post found that CSF indicators of monoamines were significantly higher after 4 hours hyperactivity than in the same patients after bed rest.

Central Vs Peripheral

There are two types of monoamine pathways, central and peripheral. Most human research is based on the measurement of peripheral monoamines or their derivatives. The question is how much do peripheral monoamine levels affect central monoamine levels? Chaouloff (1997) found circulating blood tryptophan levels directly increased brain tryptophan levels. Serotonin is a derivative of tryptophan so an increase in tryptophan should increase serotonin synthesis.

Peripheral 3-methoxy-4-hydroxy phenylglycol (MHPG) levels that have been suggested to reflect brain noradrenaline activity. Maas and Leckman (1983) found that 60 % of MHPG is derived from the brain while Blombery *et al* (1980) estimated that only 20% is derived from the brain. Increasing evidence indicates that central and peripheral adrenaline systems work as a linked unit. Mass & Leckman (1983) supports the theory that regardless of the relative amounts of centrally derived MHPG in the periphery, changes in peripheral MHPG are related to central noradrenaline activity.

Factors affecting central monoamine levels.

Are monoamine levels elevated during and after exercise? Evidence exists for acute changes in brain monoamine turnover with exercise (Chaouloff, 1989). Tryptophan is carried in two ways in the blood, bound to albumin and free. There is competition for albumin binding sites from other large neutral amino acids (LNAA) and free fatty acids. Lipolysis from acute exercise increases the amount of circulating free fatty acids so less tryptophan is carried bound to albumin. Blomstrand *et al* (1989) thought that blood free tryptophan governed brain tryptophan. Whether free or total tryptophan increases brain tryptophan still awaits a conclusion (Chaouloff, 1997).

The LNAA 's also compete for entry into the brain with tryptophan so more circulating LNAA's will result in less circulating tryptophan entering the brain. An additional factor governing brain tryptophan is the blood brain barrier permeability which isn't specific to tryptophan but will alter the amount of tryptophan reaching the brain.

To summarise, the amount of circulating tryptophan, the circulating level of LNAA's and the blood brain barrier permeability interact to govern the levels of tryptophan in the brain.

Monoamines and acute exercise.

The ratio of free tryptophan over the sum of other competing amino acids is increased by physical activity (via lipolysis) which indicates that exercise increases the amount of tryptophan going into the brain. Results from rat studies (Blomstrand *et al*, 1989, Chaouloff *et al*, 1989) confirm that exercise increases the level of brain tryptophan, although not via increased permeability of the blood brain barrier (Chaouloff *et al*, 1986) but through increased free tryptophan.

One problem is how much the elevated brain tryptophan levels increase serotonin levels. Chaouloff (1997) stated "increases in brain tryptophan that do not exceed 50% lead to marginal changes in tissue 5-HT (serotonin) levels"(page 185).

The effect of aerobic exercise on the aminergic receptors in the central amine pathways of rats has also been studied (Brown *et al*, 1979). Rats that exercise had more dopamine receptors to bind onto meaning that more of the dopamine is synthesised for use. Brown & Van Heuss (1973) found a similar increase in central monoamine levels; chronic exercise produced increases in brain [noradrenaline] of rats. Rat studies suggest acute exercise boosts serotonin and neurogenesis (neuron growth).

Conclusion

Research has looked at serotonin and noradrenaline as the main monoamines implicated in mood changes. Central and peripheral monoamine pathways are suggested to work together but how much tryptophan is needed to cross into the brain to affect serotonin is unknown. Animal studies suggest an increase in brain [serotonin] and [noradrenaline] with acute exercise; this has still to be linked causally to affect changes that are seen with physical activity.

Endorphin Hypothesis

Humans have used opiates for thousands of years. Their analgesic, euphoric and addictive effects have been the subject of intense clinical research for most of the last century (Hoffman, 1997). The endorphin hypothesis suggests that the feel-good factor is due to the increased release of endorphins with exercise. The term endorphin refers to any endogenous (naturally occurring) opiate like substance that duplicates the action and effects (analgesia and euphoria) of exogenous opiates such as morphine or heroin (Pargman and Baker, 1980).

Endorphin functions

Endorphins are types of neurotransmitters and neuromodulators, which are chemicals released from neurons and have an effect, usually inhibitory, on the postsynaptic neurons or muscles. Endorphins are released in response to a signal and the most common function is of pain reduction. They are found in areas of the brain and pain pathways. There are two systems of endorphins, peripheral (pituitary) and central (hypothalamus etc), these systems are thought to work separately as the blood brain barrier is relatively impermeable to circulating endorphins and they both serve different functions. The peripheral endorphins are primarily responsible for pain relief (LaForge, 1995). The central endorphin receptors are located in the area of the brain responsible for modulating emotion and so are thought to act upon mood and emotion.

Endorphins and exercise.

There are a number of reasons to link an exercise induced feel-good factor and endorphins:

- opioids can produce emotional mood states of euphoria and enthusiasm after ingestion which is similar to post exercise mood states (Farrel *et al*, 1987)
- Pain tolerance can increase post exercise which is one of the major roles of endorphins (Yao *et al*, 1982a, 1982b)
- Exercise can be addictive, as can opioids (Daniel *et al*, 1992).
- Investigators have shown an increase in peripheral blood beta–endorphin concentration following exercise (Colt *et al*, 1981, Farrel *et al*, 1987).

Endorphin systems.

The central endorphin system is of interest as it regulates blood pressure, pain perception, mood elevation and the control of body temperature within the brain. The second independently regulated endorphin system (peripheral) is found in the anterior pituitary, where both beta–endorphin and ACTH (stress hormone) are synthesised. Most of the beta-endorphin measured in peripheral blood reflects co–release with ACTH rather than central beta–endorphin activity. The levels of peripheral endorphins increase in response to physical activity in animal and human studies (Hoffman, 1997). Farrel *et al* (1987) found decreases in anxiety levels after exercise, these decreases were not related to changes in plasma levels of beta-endorphin in this study, these results were confirmed by Hatfield *et al* (1987). As the blood–brain barrier is relatively impermeable to peripheral concentrations of beta–endorphin, peripheral levels would not be expected to modify central beta–endorphin activity (Hoffman, 1997).

Psychiatric research.

The plasma beta-endorphin level increase post exercise is much smaller than those induced in psychiatric patients who have been treated with large doses of beta endorphin intravenously (Colt *et al*, 1981). It may be that baseline measures are far lower for psychiatric patients and that they need a far greater level of endorphin to produce a normal mood before getting the euphoric effects of the raised [endorphins].

Can exercise alter the permeability of the blood brain barrier (LaForge, 1995) or could the increased core temperature change the blood brain barrier receptivity to circulating beta-endorphin? As yet there has been little research to investigate these suggestions.

Measuring Central Endorphin levels

It has proven difficult to measure central endorphin levels in humans for ethical reasons. One method is to use naloxone and naltrexone, which block the effects of endorphins released into the brain. The other method is to use animals, generally rodents with forced exercise and then look at central endorphin concentration.

Blocking agents.

Naloxone administered peripherally penetrates the brain rapidly and has a fast onset as an antagonist (Hoffman, 1997). The failure of naloxone to consistently alter the physiological responses to exercise may be because inadequate (low) doses have been used (from 0.4mg to 5mg). It can be hypothesised that higher doses of naloxone are required to antagonise the effects of endogenous opioids and higher still all the opioid receptors (Thoren *et al,* 1990). Previously only naloxone and naltrexone have been used but they have preferred affinity for specific receptors, which have an analgesic function. Additionally excess nalaxone induces mildly dysphoric mood changes in humans (File and Silverstone, 1981), but administering higher doses have not usually been found to intensify experimental pain in humans (Steinberg and Sykes, 1985).

Allen and Coen (1987) tested 12 runners before and after a 45 minute run. They found insignificant mood changes for the run tests pre-treated with naloxone (5mg before and 5mg during the run) but increases in positive mood states for the placebo, producing a calm state for measurements of depression, vigour and fatigue. The authors found that the elevated [endorphin] produced a calm state and physical activity was the way of doing it. Janal *et al* (1984) demonstrated that joy and euphoria were elevated after a 6.3 mile run but naloxone (0.8mg, intravenously, post–run) reversed this psychological response to exercise. One problem with this study is that exercise intensity and speed was uncontrolled. Markoff *et al* (1982) used 11 subjects, who completed at least one placebo and one naloxone trial, and found that 2 × 0·4mg of subcutaneous naloxone failed to show a placebo–naloxone difference as measured by the POMS although the duration and pace was not set for each subject.

<u>Animal studies.</u>

Animal studies have provided the most compelling evidence for the exercise–induced activation of central opioid systems. Blake *et al* (1984) found that prolonged submaximal exercise increases brain beta–endorphin content and induces an endogenous opioid system (possibly endorphin) mediated increase in pain threshold in rats, this was not found for brief strenuous exercise (Metzger *et al,* 1984). The animals are generally forced to exercise which can have implications on stress hormone and opioid release (Hoffman, 1997). Hoffman *et al* (1984) observed a significant increase in beta–endorphin concentration in the cerebrospinal fluid (CSF) of rats trained to run spontaneously compared to the CSF of sedentary controls.

Yao *et al* (1982a, 1982b) simulated the effects of exercise by stimulation of the sciatic nerve; this had several effects after 30 minutes. Firstly, the pain threshold of the rats was markedly increased long after nerve stimulation ceased. The increase in pain threshold could be blocked by naloxone. They found a behavioural calm after the stimulation that was similar to the effects seen post exercise in humans.

Since central opioid release triggered by activation of muscle may be responsible for many of the behavioural changes seen in exercising rats, mood changes seen in humans after exercise may be due to similar mechanisms (Thoren *et al,* 1990).

Training effect.

Blake (1984) failed to demonstrate any enhancement in central opioid levels in 16 rats after an 8-week training programme compared to 8 sedentary controls, regardless of prior training. After chronic exercise beta-endorphin levels were normalised but they increased again immediately after a new exercise bout.

Methodological problems

Some of the controversy that has arisen is due to methodological errors:

- relative impermeability of the blood brain barrier to peripheral endorphins which levels are raised during exercise (Hoffman, 1997)
- difficulty in measuring central endorphin levels (Hoffman, 1997)
- using varying dosages of endorphin blocking agents (Allen *et al,* 1987, Janal *et al,* 1984, Markoff *et al,* 1982)
- Using non-specific levels of exercise intensity (Janal *et al,* 1984, Markoff *et al,* 1982).

Conclusion

The amount of beta-endorphin that crosses the blood brain barrier is unknown but levels of plasma beta-endorphin are known to rise during and post exercise. Central endorphin levels in rodents rise during and post exercise but whether similar changes will be found in humans is as yet unknown. Methodological issues have hampered research when using blocking agents such as naloxone. There is considerable variability in the amount of change in endorphin activity observed with exercise but, even if a correlation between exercise and endorphin levels is found, this does not necessarily demonstrate a causal link.

Thermogenic hypothesis

Various therapeutic techniques have employed elevation of body temperature to produce mental health benefits for many centuries. This practice dates back to 800 AD in many Scandinavian countries. Residents took regular sauna baths for their alleged health benefits and the sensation of well–being. Evidence shows that muscle tension levels (i.e. somatic anxiety) are reduced following a sauna session (DeVries *et al,* 1968, Kuusinnen and Heinonen, 1972). This hypothesis suggests that an increase in core temperature may be responsible for mediation of changes in mood following exercise. This does not rule out other physiological causal mechanism's as there may be a number of physiological interactions with core temperature.

Core temperature

Core temperature is in the area of the body that houses the brain, spinal cord, heart, liver, kidneys, pancreas and intestinal tract, the vital organs of the body (Edholm, 1978). Core temperature is maintained close to 37°C and is done by controlling heat losses and heat production. Changes in core temperature above 42 °C or below 34°C can cause protein destruction and abnormal cardiac function respectively, both of which can result in death (Edholm, 1978). Humans spend their lives only a few degrees from their thermal death point.

Core temperature and Exercise.

During exercise, heat production increases due to an increase in metabolic rate by the working muscles, core temperature is regulated by making adjustments in the amount of heat that is lost. Vigorous exercise can produce a core temperature elevation of up to 40° C without thermal injury, this can remain high for several hours (Haight & Keatinge, 1973). The venous blood draining the exercising muscle distributes excess heat throughout the core. As core temperature increases thermal sensors in the hypothalamus sense the increase in blood temperature. The response is to direct the nervous system to initiate sweating and increase blood flow to the skin to dissipate heat. This increases the body heat loss and minimises the increase in core temperature. When heat production and heat loss have balanced, the core temperature reaches a new, elevated steady state level. The thermal regulatory centre's aim is to return the core temperature back to resting levels, but it is incapable of doing so in the face of the sustained heat production associated with exercise (Haight and Keatinge, 1973). During prolonged exercise in a moderate environment, core temperature will increase gradually above the normal resting value and will reach a plateau at approximately thirty to forty-five minutes (Haight and Keatinge, 1973). Conn *et al* (1990) experimented on female hamsters and found elevations in core temperature resulting from exercise that persisted during the non-exercise period.

Ambient temperature effects.

During constant load exercise the core temperature increase is directly related to the exercise intensity (Davies *et al*, 1976) and is independent of ambient temperature within normal values and low relative humidity. Exercise intensity and not the environment determine the rise in core temperature during exercise during normal ambient conditions (Davies *et al*, 1976, Galloway, 1999). Heat loss during continuous exercise can be modified according to ambient conditions.

Increasing Core temperature and mood

Raglin & Morgan (1985) reported that a 5-minute shower at a water temperature of 38.5 °C was associated with a significant decrease in state anxiety. Bulbulian & Darabos (1986) looked at light to moderate and high intensity exercise and measured metabolic cost thereby indirectly measuring core temperature. EMG levels decreased for light to moderate exercise but a larger decrease was seen for the high intensity condition. The findings from this study are consistent with the thermogenic hypothesis as there are increasing psychological benefits with increasing core temperature. This study's results have not been replicated (Cox *et al*, 2000, Dishman, 1995). In Bulbulian and Darabos's study (1986) 75% VO_2 max was used as the high intensity condition. ACSM (1995) use this as the end point for moderate and starting point for high intensity so this may not represent true high intensity for all subjects additionally a small sample size was used (n=10).

I f increasing core temperature improves psychological mood how does this take place? The following are possible methods to improving mood with increased core temperature:

- decrease muscle spindle activity
- decrease gamma motor neuron activity
- increase electroencephalogram alpha wave activity
- Increasing monoamine activity
- Increased beta-endorphin activity

Muscle spindle activity.

Petruzzello *et al* (1993) found that an increase of up to 41°C would decrease muscle spindle activity resulting in a decrease in muscle tension (somatic anxiety). Further core temperature increases will generally increase muscle spindle activity resulting in an increased somatic anxiety. Decreasing muscle tension following both exercise and a sauna bath has been observed by DeVries *et al* (1981); measurement was taken electromyographically (EMG). Temperature elevations in the brainstem, or whole body, may decrease muscle spindle activity and synchronised electrical activity in the cortex, both of which are typical of a relaxed state. This would explain the increase in anxiety seen in high intensity or maximal exercise studies (Cox *et al,* 2000, Kerr and Svebak, 1994 Steptoe and Cox, 1988).

Gamma motor neuron activity.

Animal research carried out with cats, rats and hamsters has revealed that whole body warming has a profound effect on central and peripheral neuron activity (DeVries *et al,* 1968, Von Euler & Soderberg, 1957). Gamma motor neuron activity is inversely related to hypothalamic temperature (Von Euler & Soderberg, 1957) while contributing significantly to muscle tension (DeVries *et al,* 1981). As core temperature increases, gamma motor neuron activity decreases leading to a decrease in muscle tension. This has been seen in exercise (Bulbulian and Darabos 1986, Petruzzello *et al*, 1993, DeVries *et al*, 1981) and reduced gamma motor neuron activity which may be the method that reduces somatic anxiety not the actual exercise session.

Increased (EEG) alpha wave activity.

Moderate increases in temperature will increase alpha wave activity, which produces relaxation, but further increases showed an arousal reflex, i.e. an increased EEG beta activity. This would agree with the studies finding that the largest psychological benefits are with moderate intensity exercise (Cox *et al.,* 2000, Kerr and Svebak, 1994, Steptoe and Cox, 1988).

Monoamine activity.

Temperature elevations can influence the release, synthesis or uptake of certain brain monoamines (Koltyn, 1997, Galbo *et al*, 1979). The possible changes in brain monoamines may not occur as a result of exercise, *per se*, but the changes may be due to the effects of increased brain temperature on the metabolism of these neurotransmitters. Brown and Van Huess (1973) tested rat brains and found an increased monoamine level in the brain following exercise that increased core temperature. Barchas and Freedman (1962) found that manipulating the core temperature of rats altered brain [serotonin] and [noradrenaline] levels.

Beta-endorphin activity.

In a study using cancer patients as subjects Robins *et al* (1987) found that hyperthermia treatment increased beta-endorphin levels significantly. There was a linear relationship between thermal stress and beta-endorphin levels.

