‘Does nasal breathing affect exercise tolerance?’

Gemma Cox
Jenna Baxter, Michelle Lock, Charlotte Mock, Vicky Phillips and Sandy Thomas

UNIVERSITY OF THE WEST OF ENGLAND
Bristol

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Abstract

Objectives: Nasal breathing is advocated for asthmatics to reduce symptoms of exercise induced asthma (EIA) however the effects on exercise tolerance are relatively unknown. This study will provide baseline data into the effects of nasal breathing on exercise tolerance using healthy participants.
Design: A preliminary experimental within-subject design.
Setting: St. Matthias Gymnasium**,** University of the West of England, Bristol.
Participants: Twelve voluntary undergraduate students (8 males and 4 females, mean age 22.75 years) free from asthma.
Method: Participants completed the 20m Multi-stage Shuttle Test (MST) on two separate occasions, once nasal and once oral-nasal breathing with the order being randomised.
Outcome measures: Maximum oxygen consumption (VO_2peak) was measured for exercise tolerance, calculated from number of shuttles reached. Subsidiary measures of end-tidal carbon dioxide ($ETCO_2$), oxygen saturation of arterial blood (SaO_2,) respiratory rate (RR), blood pressure (BP), heart rate (HR) and the Borg perceived rate of exertion.
Results: Exercise tolerance was significantly lower with nasal breathing when compared to oral-nasal breathing ($p<0.05$).
Conclusion: The methodology was found to be acceptable to predict exercise tolerance in healthy subjects. The results of this preliminary study provide data to power a larger study and suggest that exercise tolerance decreases with nasal breathing.

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Introduction

Background

Asthma is an increasing health problem which is placing a huge economic burden on the NHS. Whilst there is support for alternative asthma treatments, critics have highlighted that few controlled studies have been undertaken to confirm their effectiveness (Cooper *et al*, 2003). It has been argued by Keeley and Osman (2001) that there is ‘no good evidence that breathing therapy benefits patients with asthma’ (p.1076). If alternative treatments for asthma are to be validated, further research is required. This includes whether breathing techniques can effectively be employed during exercise and if nasal breathing affects exercise tolerance, something that this study will examine in further detail.

The United Kingdom (UK) has one of the highest rates of people with asthma of any country in the world (Asthma UK, 2004) and is reaching epidemic proportions (Kellett and Mullan, 2002). In the UK alone, 5.1 million people are affected by this chronic respiratory disease (Bishop *et al*, 2007). With so many people affected by asthma the economic burden of the disease is enormous. Asthma is costing the UK over £2.3 billion a year (Asthma UK, 2004) with 83% of this amount being spent on medication (Kellett and Mullan, 2002). Due to the scale of the problem and economic cost there is an increasing emphasis on understanding asthma and its long term management solutions.

Asthma is a complex respiratory disease characterised by acute exacerbations of bronchoconstriction associated with airway inflammation and airway smooth muscle hyper-responsiveness (Kairaitis *et al*, 1999). The exact aetiology of the disease remains controversial (Kellett and Mullan, 2002) although genetics, allergens and climate are possible explanations (Pryor and Prasad, 2002). Research is currently being undertaken into possible links between asthma and paracetamol use (Shaheen, 2008) which if proven may have important future implications for asthma prevention.

Mechanisms of ventilation are possible contributing factors to the pathogenesis of asthma. When at rest, Kairaitis *et al* (1999) believe both healthy people and asthmatics breathe nasally, while Bishop *et al* (2007) state asthmatics breathe either oral-nasally or orally. They argue this often leads to hyperventilation or over-breathing; an abnormal breathing pattern which is referred to as hyperventilation syndrome or dysfunctional breathing. Research indicates that a third of women and a fifth of men with asthma are dysfunctional breathers (Thomas *et al*, 2001). However, the similarity in symptoms between asthma and hyperventilation syndrome mean that numerous asthmatics maybe misdiagnosed (Keeley and Osman, 2001, p.1075).

Many asthmatics experience acute exacerbations of their symptoms during exercise, known as exercise-induced asthma (EIA). EIA refers to transient narrowing of the airways that follows exercise (Anderson and Daviskas, 2000). As seen in hyperventilation syndrome, EIA is possibly triggered by increased ventilation, exaggerated in cold or dry conditions (Pryor and Prasad, 2002). The prevalence of EIA in asthmatics ranges from 70% (Anderson and Holzer, 2000) to 90% (Nish, 2005, McKeown, 2005). Patients with asthma should not avoid exercise, as the benefits gained from improved aerobic fitness have been shown to outweigh the provocation of symptoms and thus regular exercise is encouraged in the management of asthma (Morton *et al*, 1995).

As the benefits of exercise outweigh the risks of EIA, the physiological mechanisms which lead to EIA need to be addressed as they may hold the key to tackling this condition. The precise mechanisms of how 'over-breathing' leads to EIA have caused debate in the literature. One theory argues that EIA is the result of 'dehydration injury' caused by increased ventilation (Anderson and Holzer, 2000, p.419). When water loss combines with decreased temperature in the respiratory tract, mast cells release mediators. This induces bronchialoedema and bronchospasms (Pryor and Webber, 1998) resulting in the common symptoms of EIA of coughing, wheezing and chest tightness (Nish, 2005). According to Anderson and Holzer (2000) (cited in McKeown, 2005) the greater the volume of ventilation, the greater the water loss and cooling of the airways and thus the greater the severity of bronchoconstriction.

An alternative explanation for EIA concerns the physiological alterations in blood gases in response to exercise, in particular that of carbon dioxide (CO_2). It has been claimed that 'hyperventilation is synonymous with hypocapnia' (Pryor and Webber, 1998 p.449). The normal range for the partial pressure of CO_2 in arterial blood ($PaCO_2$) is between 35-45 mmHg/ 4.7-6.0 kPa (Hough, 2001). CO_2 is a known bronchodilator and acts directly on airway smooth muscle (Al-Delaimy *et al*, 2001; Bruton and Clark, 2004). Increased ventilation causes a reduction in $PaCO_2$ levels due to the body 'blowing off' excess CO_2 and thus often results in an episode of bronchoconstriction and EIA. This was explored by Van Den Elshout *et al* (1991) who confirmed that hypocapnia increases airway obstruction in asthmatics, but not in healthy subjects, even when water and heat loss were prevented. This directly challenges the dehydration injury theory.

The conflicting debates surrounding the aetiology of EIA and asthma are reflected in the management of the disease. There is currently no cure for asthma and treatments are aimed at controlling EIA or relieving symptoms (Bishop *et al,* 2007). Whilst medication is the mainstay of asthma management, alternative treatments are being sought. This includes breathing techniques which are well established in Eastern and Western societies (Holloway, 2004) and generally focus on manipulating the respiratory pattern to reduce respiratory frequency and hyperventilation (Thomas, 2003). It has been claimed that 30% of asthmatics use breathing retraining techniques in an attempt to alleviate their symptoms (Ernst, 2000). This figure indicates the popularity of alternative asthma treatments to drug therapy.

Physiotherapists teach patients breathing control and sputum clearance techniques to self-manage asthma (Thomas, 2004). Critics claim these physiotherapy techniques may have adverse effects on asthmatics due to the encouragement of deep breathing, which may cause the patient to hyperventilate and provoke their symptoms (Stalmatski, 1997). Other techniques aimed at reducing asthmatic's ventilation have been shown to result in significant improvement in quality of life (Thomas, 2004) and have grown in popularity. One such treatment is the Buteyko Breathing Technique

(BBT) which gained popularity in the UK after the BBC dedicated its QED ‘breathless’ programme to the treatment (BBC, 1998).

The BBT was developed in Russia by the late Professor Buteyko and is based on the theory that overbreathing is the root cause of asthma (Stalmatski, 1997). The BBT ‘package’ teaches patients to ‘under-breath’ through breath control and breath holding while eliminating hyperventilation. Research has indicated that the BBT reduces minute ventilation after 3 months of practice (Bowler *et al*, 1998). ‘Under-breathing’ will effectively normalise the body’s CO_2 levels, eliminate bronchospasms and the need for bronchodilators and anti-inflammatory medication (Kellett and Mullan, 2002).

Another important aspect of the BBT in assisting under-breathing is the focus on breathing through the nose. The benefits of nasal breathing are well known in terms of improved inspired air by humidification, warming and the filtering of allergens and pollutants (Bishop *et al,* 2007). While the nose plays an ‘important frontier role’ in protecting the lower airways from unconditioned air (Bjermer, 1998, p.26), it has the advantage of increasing airway resistance (Hough, 2001), thereby aiding the body in retaining CO_2. Thus it has been claimed that EIA can be modified by altering the route of breathing (Kairaitis *et al*, 1999) and this could have important implications for the treatment of asthma if proven to be true.

Literature Review

The volume of relevant studies relating to nasal breathing and exercise tolerance are somewhat limited nevertheless a critical examination of the literature will help to direct the focus of the present study.

Bishop *et al* (2007) conducted a preliminary study examining the effects of nasal breathing on end tidal CO_2 ($ETCO_2$) at rest, using subjects with mild asthma. The authors concluded that $ETCO_2$ increased in asthmatics during nasal breathing, particularly in those who normally breathe through their mouth. The study collected data from participants instructed to relax and 'breathe normally' and provides valuable data to support the theory that nasal breathing helps to maintain higher levels of CO_2. The present study will determine whether similar increased CO_2 levels are found in subjects who are nasal breathing whilst exercising. The external validity of Bishop *et al*'s (2007) study may be affected by the small sample size (N=9) and the lack of 'blinding'. The breathing conditions not being randomly assigned also gave potential for the 'practice effect' (Hicks, 1992). It is for this reason that the present study will randomise breathing routes to minimise bias and have a larger sample size to increase validity.

The randomisation of breathing routes to prevent a 'practice effect' was also used by Al-Delaimy *et al* (2001) whose study attempted to explain the positive effects of the BBT on asthma. Al-Delaimy *et al* (2001) exercised asthmatics on a treadmill breathing 3% CO_2 and concluded that breathing 3% CO_2 did not prevent EIA. However, their results indicated that CO_2 did have a direct relaxant effect on the airways. This needs further investigation due to the possible implications for asthma management. Unlike Bishop *et al* (2007), the study increased its internal validity by 'blinding' both the participants and the researchers. Based on the findings of a previous study, Al-Delaimy *et al* (2001) claimed that breathing 6% CO_2 was needed to abolish EIA, which could also be achieved by several minutes of profound voluntary hypoventilation. The present study will use nasal breathing to measure the impact on CO_2 levels whilst exercising to see whether this mode of breathing can achieve CO_2 levels greater than 6%. If found, this data maybe used as supporting information by advocates of nasal breathing for the reduction of symptoms of EIA.

Using the same mode of exercise as Al-Delaimy *et al* (2001), Morton *et al* (1995) studied the level of physical intensity that healthy subjects could achieve via different routes of breathing, whilst running on a treadmill until volitional exhaustion. The study compared mouth-only, nose-only and mouth plus nose breathing to determine how the maximal oxygen consumption (VO_2max) varied with each breathing route. It was concluded from the data that there was a 'significantly' greater reduction in ventilation in nasal breathers, when compared to other routes of breathing. This decrease in ventilation for nasal breathers was three times the decrease in VO_2max. The variations in results between oral and oral-nasal breathing were marginal and for this reason the present study will only compare nasal and oral-nasal breathing.