Refution of the thermogenic hypothesis

Holland *et al* (1985) provides limited evidence refuting the thermogenic hypothesis. In their experiment subjects were immersed in warm, or thermoneutral, water and asked to perform memory and reasoning tasks. Mood was also assessed before and after the immersion sessions. A significant increase in irritability was found in the heated, versus the control, condition. These results should be viewed with caution, however, because the memory and reasoning tasks themselves may have been a source of irritation. The mood assessment should also be viewed with caution, as subjects used a visual analogue scale marking a line across a scale (almost asleep to highly alert and completely calm to highly irritable) which has not been validated for mood.

Psychiatric patients

Pyrogenic treatment has been used in the past for individuals suffering from paresis resulting in an elevated core temperature for up to 2 hours and this was associated with improved alpha wave frequency (Bennet *et al,* 1941). Evidence for the thermogenic hypothesis has been observed in-patients with affective disorders in that they have an abnormal temperature regulation. Avery *et al* (1982) compared 9 drug free patients, with primary affective disorder, with 12 normal control subjects and concluded that the amplitude of the 24-hour rectal temperature was significantly reduced in the depressed subjects versus controls. 'Normal' individuals appear to experience a mood elevation concurrent with an elevation in core temperature and patients with mood disturbances often suffer from temperature dysregulation that normalises with an improvement in mood (Avery *et al*, 1982). Additional evidence comes from Robins *et al* (1987) in the treatment of cancer patients and whole body warming (hyperthermia). An improved sense of well being and a marked pain relief was seen after treatment.

Methodological issues

Testing the thermogenic hypothesis is difficult without affecting the variables being measured. Studies that involve subjects exercising with additional clothing, masks, icepack collars (Reeves *et al*, 1985, Petruzzello *et al,* 1993) may be affecting anxiety levels with the experimental procedure. Additionally blocking the core temperature increase by cooling the body prior to exercise may also affect baseline mood changes negatively (Koltyn and Morgan, 1990). A number of studies have looked at exercise under water (Koltyn and Morgan, 1992, Koltyn *et al*, 1993, Youngstedt *et al,* 1993). The novelty for the subjects from the Youngstedt *et al (*1993) study may have affected mood changes. The other underwater studies used experienced sub aqua divers who exercised in different temperatures of water with and without a wetsuit. There was an increase for state anxiety in the condition that produced a core temperature decrease and in one condition without a core temperature change. This would provide refution of the thermogenic hypothesis but using experienced sub aqua divers and a small sample size (n=10) may have biased results.

One other factor that may bias measurement of affect is the procedure for taking core temperature readings. Core temperature measurements may cause discomfort, embarrassment and anxiety that may change baseline measures of affect therefore masking any exercise effect (Youngstedt *et al*, 1993).

Conclusion

Whether temperature effects *per se* produce the reduced anxiety and sensation of well–being remains to be demonstrated. Most temperature research has looked at anxiety changes to get a bigger picture of the thermogenic hypothesis. All aspects of affect should be monitored with increasing or blocking core temperature research.(Koltyn, 1997). The thermogenic hypothesis is certainly tenable (Koltyn, 1997, Morgan & O'Conner, 1988) and its confirmation or refutation awaits future research.

Psychological and physiological mechanisms conclusion

There is no single mechanism that current research would support as being the most feasible. Different mechanisms may become more important at different stages of exercise. Self-efficacy appears to predict maintenance of moderate activity and adoption of vigorous activity (Sallis *et al,* 1986). Social interaction may help individuals to maintain exercise in their life, the opponent process may be more important at the beginning to increase the feel-good factor. As yet these models have generally been looked at to try to find the one model that produces improved affect. As research goes on this becomes increasingly unlikely.

The controversy surrounding the various psychological and physiological mechanisms have led several authors to conclude that an integrative psychobiological model that combines components of each hypothesis offers the most likely explanation (Paluska & Schwenk, 2000, LaForge, 1995, Petruzzello *et al,* 1991, North *et al,* 1990). To do this though we may have to look more in depth at each one specifically to decipher where each, if any, fit into an integrative model. LaForge (1995) produced an integrative neurobiological model on the assumption that all emotions have a neurological explanation. Unfortunately this model has not looked at the neural explanation of the psychological models, i.e. self-esteem or mastery, but given improving research capabilities (Biddle and Mutrie, 2001) looking at brain activation and pathways with achievement will allow research to link this and any other psychological models into an integrative model.

The thermogenic hypothesis was chosen for study as the majority of previous studies had employed experimental designs, which blocked the normal mechanisms of the body or used unnatural environments. The research swings in favour of refutation of the thermogenic hypothesis but experimental conditions used have made it difficult to come to a conclusion.

The distraction hypothesis was also chosen for this study as it is a plausible causal mechanism that can be examined in a natural setting. The majority of research has examined this hypothesis in an experimental laboratory, which may influence baseline affect values. Additionally some of the distraction conditions have been in a lecture or sitting eating lunch this study was designed to allow subjects a period of quiet rest without other factors influencing affect.

Aims of study

The second aim of this thesis is to determine if either thermogenesis or distraction could explain positive affect change from acute exercise.

These aims will be addressed in study 3, however there are 2 areas in which preliminary analysis is required. Study 1 investigated 3 temperature measurement sites to determine which would be sensitive enough to measure small core temperature changes without influencing mood before or after the exercise bout. Study 2 investigated affect questionnaires in order to assist decision making for the main study.

Chapter 3 Study 1 - Temperature site measurement

The thermogenic hypothesis is one of the possible mechanisms suggested to explain the improved affect associated with exercise. The thermogenic hypothesis (DeVries *et al*, 1981, Morgan, 1985) states that an increase in core body temperature produces positive mood changes plus decreases in muscle tension. However it should be noted that the exercise is merely one of a number of methods available to increase core body temperature.

The aim of this study was to provide information about core temperature measurements at three sites to aid decision making for the main study. This study was carried out to test the sensitivity of three sites that are commonly accepted as approximating core temperature changes: oral, rectal and tympanic.

Thermoregulation and exercise

The body maintains core temperature between the normal range of 36.1 to 37.8°C (Heath, 1995) by balancing heat production/gain and heat loss. The body does this by a negative feedback control loop system. Upon disturbance of the body's temperature, thermoreceptors sense the disturbance, and nervous impulses are fed via the nervous system in to the appropriate part of the brain: the hypothalamus. In the hypothalamus signals from the various thermoreceptors are integrated and translated, control actions from the autonomic nervous system are put into effect and a response is made. The control actions depend upon the strength of the signals in order to appropriately correct and restore body temperature.

The rise in body temperature during exercise is dependant upon exercise intensity (Edholm, 1978, Galloway, 1999) given normal ambient conditions, for example, percentage of peak oxygen consumption (% VO_2 max, Saltin and Hermansen, 1966), $VO_2 l \cdot min^{-1}$ (Nielsen, 1968) or external power output (watts, Taylor *et al*, 1990). During exercise excess heat production by working muscles produces an increase in core temperature, which stimulates activation of heat loss mechanisms, such as sweating. Core temperature eventually stabilises at a new higher equilibrium, or setpoint, as heat production from exercise is balanced by heat loss. Core temperature as previously mentioned can exceed 40 °C during exercise (Haight and Keatinge, 1973). These small increases can make muscles energy systems more efficient, but larger increases can cause collapse (Edholm, 1978). If core temperature rises above 42°C (Edholm, 1978) irreversible changes begin as proteins can become coagulated. However, if core temperature rises above 41 - 42 ° C for long periods of time, cells within the body can be damaged and the functioning of vital organs such as the heart, brain, liver and kidneys can be affected (Clancy & McVicar, 1995). Only after exercise, when excess heat production has ceased, will core temperature reduce to pre-exercise levels. It can take up to 2 hours for the core to return to baseline temperature.

Because our body works within such a tight range it is important to understand the mechanisms explaining how we lose heat to stay within this range.

If core temperature is to be maintained within tight limits, the rate and amount of heat produced via physical activity cannot be much higher than the rate of heat loss. Heat will be exchanged between the environment and the body, when the temperature of the body and its surroundings are different. The heat transfer occurs through physical means, from the system with a higher temperature to that of a lower temperature. These mechanisms include evaporation (sweating, air-skin interface), radiation (65% heat loss, only works when body temperature is greater than ambient temperature), conduction (direct contact between person and surfaces) and convection (movement of air). The principal means of heat loss in humans on land is convection and radiation while evaporation accounts for the remainder of heat loss (Clark and Edholm, 1985).

Bardswell & Chapman (1911) found that the higher the exercise intensity, the larger the increase in core temperature. Subjects running at five miles per hour (mph) raised core temperature to 38.6 degrees centigrade and at six mph the core temperature rose to 39.1 degrees centigrade. There is extensive evidence that core temperature is increased in proportion to the intensity of exercise that the individual performs (Raglin & Morgan, 1985).

The sites commonly used to measure core temperature are rectal, oesophageal and tympanic sites. The benefits and difficulties of each will now be discussed.

Rectal temperature

Rectal temperature has been used in many of the core temperature studies (Morgan, 1997). Bardswell & Chapman (1911) claimed that rectal temperature was the only site that represented the internal temperature of the body. During exercise the temperature of the thermoregulatory centre in the brain increases more rapidly than rectal temperature. Nielsen (1969) stated that the time interval until a new equilibrium between core and rectal temperature is established at approximately 30 minutes. Robins *et al* (1985) found that there was a 15-minute delay in rectal temperature measurements but after the 15 minutes there was no difference between oesophageal and rectal temperatures. The rectal temperature has been calculated to be approximately 0.2 – 0.5 degrees centigrade lower than the site of the thermoregulatory centre. Rectal temperature is generally measured using a ten-centimetre probe inserted into the anus. The classical site of measurement in exercise testing is the rectum (Astrand & Rodahl, 1986). Some problems arise using rectal when measuring mood, emotion and affect. Using the rectal probe can at first be anxiety provoking and uncomfortable, this could affect mood scores when core temperatures are measured. There is also a matter of modesty as subjects often report feelings of discomfort when attempting to insert the probe.

Oesophageal and oral temperature

Oesophageal temperature has also been suggested to be a good indicator of core body temperature (Astrand & Rodahl, 1986). Saltin & Hermansen (1966) suggest that oesophageal temperature reflects very closely temperature changes taking place in the central arterial blood. Saltin & Hermansen (1966) also stated that although oesophageal temperature is not identical to the changes within the thermoregulatory centre, it is supposed to parallel the changes. Oesophageal temperature is generally measured by a copper constantin thermocouple inserted through the nose to a depth of 2-3cm above the diaphragm (Saltin & Hermansen, 1966). Morgan (1997) felt that the measurement of oesophageal temperatures can be repulsive to some individuals and that using oesophageal probes can cause anxiety to many of the individuals. For this reason oesophageal probes may not be useful to measuring core temperature in studies measuring mood states. Oral temperature has been suggested to correlate with oesophageal temperature. Nielsen found good correlations between oral and oesophageal temperature changes when she used steady state condition. Gerbrandy *et al* (1954) also found a good correlation between changes in oral temperature and heat change induced. Oral temperature is taken by placing a thermometer sublingually with the mouth closed. Bardswell & Chapman (1911) stated that taking the temperature in the mouth is close to core temperature.

Tympanic temperature

Benzinger (1959) proposed the tympanic membrane as a site to measure core body temperature. Tympanic temperature is also claimed to mirror changes in the thermoregulatory centre (Nielsen, 1969), although it is not identical to the temperature in the thermoregulatory centre (Benzinger & Taylor, 1963). Tympanic temperature is measured by inserting a thermocouple through the external ear and placing it against the eardrum. One problem that Nielsen (1969) found measuring tympanic temperature is that it varies with ambient temperature. A study by Mellergard & Nordstrom (1990) found gaining access to this measurement site was difficult in trying to get correct placement without causing discomfort to the individual. Most research testing the relationship of tympanic temperature to hypothalamic temperature has been from animal studies and this has had varied results. Overall it is unclear how close the relationship is between tympanic and core temperature.

The classical measurement site of core temperature is the rectum; it has been stated however that a delay exists between core and rectal temperature. This site was tested to determine if small changes of core temperature could be detected immediately after exercise. Oesophageal measurements would definitely affect mood states and so oral temperature was used to determine if this site was sensitive enough to detect small core temperature changes. Tympanic measurements although said to closely mirror core temperature changes were tested to determine if the site was easy to measure and if it was sensitive enough to detect small core temperature measurements.

The aim of this study is to determine the most sensitive core temperature site to use for the main study and to gauge subject's responses to each method.

Methods

Subjects

Ten subjects (5 males and 5 females) were recruited to take part in this study. The subjects (mean age 21.2, standard deviation 3.2 years) were students at the University of Glasgow and involved in a sports related undergraduate degree programme.

Apparatus

Subjects used three different temperature probes: tympanic, rectal and oral. The oral measurement was taken using an oral thermister (Glasgow University engineering department). The tympanic measurement was taken using a specifically designed thermister (Glasgow University engineering department) to avoid poor placement and to avoid ambient temperature effecting the measurement. Rectal measurements were made using a rectal probe (Grant Instruments, Cambridge, England) situated 10 cm beyond the external anal sphincter. A powerjog treadmill (Powerjog GX100, Sport Engineering Ltd, Birmingham, U.K.) which was calibrated weekly, was used for the exercise bout. The Polar monitor measured heart rate, from which exercise intensity was estimated.

Procedure

Screening

After recruitment, all subjects completed a Physical Activity Readiness Questionnaire (PAR-Q) and gave their informed written consent (Appendix A) to participate prior to testing. These forms highlighted the possible dangers and explained the experimental procedures to the subjects.

Familiarisation

Subjects were asked to attend an initial session to become familiar with using the three different temperature measurement probes. Subjects inserted each of the probes by themselves after receiving instructions from the experimenter. During this session the subjects used each of the probes until they felt confident using and getting results from them. Following completion of the familiarisation session subjects were asked to sit and rest for a 5-minute duration. Following the rest period heart rate was recorded. The heart rate was then used to determine the heart rate reserve for the main study.

Testing session

All subjects were then asked to perform a sub maximal exercise bout on the treadmill in the main Sports Science laboratory in the Kelvin building at Glasgow University. Prior to starting the exercise session each subject measured oral, tympanic and rectal temperature. The subjects completed a 5 minute warm up on the treadmill at an intensity which they rated as between 10 and 11 on Borg's Rating of Perceived Exertion scale (RPE) 6 – 20 scale (Borg, 1967). Subjects were then given a heart rate value using the Karvonnen formula (Karvonnen, 1957) to allow all subjects to be working at the same relative exercise intensity. The resting heart rate was taken from the familiarisation session when it was thought that subjects might be less anxious. Subjects worked at 65% of their heart rate reserve, which constitutes moderate intensity (ACSM guidelines, 1995). The speed and gradient of the thirty minute exercise bout was self-selected by each subject. The only stipulation was their heart rate had to be at 65% of their heart rate reserve, which was supervised by experimenter. RPE was also recorded to check that subjects were working at the correct intensity (between 12 – 13). The exercise duration was thirty minutes after reaching the desired exercise intensity. On completion of the 30-minute exercise bout subjects completed a 2-minute active recovery period before measuring core temperature simultaneously from the three sites. On completion of the core temperature measurements subjects performed a 5-minute cool down.

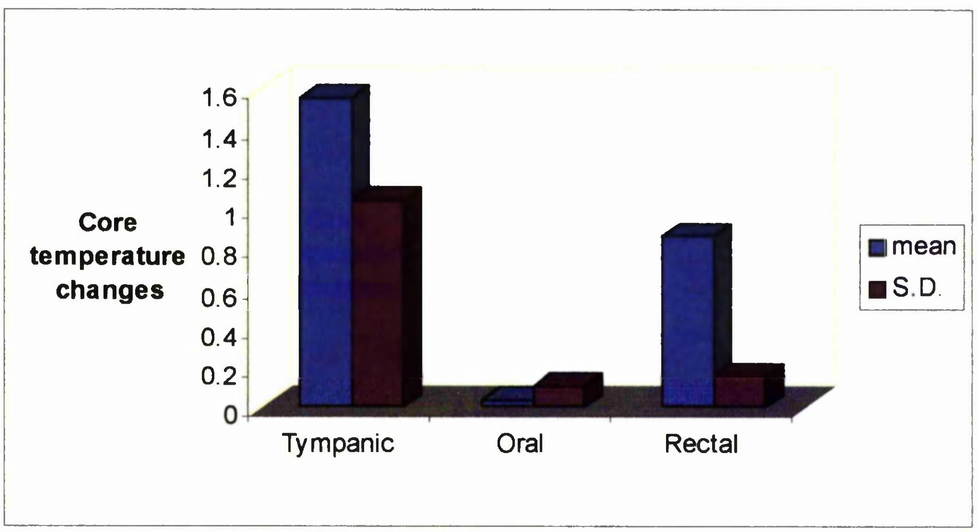
Statistics

Three one-sample t-test's were performed to determine differences the three temperature sites. This was followed by a Pearson correlation to determine the relationship between the three core temperature measurement sites.

During the exercise bout each subject recorded RPE, the average value was 13 for each subject. One subject rated the RPE as 15 for the last 8 minutes of the test although heart rate stayed in the correct range. Each subject was given a desired heart rate value to maintain. The subjects managed to complete the exercise bout staying within +/- 6bpm of their heart rate range.

The core temperature differences from pre to post were calculated for each site and a one-sample t-test was calculated to determine if the temperature changes were significant. Figure 3.1 represents the mean changes in core temperature and the standard deviations. Tympanic temperature shows the largest changes but also a large standard deviation. Oral temperature has a larger standard deviation than mean change, and rectal has a relatively small standard deviation.

Figure 3.1: Mean core temperature and standard deviations after an acute exercise bout.



Tympanic and rectal temperature changes were found to be significant, oral temperature was found not to have significantly changed after an acute exercise bout. This non-significant change indicates that the measuring apparatus may not be as sensitive to core temperature changes as rectal temperature. The exercise bout was at an intensity that should be sufficient in elevating core temperature so oral measurements do not appear to be sensitive enough to measure small core temperature change.

Table 3.1 Temperature changes after an acute exercise bout for three different temperature measurement sites (bold values indicate significant changes).

	Mean temperature change (°C)	Standard deviation	Confidence interval
Tympanic	1.56	1.05	(0.81, 2.30)
Oral	0.03	0.10	(-0.04, 0.11)
Rectal	0.86	0.15	(0.75, 0.97)

Table 3.1 and Figure 3.2 show that confidence intervals demonstrate the non-significant temperature change for the oral site and the significant result for both the tympanic and the rectal temperature sites. Additionally we can see the larger standard deviations for the tympanic site. The blue line indicates the point of zero. If the brackets cross the blue line this indicates a non-significant result.

Figure 3.2: Confidence intervals for core temperature changes after an acute exercise bout.

```
         ------+---------+---------+---------+
Tympanic                  (---------*---------)
Oral         (---*---)
Rectal             (----*----)
         ------+---------+---------+---------+
             0.00      0.70      1.40      2.10
```

The standard deviations (Table 3.1) show less variation in core temperature change for the rectal measurement site. The largest variation was found in the tympanic site. This would indicate that the tympanic site might be more variable to ambient temperature fluctuations.

A Pearson correlation (Pearson and Hartley, 1958) between each of the temperature sites was carried out to determine whether there was a relationship between any of the measurement sites. The relationships are shown in Table 3.2. None of these calculations were found to have a significant relationship as the r-values shown above represent very weak relationships. The r-values are negative for tympanic and oral, and tympanic and rectal indicating as one value went up the other dropped. The P values indicate if there was a significant relationship between the temperature changes and none are significant as p>0.05.

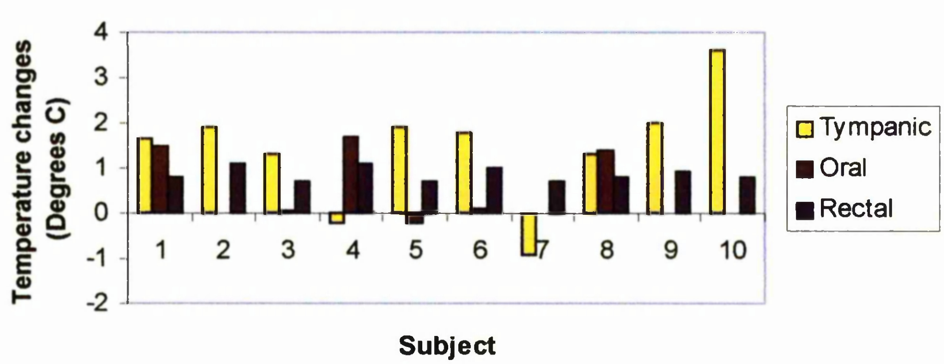
Table 3.2 Pearson correlation of temperature changes

	r-value	p-value
Tympanic and oral	-0.27	0.44
Tympanic and rectal	-0.12	0.75
Rectal and oral	0.29	0.41

Figure 3.3 shows both tympanic and oral measured increases and decreases in core temperature; rectal was the only measurement site that consistently increased after acute exercise. This can be understood by looking at Figure 3.3. For some of the subjects core temperature increased for all three sites, i.e. subject 1 and 8, but for other subjects there was a large increase in one site while very little increase for other sites, i.e. subject 2 and10.

Figure 3.3 demonstrates the consistency of changes for the rectal temperature, the large

Figure 3.3: Temperature changes after an acute exercise bout



fluctuations of the tympanic site and the generally smaller readings for the oral site.

Discussion

Moderate intensity exercise was chosen for this study as core temperature increases with exercise intensity (Raglin and Morgan, 1985, Galloway, 1999). Moderate intensity exercise should produce a significant core temperature change without causing distress. The amount of core temperature change will vary from subject to subject as body fat, age, circadian rhythm, all interact to adjust the body's internal environment (Havenith *et al*, 1998).

The exercise bout lasted for a 30-minute duration, which should have allowed the rectal temperature measurements to catch up with core temperature measurements. As Neilson (1969) and Robins *et al* (1985) found rectal temperature measurements tended to lag behind other methods, the exercise duration was 30 minutes to reduce the likelihood of the delayed response producing a non-significant result.

Results depicted in Table 3.1 identify that both tympanic and rectal sites could significantly identify changes in core temperature. The oral measurement site did not produce a significant result. This indicates that the oral measurement site is not sensitive enough to pick up small changes in core temperature. It is possible that oral temperature is not close enough to core temperature to measure a significant difference after the exercise session. Oral temperature did not produce a significant result possibly because oral temperature does not actually mirror oesophageal temperature to the degree, which was originally thought (Nielsen, 1969, Gerbrandy *et al*, 1954). Of the two more sensitive measures of core temperature Figure 3.1 shows the standard deviations. The tympanic site produced a large standard deviation (standard deviation = 1.05) in comparison to the rectal site (standard deviation = 0.15). This would indicate that the rectal site is a more consistent site for measuring small changes in core temperature. Figure 3.3 identifies the large changes in core temperature between the subjects for tympanic measurements with some subjects showing large increases in temperature and other students showing decreases. This may be due to subjects not correctly inserting the tympanic probe or ambient temperature affecting the results. Figure 3.3 highlights the consistency of rectal temperature changes.

This study has identified that rectal temperature appears to be the most attractive option although there are still problems with the process as personal modesty can govern mood state changes. During this study there was a degree of awkwardness noted by the subjects during the familiarisation period when inserting the rectal probe. After familiarisation during the actual test period the subjects displayed less self-consciousness regarding this measurement.

Rectal temperature appears to be sensitive enough to measure small core temperature changes without large fluctuation. Subjects expressed discomfort when first using the rectal probe. After the familiarisation period subjects felt more comfortable using the rectal probe. Subjects did not think that it would affect how they felt before and after an exercise bout. Rectal temperature measurement site will be used in the main study as a method to measuring core temperature.

Chapter 4 Sensitivity of mood scale questionnaires

Affect, mood and emotion

Narrative reviews have documented that a single bout of physical activity is associated with significant affective changes (Paluska & Schwenk, 2000, Ekkekakis & Petruzzello, 1999,Yeung, 1996). There are many methodological issues that confound these results such as issues of inadequate sample sizes, healthy active students as subject groups and lack of control conditions (Morgan, 1997), one of the more prevalent methodological issues that has received considerable attention is how to measure psychological changes (Ekkekakis and Petruzzello, 2000).

One of the problems lies in the definition of what we are measuring. There are a range of definitions of emotion, mood and affect but there is no clear definition in which the majority agrees. Research would benefit from an accepted definition of affect, mood and emotion (Ekkekakis and Petruzzello, 2000, 2002).

Fox *et al* (2000) used the term emotion and affect synonymously, Ekkekakis and Petruzzello (2000) separated them; emotion being a short duration, high intensity response to specific situation, mood being less intense and longer lasting and affect being a much broader measure.

Lane and Terry (2000) felt that a clear distinction between mood and emotion was not always possible. Mood is seen as "a set of feelings, ephemeral in nature varying in intensity and duration, usually involving more than one emotion" (page 17). They view affect as being similar to feeling states that vary on a continuum from positive to negative, but a very vague measure.

General psychology definitions have a consistent distinction between mood and emotion, with emotions being relatively brief but intense and moods being less intense but longer lasting (Davidson and Ekman, 1994, Parkinson *et al*, 1996). This is similar to Ekkekakis and Petruzzello's (2000) definitions of mood and emotion.

For this study affect is viewed as the broadest approach to psychological changes. Perhaps the best approach is to study exercise and affect to get a general picture before moving onto the more specific categories of mood and emotion (Ekkekakis and Petruzzello, 2002).

Affect, mood states and emotions can be measured quantitatively (via Questionnaire) or qualitatively. Questionnaires measuring psychological well being have developed from general psychology questionnaires to broader dimensional scales and to exercise specific measures (Ekkekakis & Petruzzello, 2000). The various questionnaires will be discussed in the next section.

<u>General psychology questionnaires</u>

Initially mood changes were measured by questionnaires that relied on "self report instruments that were developed in general psychology in the late 1960's and early 1970's" (Ekkekakis & Petruzzello, 2000, page 74). One of the more popular was the Profile of Mood States (POMS; McNair, Lorr & Droppleman, 1971). The POMS has been praised for it's 'easy to understand' format and its psychometric qualities have received favourable reviews. Other questionnaires that were used at this time included the Multiple Affect Adjective Check List (MAACL; Zuckerman & Lubin, 1965) and the State-Trait Anxiety Inventory (STAI; Speilberger, Gorsuch & Lushene, 1970). The monopolar POMS has been used extensively in research (LeUnes and Burger 2000) for the past 25 years (Berger and Motl 2000).

The POMS was designed for use with psychotherapy patients or for counselling in outpatient settings (Lorr *et al*, 1971) but is used for research with these populations. As the POMS was developed to measure improvements in negative mood, one of the problems with the POMS arises when pre exercise scores are already low on negative mood with the 'normal population' with little room for improvement with exercise, this is known as the floor effect (Dishman, 1995). In an attempt to alleviate the floor effect the POMS-Bipolar (Appendix B) as developed to measure the positive side of affect (Lorr *et al,* 1984). Table 4.1 illustrates the problem with the monopolar POMS as it only has one positive subscale (vigour) the rest measure negative feelings (Mutrie and Biddle, 1995, Gauvin and Brawley, 1993). The POMS-Bipolar is based on one factor of affect, so a sliding scale of mood exists, i.e. an individual will be somewhere on the scale between Elated – Depressed. The POMS bipolar version includes positive adjectives such as "light-hearted, playful, active and jolly" to capture the positive affect changes.

Table 4.1 Outline of the monopolar and the bipolar versions of the POMS.

Monopolar	**Bipolar**
Tension	Composed - Anxious
Anger	Agreeable - Hostile
Depression	Elated - Depression
Vigour	Energetic - Tired
Confusion	Clearheaded - Confused
Fatigue	Confident - unsure
Total mood disturbance	Global mood changes

In the POMS-bipolar scale subjects are asked to measure on a Likert type scale of 0 = much unlike this to 3 = much like this how they feel "right now". The lowest score for any subscale is 0 the highest score being 48. An increase in score means the participant moves towards being more positive, for example, if a subject scores higher on the agreeable – hostile scale post exercise, this means that they have moved towards the agreeable end of the scale and further away from the hostile end.

An additional issue with the POMS is the time it takes to complete. Fiske and Taylor (1991) suggest that situational stimuli can rapidly alter mood states. The bipolar version can take up to 5 minutes to complete, it requires a response to 72 items. For this reason it has been criticised for not being sensitive enough to capture transient affective states (Weckowicz 1978). After an anxious or emotional event the initial POMS items may produce different results than responses to later POMS items, as emotions can be transient.

This problem was revised with the production of a number of brief versions of the POMS. The Brief Assessment of Mood or Incredibly Short POMS (BAM / ISP, Dean *et al,* 1990) and the Schacham short POMS (Schacham, 1983) were designed based on the POMS and produced high correlations with the original version, unfortunately, because of the floor effect problem, these were based on the unipolar POMS. The use of a scale that only measures level of negative mood state is not effective in producing conclusions on the effect of exercise (Ekkekakis and Petruzzello 2000).

The POMS measures specific aspects of mood, it offers information about changes in the 6 subscales of mood (Table 4.1). This does not encompass overall views of affect as it is a categorical questionnaire that looks specifically at those 6 subscales of mood. Although the POMS has a total mood score which is calculated by adding up the changes in the 6 subscales, this does not give us information about the broader affect changes as adding up 6 categorical scales will not necessarily give us a measure of overall affect. For this reason broader questionnaires were developed to measure general changes in affect.

The STAI (Speilberger *et al*, 1970) was deemed too narrow for this study as it only measures state/trait anxiety and so it was not considered. The MAACL has not been used as much as the POMS in research (McDonald and Hodgkin, 1991) and the MAACL consists of 132 adjectives, which takes even longer to complete than the POMS therefore encountering similar problems in terms of transient mood changes. Additionally the MAACL is based on a unipolar scale.

<u>Dimensional affective questionnaires</u>

The development of broader dimensional questionnaires offers a clearer understanding of the basis of affect and exercise. Gauvin & Brawley (1993) argue there isn't a clear understanding of the relationship between exercise and affect. This is agreed by a review by Ekkekakis and Petruzzello (2000, 2002) who felt that researchers should investigate the basis of affect before concentrating on specific emotions.

These scales look at overall affect changes (positive affect and negative affect) rather than specific categories of mood (anxiety, depression or tension). These include the

Positive Affect and Negative Affect Scale (PANAS; Watson, Clark & Tellegen 1988) (Appendix C) and the Activation Deactivation Adjective Check List (AD ACL; Thayer, 1986).

One frequently used questionnaire is the PANAS (Watson *et al*, 1988). This scale asks subjects to rate themselves on a scale of "very little" to "extremely". This scale consists of 20 emotion related words and an increase in PA score indicates an improvement in positive affect while an increase in NA indicates a worsened score. This takes a much shorter period of time to complete than the POMS therefore alleviating one of the problems.

Affect is measured as a sliding scale in the POMS but as two separate dimensions in the PANAS. The dimensional measures are supported by Watson & Tellegen (1985) whose self - report mood studies support the findings that positive mood state and negative mood state are not extremes of a single mood continuum, but two separate dimensions. The two-factor structure of affect has been gaining widespread recognition in the field of psychology as one of the most widely used and elegant models of affective experience (Gauvin & Brawley, 1993).

Watson & Clark (1985) contend that the two fundamental dimensions of affect are positive and negative affect. Individuals with high activation in positive affect are enthusiastic, active and alert, while those with low activation experience depression, lethargy and fatigue. High activation negative affect is characterised by feelings of anger, contempt, disgust and fear, while low activation experience calmness and serenity. The PANAS is therefore a two-factor scale with both factors being bipolar.

One issue with the development of the PANAS was using only high activation terms in an attempt to keep positive and negative affect at a zero correlation which would indicate no relationship between the two dimensions. Researchers have contested this, Larsen & Diener (1992) ascertained that very few people if anybody had found positive and negative affect to be completely independent. There is agreement that positive and negative affect are not necessarily independent dimensions (Ekkekakis & Petruzzello, 2001). Additionally the PANAS has been criticised for not being sensitive enough to measure acute exercise changes (Petruzzello and Landers, 1994). They found in their acute exercise bout study that no changes were found in either positive or negative affect, while STAI measured significant anxiety reductions.

A number of factors in data collection and analytical methodology can substantially influence the relationship between positive and negative affect, swaying the results from bipolarity towards independent factors i.e. time frames of measurement, unequal items in factor analysis. Long time frames of response diminish the negative correlation between positive and negative affect thereby reducing the bipolarity and facilitate the formation of independent factors.

Exercise Specific Questionnaires

The exercise specific questionnaires to be discussed are the Exercise Feeling Inventory (EFI; Gauvin & Rejeski, 1993) and Subjective Exercise Experience Scale (SEES; McAuley & Courneya, 1994). These were developed in a desire to measure the 'stimulus properties' of exercise (Ekkekakis & Petruzzello 2000). Both the SEES and the EFI were developed using items that were presumed to be relevant and responsive to the effects of exercise. Problems arise, when trying to compare non-exercise controls to exercise conditions; it is not feasible to measure exercise-related properties for a group that haven't done any exercise. This could produce biased data, as obviously the exercise conditions will improve more on the exercise related topics.

An additional problem described by Ekkekakis & Petruzzello (2000) with these types of scales is that it assumes a global measure of what happens to people when they exercise. This does not take into account any difference between populations as the research was carried out on young, healthy, active individuals.