The results from Morton *et al*'s (1995) study indicate that nasal breathing encourages subjects to 'under-breath' shown by a reduction in minute volume (MV). This reduction was due to nasal breathers having a reduced respiratory rate (RR), as no change was noted in tidal volume (TV). Morton *et al* (1995) also observed evidence of hypoxaemia and hypercapnia in nasal breathers after maximum exercise, which was attributed to the decrease in MV. The findings of hypercapnia support the theory put forward by Buteyko that nasal breathing helps to maintain CO_2 levels (Stalmatski, 1997) and CO_2 will be measured for comparisons by the present study.

Morton *et al* (1995) theorised that although a reduced MV affects blood gases, there were simultaneous compensatory mechanisms taking place. A combination of the reduced RR and unaltered TV allowed for a relative increase in diffusion time of blood gases, helping to preserve homeostasis. However, this increased diffusion was not sufficient to compensate for the overall affect of decrease MV on blood gases. Morton *et al* (1995) were unable to confirm that nasal breathing facilitates the oxygen saturation of arterial blood (SaO_2) due to exclusion of SaO_2 as an outcome measure. This gap in the data will be addressed in the present study with the use of SaO_2 as an outcome measure.

There appears to be discrepancies within the research on VO_2max levels when nasal breathing while performing differing modes of exercise. A study by Michailow (1976) (cited in Morton *et al*, 1995) investigated the possibility of nasal breathing during intensive muscle work and is cited indirectly as it is in German. Michailow (1976) (cited in Morton *et al*, 1995) used a cycle ergometer and found a 33.3% reduction in VO_2max in nasal breathers as opposed to oral breathers. Morton *et al* (1995) however only observed a 10.3% reduction in VO_2max from oral to nasal breathing when running on a treadmill. This disparity in the results may be attributed to the differing modes of exercise and the intensity at which the test were conducted. The present study will address this inconsistency by comparing the effects on VO_2max of nasal and oral-nasal breathing using the 20m multi-stage fitness test (20m MST) to determine exercise tolerance. This offers a pre-determined incremental test which could lead to a more consistent method of assessing VO_2max and allow a larger comparable range of data. The present study will examine the feasibility of using the 20m MST as a field test while nasal breathing.

The present study will also establish whether an aerobic training effect can be achieved while nasal breathing and completing the 20m MST. This would support the findings of Morton *et al* (1995), who concluded that subjects could achieve an aerobic training effect whilst breathing nasally and running on a treadmill. This 'effect' refers to increased cardio-respiratory endurance and has implications for asthmatics wishing to increase their cardiopulmonary fitness while employing nasal breathing to prevent the symptoms of EIA (Morton *et al,* 1995).

Existing research on the physiological effects of nasal breathing employ a variety of methodological techniques, including mouth taping (Bishop *et al*, 2007; Morton *et al*, 1995) and face masks (Morton *et al,* 1995; Michailow, 1976 (cited in Morton *et al*, 1995); Kairaitis *et al*, 1999). Kairaitis *et al* (1999) studied routes of breathing in both healthy and asthmatic patients. The internal validity of this study was increased due to the 'blinding' of all participants and by the use of a control group to allow comparisons. According to Kairaitis *et al* (1999) healthy subjects usually breathe exclusively via the nose when wearing a face mask. Conversely, asthmatics switch from nasal to oral-nasal breathing when wearing a face mask, due to increased airways resistance and increased ventilatory demand (Kairaitis *et al,* 1999). As Kairaitis *et al* (1999) employed asthmatic subjects, the use of face masks may have affected the validity of their results. Morton *et al* (1995) used healthy subjects and thus the use of face masks should not have affected their outcomes. It is hoped that the present study will be used to power future research using asthmatic participants so face masks were deemed inappropriate to in order to prevent future limitations.

The current literature points to nasal breathing having an impact on exercise tolerance but further research is required to confirm these claims, using a different mode of exercise. There are indications that altering breathing routes can impact on blood gases, particularly CO_2**,** which again needs further confirmation. The existing evidence also suggests that it is possible to reach an aerobic training effect while nasal breathing and running on a treadmill. There is a gap in the literature as to whether this effect can be achieved while nasal breathing and using a different mode of exercise.

Rationale

The literature has highlighted specific areas which need addressing in order to gain a greater understanding of the relationship between nasal breathing and asthma.

The focus of this study will be to compare how nasal breathing effects exercise tolerance. Whilst it would seem logical to use asthmatic participants in this study, given that nasal breathing is taught to asthmatics to help control their symptoms, there is a dearth of baseline data as to the physiological outcomes of nasal breathing on healthy subjects. This piece of research will be a preliminary study to identify the impact of nasal breathing on exercise tolerance using healthy individuals free from respiratory disease. The wider implications of whether a training effect can be achieved whilst nasal breathing and the effects on blood gases will also be addressed.

It is hoped that the data collected from this focused study will provide information to power future research into the effects of nasal breathing on exercise tolerance in asthmatic subjects. This knowledge will be useful to physiotherapists when prescribing exercise to asthmatics fearful of provoking EIA. With the prevalence of asthma increasing, it is anticipated this information could improve the quality of life for people with asthma, reducing their need for drug therapy and offering more efficient and cost-effective physiotherapy management.

Main aim and research question

1. Does nasal breathing affect exercise tolerance?

Hypothesis

H_o – There is no difference on exercise tolerance between nasal breathing and oral-nasal breathing.

H_1 – There is a difference on exercise tolerance with nasal breathing

Subsidiary aims

2. Is it possible to achieve an aerobic training effect while breathing only nasally?
3. What affect does nasal breathing have on blood gases when exercising at maximum intensity?
4. Is it feasible to use the 20 MST as a field test while nasal breathing?

Method

Research Design

This piece of research was a quantitative primary data collection using a preliminary experimental within-subject design. This design was chosen to eliminate the distorting effects of individual subject difference (Hicks, 1992).

Methodological Considerations

Familiarisation session rationale:

Participants attended a session to practice the 20m MST while nasal breathing and to improve their test accuracy (ACSM, 2001). This decreased the potential of a 'practice effect' (Hicks, 1992) seen by Leger and Lambert (1982). Participants signed consent forms (Appendix 1) and health questionnaires (Appendix 2) and were given the opportunity to ask questions.

Mouth taping rationale:

It was initially planned to use mouth taping to ensure that participant's were nasal breathing. This practice is supported in the literature to no adverse effect (Morton *et al*, 1995; Bishop *et al*, 2007; Stalmatski, 1997). Unfortunately, this proposal was denied by the UWE Faculty of Health and Social Care Ethics Sub-Committee (Appendix 3). Thus the research took place by asking participants to voluntarily keep their mouth closed and inform us when they could no longer continue.

Procedure rationale:

The most valid physiological indicator of cardiovascular function is a laboratory determination of the maximal oxygen uptake (VO_2max) (Cooper *et al*, 2005). VO_2max is the highest amount of oxygen an individual can consume while performing dynamic exercise. VO_2peak is the maximal VO_2 observed during a specific exercise test (Pryor and Prasad, 2002). VO_2peak is the gold standard for assessing exercise tolerance (Vanhees *et al*, 2005) and was the main outcome measure for this study. Laboratory experiments require expensive equipment which was unavailable for this study and so the 20m MST was used. This field test has been identified as a reliable, repeatable, valid and cost effective measure to predict maximal aerobic capacity (Leger and Lambert, 1982; Freeman *et al*, 1990; Ahmaidi *et al* 1993; Cooper *et al*, 2005; Lamb and Rogers, 2007). The 20m MST aims to stimulate a continuous incremental exercise test to volitional exhaustion (Cooper *et al*, 2005). The number of shuttles reached by the participant relates directly to the exercise intensity and is used as a prediction of maximal aerobic power (Leger and Lambert, 1982).

Standardisation rationale:

- Time between tests: Participants had 7 – 14 days between tests, depending on availability. One week allows for adequate recovery from delayed onset of muscle soreness (DOMS) and muscle stiffness (Appell *et al*, 1992). Research has shown that the 20m MST is highly reproducible one week apart (Leger and Lambert, 1982).

- Order randomisation: To counterbalance the design and to prevent a practice effect, it was ensured the order of the test was randomisation (Hicks, 1992). Participants picked one of two envelopes containing either 'nasal' or 'oral-nasal' breathing. This dictated which breathing route would be employed on the first test. On the subsequent visit, the participant performed the test using the alternative route of breathing.

- Positioning standardisation: Researchers 3 and 4 stood half way along and either side of the 20m line to closely observe the nasal breather's faces to ensure their mouths were closed. This increased the study's reliability. Researchers 1 and 2 stood at either ends of the line to ensure that the participants reached the line before the next beep.

- Motivational comments: Motivational comments were consistent to ensure validity of the results. At the end of each level, researcher 3 shouted '*Well done! Keep going*!' and for nasal breathers added '*Keep your mouths closed*!'

- Standardisation of results: Participants were not informed of their scores until both 20m MST were completed to prevent any potential bias of results.

- Calculation of VO_2peak: An estimation of VO_2peak was obtained from the final level and the number of shuttles completed using table of predictive values (Freeman *et al*, 1990). For those levels not stated, the level reached was consistently rounded up to the next VO_2peak, as advised by the research supervisor.

- Standardisation of runners: Whilst an advantage of the 20m MST is that it can assess large numbers of subjects simultaneously (Leger and Lambert, 1982; Cooper *et al*, 2005). Due to spatial and time constraints the participants ran in pairs.

Subsidiary outcome measures rationale:

Blood pressure (BP) – Checked for safety reason to ensure within normal parameters - systolic/ diastolic: 95/60 and 140/ 90 mmHg (Pryor and Prasad, 2002).

Oxygen saturation of arterial blood (SaO_2) - Taken by an oximeter probe on the index finger to address the subsidiary aim of the effect of nasal breathing on blood gases.

Heart rate (HR) – Measured by oximeter probe to give additional information on:

1. Whether participants achieved an aerobic training effect, calculated as 55-90% of maximum HR (ACSM, 2001).

2. Whether the participants were working to their maximal intensity, as 100% maximal HR is equal to 100% VO_2peak (McArdle *et al*, 2001).

The maximum HR was expressed as a percentage of the predicted maximum HR (220-age) (Miller *et al*, 1993***;*** Freeman *et al*, 1990). While research questions the reliability of this calculation due to individual discrepancies (Robergs and Landwehr, 2002;

Gellish *et al*, 2007; ACSM, 2006), there is controversy surrounding alternative techniques. Therefore this version was used as it is the most standardised, allowing comparisons to other studies such as Morton *et al* (1995).