Circumplex model

The circumplex model was developed as a possible solution to the above problems. Ekkekakis and Petruzzello (2002) felt the circumplex model might present a well-developed solution to the problem of measuring affect changes with exercise. At this point in time it isn't a specific measuring tool but rather a conceptual model. It satisfies the dimensional criteria that measures the broad basis of affect, it is global and not exercise specific. One of the problems that exist with the circumplex model is that it does not allow for specificity of categorical models but as previously discussed the dimensional approach has been suggested as the way forward until the association between affect and exercise has been more clearly established.

One problem with the use of these types of questionnaires is the terminology. Clore *et al* (1987) approached the study of emotion through an examination of people's perceptions of affective connotations of emotion words. They analysed words used in a number of questionnaires including POMS and PANAS and almost half of the words used in both of these questionnaires included affect laden words. In general colloquial expressions and not affect-laden terms are used to express emotions; these measures may not be effective in measuring affect. As yet there has not been one type of scale that is the gold standard for measuring mood or affect, the research continues, Ekkekakis & Petruzzello (2000).

The POMS was chosen, as it has been the standard affect questionnaire used in this type of research for a number of years. Additionally a bipolar version existed which was preferable to avoid the floor effect problem. The other general psychology questionnaires were rejected as the STAI (Speilberger *et al*, 1970) only measures anxiety and so won't give a picture of global mood changes and the MAACL (Zuckerman and Lubin, 1965) is based on a unipolar scale. The shortened versions of the POMS are also based on the unipolar POMS so they were also rejected. Although the POMS was chosen it was recognised that there are some problems in terms of time taken to complete and that it measures only categories of mood. The PANAS was chosen to avoid both these problems as it takes a short time to complete and it is a dimensional questionnaire for measuring affect. PANAS has been questioned as to whether it is sensitive enough to detect changes as a result of an acute bout of exercise. Previous research has generally used PANAS with chronic studies (Clark and Watson, 1988, Watson, 1988) only one acute exercise bout study (Petruzzello and Landers, 1994) used PANAS. This study identified that the PANAS was not sensitive enough to measure acute exercise bout affect changes. The PANAS was chosen for this study to test the sensitivity of the scale against a recognised method of measuring changes in mood states, the POMS. The exercise specific questionnaires were disregarded as the main studies included non-exercise controls and these questionnaires would produce problems measuring the non-exercise conditions. The exercise specific questionnaires are positively biased towards exercise conditions.

The aim of this study was to assess a standard questionnaire, the POMS-bipolar (Lorr *et al*, 1984) against the PANAS (Watson *et al*, 1988) to determine if the PANAS was sensitive enough to measure affect changes with acute bouts of exercise. This would inform decision making about which scale to use in the main study.

Methods

Subjects

Fifty-two subjects agreed to participate in an acute aerobic exercise bout and gave informed consent (Glasgow University ethical committee). The purpose of the study was not discussed with the participants. All subjects were members of the undergraduate Physiology and Sport Science class at the University of Glasgow. As part of their laboratory class in exercise psychology all participants had signed a risk appraisal and an informed consent form. The subjects completed a Physical Activity Readiness Questionnaire (PAR-Q) prior to commencement on the test. Nine subjects were excluded as they:

- had a current injury or illness;
- were taking prescribed medication;
- had already exercised vigorously that day.

Nineteen females and twenty-four males (n= 43) between the ages of 17-28 (mean age 19.3 years standard deviation 6.2) took part in the acute exercise bout.

Apparatus

The Borg (6 – 20) scale was used to help subjects monitor intensity. There were 2 Borg scales at either end of the gymnasium. A heart rate chart was used as an additional measure of exercise intensity. These were displayed on the other two walls. A tape instructed the subjects telling them what movements to carry out and for how long, this was used for the whole of the exercise session.

Procedure

The subjects completed a Profile of Mood States Questionnaire (POMS-bipolar, Lorr *et al,* 1984) and a Positive Affect and Negative Affect Scale questionnaire (PANAS, Watson *et al*, 1988). No instruction was given to the order of completing the questionnaires. All subjects were given advice on how to use the RPE scale to monitor intensity. They were familiar with the RPE scale through their sports related course at the University of Glasgow. Students were advised to work at a moderate intensity, advice was given on keeping the intensity of exercise between 12 – 13 on the RPE scale. Subjects were also asked to take a number of heart rate readings throughout the exercise sessions and to keep their heart rate between 60% to 80% heart rate maximum (ACSM 1995). Participants worked out their individual heart rate for moderate intensity exercise using the heart rate maximum equation (220 – age). The subjects completed a 5-minute group warm up and then started the main exercise bout. The main aerobic section of the exercise bout lasted for twenty minutes. The subjects were encouraged to exercise between 12 to 13 on the RPE scale for the twenty-minute duration. Heart rate was taken by each student at the beginning of the main exercise session manually to determine if subjects were in the correct zone, this was measured during the aerobic section at 5 minutes and 15 minutes by each subject. On completion of the twenty minutes exercise session subjects completed a 5-minute cool down session and then completed both the POMS and PANAS questionnaires.

Statistical analysis

All questionnaires were collected then data was analysed using one sample t-tests.

Results

The difference (post – pre) in scores were measured by a one sample t-test and results are displayed in Table 4.2.

POMS

The global mood change for POMS showed a significant positive change indicating that the global mood improved significantly. Four out of the six subscales of mood as measured by the POMS also found a significant improvement. The two changes that did not reach significance (agreeable – hostile, energetic – tired) both demonstrated an increase in mean scores. These changes are represented in Figure 4.1.

PANAS

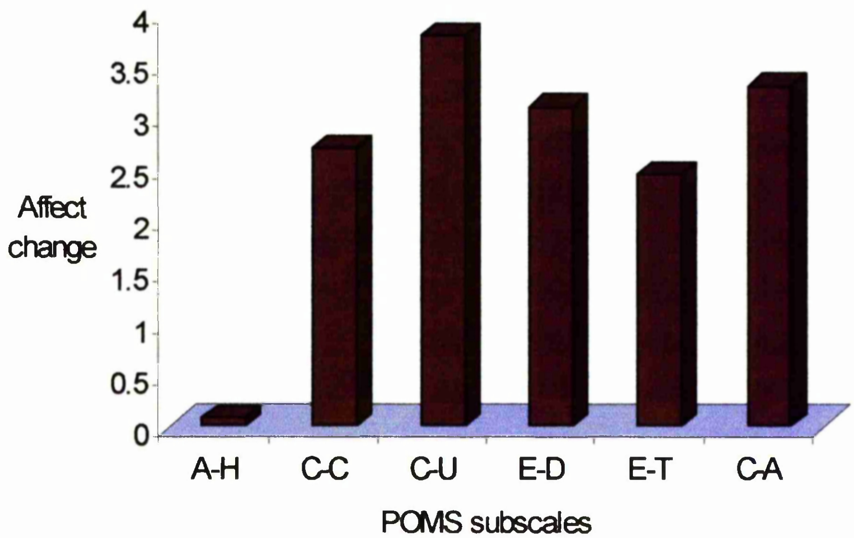
Both the positive and negative affect scores changed significantly with an exercise bout. This means that items on the positive scale increased suggesting a mood improvement. Negative affect (post – pre) score change became more negative indicating there was a significant improvement in negative affect. These are represented in Figure 4. 2.

Table 4.2 Mood score changes after an acute exercise bout (figures in bold represent significant mood change).

	Mean score change	Standard deviation	95.0% Confidence Interval
Agreeable – hostile	0.74	5.23	(-0.86, 2.35)
Clearheaded - confused	2.69	5.37	**(1.04, 4.35)**
Confident - unsure	3.79	4.54	**(2.39, 5.19)**
Elated - depressed	3.09	8.56	**(0.29, 5.89)**
Energetic – tired	2.44	8.11	(-0.31, 5.20)
Composed – anxious	3.30	6.73	**(1.23, 5.37)**
Global mood change	16.07	21.70	**(9.39, 22.75)**
Positive Affect	2.51	5.62	**(0.78, 4.24)**
Negative Affect	-1.25	2.45	**(-2.01, -0.50)**

Figure 4.1 indicates the magnitude of change for each of the POMS subscales, clearly the agreeable – hostile subscale has a very small mean affect change in comparison to the other subscales. The energetic – tired subscale was the next smallest change and this was not significant either. Large standard deviation's are shown especially for the elated – depressed and the energetic – tired subscale.

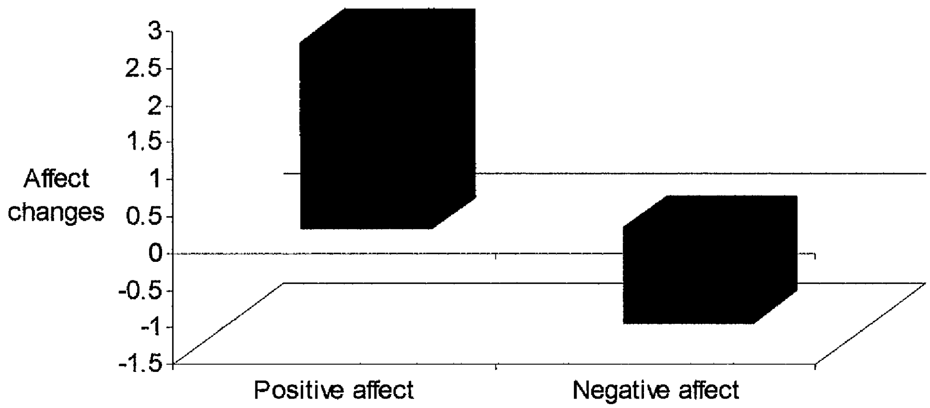
Figure 4.1 Mean affect changes for sub-scales of the POMS.



A-H = Agreeable - Hostile
C-C = Clearheaded - Confused
C-U = Confident - Unsure
E-D = Elated - Depressed
E-T = Energetic - Tired
C-A = Composed - Anxious

Positive and negative affect show a small but significant affect improvement; positive affect has the larger standard deviation. Figure 4.2 shows the improvement in positive affect and a reduction in negative affect.

Figure 4.2. Mean affect changes for the PANAS.



Discussion

POMS

The POMS subscales indicated that an acute exercise bout produced positive changes in the subscales and global mood. The agreeable – hostile subscale showed very little change indicating that acute exercise had very little effect on subjects for that scale of mood. The relevance of words like agreeable and hostile has been questioned in its relation to exercise (Ekkekakis and Petruzzello 2001b). The other non-significant subscale was the energetic – tired subscale. Fitness level was not measured and the intensity although controlled was not specific for different fitness levels. This may have skewed results as some may be fitter and have wanted to exercise at a higher intensity for some may have been of a lower fitness level and have perceived the exercise as much harder than moderate and left them feeling more tired than energetic. There was an improvement in this subscale although not significantly.

There was scarce literature pertaining to the use of the POMS-Bipolar, which avoids the problem of the floor effect with the monopolar POMS. In a narrative review (LeUnes and Burger, 2000) highlighted all the previous, present and future research on the POMS. They did not mention the POMS-Bipolar in reference to past, present or future studies although they did highlight recommendations by Yeung (1996) and Watson &

Clark (1997) that there was a failure of the POMS to effectively measure the positive mood domain. The only study found in this review, which used the POMS-Bipolar, was Daley and Parfitt (1994).

The POMS subscales make it easier to see the changes in each mood state. However it is difficult to determine if the mood change was an increase in the positive mood state or a decrease in the negative mood state, this problem is rectified by using the PANAS which displays changes in positive and negative affect (Ekkekakis and Petruzzello, 2000).

PANAS

Both factors of affect produced significant results. The PANAS appears to be sensitive enough to measure the dimensional changes of affect with exercise conflicting with the results from Petruzzello and Lander's study (1994). The larger change was in the positive affect factor indicating that most of the improvements were seen in the positive affect which is a bipolar scale so our subjects moved towards feeling more enthusiastic, active and alert. Dimensional scales do not allow us to gain more information on specifics of mood although at this point in research we need to clarify the overall affect changes with exercise before we start to look at the specifics (Gauvin & Brawley, 1993, Ekkekakis and Petruzzello, 2000). The information measured by the PANAS appears sensitive enough to register changes until a fuller understanding of exercise and affect is established.

Conclusion

The PANAS had previously been criticised as not being sensitive enough to pick up small affect changes, this pilot study found that the PANAS could detect small affect changes with acute bouts of exercise. The PANAS was then chosen above the POMS due to the following,

- the duration it takes to complete the POMS
- the non-significance in two mood subscales
- the aim is to measure dimensional changes in affect not categorical changes in mood scale

- the scarcity of research that has used the POMS-Bipolar.

The PANAS will be used in the main study to determine if affect changes take place with a variety of exercise and rest conditions.

Chapter 5: Acute exercise and affect: determining an optimal dosage and testing thermogenesis plus distraction as plausible mechanisms

There are two aims of this study. The first, mentioned at the end of chapter 1, was to determine an optimal exercise dosage. A number of questions arise from this aim, is there an optimal exercise intensity? Is there an optimal exercise duration? Does an optimal intensity and duration interaction exist? Does fitness level affect mood alterations at different intensities of exercise?

The second aim, mentioned at the end of chapter 2, was to determine if either thermogenesis or distraction could explain positive affect change from acute exercise. A number of questions arise from this aim, do affect changes correlate with core temperature changes? Does quiet rest produce affect changes? Are affect changes similar for quiet rest and exercise?
These questions will be answered in the main study.

Methods

Subjects

Thirty-six subjects (19 males and 17 females) gave informed consent (Glasgow University Ethical Committee, Appendix D & E) to take part in the study. Subjects were recruited through the use of posters and word of mouth around the University of Glasgow's campus. After volunteering, all subjects completed a Physical Activity Readiness Questionnaire (PAR-Q). These forms highlighted the possible dangers and explained the experimental procedures to the subjects.

Forty-two subjects initially enrolled for the study, however 6 subjects were excluded since they did not conform to the following criteria:

- No history of cardiorespiratory diseases
- No prescribed medication
- No musculoskeletal injuries

The subjects activity levels ranged from sedentary (no regular exercise in the previous six months) to maintaining activity (5-6 activity bouts per week for the previous six months) determined by the Stages of Change Questionnaire (Prochaska and DiClemente 1983) (Appendix F).

Different subjects were used for the control group, as we wanted to maintain similar settings for each of the weeks of testing. Term lasted for a period of ten weeks and we did not want to attempt to replicate similar mood states when the students were on holiday. No further information other than that outlined in the subject information sheet (Appendix E) was given to the subject during the study. The subjects received no financial incentives to be a part of this study.

Randomisation of subjects

Subjects were assigned a number 1 to 36 in no specific order. We used randomly assigned blocks of 6 people at a time, i.e. a random ordering of 3 Controls and 3 Exercise. E.g. ECCECE

Controls were allocated using 3 pairwise Latin based rectangular designs (Fisher and Yates, 1963) of 6 controls at a time.

e.g. ABC for Subject 1

BCA for Subject 2

CAB for subject 3

ACB for subject 4

BAC for subject 5

CBA for subject 6.

The Exercisers were allocated as two 9 by 9 Latin squares using the 9 combinations of the 3 intensities and 3 duration's.

Apparatus

Subjects exercised on a Monark cycle ergometer (Model 818E, Varberg, Switzerland) and used a heart rate monitor (Polar Sport Tester, Polar Electro Oy, Kempele, Finland) to determine exercise intensity. The Monark cycle was calibrated monthly by following the standard protocol outlined by the makers: releasing the fastening spring and then fastening a 4kg weight to the spring and reading the meter panel for 40 Newtons. If the weight did not correspond to 40 Newtons the adjusting screw was turned until the 4kg weight correlated to 40 Newtons. Rating of Perceived exertion was also measured using the Borg RPE 6 – 20 scale (Borg 1994). A rectal temperature probe (Glasgow University engineering department) was used to measure core temperature. The rectal probe was calibrated on a weekly basis using a water bath with 3 different temperatures, 0°C, 21°C (room temp.), and 60°C. The lowest temperature was measured with both thermometers and the probe inserted in a beaker containing ice cubes, for the warmer temperature a kettle was boiled and the boiled water was placed in a water bath to maintain the desired temperature. Each week the temperatures were measured and checked against two additional thermometers for reliability of temperature measurements.

Affect measurement

The Positive and Negative Affect Schedule (PANAS) assesses both positive and negative affect (Watson, Clark & Tellegen, 1988). Procedures for completion are documented in Chapter 4.

Procedure

Maximal test

The maximal test was completed prior to the testing cycle. The Astrand cycle ergometer heart rate maximal test (1965) was used to determine VO_2 max for each subject (cited in Heyward, 1991). The protocol is as follows: After a brief warm up (25w, 5mins) the subjects then exercised for 2 - 3 minutes at a given workload. Initially the power output is set at 50 watts for women and 100 watts for men. Thereafter the power output was then increased by 25 watts for women and 50 watts for men until the pedalling rate could not be maintained or until the subject was exhausted. After over coming the initial inertia, cadence was maintained at 50 ($\pm$ 1, rpm) throughout. Heart rate readings were taken at the end of every minute. Before an increment in workload the subject had reach a steady state (heart rate within 5 beats per minute of last minutes reading). The ACSM's revised leg ergometry equation was used to estimate VO_2 max (Heyward, 1991). The final heart rate measured was used in the heart rate maximum equations to find low, moderate and high intensity levels for each participant.

Familiarisation

The testing protocol took place in a different location to the max test. The new location was a quiet room in the University's main sports facility. Each subject was familiarised with the new testing environment and protocol in use for the remainder of the study. Both groups were asked to cycle for 5 minutes at each stage, 45 - 55% Hrmax, 65 - 75% Hrmax and 80 - 90% Hrmax at 50rpm to ensure correct workload had been selected for the study. Heart rate and Ratings of Perceived Exertion were taken at the end of each minute to ensure correct exercise intensity had been selected. Both groups spent 5 - 10 minutes familiarising themselves with the environment. All subjects were then introduced to the PANAS questionnaire and were given verbal instructions on inserting the rectal probe. It was not revealed to the subjects that there were two groups, an exercise group and a control group.

Testing pattern

Each subject was asked to leave an hour free for the test period each week and told there would be a mixture of tests including exercise or rest. They were informed that a randomised pattern existed for each subject that might include all exercise, all rest, or a mixture of both. None of the subjects knew what exercise or rest period they were doing on particular weeks until core temperature measurement and PANAS were completed.

Testing phase - Exercise group.

Subjects picked a convenient time and day for the following nine weeks to participate in the next stage of testing. Subjects, as already mentioned, were randomly allocated to a Latin square design of the nine exercise sessions. Each subject followed his or her own specific pattern of exercise bouts. The nine exercise bouts consisted of short (10 minutes, medium (20 minutes) and long (40 minutes) duration exercise and light (45 - 55% Hrmax), moderate (65 - 75% Hrmax) and high (80 - 89% Hrmax) intensity exercise (ACSM guidelines, 1995). When entering the testing room subjects were asked to sit down and relax for a short five-minute period before core temperature or psychological variables were measured. The subject inserted the rectal probe ten centimetres into the rectum in the testing room alone and waited for a one minute period or until the temperature had stopped fluctuating and core temperature was recorded. Subjects filled in the PANAS questionnaire answering on how the subjects felt at that time. The exercise bout was then revealed to the subject and the subject commenced upon a standardised warm-up and then proceeded with the exercise bout. The height of the bike seat was adjusted to the same height that they had used during the maximal test; this was kept constant throughout the testing period. Each subject worked within his or her pre determined heart rate range that had been calculated from the maximum bicycle test. Resistance was adjusted to allow subjects to keep within their designated heart rate zone. On completion of the exercise bout the subject was asked to lower the intensity to a comfortable speed and resistance for a period of 4 –5 minutes and then rectal temperature was measured and the PANAS completed.

Testing phase - non-exercise group.

Each of the subjects picked a specific day and time to be tested for the following nine weeks. Short duration consisted of 10 minutes of quiet rest, medium was 20 minutes of quiet rest and long duration was 40 minutes of quiet rest. During that time frame they were allowed to read magazines or books or simply sit and rest. Each subject measured core temperature and completed the PANAS questionnaire prior and immediately following the quiet rest period. The subjects were not told which condition they were doing until they had completed core temperature measurements and questionnaires. On completion of the quiet rest period subjects were asked to take rectal temperature and then complete the PANAS. Once the subjects had completed the three quiet rest periods they were then told that they were not needed for additional tests and that their participation within the study was complete.

Statistical analysis

All data was collated and results for temperature, positive affect and negative affect were calculated post minus pre. A Bonferroni based set of multiple intervals (collectively have a 95% confidence) were used to determine significance for core temperature differences, positive and negative affect differences for all the acute exercise bouts and for the control conditions. A Pearson (Pearson and Hartley, 1958) correlation was computed to determine the relationship between temperature differences and positive affect differences this was repeated for core temperature and negative affect for the exercise conditions and then for the control conditions. A one-way ANOVA was computed to determine if there was a difference between the mood change for the exercise group or the quiet rest group. A repeated measures ANOVA on the difference (post – pre) was computed for the effects of duration, intensity and the interaction of duration and intensity for the exercise group and the control group. Bonferroni multiple comparison confidence intervals were calculated for the significant results found from the intensity and duration and interaction section. A GLM ANOVA was calculated for fitness level effects.

Results

Subject Demographics

Age, height and weight were analysed for both groups prior to testing. VO_2 max was estimated during the maximal cycle ergometer test in the pre testing phase. A one sample t-test was carried out to determine if VO_2 max was different between groups, the results were non-significant ($p>0.05$) therefore fitness level was not significantly different between the two groups. Results are displayed in Table 5.1

Table 5.1. Exercise and quiet rest group demographics

	Exercise group n=18, 7 females and 11 males		Quiet rest group n = 18, 10 females and 8males	
	Mean	Standard deviation	Mean	Standard deviation
Average age (years)	21.01	2.28	20.32	1.35
Average Height (cm)	178.00	18.48	170.15	22.54
Average Weight (kg)	73.20	15.81	69.32	12.22
Average VO_2 max ($ml.kg^{-1}.min^{-1}$)	33.94	4.42	34.67	5.64

There is very little difference between the groups in terms of age, height and weight as can be seen in Figure 5.1.

Does an optimal exercise intensity, duration or interaction exist?

The first aim of this thesis was to determine if an optimal exercise intensity, duration or interaction existed for affect changes. Initially changes in affect for the nine exercise bouts were calculated. Table 5.2 displays the mean positive and negative affect changes as measured by the PANAS questionnaire. The bonferroni based set of multiple intervals (i.e. collectively have a 95% confidence) to determine if affect changes are significant are also displayed in Table 5.2.

Table 5.2. Effect of an acute exercise bout on mood change (set of simultaneous 95% confidence intervals).

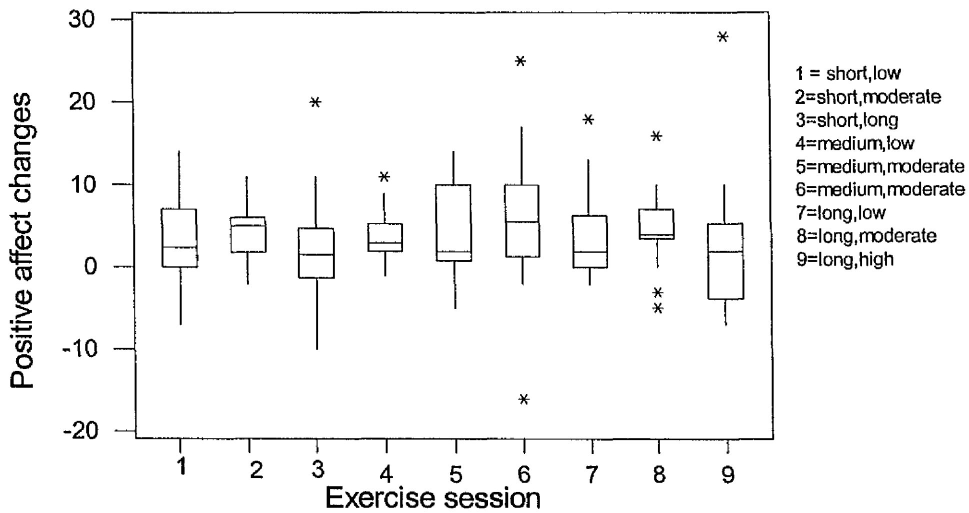
	Positive affect (mean change)	Confidence interval	Negative affect (mean change)	Confidence interval
short low	2.67	(-1.73, 7.07)	-3.55	**(-6.36 -0.75)**
short moderate	4.39	**(1.97, 6.81)**	-2.22	**(-4.51, -0.06)**
short high	2.11	(-2.83, 7.06)	-1.44	(-3.29, 0.41)
Medium low	3.67	**(1.54, 5.79)**	-2.33	**(-4.04, -0.63)**
Medium moderate	4.22	**(0.35, 8.09)**	-2.44	**(-4.24, -0.65)**
Medium high	3.61	(-0.75, 7.97)	-1.50	(-3.32, 0.32)
long low	3.78	(-0.29, 7.84)	-1.56	(-3.42, 0.31)
long moderate	4.61	**(1.15, 8.07)**	-2.50	(-5.15, 0.11)
long high	2.67	(-3.41, 8.74)	-1.61	(-4.36, 1.13)

(Significant results in bold)

Positive affect

The mean change for all conditions is positive indicating that all nine exercise bouts improved positive affect. Each of the moderate intensity conditions produced a significant improvement in positive affect. Additionally the low intensity medium duration condition produced a significant positive affect improvement. None of the high intensity conditions significantly improved positive affect. Moderate intensity exercise irrespective of the duration, significantly improves positive affect. Figure 5.1 demonstrates the mood alteration for each of the nine exercise bouts.

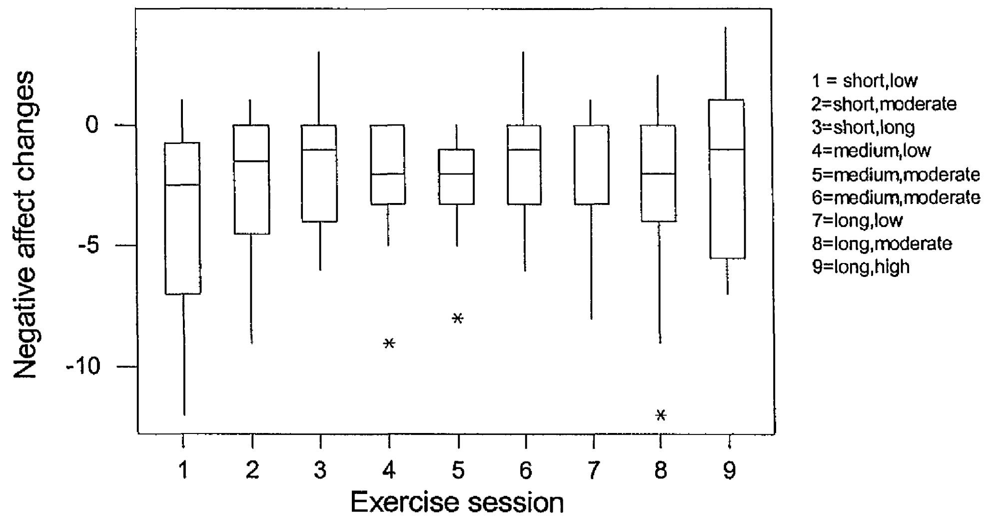
Figure 5.1 Positive affect mood changes for each acute exercise bout.



Negative affect

Similarly each of the exercise conditions improved negative affect. The more negative the mean score change the bigger the psychological improvement. The low and moderate intensity exercise bouts at short and moderate duration both produced a significant improvement in negative affect. None of the high intensity conditions improved negative affect significantly. Negative affect changes are displayed graphically in Figure 5.2. Some of the other affect changes are very close to significance, i.e. long duration, moderate intensity with a confidence interval of (-5.15, 0.11).

Figure 5.2 Negative affect mood changes for each acute exercise bout.



Does an optimal exercise intensity exist?

Low intensity exercise produced some significant affect improvements. Moderate intensity most consistently improves both positive and negative affect. High intensity exercise was not associated with any significant affect changes.

Does an optimal exercise duration exist?

Short duration exercise improves affect in some conditions. Medium duration exercise most consistently improves positive and negative affect. Long duration exercise improved affect for only one condition.

Does an optimal exercise interaction / duration interaction exist?

Results from Table 5.3 indicate that no significant interaction or duration exists for affect changes.

To determine if there is a significant difference for intensity, duration or the interaction of intensity and duration on affect a repeated measures ANOVA on the difference (post – pre) was computed. Results are displayed in Table 5.3.

Table 5.3. Intensity, duration and intensity duration interactions effect on mood changes

	Intensity effect	Duration effect	Interaction effect
Positive affect	0.44	0.27	0.41
Negative affect	**0.05**	0.48	0.20

The only significant outcome was the result of exercise intensity for negative affect. Manipulating exercise intensities will result in changes in negative affect. Intensity, duration and the interaction were non-significant for positive affect. Duration and the interaction were non-significant for negative affect. The significant intensity results from Table 5.3. was tested using a Bonferroni comparison (Figure 5.3) to determine if any of the exercise intensities are significantly different from the others.

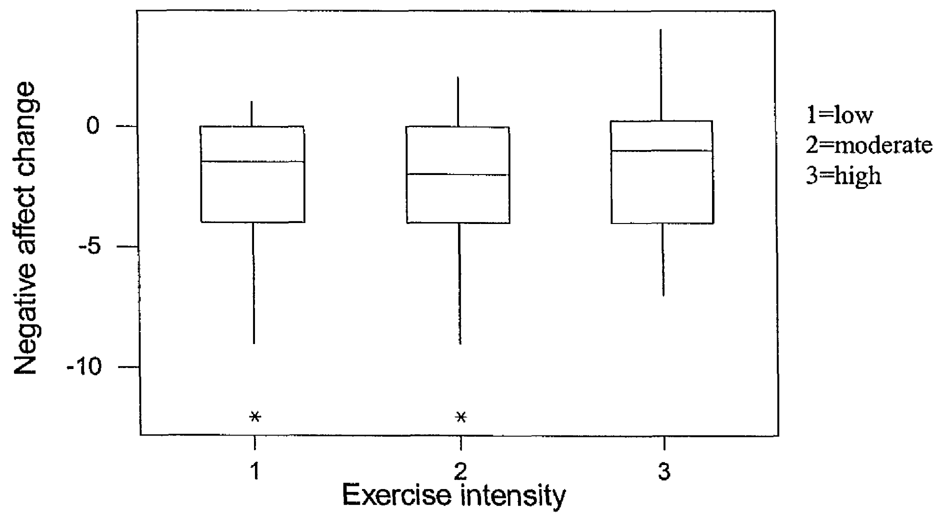
The blue line identifies the point of zero. If the brackets cross over zero then the result is non-significant. There are two borderline readings from Figure 5.3, the closest to significance are the high and low intensity comparisons with low intensity producing a much bigger improvement in affect than high intensity exercise. The high and moderate intensity comparison was also borderline again the high intensity condition produced much lower affect improvements. The moderate and low comparison were similar as the centre point was almost zero (0.092).

Figure 5.3. Bonferroni 95.0% Simultaneous Confidence Intervals comparison for exercise intensity and negative affect.

```
-+--------+---------+---------+------   Comparisons
  (--------+-*---------)                moderate - low
        (-+---------*---------)         high - low
        (-+---------*---------)         high - moderate
--+-------+---------+---------+------
 -1.0     0.0      1.0       2.0
```

Figure 5.4 graphically demonstrates the borderline significance between the three exercise intensities for negative affect. There isn't a clear-cut optimal exercise intensity, although high intensity exercise definitely does not significantly improve affect for any duration. Moderate and low intensity exercise both produce significant results although moderate intensity exercise bouts produce these changes more significantly.

Figure 5.4. Exercise intensity and negative affect changes



Does fitness level alter positive or negative affect changes?

Fitness level was tested to determine whether being fit would change affect scores for the different exercise intensities and duration's. A GLM on fitness level for positive affect for all exercise conditions found that P=0.46, a non-significant relationship to indicate that fitness level had no effect on positive affect changes. A similar non-significant result was found for negative affect (p=0.88) so fitness level did not appear to have any effect on mood changes.

The next section is concerned with the second aim of the thesis, to determine if either thermogenesis or distraction could explain improved affect change from acute exercise.

Thermogenic hypothesis

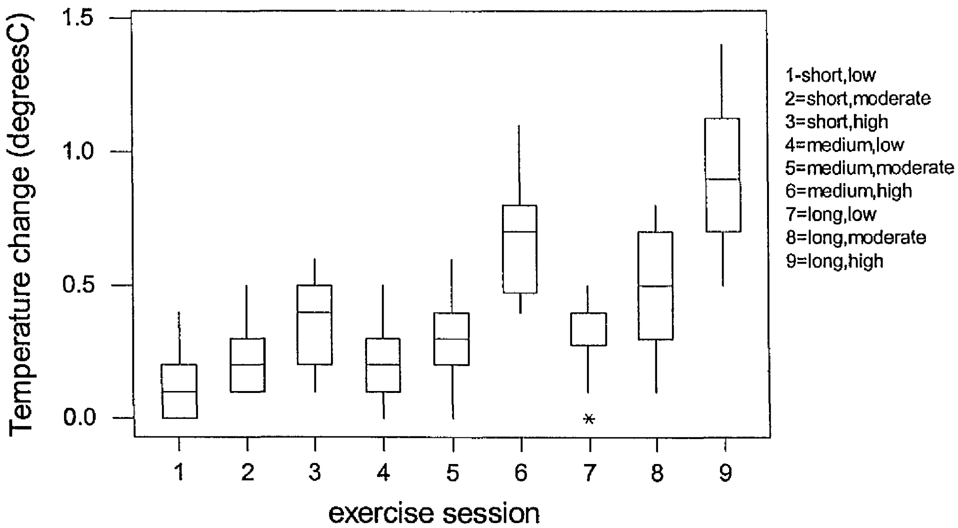
To test the thermogenic hypothesis core temperature changes were recorded for each exercise bout. The core temperature changes were calculated via a Bonferroni based set of multiple intervals (i.e. collectively have a 95% confidence), results are shown in Table 5.4. The core temperature changes were measured rectally before and after each exercise bout. Each exercise bout produced a significant core temperature change from baseline values. The high core changes were in the higher intensity conditions for long duration and medium duration as seen in Figure 5.5.