End tidal carbon dioxide ($ETCO_2$) – Whilst the gold standard for measuring CO_2 levels is arterial gas analysis (Bruton and Clark, 2004) invasive methods were deemed inappropriate for this study, potentially causing anxiety and hyperventilation (Bishop *et al*, 2007). $ETCO_2$ levels were measured non-invasively through expired air via a portable capnometer. This measurement was taken to address the subsidiary aim of the effect of nasal breathing on blood gases.

Respiratory rate (RR) – This measurement was taken to confirm whether nasal breathing resulted in decreased ventilation rates by a portable capnometer.

The Borg scale - The Borg scale of perceived exertion estimates effort, breathlessness and fatigue during physical work (Borg, 1998). In conjunction with HR monitoring (ACSM, 2006), the Borg indicates as to whether the participants actually achieved their VO_2peak (Chen *et al*, 2002).

Equipment

List of equipment and facilities used during the study

• Hall: St. Matthias campus gymnasium, UWE
• 20m MST cassette tape
• Audiocassette player
• Stop watch
• Measuring tape
• Cones, string and tape to mark either end of 20m line
• Blood pressure monitor and cuff with oximeter probe attached Model: Welch Allyn Spot Vital Signs model 42NOB.
• BCI Capnocheck® Capnometer
• Scissors
• Sticky labels
• 2 Envelops containing notes: one saying 'oral-nasal breathing', the other 'nasal breathing'
• Antiseptic wipes
• Facial tissues
• Room thermometer
• Borg scale rate of perceived exertion (Appendix 7)
• Information sheet (Appendix 4)
• Medical screening questionnaire (Appendix 2)
• Consent forms (Appendix 1)
• Data recording sheets (Appendix 6)

• VO_2peak Loughbough Index conversion table (Appendix 8)
• Mobile telephone
• Seating for participants
• First aider with first aid kit on standby
• Drinking water

Table 1

Sample

A convenience sample of 12 (8 males and 4 females, age range 20-27 years) was recruited from 3rd undergraduate Physiotherapy student from the Faculty of Health and Social Care at the University of the West of England (UWE). Being a preliminary pilot study, power calculations were not deemed appropriate to determine sample size and the aim was to recruit a convenience sample of 20 subjects. Whilst 25 students initially signed up to participate, only 12 sets of data were complete due to illness or non-attendance.

The participants were recruited through poster campaigns, emails and promotional talks in lectures. Those students who agreed to participate signed up to 3 different dates (1 familiarisation session and 2x 30 minute data collection sessions) and were emailed an information sheet (Appendix 4) explaining the nature of the research. This information allowed participants to make informed decisions (CSP, 2001) and all volunteers signed a consent form (Appendix 1).

Inclusion Criteria	Exclusion Criteria
Age: 18+ years	Age: male > 45 years, female > 55 years - due to increased risk of cardiovascular complications (ASCM, 2001)
Prepared to complete the 20m MST, exercising maximally on 2 occasions	Unable to attend the familiarization session and 2 subsequent dates
	Unable to breath comfortably via nose only
	Any medical problems indicated from the medical screening questionnaire
	Respiratory tract infection on the day of data collection - due to the necessity of normal pulmonary function for reliable results (Morton *et al*, 1995)
	Musculoskeletal injury or illness on the day of data collections, or 2 weeks prior
	Asthmatics - due to the daily variations in symptoms and pulmonary function (Morton *et al*, 1995). Research has also demonstrated the potential for the 20m MST to provoke EIA (Freeman *et al*, 1990)

Table 2: Inclusion and exclusion criteria of participants

Researcher roles

Researcher	Role
1	• Greeted participants on arrival • Covered health and safety aspects prior to testing (including asking if any health changes from previous session) • Confirmed inclusion/ exclusion criteria • 5 minute warm up of stretches and jogging • Gave tissues to each participant before running • Offered participants refreshments once the test was completed
2	• Checked room temperature • BP, HR and SaO_2 measurements before and after test • Motivational comments after completion of each level
3	• Checked participants names and contact details on arrival • Checked each participant had signed up to 2 subsequent sessions and ensured they were aware at what times • CO_2 and RR measurements before and after test • Borg scale of perceived exertion after test
4	• Supervised signing consent forms and medical screening questionnaires • Documented age and gender of participants • In charge of random allocation of breathing order • In charge of documenting number of shuttles completed • Conversion of shuttles into VO_2peak • Data protection management
5	• Calibrated 20m MST audiocassette tape and play instruction • 5 minute cool down and advice if experience DOMS • First aider and responsible for first aid kit
Research Supervisor	• Asking participants reasons for stopping the test • Rewound and started tape at correct point for each test

Table 3: Researcher roles

Procedure

Familiarisation session:

1. Participants greeted on arrival and taken through health and safety checks (fire exits, toilets, refreshment area, first aider)
2. Participants were asked to sign consent form, medical screening questionnaire and check inclusion/ exclusion criteria.
3. Participants names, ages and contact details were taken and it was ensured each participant had signed up to 2 subsequent sessions and the time confirmed
4. BP measurements taken to ensure within normal range
5. Capnometer readings taken for familiarisation
6. Participants taken through 5 minute warm up
7. The tape was calibrated and instructions played to participants
8. Participants practice the 20m MST to familiarised themselves with nasal breathing while exercising (as previously discussed)
9. Participants taken through 5 minute cool down
10. Participants were given the opportunity to ask questions

Data collection sessions:

1. Participants greeted on arrival: asked if any health changes from previous week; reminded free to stop the test at any time; fire exits, toilets and refreshment area shown and participants reminded that one warning given if beep missed. Temperature of hall taken to ensure a constant 15ºc
2. On the initial test participants picked envelops containing breathing route and were given a sticker stating number and breathing route
3. Instructions for the tape played then rewound to correct place
4. Initial measurements taken (BP, HR, SaO_2, RR and CO_2)
5. Participants taken through 5 minute warm up
6. Participants were given tissues to ensure clear nasal breathing
7. The researchers and participants took their positions (as previously discussed)
8. The participants began the 20m MST running at incremental speeds dictated by the tape, between two points, 20m apart. A single beep denotes the end of each shuttle and three beeps for the start of the next level. The test comprises of 23 levels, each lasting one minute. The starting speed is 8.5km/hr which increases by 0.5km/hr at each level.
9. Motivational comments given at the end of each level (as previously discussed)
10. The number of shuttles reached was recorded
11. The test was stopped either by the investigator when the participant could not keep up with the prescribed pace or by the participant when they could not keep up (Freeman *et al*, 1990).

12. Nasal breathers were encouraged to continue breathing nasally once the test was finished and were shown to a seat and offered tissues
13. Initial measurements immediately re-taken plus the Borg scale
14. Participants questioned as to reasons for stopping and advised if any delayed unexplained symptoms to consult with doctor
15. While data was collected, the tape was rewound for the next participants
16. Participants taken through 5 minute cool down
17. The participants were offered refreshments
18. The participants were thanked for taking part

Depending on the level reached, this procedure took 15 to 25 minutes for each subject.

19. Each participant's VO_2peak was calculated using the Loughbough Index standardisation table (Appendix 8) for both breathing routes
20. The data collected was put into graphs using Excel and then into SPSS for statistical analysis

Figure 1: Two participants taking part in the 20m MST test (consent gained).

Figure 2: Researches 3 and 4 collecting data from participant (consent gained).

Ethical considerations

This piece of research was ethically approved by the UWE Faculty of Health and Social Care Ethics Sub-Committee.

The requirement of research projects is to be independently reviewed meets government standards (DoH, 2005). This piece of research conformed to research governance legislation which stated that, 'The dignity, rights, safety and well-being of participants must be the primary consideration in any research study' (p.11).

Participation in this study was voluntary and subjects gave informed consent to take part after reading an information sheet giving detail as to the nature of the research (Appendix 4). Participants were aware they were allowed to withdraw from the study at anytime.

Ethical data protection ensured anonymity of results. Participant names and contact details were taken in case for unforeseen circumstances. To ensure anonymity, each participant was assigned a corresponding number which was documented on a single sheet (Appendix 5) and given to the dissertation supervisor to be locked in a cupboard for a period of 1 year. There was no other record which could link the participants name to their numbers and this ensured ethical protection of participant data (DoH, 2005).

Any potential health risks to participants were reduced by the medical screening questionnaire. Safety of both the participants and the researchers was ensured at all times during his project by the presence of a first aider and health and safety representative. Participants were questioned as to their physical state before and after the test and advice was given if any delayed symptoms were experienced. It was ensured that equipment was kept clean using antiseptic wipes to prevent possible cross contamination of infection.

Computer software

For the statistical analysis of the data, the software packages SPSS for Windows version 15 and Microsoft Excel were used.

Statistical analysis

The method of statistical analysis was decided before completion of this piece of research. To calculate whether the results were normally distributed the Shapiro-Wilk test was to be used, due to the sample size being less that fifty.

If the results displayed a normal distribution, then the parametric t-test was proposed. If the results did not demonstrate a normal distribution, the Wilcoxon test was to be used for statistical analysis of the data.

Results

The study's raw data is shown in Appendix 9.

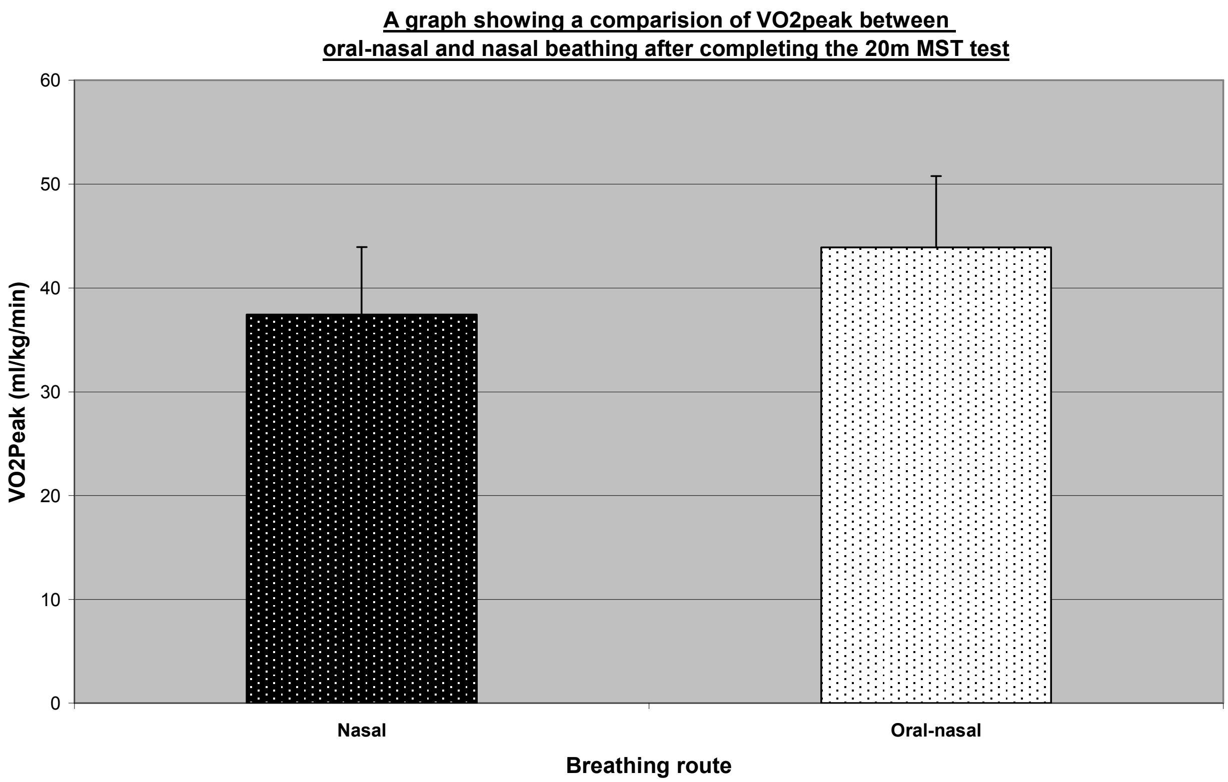

Chart 1

VO$_2$peak:

Normal distribution: The data on VO$_2$peak was tested for normal distribution using the Shapiro-Wilk test. This test was chosen as there were <50 subjects. This test showed that there was no statistically significant difference of the data from the norm ($p>0.05$) and the data can be considered normally distributed. This, when combined with the data being interval in nature, of equal variance and randomly selected participants, allows the use of the parametric paired/related t-test. Parametric testing is preferable due to it being 'more sensitive' than its non-parametric equivalent (Hicks, 1992).

Descriptive: Results comparing VO_2peak mean difference / standard deviation (SD) values for nasal (37.43 / ±6.49) and oral-nasal breathing (43.89 / ±6.86) can be seen in chart 1. Results demonstrate a 14.72% reduction in VO_2peak from oral-nasal breathing to nasal breathing. The range in VO_2peak values were 27.6-48.0 (nasal) and 33.6- 55.4 (oral-nasal). All but 1 of the 12 participants (91.7%) increased their nasal breathing VO_2peak scores when oral-nasal breathing.

There is relatively little overlap between the 2 sets of data, with the SD value for nasal breathing being only slightly higher on the graph than the mean value for oral-nasal breathing. In both breathing routes, the SD is relatively small compared to the mean itself.

Inferential - t-test: The paired sample test reported a statistically significant difference ($p<0.05$) between nasal and oral-nasal breathing on exercise tolerance ($t = 3.634$,

$p = 0.004$, df= 11) and thus the null hypothesis (H_o) can be rejected.

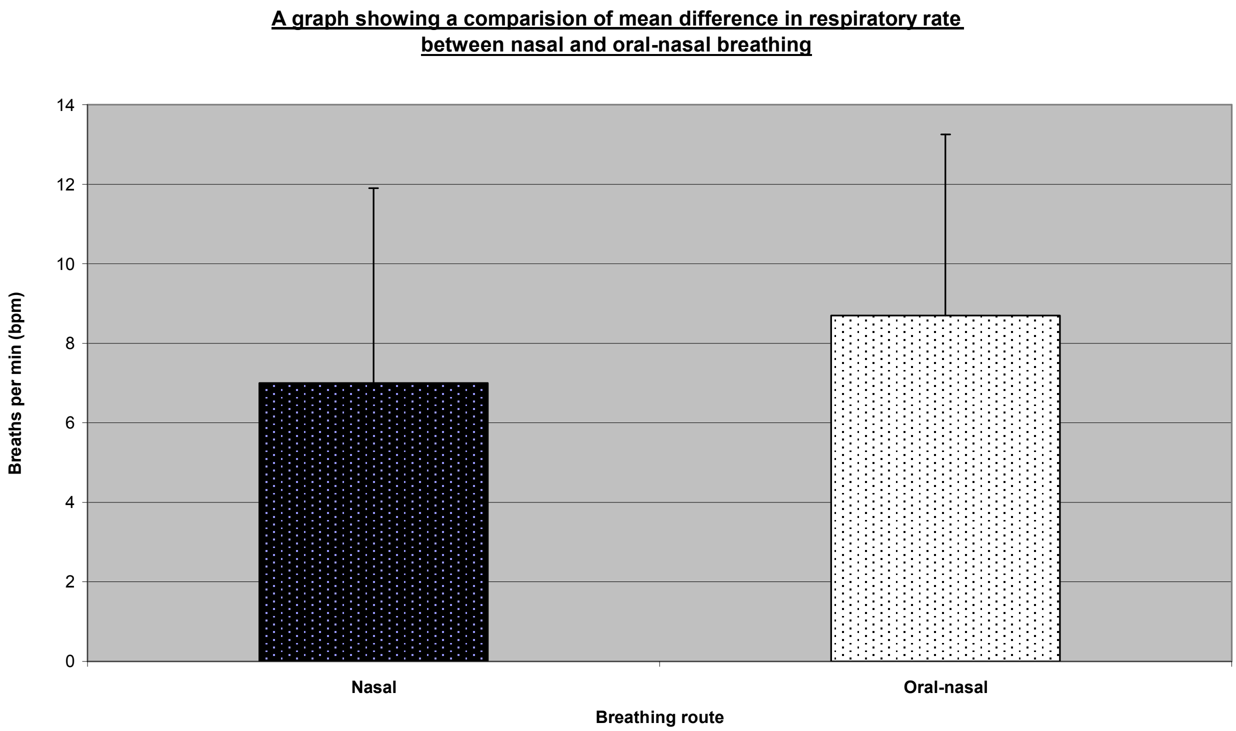

Chart 2

<u>Respiratory Rate (RR)</u>:

Descriptive: Results comparing RR mean difference / SD for nasal (7.0 / ±4.9) and oral-nasal (8.7 / ±4.55) breathing are shown in chart 2. The range of RR pre-test varied little between nasal (6-23 bpm) and oral nasal (5-24bpm) breathing. The range of RR post test was the same in both nasal and oral-nasal breathing (14-30bpm). 1 of the 12 participants (8.3%) decreased their RR from pre- to post test when nasal breathing.

There was a reduction in the mean RR with nasal breathing, when compared to oral-nasal breathing, although both breathing routes had similar SD values.

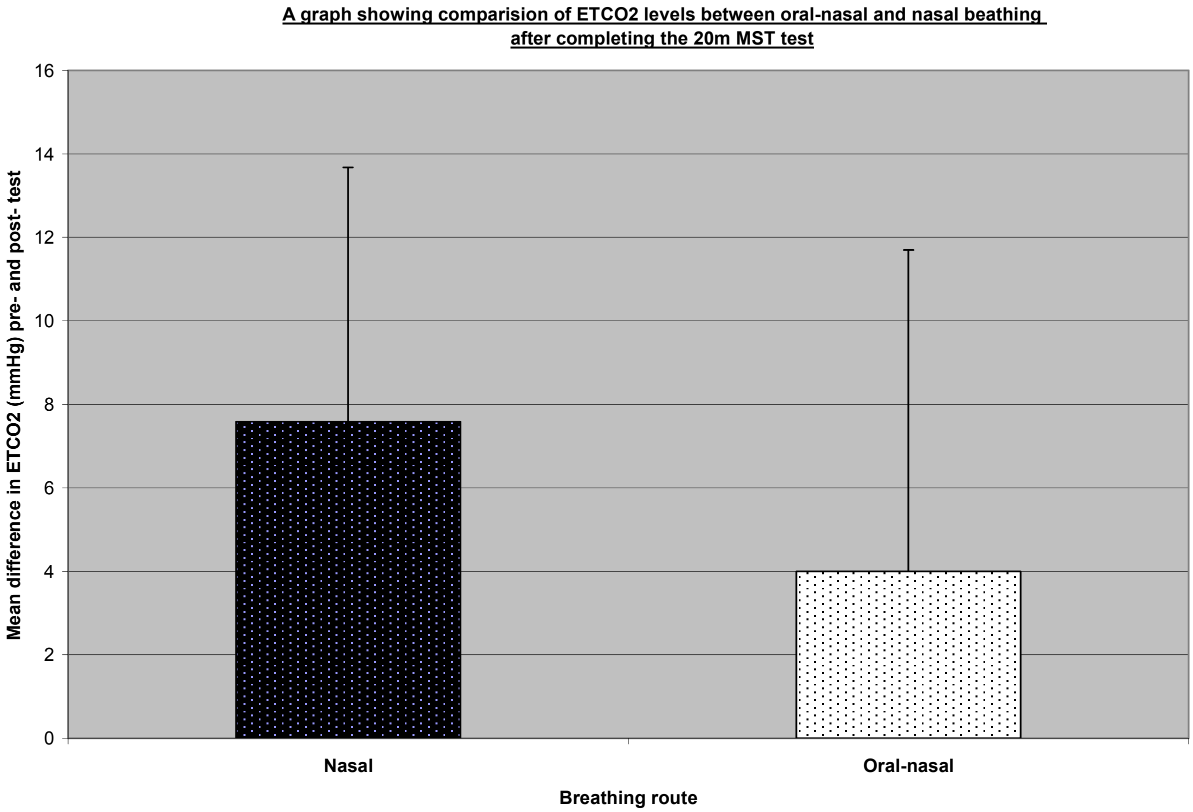

Chart 3

<u>End tidal CO_2 ($ETCO_2$)</u>:

Descriptive: Results comparing $ETCO_2$ mean difference / SD values for nasal (7.58 / ±6.1) and oral-nasal (4 / ±7.69) breathing can be seen in chart 3. The $ETCO_2$ pre-test readings ranged between 36-45mmHg (nasal) and 34-49 mmHg (oral-nasal). Post-test $ETCO_2$ readings ranged between 34-51 mmHg (nasal) and 28-49 mmHg (oral-nasal). 8 of the 12 oral-nasal breathers (66.7%) and 10 of the 12 nasal breathers (83.3%) had an increase in their $ETCO_2$ post- test.

There is a relatively large difference in the mean difference values between the 2 breathing routes, with nasal breathing showing a greater difference pre- to post-test than oral-nasal breathing. The SD was larger for oral-nasal breathing.