Table 5.4 Effect of acute exercise bouts on core temperature (significant results in bold).

	Mean temp change (°C)	Confidence interval
short low	0.11	**(0.02, 0.20)**
short moderate	0.24	**(0.14, 0.34)**
short high	0.38	**(0.26, 0.49)**
Medium low	0.22	**(0.11, 0.32)**
medium moderate	0.32	**(0.19, 0.43)**
medium high	0.64	**(0.49, 0.79)**
long low	0.32	**(0.21, 0.42)**
long moderate	0.49	**(0.34, 0.64)**
long high	0.91	**(0.70, 1.11)**

The patterns of core temperature changes are displayed graphically in Figure 5.5. The high intensity conditions produced the larger core temperature changes as Haight & Keatinge (1973) agreed that core temperature elevation increases directly in line with exercise intensity.

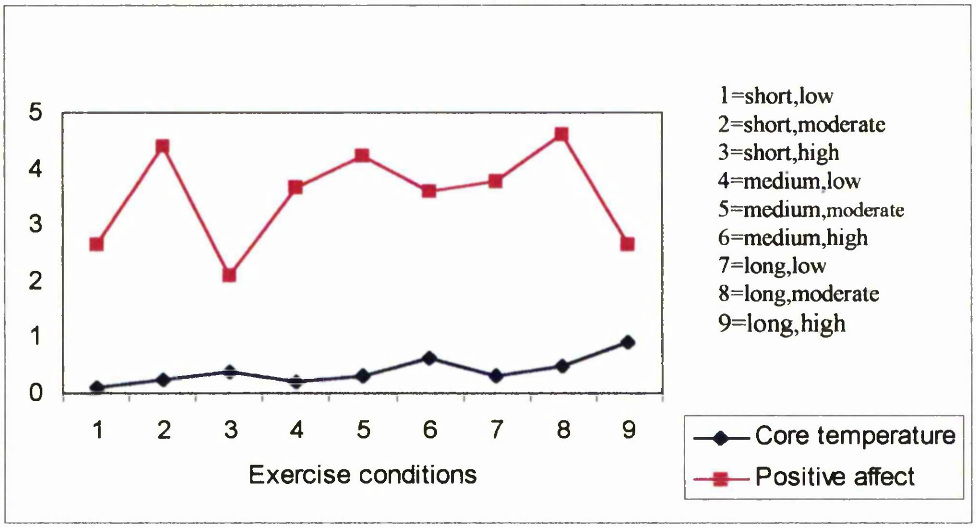
Figure 5.5 Temperature change with each acute exercise bout.



The largest temperature change is clearly seen in condition 9 the long duration, high intensity condition and then condition 6 the long duration, moderate intensity condition. The smaller temperature changes are seen in the expected conditions, the low intensity exercise bouts, condition 1, 4 and 7.

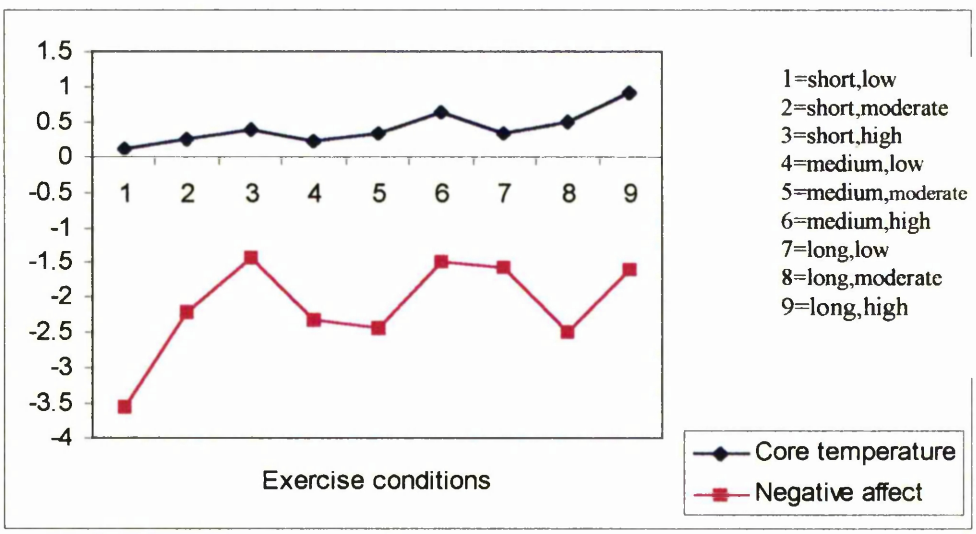
Table 5.2 and 5.4 show the significant values of affect changes and temperature changes. Most of the significant affect changes are in the moderate intensity, short and medium duration conditions. All the conditions produce significant core temperature changes but the high intensity conditions produce the larger core temperature increases. Figure 5.6. highlights the pattern changes for core temperature and positive affect. There is almost no similarity in pattern between core temperature changes and positive affect changes. This would indicate that an increase in core temperature does not change affect results.

Figure 5.6. Pattern of core temperature and positive affect change



A similar graph was constructed to look at the pattern between core temperature and negative affect.

Figure 5.7. Pattern of core temperature and negative affect.



As already discussed the more negative the affect change then the more improvement in negative affect. As Figure 5.6. also suggests there is no similarity of pattern between core temperature and negative affect changes. The correlation of core temperature with positive and negative affect was tested. A Pearson (Pearson and Hartley, 1958) correlation was computed and results are displayed Table 5.5.

The results confirm there is no evidence of a relationship between core temperature and mood change. The highest correlation was seen in the medium duration, low intensity condition for both positive and negative affect. The short duration, low intensity condition was the next best correlation although these values are still low indicating that realistically there is no relationship between temperature and mood change. P values in Table 5.5 suggest that there is no significant relationship between core temperature and affect change.

Table 5.5 Correlation of core temperature change and mood change after an acute exercise bout (P values in brackets).

	Positive affect		Negative affect	
	r value	p value	r value	p value
short low	0.21	0.41	-0.30	0.22
short moderate	-0.02	0.99	0.04	0.87
short high	0.03	0.92	0.16	0.54
medium low	0.39	0.11	-0.31	0.20
medium moderate	0.04	0.88	-0.02	0.95
medium high	0.18	0.47	0.11	0.66
long low	-0.22	0.37	-0.18	0.47
long moderate	0.05	0.80	0.02	0.99
long high	0.16	0.54	0.13	0.61

There was no comparison between significant affect changes and core temperature changes. No relationship was evident to suggest that core temperature had any influence on positive or negative affect changes.

Distraction hypothesis

The quiet rest group was used to test the distraction hypothesis. A Bonferroni based set of multiple comparison intervals (collectively have a 95% confidence interval) was carried out to determine affect change for the different rest duration's. Results were computed and presented in Table 5.6.

Positive affect

All conditions improved positive affect but only the medium duration improved significantly. The smallest change (0.17) was produced in the short duration condition. These results are displayed graphically in Figure 5.8.

Table 5.6 The effects of differing duration of quiet rest on mood change (significant results are in bold).

	Positive affect (Mean change)	Confidence interval	Negative affect (Mean change)	Confidence interval
short duration	0.17	(-3.11, 3.44)	-1.89	(-4.47 0.69)
medium duration	3.50	**(1.78, 5.22)**	-4.33	**(-6.65, -2.01)**
long duration	2.06	(-0.19, 4.30)	-1.39	(-5.04, 2.26)

Negative affect

All duration's improved negative affect, the only significant change was produced in the moderate duration condition. The smallest change this time was produced by the long duration condition. These results are displayed graphically in Figure 5.9.

For periods of quiet rest the medium duration condition produced the greatest improvements in mood. Although the shorter and longer duration condition improved mood scores they weren't significant for either positive or negative affect.

Figure 5.8 Quiet rest duration and positive affect changes.

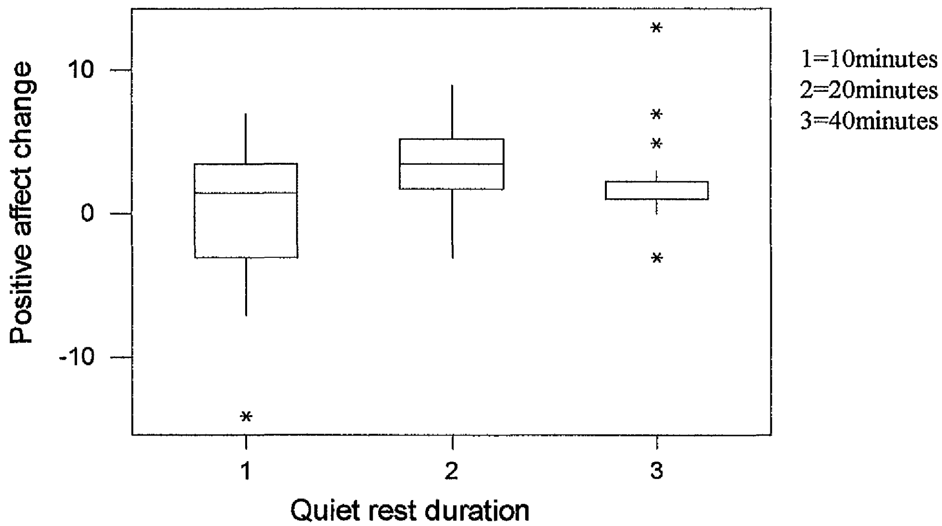
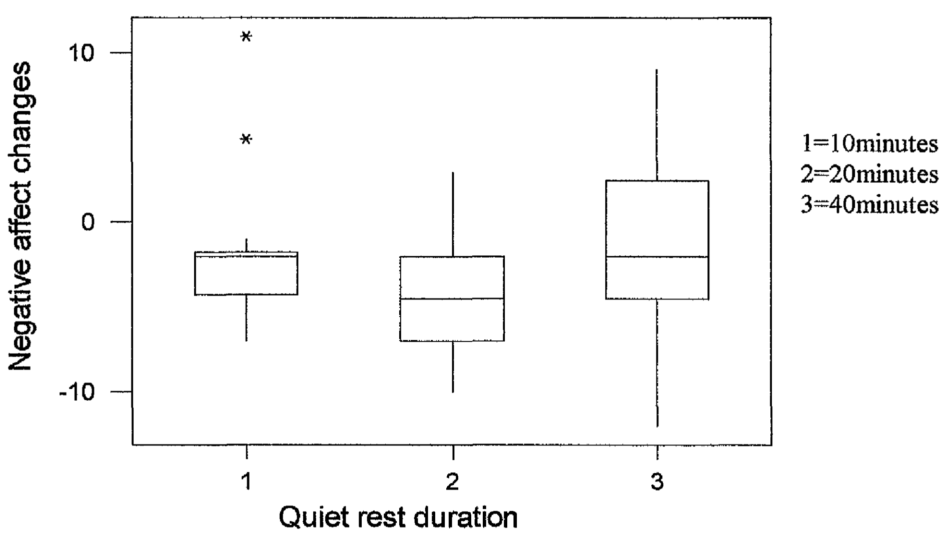


Figure 5.9. demonstrates the effect of the three durations of quiet rest on negative affect change. As with positive affect, the significant improvements in negative affect are produced in the medium duration condition.

Figure 5.9 Quiet rest duration and negative affect changes.



A repeated measures ANOVA on the difference (post – pre) was computed to determine if duration significantly affected positive and negative affect. Results are displayed in Table 5.7. The quiet rest group produces different results from the exercise group; duration does produce a significant difference for positive and negative affect changes.

Table 5.7. Duration effect of quiet rest on positive and negative affect

	Quiet rest duration
Positive affect	**0.05**
Negative affect	**0.05**

Bonferroni multiple comparison confidence intervals were calculated for the significant results from Table 5.7. This was to determine if one of the duration's produced significantly different results from the others. Figure 5.10. displays the Bonferroni confidence intervals. The only significant result is in the medium and short duration comparison. Medium duration produces greater positive affect improvements than short duration. The last comparison although not significant shows moderate duration produces greater positive affect improvements than long duration. The long, short comparison was not significant, but long duration produced more positive results than short duration.

Figure 5.10 Bonferroni 95.0% simultaneous confidence intervals comparison for quiet rest positive affect changes

```
----+---------+---------+---------+--Comparisons
              (---------*--------)     medium - short
           (--+------*---------)       long - short
  (--------*-----+---)                 long - medium
----+---------+---------+---------+--
  -3.5       0.0       3.5       7.0
```

The other significant result from Table 5.7 was with duration and negative affect. This was tested using a Bonferroni multiple comparison confidence interval results are displayed in Figure 5.11. There were no significant results for negative affect and duration from the Bonferroni confidence intervals. There was one borderline significant result for medium and long duration. Medium duration quiet rest produced more improvements than long duration quiet rest period. The other two confidence intervals don't reach borderline significance suggesting that there isn't much a difference in negative affect between long and short duration, and medium and short duration.

Figure 5.11 Bonferroni 95.0% Simultaneous Confidence Intervals comparison for quiet rest negative affect changes.

```
--------+-----------+---------+----------+   Comparisons
    (---------*-----|----)                   medium - short
           (----|--*--------)                long - short
                |(--------*--------)         long - medium
------+---------+|---------+-------+
    -3.5      0.0      3.5      7.0
```

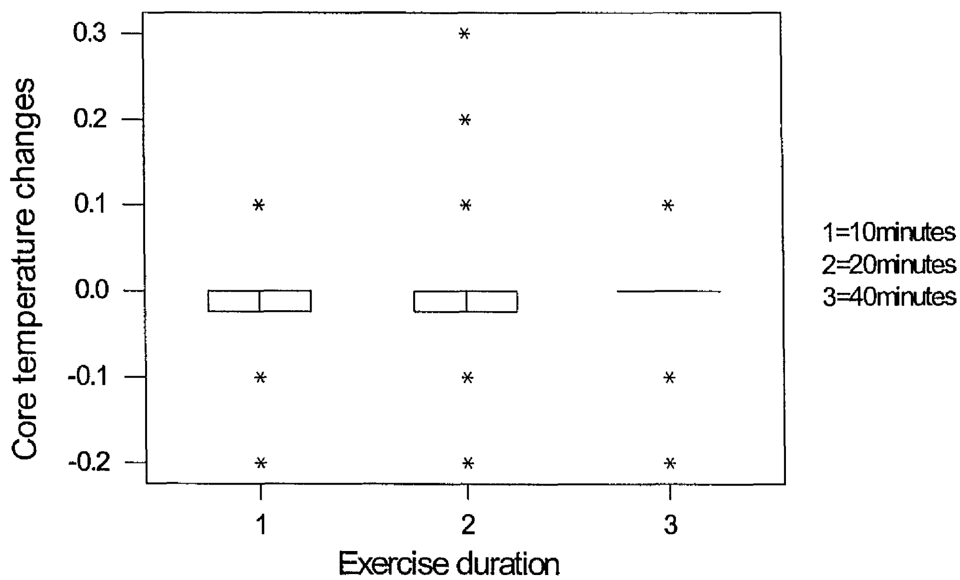
Core temperature was also measured for this condition to determine if there was any change with resting quietly. These results are presented in Table 5.8. The mean temperature change was measured and the Bonferroni based set of multiple intervals (i.e. collectively have a 95% confidence) were computed to determine whether there was a significant temperature change.

Table 5.8 Core temperature changes after quiet rest periods.

	Mean temp change (°C)	Confidence interval
short duration	-0.02	(-0.07, 0.20)
medium duration	0.00	(-0.07, 0.07)
long duration	0.00	(-0.05, 0.04)

None of the quiet rest conditions increased or decreased core temperature significantly. Resting quietly did not change core temperature no matter what duration the subjects spent resting. These results are displayed graphically in Figure5.12.

Figure 5.12 Quiet rest duration and changes in core temperature.



There are a number of outlying points for all conditions although the medium duration condition contains the most. The graph scale is within a range of 0.5 degrees so although the outlying points look large there is very little difference between the points. This graph indicates that the amount of change in core temperature is very small and it isn't affected by the different duration's.

A Pearson (Pearson and Hartley, 1958) correlation was then computed to determine if there was a relationship between core temperature and changes in positive and negative affect after different periods of quiet rest. These results are displayed in Table 5.9.There is no suggestion of a relationship between core temperature change and affect change with quiet rest periods. The highest correlation is in negative affect and medium duration quiet rest condition (r=0.35, p=0.15) this value does not approach significance as p>0.05.