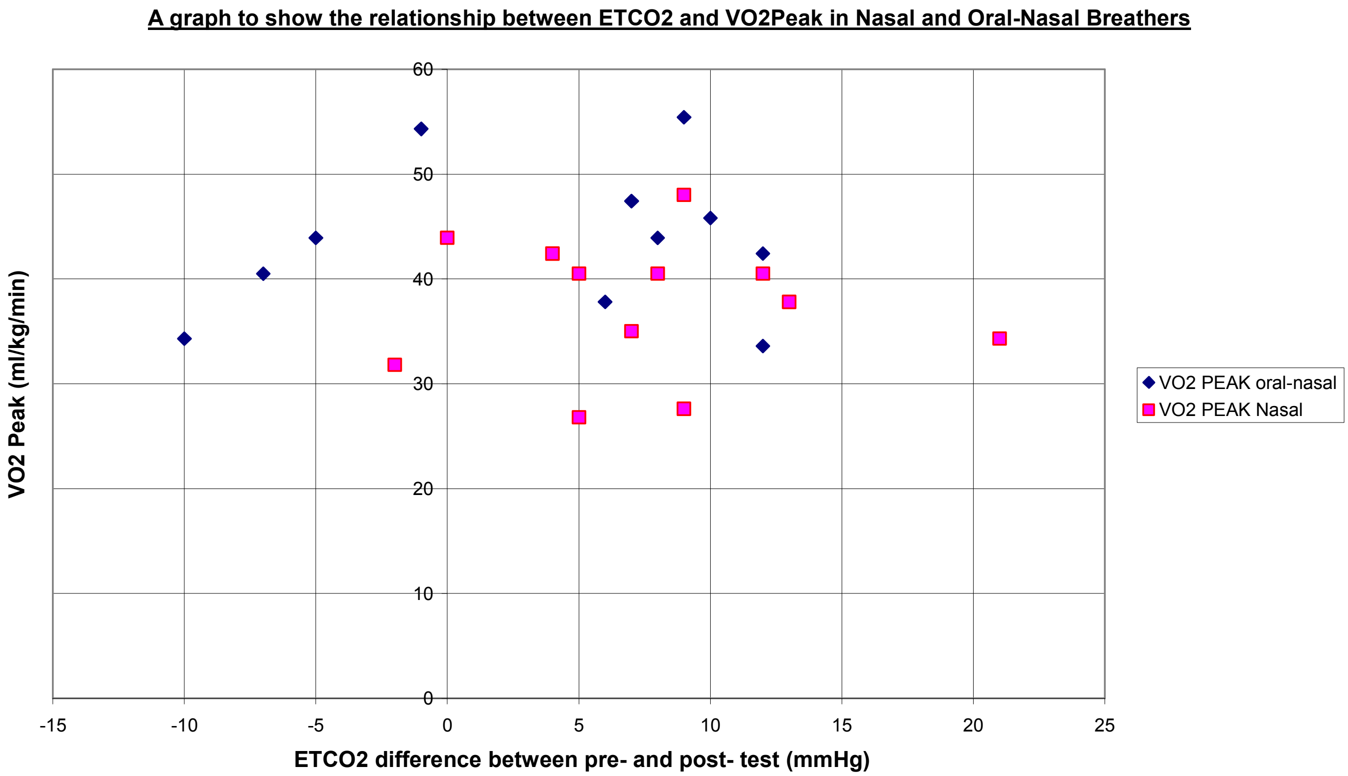

Chart 4

Post hoc inferential: correlation coefficients (of VO_2peak and $ETCO_2$): The Shapiro-Wilk test for $ETCO_2$ showed normal distribution for nasal breathing but not for oral-nasal breathing. To ensure standardisation for both breathing routes the non-parametric Spearman test was used, results shown in chart 4. This test gave the correlation coefficient values for VO_2peak and $ETCO_2$ in nasal breathing ($r= -0.088$) and oral-nasal breathing ($r=+0.099$, $df= 10$). Therefore there is no strong correlation between VO_2peak and $ETCO_2$ in either breathing routes. The test revealed the significance values for nasal breathing ($p=0.760$) and oral-nasal breathing ($p=0.785$)

which also shows that there is not a significant relationship between the 2 breathing routes ($p>0.05$).

There does appear to be a linear relationship within the negative values of $ETCO_2$ for oral-nasal breathers, shown by 4 data points.

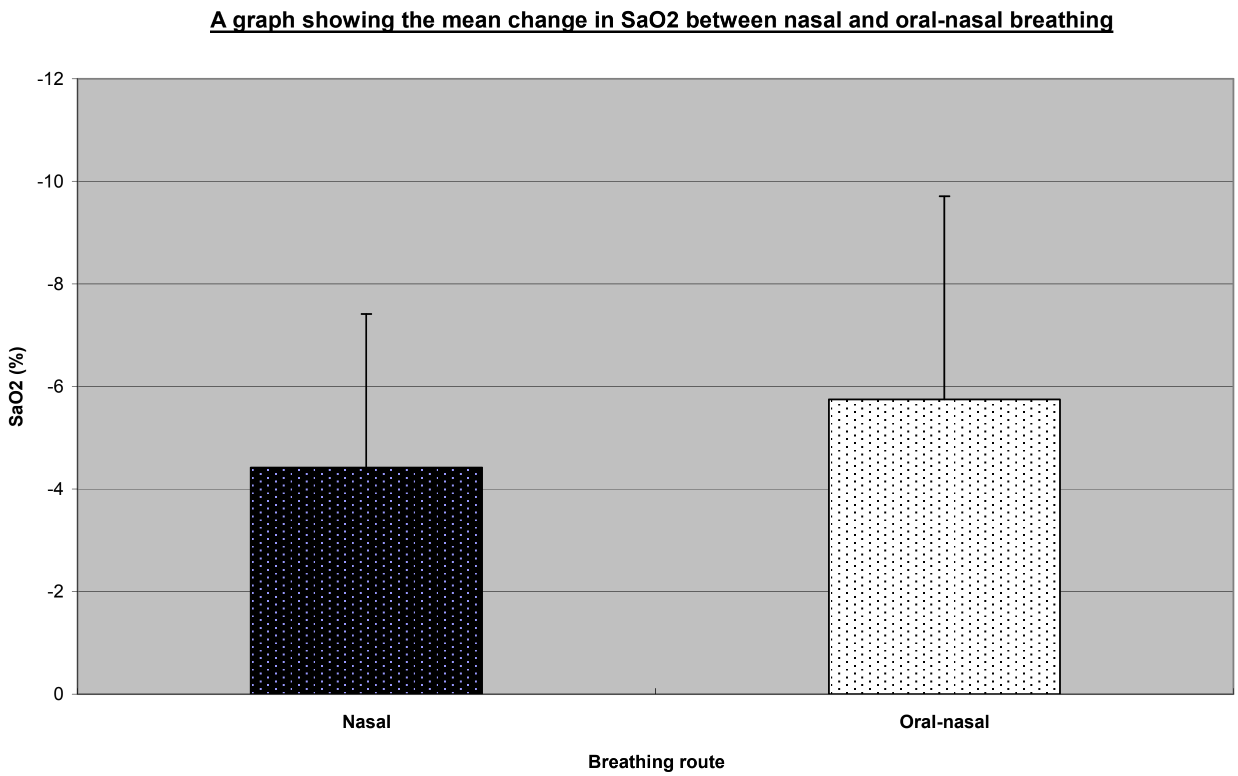

Chart 5

<u>Oxygen saturation of arterial blood (SaO_2):</u>

Descriptive: Results comparing SaO_2 mean difference / SD values for nasal (-4.42 / ±2.99) and oral-nasal (-5.75 / ±3.96) breathing are shown in chart 5. Pre-test SaO_2 readings ranged between 95-100% (nasal) and 96-100% (oral-nasal). Post-test SaO_2 readings ranged between 90-99% (nasal) and 85-100% (oral-nasal). 1 of the 12 (8.3%)

participants in both breathing routes had either a positive mean difference or no change in SaO_2 between pre- and post- test.

There was a greater reduction of SaO_2 mean values in oral-nasal breathing compared to nasal breathing, with a larger SD.

<u>Heart rate (HR)</u>:

Breathing route	Mean (difference pre- & post-test)	SD	Range pre-test	Range post-test
Nasal	63.9	± 9.43	61-112	121-170
Oral-nasal	70.5	± 20.67	57-101	118-168

Table 4: Table showing mean, SD and range of results for HR

Descriptive: HR measures for oral-nasal breathing demonstrated a larger mean variation then nasal breathing with a greater SD value. The participants who were nasal breathing had an increased range of HR when compared to oral-nasal breathers.

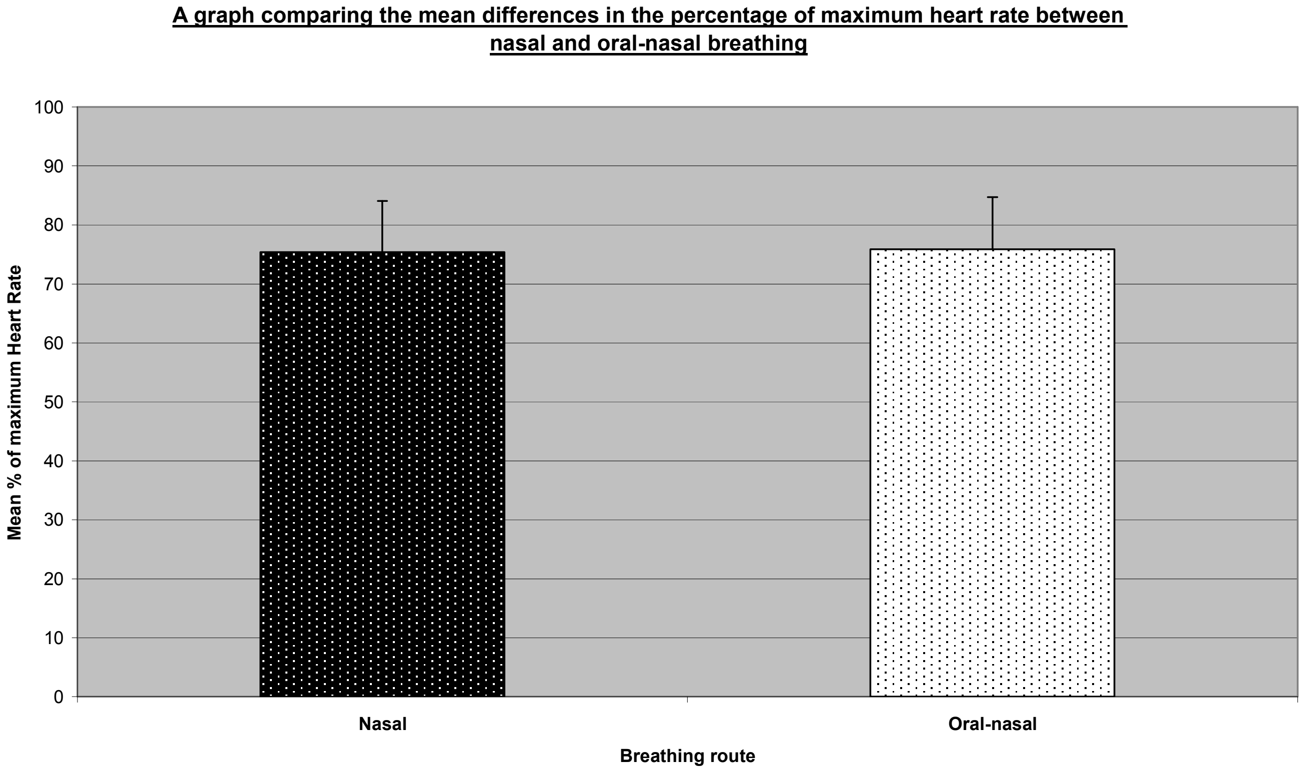

Chart 6

Percentage of maximum HR (%max HR):

Descriptive: Results comparing the %max HR reached (mean / SD) for nasal (75.39 / ±8.67) and oral-nasal (75.87 / ±8.83) breathing can be seen in chart 6. There were similarities in the %max HR in both mean and SD value between nasal and oral-nasal breathing.

Borg:

Breathing route	Mean	SD	Range
Nasal	4.92	± 2.11	2 – 9
Oral-nasal	4.79	± 2.35	1 – 8

Table 5: Table showing mean, SD and range of results for the Borg.

Descriptive: The mean Borg scores for nasal and oral-nasal breathing were relatively similar, as were both of the SD values.

Subjective comments – reasons for stopping:

Appendix 10

Discussion

The main aim of this preliminary study was to examine the effects of nasal breathing on exercise tolerance, measured using VO_2peak. The results in chart 1 show that participants who performed the 20m MST while nasal breathing achieved a lower mean VO_2peak than when oral-nasal breathing. This demonstrates that nasal breathing decreases exercise tolerance when compared to oral-nasal breathing using this mode of exercise and thus the experimental hypothesis (H_1) can be accepted. The parametric t-test confirmed a significant difference between nasal and oral-nasal breathing (p=0.004). When oral-nasal breathing, one participant had a slight reduction in their VO2peak score when compared to nasal breathing. It is speculated that this anomaly was due to the participant being physically tired after playing rugby the previous day.

The results demonstrate a 14.72% mean reduction in VO_2peak from oral-nasal to nasal breathing after completing the 20m MST. This value maybe compared to other studies. Morton *et al* (1995) observed a 10.3% reduction in VO_2peak in nasal breathers when exercising subjects on a treadmill. Michailow (1976) (cited in Morton *et al*, 1995) noted a 33.3% reduction in VO_2peak with nasal breathing when using a cycle ergometer. The discrepancies between the results maybe attributed to the differing modes of exercise. The treadmill and the 20m MST both involved running, which may explain their similarity of results. The present study offers further evidence of a difference in exercise tolerance between nasal and oral-nasal breathing.

The only alterations in the methodology of the data collection sessions were the independent variables of nasal and oral-nasal breathing. Therefore the mechanisms by which breathing routes differ were shown to have a fundamental influence on exercise tolerance. Nasal breathing increases both the airway resistance and the volume of dead space in the respiratory tract (Hough, 2001). This increases the work of breathing and leads to reduced respiratory rate (RR) and hypoventilation. Chart 2 shows that a greater mean reduction in RR was seen in participants who were nasal breathing when compared to oral-nasal breathing. The reduction in rate of ventilation is thus a likely influencing factor as to why nasal breathing negatively affects exercise tolerance.

The reduced RR noted in nasal breathers causes alterations in blood gases. $ETCO_2$ is equivalent to $PaCO_2$ (Bishop *et al*, 2007) and the affects of the different routes of breathing on $ETCO_2$ can be seen in chart 3. The graph shows a greater increase in the mean difference for $ETCO_2$ in nasal breathing than in oral-nasal breathing and therefore it can be seen that nasal breathing facilitates the retention of CO_2. These results support the findings of Morton *et al* (1995) who concluded that nasal breathing encourages the preservation of CO_2. The results also support the Buteyko theory that nasal breathing helps the body to retain CO_2 (Stalmatski, 1997). This maybe explained by the increase in airway resistance, which enforces hypoventilation and thereby prevents the body from 'blowing off' excessive CO_2.

A post-hoc statistical analysis for a correlation coefficient between the mean VO_2peak and $ETCO_2$ values revealed there was no significant relationship between them, as seen in chart 4. In healthy nasal breathers $ETCO_2$ bears no direct relationship to

VO_2peak and subsequently neither to exercise tolerance. Further research is required to discover whether a direct relationship exists between these two factors in asthmatics. Chart 4 appears to show a linear relationship within the negative values of $ETCO_2$ for oral-nasal breathers. This indicates that the more CO_2 'blown off', the lower the exercise tolerance. Speculatively, this is due to RR increasing in oral-nasal breathers, causing hyperventilation. Further studies are needed to examine this trend in asthmatics as this information maybe potentially valuable for advocates of nasal breathing.

A study by Al-Delaimy *et al* (2001) concluded that breathing 6% CO_2 during and after exercise will abolish EIA. The present study found a 19% mean increase in $ETCO_2$ after exercising while nasal breathing when compared to oral-nasal breathing. The body therefore has tripled the recommended 6% increase in CO_2 when exercising and nasal breathing. Following Al-Delaimy *et al*'s (2001) recommendations, nasal breathing has the potential to eliminate EIA and thus has great potential clinical implications.

Nasal breathing increases airways resistance resulting in a decreased RR, lower MV and retention of CO_2 (Morton *et al*, 1995). This mechanism also has an affect on SaO_2 levels. Chart 5 shows the mean difference in SaO_2 for nasal and oral-nasal breathers pre- and post- testing. Both breathing routes saw a decrease in their mean SaO2 value. This is to be expected due to increased oxygen demand when exercising. The graph shows that there was a greater reduction in the mean SaO_2 with oral-nasal breathing, with 4 out of 12 (33.3%) participants dropping their SaO_2 levels below 90%. 1 of these

4 participants dropped their SaO_2 levels from 99% pre-test to 85% post-test. Comparatively, only 1 of the 12 (8.3%) nasal breathing participants dropped their SaO_2 levels to 90%. These results indicate that exercising while oral-nasal breathing can lead to hypoxaemia, defined as reduced oxygen in arterial blood with SaO_2 <90% (Hough, 2001). It has been noted by Hough (2001) that resting PaO_2 values are usually maintained during exercise, even at VO_2max. The disparity in the results of the present study maybe attributed to the method of taking SaO_2 measurements and further research is needed to investigate these atypical findings. Morton *et al* (1995) hypothesised that nasal breathing would increase SaO_2 levels when compared to oral-nasal breathing but were unable to verify this due to not taking SaO_2 measurements. Thus the present study supports their theory.

Both routes of breathing saw a reduction in SaO_2 levels, more so in oral-nasal breathers. Theoretically, the higher SaO_2 values in nasal breathers may have a positive affect on exercise tolerance. It is proposed however that the relative increase in gaseous exchange, bought about by a reduced RR, is not sufficient to compensate for overall effect on blood gases and thus nasal breathing decreases exercise tolerance.

It has been argued by Morton *et al* (1995) that the observed hypoxaemia and hypercapnia in nasal breathers is the direct result of decreased ventilation. Nasal breathing increases airways resistance and reduces MV (Morton *et al*, 1995). TV was not measured in the present study, but based on previous research it maybe speculated that due to increased airways resistance in nasal breathers, MV reduced, thereby increasing diffusion time for gas exchange. To some extent this mechanism was able to compensate for the overall changes in blood gases bought about by nasal breathing, although notable increases in CO_2 were still recorded. Further research is needed to measure the affect of nasal breathing on both RR and TV to confirm Morton *et al*'s (1995) work.

Each participant's HR was taken before and after completion of the 20m MST and the percentage of maximum HR (%maxHR) was calculated. The results can be seen in chart 6. There is little difference between both the mean values for nasal and oral-nasal breathing, suggesting that the %maxHR is not greatly affected by varying breathing routes. A subsidiary aim of this project was to see whether it is possible to achieve an aerobic training effect while nasal breathing. The number of participants who achieved this depends on which value is used in the calculations. The ACSM (2001) states that subjects must be working between 55% - 90% of their %maxHR to achieve a training effect. Using this value, all participants in both breathing groups were successful. Morton *et al* (1995) however state that 65% - 90% of maxHR is necessary to obtain an aerobic training effect. The group's mean results indicate this was holistically achieved. However, both nasal and oral-nasal breathing saw 2 of the 12 (16.7%) participants fail to reach >65% of their %maxHR and therefore individually not all of the participants in either breathing route reached an aerobic training effect. When exercising their subjects on a treadmill, Morton *et al* (1995) found that all subjects could attain a work intensity great enough to produce an aerobic training affect. The disparity between the two studies maybe attributed to the differing modes of exercise, with Morton *et al* (1995) running their participants on an inclined treadmill.

The %maxHR also indicates whether the participants were working to their maximal intensity, which would be 100% of their predicted maxHR (McArdle *et al*, 2001). The results of this study reveal that none of the participants in either breathing groups achieved 100%maxHR. The Borg rating of perceived exertion verifies that participants were not working to their maximum, with the mean score being <5 from the possible 10 scale in both groups (Table 5). Whether the Borg is a true reflection of exertion levels is questionable after studying the participant's reasons for stopping (Appendix 10). While several of the participants claimed they could have kept going, other comments suggest that the participants were working to a greater intensity than the Borg indicates.

The information gained from the Borg allows comparisons of the perceived levels of exertion between the two breathing routes. The mean values of the Borg's results indicate that the participants did not find nasal breathing more challenging than oral-nasal breathing. This is not reflected in the subjective comments (Appendix 10) which show that 8 of the 12 (66.7%) nasal breathing participants claimed they could 'not get enough air'. Breathing via the nose was the most common limiting factor as to why the participants stopped the test and can be seen to affect exercise tolerance.

The subjective comments offer additional explanations as to why the nasal breathing participants had a reduction in exercise tolerance. Nasal breathing while exercising is unnatural to most people and as with anything which is not automatic requires concentration. Participant 11 cited difficulties with concentration as a limiting factor, finding it hard to focus on the turn and keeping the mouth closed simultaneously. This is supported with the comments by participant 9, who stated it was a ‘real effort’ to keep their mouth closed, resulting in feelings of claustrophobia. Similarly, participant 4 claimed that they felt increasingly anxious and less confident while nasal breathing. 10 of the 12 (83.3%) nasal breathing subjects had an increased pre-test HR to when oral-nasal breathing. Speculatively, this could be attributed to feelings of apprehension, stress or anxiety as faced with the unfamiliar task of nasal breathing while exercising.

Limitations**:**

There are limitations in the present study’s methodology which may have affected the results.

Participants were recruited from the 3rd year physiotherapy programme at UWE and this study may have been influenced by volunteer bias, affecting the external validity of the results. The nature of this study made it impossible to blind either participants or researchers and therefore the results may have been affected by subject biased.

It was initially hoped that nasal breathing would be ensured by mouth taping, to test the clinical application of this component of the BBT. As discussed, this was denied by Ethics and the participants were asked to keep their mouths closed while running, closely observed by the researchers. While it is believed that all of the participants were honest and stopped the test when they were unable to continue breathing nasally, the reliability of the method is questionable. This may have implications for future studies wishing to simulate the test.

The method by which participant VO_2peak values were calculated is also a potential limitation of this study. The predictive table used (Appendix 8) stated the conversion for every-other shuttle level reached. As such, those levels which were not given were rounded up to the next level. Although this method was consistent, it may have affected the accuracy of the results.

Each of the participants had measurements taken before the test was completed. The reliability of the pre-test readings would have been increased had procedure standardisation been ensured. There were inconstancies in the time between the arrival of the participants and when their readings were taken. Additionally, some of the participants were standing and others were sitting when these initial measurements were taken, potentially affecting the internal validity of the results. On reflection the participants should have been asked to sit quietly for a period of time, to allow for those who have walked or cycled to recover to resting physiological levels.