Table 5.9 Correlation between core temperature and positive and negative affect for differing duration of quiet rest periods.

	Positive affect		Negative affect	
	p value	r value	p value	r value
Short duration	-0.21	0.42	0.19	0.46
Medium duration	-0.29	0.24	0.35	0.15
Long duration	0.04	0.85	-0.20	0.42

<u>Comparison of quiet rest and exercise affect changes</u>

The next stage of research was to compare exercise with quiet rest for changes in affect to determine if they were comparable in affect changes.

Figure 5.13. and 5.14 demonstrate the mean changes, standard deviations and the confidence intervals for positive and negative affect changes in the exercise and non-exercise conditions.

The blue line indicates the point of zero, if any of the brackets cross zero this highlights a non-significant change.

Figure 5.13 indicates that the only comparable between group results are in the medium duration category where the only non-significant result is for high intensity exercise.

Figure 5.13. demonstrates the mean changes, standard deviations and the confidence intervals for positive affect changes for exercise and non-exercise conditions

Level	N	Mean	StDev
Short, low	18	2.66	5.95
Short, moderate	18	4.38	3.27
Short, high	18	2.11	6.68
Short, control	18	0.16	5.19
medium, low	18	3.67	2.87
medium, moderate	18	4.22	5.23
medium, high	18	3.61	5.60
medium, control	18	3.50	2.72
long, low	18	3.77	5.49
long, moderate	18	4.61	4.68
long, high	18	2.66	8.21
long, control	18	2.05	3.57

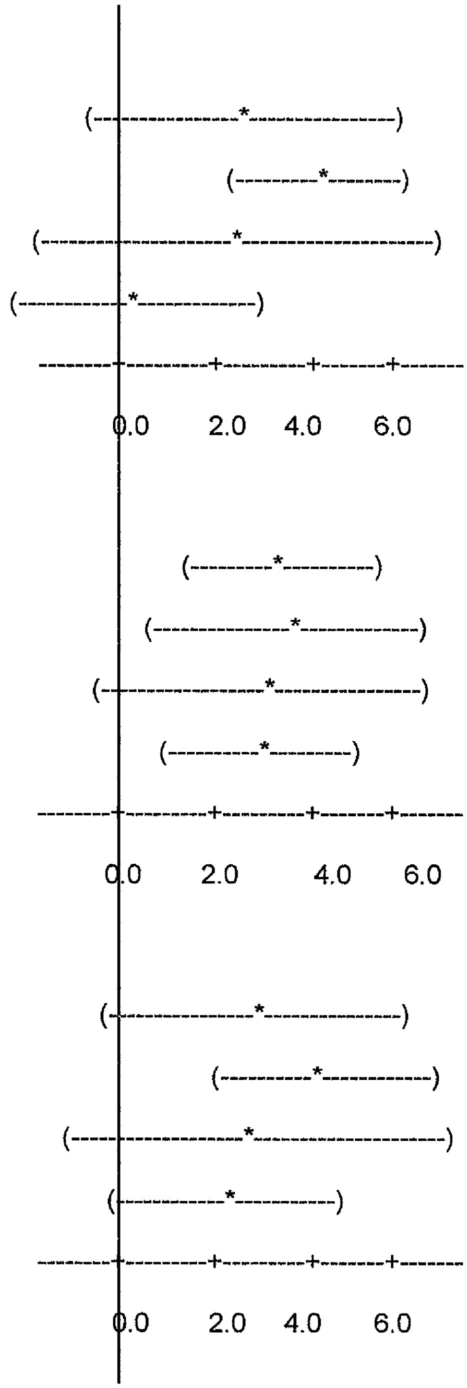
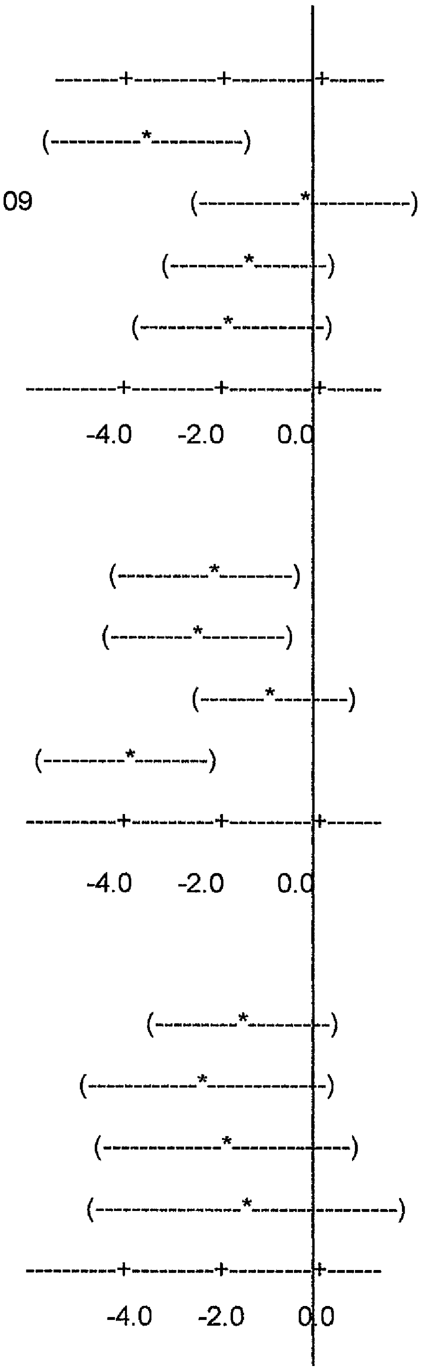


Figure 5.14. demonstrates the mean changes, standard deviations and the confidence intervals for negative affect changes for exercise and non-exercise conditions.

Level	N	Mean	Std
Short, low	18	-3.55	3.79
Short, moderate	18	-2.22	3.09
Short, high	18	-1.44	2.50
Short, control	18	-1.88	4.10
Medium, low	18	-2.33	2.30
Medium, moderate	18	-2.44	2.43
Medium, high	18	-1.50	2.45
Medium, control	18	-4.33	3.67
Long, low	18	-1.55	2.52
Long, moderate	18	-2.50	3.56
Long, high	18	-1.61	3.72
Long, control	18	-1.38	5.79



<u>Short duration</u>

For short duration periods, exercise of moderate intensity appears to be the best for improving positive affect and reducing negative affect. During short duration conditions it would appear that exercise of low or moderate intensity is more beneficial than quiet rest in increasing positive affect and reducing negative affect.

Medium duration

During medium duration sessions, exercise and quiet rest both increase positive and decrease negative affect significantly. The biggest overall mean change for negative affect however is with the quiet rest condition. The moderate intensity exercise condition produces a comparable change with quiet rest condition for positive affect.

Long Duration

During long duration sessions, the high intensity exercise produces the smallest improvements in both negative and positive affect. The control condition did not significantly reduce negative affect or increase positive affect. Significant improvements for the exercise group in positive affect were seen for the moderate intensity conditions although not for negative affect change. Long duration produced the least significant psychological improvements for all intensities or rest.

Looking at the statistical analysis between the exercise condition and the quiet rest conditions a one-way ANOVA was calculated to determine if there was a difference between affect change for groups. There was a significant difference between conditions for positive affect ($p=0.03$) and no significant difference for negative affect ($p=0.53$). This suggests that negative affect change is not different if the individual exercises or rests.

The exercise conditions results were added together and a mean produced (Table 5.10), as were the results for the non-exercise group. These results were displayed graphically in Figure 5.15.

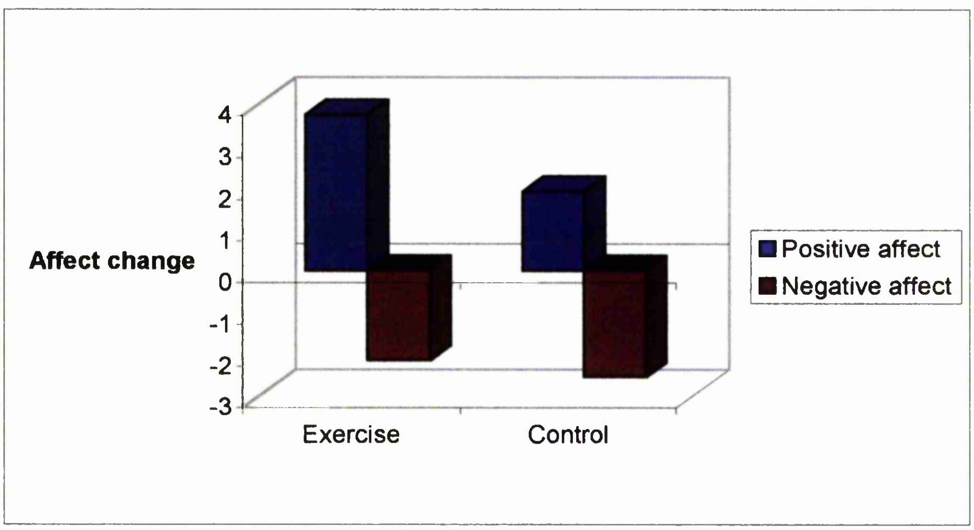
Table 5.10 shows there are differences in the mean changes for positive affect with the groups. The difference is much smaller for negative affect. Positive affect appears to improve more with exercise but this is not the case for negative affect. Quiet rest improves negative affect more than exercise although this is a non-significant margin.

Table 5.10. Mean change and standard deviations for positive and negative affect changes for an acute exercise bout and a period of quiet rest.

	Exercise group		Control group	
	Mean change	Standard deviation	Mean change	Standard deviation
Positive affect changes	3.74	5.91	1.91	4.12
Negative affect change	-2.13	2.98	-2.53	4.70

Figure 5.15 demonstrates graphically that positive affect is significantly improves more with exercise and Table 5.10 confirms this, while negative affect improves more with quiet rest although not significantly.

Figure 5.15 Positive and negative affect changes for the exercise and non-exercise control group



Discussion

The aims of this thesis were, firstly to identify if an optimal exercise dosage existed, and secondly to determine if thermogenesis or distractions were the causal mechanisms underlying improved affect with exercise.

Does an optimal exercise intensity exist?

Table 5.2 indicates that the moderate intensity condition produced the most significant psychological benefits. This would agree with previous research (Berger and Owen, 1988, 1992, Motl *et al*, 1996, Parfitt *et al* 1994, 1996) that moderate intensity exercise consistently produces improvements in psychological well being. There was no decrement in affect with the high intensity exercise which Parfitt *et al* (1994, 1996) and Steptoe and Cox (1988) found although other researchers have found no mood change (Berger and Owen, 1992, 1988). The high intensity conditions did not produce any significant improvements or decrements in affect in this study.

Each condition was consistently rated at the correct RPE on Borg's scale and heart rate zones were strictly adhered to. Some previous research used inconsistent intensities (Steptoe and Bolton, 1988, Steptoe and Cox, 1988.).

Low intensity exercise produced significant improvements in half of the conditions, but not for long duration. It is possible that pedalling at such a light wattage for 40 minutes became irritating for some of the subjects. The majority of them were used to exercising vigorously so exercising for 40 minutes at a fairly light intensity may become frustrating. Other research has suggested that exercise intensity has no effect on affect (Steptoe *et al,* 1993, Pronk *et al,* 1995). Both these studies measured affect with the unipolar POMS (Berger and Owen, 1998, Raglin and Wilson, 1996) which only measures one dimension of affect whereas the PANAS measures a two-factor affect. This may be part of the difference between studies. Table 5.3 indicates a significant effect of intensity for negative affect. The Bonferroni indicates that there isn't a significant difference between comparisons only borderline significance with moderate intensity being better for affect than low or high intensity.

Does an optimal exercise duration exist?

The short duration condition produced a few significant changes whereas the longer duration only produced one significant affect improvement. There were more significant changes in the moderate duration condition. The repeated measures ANOVA confirmed that duration did not significantly influence positive or negative affect as Figure 5.3 demonstrated agreeing with Ekkekakis and Petruzzello (1999). This disagrees with studies (Thayer, 1987, 1996, Berger *et al*, and O'Connor *et al*, 1997) who found changes in affect dependent upon exercise duration. In this study exercise duration was not a significant influence on affect.

Does an optimal interaction between intensity and duration exist?

There was no optimal interaction of exercise intensity and duration but only trends seen in Table 5.2. Steptoe and Cox (1988) suggested that positive improvements in affect with exercise might be the result of the interaction between duration and intensity. This study found no evidence to support Steptoe and Cox (1988). No significant optimal intensity, duration interaction was found, although the most consistently significant results were found in the moderate intensity conditions and the medium duration conditions. The trend was towards the moderate intensity, medium duration condition, although as previously mentioned this was not found significant.

Can fitness level influence affect changes?

Contrary to Parfitt *et al* (1994, 1996) and Steptoe *et al* (1993), fitness level in this study did not make any difference to the changes in affect with any of the different conditions. These results agree with results from Motl *et al* (1996) they used highly fit cyclists and compared them to students although they used maximal exercise testing and 2 groups, one highly fit and the other group was students. This study measured each subject's VO_2 max value to determine if there was a pattern of affect responses for differing levels of fitness. No such pattern emerged.

Could the thermogenic hypothesis be a causal mechanism?

The second aim was to determine if thermogenic or distraction was a feasible causal mechanism. Examining the thermogenic hypothesis was an integral part of the study. To establish whether temperature had a significant effect on mood, subjects participated in 9 different exercise conditions of varying intensities and durations.

It was hypothesised that thermogenesis would be refuted and results support this hypothesis. The changes in core temperature did not form a pattern with the changes in affect as demonstrated in Figure 5.6 and 5.7. The largest core temperature change was after long duration, high intensity condition, this condition produced one of the smaller affect changes which was not significant (C.I. –3.41, 8.74 for positive affect and –4.36, 1.13 for negative affect). The significant mood changes were in the moderate conditions for all three duration's and for the low intensity, medium duration for positive affect. Each of these conditions produced a significant core temperature change, but not the largest core temperature change. A core temperature increase of 0.32°C was produced in the medium duration, moderate intensity condition which produced significant improvements in positive and negative affect (Table 5.2 and 5.4), but an identical temperature change in the long duration, low intensity condition produced no significant affect improvements. Additionally the long duration, moderate intensity condition produced a significant improvement in positive affect, this condition produced a core temperature change of 0.49°C. This is higher than the temperature change produced in the long duration, low intensity condition and the short duration high intensity condition, neither of which produced a significant temperature change. The absence of a correlation between core temperature and affect changes indicates that there is no pattern between core temperature changes and affect. Core temperature is said to increase in proportion to the intensity of exercise (Bardwell and Chapman, 1911, Raglin and Morgan, 1985). Core temperature increased as expected in accordance to the length of time and intensity of the session. Manipulating core temperature should not have provoked anxiety, as we were not trying to block the normal body systems by cooling prior to or during the exercise bout.

Studies looking at the thermogenic hypothesis have looked mainly at anxiety levels (Petruzzello *et al,* 1993, Bulbulian & Darabos, 1986, Raglin & Morgan, 1985, DeVries *et al,* 1968, Von Euler & Soderberg, 1957). This study looked at a broader range of affect by using the PANAS. Koltyn (1997) advised looking at other changes apart from just anxiety with the thermogenic hypothesis.

Approaches to studying the thermogenic hypothesis have generally favoured blocking core temperature changes, often these blocking techniques can be stressful to the subject and anxiety is provoked i.e. exercising in 18°C for 30 minutes without any protective clothing (Koltyn and Morgan, 1993). Manipulating the intensity level and measuring mood score changes gives us an insight into the effect temperature may have on affect changes.

Could distraction be a causal mechanism?

The final part of this thesis looked at the distraction hypothesis that was developed by Bahrke & Morgan (1978). The control group was used as a method to determine whether exercise *per se* was needed to improve moods or if a distraction away from everyday worries was enough to improve affect.

The quiet rest group produces different results; moderate duration is the only duration that produces significant changes. Table 5.6 shows significant improvements for positive and negative affect during medium duration quiet rest. This agrees with studies (Bahrke and Morgan, 1978, Gauvin and Spence, 1996, Raglin and Morgan, 1985) who suggest that time-out will improve affect. The significant result was only in the medium duration (20 minutes) condition. Is duration a significant factor in whether psychological improvements occur with quiet rest? Table 5.7 indicates that duration significantly influences affect. As yet few studies have manipulated the duration of the quiet rest period. The Bonferroni equations suggest that medium duration quiet rest produces a significantly higher improvement than short duration. Why was there no significant improvement in the 10minute and the 40minute conditions? Perhaps the subjects needed a longer period of time than 10minutes before allowing them to be fully distracted from everyday life. The 40-minute duration may have been too long and possibly the subjects were starting to get bored or irritable during 40 minutes of quietly resting.

The significant results indicate that distraction has a beneficial impact on positive and negative affect. This was only produced after the medium duration condition indicating that an optimal duration exists for time-out from everyday life.

Which is more beneficial: exercise or quiet rest?