Measurements were also taken after participants had completed the test. The intervening time between finishing the test and taking the readings varied slightly between participants and may have affected the internal validity of the results. This may explain variations in the results, such as that seen with SaO_2 where one of the nasal breathing participants increased their reading from 98% to 99%. On one occasion both participants finished almost simultaneously. With only one piece of equipment available, one participant had to wait for measurements to be taken. This increased time may also have affected the results' internal validity. All of the nasal breathing participants opened their mouths once they had stopped running and before the measurements were taken. Although the participants were asked to immediately continue nasal breathing, this may have affected the readings due to oral breathing allowing for increased ventilation and normalisation of blood gases.

It was difficult to ensure standardisation of the methodology throughout this study. Due to participant availability, several of the subjects ran alone rather than in pairs. This could have affected the results due to the influence or absence of competition between the runners. A competitive element was noted particularly when male participants were running together.

Clinical significance and future implications:

Due to the use of healthy participants in this study there are no direct clinical implications for physiotherapists wishing to advocate nasal breathing for exercising asthmatics. However, the results maybe used to power future investigations into the effects of nasal breathing on exercise tolerance in the asthmatic population and therefore this study has indirect clinical significance. If similar findings are seen in asthmatics as in this study, the information will be useful to physiotherapists when prescribing exercise for asthmatics fearful of provoking EIA.

While more participants would have increased the external validity of this study, a statistically significant difference between the independent variables was found using a sample size of 12. This number was therefore adequate and future studies may use the same number of participants to achieve statistically significant results in a similar subject group.

This study showed that while nasal breathing had a negative effect on VO_2peak and thus exercise tolerance, it was still possible to achieve an aerobic training effect while running the 20m MST. This may have clinical significance and requires further research so that patients wishing to improve their physical fitness while still gaining the benefits of nasal breathing can be better informed.

The present study showed that after exercise, healthy nasal breathers had an increased $ETCO_2$ compared to oral-nasal breathers. Further studies are needed to establish whether nasal breathing aids retention of CO_2 in asthmatics while exercising. Once

collected, this information can be used by advocates of the BBT to support the theory linking increased CO_2 levels to bronchodilation.
The results of SaO_2 indicate that several of the oral-nasal breathers were hypoxaemic post-test. There are potential safety implications as prolonged or repetitive hypoxaemia can have serious affects on the brain, gut and liver (Hough, 2001). Further research is needed into possible causes for these results and whether nasal breathing offers a safer alternative means of breathing while exercising.

During data collection, problems were experienced with the BP machine, possibly due to the cuff size. As a result, a 1 hour teaching session on the correct technique will be incorporated into the UWE Physiotherapy programme for 1st year students.

This study has demonstrated the feasibility of the 20m MST as a measure of exercise tolerance. This field test has proved to be practical, cost effective, easy to administer and did not require any specialised equipment. As such, it is recommended that future studies employ the 20m MST when investigating the effects of nasal breathing on exercise tolerance in asthmatic subjects.

Conclusion

This study demonstrates that for healthy subjects completing the 20m MST, nasal breathing has a detrimental affect on exercise tolerance when compared to oral-nasal breathing. One of the key findings of this study however is that it is possible however to achieve an aerobic training effect while nasal breathing. When considering the effect on blood gases, this study also demonstrated that during exercise, nasal breathing results in increased $ETCO_2$ when compared to oral-nasal breathing.

With consideration to the present studies limitations, more rigorous studies are needed to confirm these findings in the asthmatic population. This study has also demonstrated that the proposed methodology and the 20m MST are feasible when studying exercise tolerance in the given population.

The results of this preliminary study provide data to power future studies into the effects of nasal breathing on exercise tolerance using asthmatic subjects. If similar results are found, there are important clinical implications for alternative asthma treatments such as the BBT. With the prevalence of asthma increasing, it is proposed that this information will assist in the evolution of asthma treatment from drug therapy towards more economical and effective physiotherapy management.

Reference List:

Ahmaidi, S., Varray, A., Savy-Pacaux, A and Prefaut, C. (1993) Cardiorespiratory fitness evaluation by the shuttle test in asthmatic subjects during aerobic training *Chest,* 103(4), 1135-1141

Al-Delaimy, W., Hay, S., Gain, K., Jones, D. and Crane, J. (2001) The effects of carbon dioxide on exercise-induced asthma: an unlikely explanation for the effects of Buteyko breathing training *The Medical Journal of Australia,* 174, 72-74

American College of Sports Medicine (ACSM) (2001) *ACSM's resource manual for guidelines for exercise testing and prescription,* 4th ed. London: Lippincott Williams & Wilkins

American College of Sports Medicine (ACSM) (2006) *ACSM's resource manual for guidelines for exercise testing and prescription,* 5th ed. London: Lippincott Williams & Wilkins

Anderson, S. and Daviskas, E. (2000) The mechanism of exercise-induced asthma is… *The journal of Allergy and Clinical Immunology,* 106(3), 453-459

Anderson, S. D. and Holzer, K., (2000) Exercise-induced asthma: is it the right diagnosis in elite athletes? *Journal of Allergy and Clinical Immunology,* 106(3), 419-428

Appell, H., Soares, J. and Duarte, J. (1992) Exercise, muscle damage and fatigue *Sports Medicine,* 13(2), 108-115

Asthma UK (2004) Where Do We Stand? Asthma in the UK today Available from: http://www.asthma.org.uk/health_professionals/ordering_materials/where_do_we.html [Accessed 22 April 2008]

BBC (1998) *The breathless way to 'cure' asthma* BBC News (Online) 18 August 98. Available from: http://news.bbc.co.uk/1/hi/health/153320.stm [Accessed 26 March 2008]

Bishop, A., Rawle, M. and Bruton, A. (2007) The use of mouth taping in people with asthma: a pilot study examining the effects on end-tidal carbon dioxide levels *Physiotherapy,* 93(2), 129-136

Bjermer, L. (1998) The nose as an air conditioner for the lower airways *Allergy,* 54(57), 26-30

Borg, G. (1998) *Borg's perceived exertion and pain scales* Champaign: Human Kinetics

Bowler, S., Green, A. and Mitchell, C. (1998) Buteyko breathing techniques in asthma: a blinded randomised controlled trail *The Medical Journal of Australia* (Online) 169, 575-578 Available from:
https://www.mja.com.au/public/issues/xmas98/bowler/bowler.html
[Accessed 13 April 2008]

Bruton, A. and Clark, R. (2004) A pilot study measuring mixed venous carbon dioxide levels in students with and without a diagnosis of asthma *Physiotherapy,* 90, 120-124

Chen, M.J., Fan, X. and Moe, S.T. (2002) Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis *Journal of Sports Sciences,* 20(11), 873-899

Cooper, S.M., Baker, J.S., Tong, R.J., Roberts, E. and Hanford, M. (2005) The repeatability and criterion related validity of the 20 m multistage fitness test as a predictor of maximal oxygen uptake in active young men *British Journal of Sports Medicine* (Online), 39 (4), e19 Available from:
http://bjsm.bmj.com/cgi/reprint/39/4/e19 [Accessed 3 December 2007]

Cooper, S., Oborne, J., Newton, S., Harrison, V., Thompson Coon, J., Lewis, S. and Tattesfield, A. (2003) Effect of two breathing exercises (Buteyko and pranayama) in asthma: a randomised controlled trial *Thorax,* 58, 674-679

Department of Health (DoH) (2005) *Research Governance Framework for Health and Social Care - Second Edition* (Online) Available from:
http://www.dh.gov.uk/prod_consum_
dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4108965.pdf
[Accessed 25 March 2008]

Ernst, E. (2000) Breathing techniques – adjunctive treatment modalities for asthma? A systematic review *European Respiratory Journal,* 15, 969-972

Freeman, W., Weir, D., Sapiano, S., Whitehead, P., Burge, P. and Cayton, R. (1990) The twenty-metre shuttle-running test: a combined test for maximal oxygen uptake and exercise- induced asthma? *Respiratory Medicine,* 84, 31-35

Gellish, R., Goslin, B., Olson, R., McDonald, A., Russi G. and Moudgil, V. (2007) Longitudinal Modelling of the Relationship between Age and Maximal Heart Rate *Medicine & Science in Sport & Exercise,* 39(5), 882-829

Hicks, C. (1992) *Practical Research Methods for Physiotherapists* London: Churchill Livingstone

Holloway, R. (2004) Breathing exercises for asthma (Review) *Cochrane Database of Systematic Reviews,* 1, 1-3

Hough, A. (2001) *Physiotherapy in Respiratory Care: An evidence-based approach to respiratory and cardiac management* 3rd ed. Gosport: Ashford Colour Press

Kairaitis, K., Garlick, S.R., Wheatley, J.R. and Amis, T.C. (1999) Route of breathing in patients with asthma *Chest,* 116(6), 1646-1652

Keeley, D. and Osman, L. (2001) Dysfunctional breathing and asthma *British Medical Journal,* 322, 1075-1076

Kellet, C. and Mullan, J. (2002) Breathing control techniques in the management of asthma *Physiotherapy,* 88(12), 751-758

Lamb, K. and Rogers, L. (2007) A re-appraisal of the reliability of the 20m multi-stage shuttle run test *European Journal of Applied Physiology,* 100(3), 287-292

Leger, L.A. and Lambert, J. (1982) A maximal multistage 20m shuttle run test to predict VO_2 max *European Journal of Applied Physiology,* 49(1), 1-12

McArdle, M., Katch, F. and Katch, V. (2001) *Exercise Physiology; Exercise, Nutrition and Human Performance* 5th Ed. Lippincott Williams and Wilkins; Philadelphia

McKeown, P. (2005) *Asthma Free Naturally* 1st ed. London: Harper Thorsons

Miller, W., Wallace, J. and Eggert, K. (1993) Predicting max HR and the HR-VO2 relationship with exercise prescription in obesity *Medicine & Science in Sport & Exercise* 25(9), 1077-1081. Available from: http://www.ncbi.nlm.nih.gov/pubmed/8231778 [Access 22 April 2008]

Morton, A.R., King, K., Papalia, S., Goodman, C., Turley, K. R. and Wilmore, J.H. (1995) Comparison of maximal oxygen consumption with oral and nasal breathing *Australian Journal of Science & Medicine in Sport,* 27(3), 51-55

Nish, A. (2005) Dealing with Exercise-Induced Asthma *Asthma Magazine,* 10(4), 25-27

Pryor, J. and Prasad, S. (2002) *Physiotherapy for Respiratory and Cardiac Problems* 3rd ed. London: Churchill Livingstone

Pryor, J. and Webber, B. (eds) (1998) *Physiotherapy for Respiratory and Cardiac Problems* 2nd ed. London: Churchill Livingstone

Robergs, R and Landwehr, R. (2002) The surprising history of the "HRmax=220age" equation *Journal of Exercise Physiology* (Online) 5(2), 1-10 Available from: http://www.fitmusic.com/system/files/220-agerobergs.pd [Accessed 04 April 2008]

Shaheen, Dr. S. (2008) *The role of nutrition and paracetamol exposure in the aetiology of asthma: a programme of epidemiological research* Asthma UK (Online) Available from: http://www.asthma.org.uk/researchers/fellows/dr_seif_shaheen.html [Accessed 26 March 2008]

Stalmatski, A. (1997) *Freedom from Asthma: Buteyko's revolutionary treatment* London: Kyle Cathie Limited

The Chartered Society of Physiotherapists (CSP) (2001) *Research Ethics and Ethics Committee*s Available from: http://www.csp.org.uk/uploads/documents/csp_effecprac_res07.pdf [Accessed 25 March 2008]

Thomas, M., McKinley, R., Freeman, E. and Foy, C. (2001) Prevalence of dysfunctional breathing in patients treated for asthma in primary care: cross sectional survey *British Medical Journal,* 322, 1098-1100

Thomas, M. (2003) Breathing exercises and asthma *Thorax,* 58, 649-650

Thomas, S. (2004) Buteyko: A useful tool in the management of asthma? *International Journal of Therapy and Rehabilitation,* 11(10), 476-480

Van Den Elshout, F.J.J, Van Herwaarden, C.L.A. and Folgering, H.T.M. (1991) Effects of hypercapnia and hypocapnia on respiratory resistance in normal and asthmatic subjects *Thorax,* 46(1), 28-32

Vanhees, L., Lefevre, J., Philippaerts, R., Martensa, M., Huygens, W., Troosters, T. and Beunen, G. (2005) How to assess physical activity? How to assess physical fitness? *European Journal of Cardiovascular Prevention and Rehabilitation,* 12(2), 102-114

Appendix 1

Subject Consent Form

Title of Research: Does nasal breathing affect exercise tolerance?