Is exercise or quiet rest more beneficial to people? The results from Table 5.2 and 5.6 show the differences in affect changes with the conditions. Quiet rest was significantly beneficial in improving positive and negative affect when subjects rested for 20 minutes, but not for 10 minutes or for 40 minutes. Positive and negative affect significantly improved for 10 minutes for moderate intensity, 20 minutes at low and moderate intensity. These results would suggest that if an individual only has a short duration them moderate intensity exercise will be more beneficial but if an individual has 20 minutes then exercising at either low or moderate intensity or resting quietly will be beneficial. If the individual has a longer period of time then moderate exercise can improve positive affect although it may not produce a significant change for negative affect. This has implications for the increasing avocation of short duration low/moderate intensity activity message for physical health. If we can prove psychological benefits for shorter durations and lower intensities this may help improve adherence to activity for the general public.

Conclusion

Intensity, Duration and Interaction

Medium duration for the exercise group produced the most significant affect results. Intensity was found to significantly influence negative affect but comparisons between the three intensities didn't produce any significance. Short and medium duration exercise produced significantly improved affect although no significant influence on affect was found. The interaction of intensity and duration did not significantly influence affect. High intensity and long duration conditions produced the least favourable changes.

Thermogenic hypothesis

This study does not support the thermogenic hypothesis as a mechanism to improving affect. Changes in core temperature did not correlate with changes in affect. All of the exercise conditions produced a significant core temperature change although not all conditions produced significant improvements in affect. The degree of core temperature change has no pattern on quantity or significance of affect change with acute exercise. Core temperature changes do not influence affect changes in acute bouts of aerobic exercise. These results and previous research results suggest discarding the thermogenic hypothesis as a mechanism to explain affect change with exercise.

Distraction hypothesis

This study provides some evidence for the distraction hypothesis. Quietly resting for moderate duration (20 minutes) produces significant psychological improvements. Quiet rest is viewed as a time-out or a distraction from life and everyday worries so distraction has improved affect in this study for the 20minute duration. The distraction hypothesis may explain why there is an improvement in affect for a number of the exercise conditions. It may be that it isn't exercise per se, but a distraction from everyday worries that improves affect. Additionally when working at high intensities, instead of exercise being a distraction from anxieties and stress, the high intensity exercise becomes a source of anxiety and stress itself. The distraction hypothesis is still a tenable hypothesis and should be researched further.

Methodological issues

There were a number of methodological issues that arose from this study. Using healthy, active students may bias results because they are not a true representation of the population (Morgan, 1997). However, this was the easiest group of people to recruit and test. In addition the design was only a single blind procedure. It may have been better to have an additional researcher to allocate conditions and thus make a double blind protocol but this was outwith the project resources.

One factor that may have affected core temperature measurements are the fluctuations in core temperature during the menstrual cycle. Core temperature is elevated significantly in the luteal phase (day 14 - 28) of the menstrual cycle. The elevation appears to be the result of both oestrogen and progesterone acting on the preoptic / anterior regions of the hypothalamus although the exact contributions from each hormone remain unclear (Marsh & Jenkins, 2002). Luteal phase core temperature elevations have been reported to be as much as 0.6degrees Celsius (Hessemer *et al*, 1985). The changes in baseline core temperature may have altered affect changes. Future research should look at changes in core temperature with menstrual cycle to determine if this can influence results.

Using the PANAS as a tool for measuring affect may be a methodological issue as many other studies have used the unipolar POMS. The PANAS has been found a valid and reliable way to assess the continuum of affect (Petruzzello & Landers 1994). Although the PANAS appears more sensitive to changes in the exercise environment with the normal population, the majority of studies have used the unipolar POMS, which may make this study difficult to compare.

Using different subjects as controls was a methodological issue. Ideally the study would use the same subjects for all 12 sessions. This would have been very difficult to administer as each term at Glasgow University lasted 10 weeks with a period of at least 4 weeks before the start of the next term. To avoid a large break in testing, this study used two different groups to attempt to keep all testing within a short time frame to avoid subject drop out and change in baseline affect.

The definition of exercise intensity is fundamental to this research project. The ACSM guidelines are used widely in this field of research although issues have arisen using maximum heart rate, RPE and VO_2 maximum. Maximum heart rate is used but viewed as being over simplistic as a substantial inter-subject variability exists for subjects. At the anaerobic or lactate threshold there are state changes in muscle energetics, pulmonary gas exchange and ventilation. The threshold does not occur at a fixed percentage of VO_2 maximum, but ranges from 35%-85% of VO_2 max. The ACSM definition of moderate intensity exercise as 50-74% VO_2 max could include subjects with lactate thresholds that lie at the low end of the range. If the work rate is not comfortable to continue for a reasonable period of time then this cannot be seen as moderate intensity or even aerobic. RPE has also received criticism in its ability to accurately monitor exercise intensity as it relies on the individual perception, which can be affected by day to day events. Future research may need to consider more accurate measures of intensity. Heart rate was chosen to monitor exercise intensity for this project as a more invasive measurement may have altered baseline affect.

Future research recommendations

Research looking at the effect of duration of exercise and its associated mood change would allow us to highlight a minimum duration for individuals to feel better. If participants only need to engage in physical activity for a short duration to gain psychological benefits this may improve exercise adherence or make the transition from sedentary to active much easier. No specific exercise duration or intensity produced maximal affect benefits. Instead a number of combinations produced affect change. These results suggest that there may not be one specific exercise dosage for all people that can improve affect. This implies that dosage may be highly individual. Future research may then have to look more at the individual to determine a link to optimal exercise dosage.

Results from this study and previous studies (cited in Chapter two) suggest that the thermogenic hypothesis is not a tenable mechanism to explain the changes in affect with exercise. The correlation between changes in core temperature and affect imply core temperature plays no part in affect changes. Future research should look more at other possible mechanisms rather than continue with research of the thermogenic hypothesis.

LaForge (1995) suggested that instead of looking at one specific psychological or physiological mechanism that is causal to affective changes we instead look at psychobiological models that include different aspects of several models. To integrate possible mechanisms we need to fully understand what part each individual model could play in affect change. Each possible mechanism needs to be researched to determine if they are viable mechanisms. Once each of these mechanisms are understood it may be possible to take individual aspects from each of those models and integrate them to make one functional model. The mechanism of affect change may be very specific to each individual but research needs to look at all possibilities.

It would be interesting to look at what subjects are feeling throughout exercise and quiet rest bouts to determine if an inverted U type hypothesis of intensity or duration exists. For example comparing how subjects feel at 15 minutes through a 40-minute exercise bout and 15 minutes through a 20-minute exercise bout.

Another area of future research would be to examine affect changes at different periods post exercise to determine if different intensities of exercise produced different affect changes post exercise as some studies have suggested (Parfitt *et al*, 1996).

The physiological benefits of exercise have long been known but the mental health benefits with exercise are becoming more popular in current thinking. The mental health benefit can add quality of life to us at all ages through life.
"We do not cease to play because we get old, we grow old because we cease to play" George Bernard Shaw.

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Appendix A Informed Consent Form – Temperature Site Measurement Study

Aim of study – determine which temperature measurement site detects small increases in core temperature without discomfort.

Testing Procedures

Subjects are asked to attend an initial session to receive instructions about using each of the three core temperature probes, the tympanic, rectal and the oral probe. During this session any questions the subjects have regarding this study will be answered. The subjects will be given as much time as they feel they need until they feel they are comfortable and competent at using the probes. On completion of this session heart rate will be measured once subjects feel that they are relaxed and not anxious.

The following session will consist of measuring core temperature before the exercise bout followed by a light warm up then a 30 minute controlled exercise bout on a treadmill. Heart rate monitors will be used to keep the exercise bout at moderate intensity (65% HRR). Subject can decide on the pace and gradient as long as heart rate is kept constant throughout the 30 minutes. RPE will also be recorded to ensure subjects work at moderate intensity. On completion of the 30-minute exercise bout, a 2-minute cooling down session will be carried out and then core temperature will be measured using the 3 temperature measurement sites. On completion of core temperature measurements subjects are encouraged to cool down for a further 4-5 minutes and then stretch all relevant muscle groups.

It should be noted that participation in this exercise study might not be of direct benefit to you. If you do not wish to participate in this study or you wish to withdraw at any time you may do so. As with any exercise session there are risks, but this session will be fully controlled so to minimise any risks.

I ____________________________ give my consent to the procedures outlined to me, the nature and purpose plus possible consequences of which have been fully described to me.

Signed________________________________ Date____________________

APPENDIX B

Name ....Date ....

Below are some words that describe feelings and moods which people have. Please read EVERY word carefully, then circle the number that best describes how you are feeling right now. Suppose the word is HAPPY, mark the one answer which is closest to how you are feeling right now.

The numbers refer to these phrases :-

0 = MUCH UNLIKE THIS
1= SLIGHTLY UNLIKE THIS
2 = SLIGHTLY LIKE THIS
3 = MUCH LIKE THIS

1. COMPOSED.............	0 1 2 3	25. PEACEFUL........	0 1 2 3	49. CALM..............	0 1 2 3
2. ANGRY.....................	0 1 2 3	26. FURIOUS...............	0 1 2 3	50. MAD.................	01 2 3
3.CHEERFUL................	0 1 2 3	27. LIGHTHEARTED...	0 1 2 3	51. JOLLY.............	0 1 2 3
4. WEAK.......................	0 1 2 3	28. UNSURE................	0 1 2 3	52. UNCERTAIN......	0 1 2 3
5. TENSE.......................	0 1 2 3	29. JITTERY................	0 1 2 3	53. ANXIOUS..........	0 1 2 3
6. CONFUSED.............	0 1 2 3	30. BEWILDERED........	0 1 2 3	54. MUDDLED.........	0 1 2 3
7. LIVELY.....................	0 1 2 3	31.ENERGETIC............	0 1 2 3	55. READY TO GO.....	0 1 2 3
8. SAD...........................	0 1 2 3	32. LONELY..................	0 1 2 3	56. DISCOURAGED....	0 1 2 3
9. FRIENDLY..............	0 1 2 3	33. SYMPATHETIC......	0 1 2 3	57. GOOD NATURED ...	0 1 2 3
10. TIRED.....................	0 1 2 3	34. EXHAUSTED..........	0 1 2 3	58.WEARY................	0 1 2 3
11. STRONG................	0 1 2 3	35. POWERFUL............	0 1 2 3	59. CONFIDENT.....	0 1 2 3
12. CLEARHEADED...	0 1 2 3	36. ATTENTIVE...........	0 1 2 3	60. BUSINESS LIKE......	0 1 2 3
13. UNTROUBLED......	0 1 2 3	37. SERENE................	0 1 2 3	61. RELAXED..............	0 1 2 3
14. GROUCHY.............	0 1 2 3	38.BAD TEMPERED....	0 1 2 3	62. ANNOYED.............	0 1 2 3
15. PLAYFUL...............	0 1 2 3	39. JOYFUL...................	0 1 2 3	63. ELATED..................	0 1 2 3
16. TIMID.....................	0 1 2 3	40. SELF-DOUBTING...	0 1 2 3	64. INADEQUATE.........	0 1 2 3
17. NERVOUS.............	0 1 2 3	41. SHAKY...................	0 1 2 3	65.UNEASY.................	0 1 2 3
18. MIXED - UP..........	0 1 2 3	42. PERPLEXED..........	0 1 2 3	66.DAZED.....................	0 1 2 3
19. VIGOROUS...........	0 1 2 3	43. ACTIVE..................	0 1 2 3	67. FULL OF PEP.........	0 1 2 3
20. DEJECTED...........	0 1 2 3	44. DOWNHEARTED....	0 1 2 3	68.GLOOMY.................	0 1 2 3
21. KINDLY................	0 1 2 3	45. AGREEABLE..........	0 1 2 3	69.AFFECTIONATE......	0 1 2 3
22. FATIGUED............	0 1 2 3	46. SLUGGISH.............	0 1 2 3	70. DROWSY................	0 1 2 3
23. BOLD.....................	0 1 2 3	47. FORCEFUL.............	0 1 2 3	71. SELF ASSURED.....	0 1 2 3
24. EFFICIENT............	0 1 2 3	48. ABLE TO concentrate	0 1 2 3	72. MENTALLY ALERT..	0 1 2 3

Appendix C

The PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each of the items and mark the appropriate answer with a tick underneath the category to which you feel right now, that is, at the present moment. Use the following scale to record your answers.

	1	2	3	4	5
	very slightly or not at all	a little	moderately	quite a bit	extremely
INTERESTED					
DISTRESSED					
EXCITED					
UPSET					
STRONG					
GUILTY					
SCARED					
HOSTILE					
ENTHUSIASTIC					
PROUD					
IRRITABLE					
ALERT					
ASHAMED					
INSPIRED					
NERVOUS					
DETERMINED					
ATTENTIVE					
JITTERY					
ACTIVE					
AFRAID					

Academic Secretary
Miss F. M. Aiken

UNIVERSITY
of
GLASGOW

FMA/jr

23 October 1997

Ms Stephanie Tibbert
Postgraduate Student
c/o Dr N Mutrie
IBLS
64 Oakfield Avenue

Dear Ms Tibbert,

Comparison of exercise durations and intensities on mood states: a test of the thermogenic hypothesis

Thank you for submitting this proposal to the Ethics Committee for Non-Clinical Research Involving Human Subjects. I am pleased to inform you that the Committee has approved this submission by correspondence. There was only one comment they wished to make: you identify in the submission two elements which could be perceived as having a risk factor, but you make no reference to the possible risk factor in the consent form. You may wish to consider including a sentence about this, but we do not need to see the modified information sheet.

I hope your project is successful.

Yours sincerely

Fiona Aiken

Copy Dr N Mutrie

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Appendix E

Study 3 Acute exercise study

<u>Testing procedures</u>

Subjects will be asked to complete one maximal test and then 10 sessions of varying content.

<u>Maximal test</u>

The maximal test will be carried out in the Sport and Exercise Laboratory in the Kelvin building at the University of Glasgow. Subjects will be asked to warm up at 25watts for 5 minutes before commencing the test. The initial starting intensity will be 50 watts for women and 100 watts for men; speed will be set at 50 revolutions per minute for the whole session. Heart rate and Rating of Perceived Exertion will be recorded every minute throughout the test. The intensity of the exercise bout will increase by 25 watts for women and 50 watts for men after the heart rate has steady stated (i.e. heart rate must be within 5 beats of last minutes reading). The subject will continue to cycle until he or she cannot maintain the pace or is exhausted. As with any maximal test there is a slight cardiovascular risk, but each subject's progress will be monitored throughout the test and a doctor will be on call if for the procedure. At all times in the laboratory a qualified first aider will be present. Participants can withdraw from testing at any time, as participation is entirely voluntary. If there are any questions concerning the test do not hesitate to ask.

Testing phase

The testing phase will be made up of 10 sessions each lasting up to an hour. The first is a familiarisation to the testing environment, rectal temperature probe and PANAS questionnaire. Each subject will be asked to cycle for 10 to 15 minutes during this session to check heart rate for low, moderate and high intensity heart rates.

Subjects are required to leave one hour for each testing session on the same day and time of each week for 9 weeks. The sessions will be made up of a mixture of quiet rest for short (10 minutes), medium (20 minutes) and long (40 minutes) duration and exercise bouts mixed with the three duration's with low (45 - 55% Hrmax), moderate (65 - 75% Hrmax) and high (80 - 89% Hrmax) intensity exercise. Before and after each session PANAS and core temperature will be measured. The condition the subject will be involved in will be revealed after completion of the initial PANAS and core temperature measurements.

As above subjects can withdraw at anytime throughout the study and questions are welcomed. Throughout each exercise session heart rate and RPE will be monitored to minimise any slight cardiovascular risks. A qualified first aider will be in the building at all times of research.

I______________________ give my consent to the procedures outlined to me, the nature and purpose plus possible consequences of which have been fully explained to me.

Signed ___________________________ Date __________________________

Appendix F

Stages of Change in Physical Activity

Moderate or vigorous physical activity is sufficient to make you slightly breathless and sweaty for 20 minutes. An example of a moderate activity is brisk walking. Consider any activity similar to this or requiring more exertion that lasts for 20 minutes or more.

Please tick one box next to the statement that is most appropriate for you.

1. I currently do no moderate or vigorous activity and have no plans to do so in the next 6 months. ☐

2. I currently do no moderate or vigorous activity but plan to in the next 6 months……………………
   - (a) though not in the next 30 days. ☐
   - or (b) and within the next 30 days. ☐

3. I currently participate in moderate or vigorous activities regularly (2-3 times per week)……………………
   - (a) I started within the last 6 months. ☐
   - or (b) I started more than 6 months ago ☐

4. I have participated in moderate or vigorous activities at some time in the past 6 months but have not done so recently ☐

Boxes ticked above represent the following stages of readiness to change: 1, Pre-contemplation; 2a, Contemplation; 2b, Planning; 3a, Action; 3b, Maintenance; 4, Relapse