- By signing this consent form I agree to take part in this study.
- The study has been explained to me and I have read and understood the information sheet provided.
- I have been given the opportunity to ask any questions and have understood and am happy with the answers given.
- I feel I fulfil the inclusion and exclusion criteria set by the researchers.
- I understand that my participation in this study is voluntary and I am free to withdraw from the study at any point, without having to give reasons for my withdrawal.
- I understand that all information collected about me will remain strictly confidential and anonymous throughout and after completion of the study. With this in mind, I am happy for the results to be published in a journal or on the Internet.
- I understand that I will be asked to participate for approximately 30 minutes on three separate occasions.
- I understand that on the day of testing, I will refrain from any strenuous exercise prior to completing the shuttle run, however am free to do any other exercise after the test has been completed.
- I understand that I will need to wear clothes and trainers appropriate for exercising in, and that I will be exercising to my maximum capacity.
- I understand that I will need to drink plenty of fluids in the 24 hours leading up to the test, and refrain from eating, drinking alcohol or caffeine or smoking for three hours prior to the test.
- I understand that I should not undertake the test if I have had a recent (within 2 weeks) infection including flu or a heavy cold.

SIGNED……………………………………

PRINT NAME………………………………………

DATE…………………………………..

Appendix 2

Health Questionnaires

Appendix 3

Ethics Committee – Letter of Denial

Appendix 4

Information Sheet

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

Does nasal breathing affect exercise tolerance?

Except for emergencies, our breathing was designed to take place mainly through our nose. This is because the nose is able to improve the air we inspire by warming and humidifying it, as well as being able to filter out pollutants and allergens. During exercise, we normally switch to mouth breathing in order to increase the volume of air we breathe. However, breathing through the mouth can lead to over-breathing. Asthmatics tend to breathe through their mouths more than non-asthmatics, which can make their asthma worse.

As a result, one strategy suggested to reduce asthma symptoms is to breathe through the nose. However, very little research has been done on this area to date. Therefore, our study aims to look at what effect breathing through your nose has on exercise. People with asthma will not be included in this study as we need to look at the effects of breathing through your nose in people who do not have asthma or any other respiratory problems, before this can be looked at in asthmatics.

<u>Who is being chosen for the study?</u>

Please read the following table which lays out who can (inclusion) and cannot (exclusion) be included in the study. **These criteria have been set up for your own safety; therefore, it is very important that you inform a member of the team if you are concerned that any of the exclusion criteria apply to you:**

Inclusion Criteria	**Exclusion Criteria**
Age 18 +	Age: men over 45 and women over 55
Prepared to complete maximal exercise test (shuttle run)	An inability to breathe comfortably through the nose with the mouth closed
	Those deemed to be at high risk of cardiovascular problems during exercise (as determined by the medical screening questionnaire).
	Respiratory tract infection at the time of data collection
	Any illness or musculoskeletal injury at the time of data collection or within the 2 weeks prior to data collection
	Asthmatics

It is hoped that 20 people will be recruited for this study.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part and what do I have to do?

If you decide to take part, you will be asked to attend on three occasions for about 30 minutes between the hours of 10:00am – 14:00pm. Should you not be able to attend during this time, we should be able to accommodate you. You will need to attend the first session on the date shown, but can then choose two out of the next three dates listed for the following two sessions.

Session	**Date**	**Purpose of Study**
1	Monday 18th February 2008	Familiarisation and medical screening
2	Monday 25th February 2008	Data collection
3	Monday 3rd March 2008	Data collection
4	Monday 10th March 2008	Data collection

Session 1: Familiarisation and medical screening

- You must be able to attend this session on Monday 18th February 2008
- You will be asked to sign a consent form

- You will be asked to complete a medical screening questionnaire to determine whether you are medically fit to undertake exercise
- You will be given the opportunity to familiarise yourself with the nasal breathing and undertake a practise shuttle run
- No data will be collected from this session
- You will need to wear clothing appropriate for undertaking exercise for all the sessions, namely loose clothing and trainers if possible.

Sessions 2 & 3: Data Collection Sessions

- You will need to attend on two out of the three possible data collection dates.
- You will need to drink plenty of fluids in the 24 hours leading up to the test.
- You must refrain from eating, drinking alcohol or caffeine or smoking for three hours prior to the test.
- Do not undertake the test if you have had a recent (within 2 weeks) infection including flu or a heavy cold.
- On the day of testing, it is asked that you refrain from any strenuous exercise prior to completing the shuttle run test.
- In the first session you will be asked to undertake the shuttle run test using one of two possible breathing techniques:
    1. Breathing normally through your mouth and nose
    2. Breathing nasally only with your mouth closed
- In the second sessions you will be asked to undertake the shuttle run test breathing with the technique that you did not undertake in the first session.

- Nasal breathing will involve running with your mouth closed, you will continue running until you feel the need to open your mouth in order to breathe through your mouth. At this point the test will finish. We will be observing you to monitor your route of breathing, if we observe that you accidentally open your mouth, we will give you one warning. If you are observed opening your mouth again, we must end the test immediately.
- Prior to beginning the shuttle run, one of the researchers will guide you through a 10 minute warm up session, including jogging and stretches. At the end of the shuttle run, you will also be taken though a 5 minute cool down session.
- To begin with, you will listen to instructions on the audiocassette. You will then begin the shuttle run, running at incremental speeds dictated by tape between points A and B 20m apart (marked by cones). A single beep denotes the end of each shuttle and three beeps the start of the next level.
- You will be asked to reach the highest level you can achieve on the shuttle run test. This will involve you running for as long as possible until you can no longer keep up with the speed set by the tape at which point you should voluntarily withdraw.
- The level you reach on the shuttle run will be used to calculate your exercise tolerance. You will be told what level you reached on both shuttle runs at the end of the last session, and hence what your exercise tolerance is.
- In addition to this, before the start of the shuttle run and at the end of the test, we will need to take the following measurements:

What measurements?	**What will be involved in taking the measurement**
Blood Pressure	A cuff that inflates is wrapped around your upper arm. Air is then blown into the cuff and increasing pressure and tightening is felt on the upper arm. The cuff will then deflate.
Heart Rate (your pulse)	This will involve having a clip placed on the end of one of your fingers for a few seconds
Oxygen levels	Same as above
Carbon dioxide levels	This will involve placing a small tube into the base of your nose while you breathe.
Respiratory rate (how fast you are breathing)	Same as above
Rate of perceived exertion (how out of breathe you feel)	At the beginning and at the end of the test you will be asked to rate how breathless you feel using a simple 10-point scale.

<u>What are the possible disadvantages and risks of taking part?</u>

As you will be required to exercise at your maximum capacity you may have feelings of breathlessness and fatigue during the exercise and experience muscle soreness in the immediate days following the test. You are reminded that you are free to stop at any point during the test or withdraw from the study if you wish.

What are the possible benefits of taking part?

The direct benefits to you in taking part include the positive benefits associated with exercising as well as being able to find out what your exercise tolerance is. This study aims to determine whether breathing through your nose affects exercise, in order to increase the knowledge base on nasal breathing. While our research will not directly benefit asthmatics, future studies may go on from our research to investigate whether nasal breathing can reduce asthma symptoms during exercise, and therefore be of possible benefit to asthmatics.

What is something goes wrong?

If for any reason you would like to make a complaint, please contact our supervisor, Sandy Thomas – Sandy.Thomas@uwe.ac.uk

Will my taking part in this study be kept confidential?

Any information, which is collected during the course of the research, will be kept strictly confidential. All information, which is collected about you that leaves the university, will have your name and address removed so that you cannot be recognised from it.

What will happen to the results of the research study?

This research study is being undertaken as the final year dissertation project of five physiotherapy students at UWE, and the results of the study will therefore form part of their dissertation.

The abstract of this research study will be published in the 2008 Book of Abstracts for the BSc (Hons) Physiotherapy Degree Programme (2005 Cohort), available from the Glenside library.

If you wish to obtain a copy of the abstract please provide us with your course and cohort details on an envelope, and will we post a copy to you in your pigeon hole when it is available at the beginning of May 2008.

If the study is to be published, details of this can be sent on request.

Who is organising and funding the research?

The research will be organised by five final year students, and supervised by Sandy Thomas, a member of the Physiotherapy teaching staff.

No funding is being provided for this study.

Contact for Further Information

If you require any further information or clarification on the above points, then please don't hesitate to contact:

Vicky Phillips – Victoria3.Phillips@uwe.ac.uk

Gemma Cox - Gemma3.Cox@uwe.ac.uk

Thank you for taking part in our study.

Appendix 5

Confidentiality Table

Name	**Number**
	1
	2
	3
	4
	5
	6
	7
	8
	9
	10
	11
	12

Appendix 6

Date collection sheets

Before

	Date	Oral-nasal (ON) or Nasal (N)	HR	RR	$ETCO_2$	SaO_2	BP
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Date collection sheets

After

	Date	Oral-nasal (ON) or Nasal (N)	N° of shuttles	VO_2 peak	HR	RR	$ETCO_2$	SaO_2	BP
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Appendix 7

Borg Scale of Perceived Exertion

Appendix 8

Loughbough Index conversion table

Appendix 9: Raw Data

Data collection session 1

Before

	Date	Oral-nasal (ON)/ Nasal (N)	HR	RR	$ETCO_2$	SaO_2	BP
1	25/02	ON	101	_	39	100	133/86
2	25/02	N	78	_	3	100	112/71
3	25/02	ON	99	_	43	99	131/74
4	25/02	ON	97	14	36	100	142/85
5	25/02	N	90	11	38	100	136/81
6	25/02	ON	57	13	42	100	140/63
7	25/02	ON	94	13	42	96	130/84
8	25/02	N	85	10	38	100	137/74

After

	Date	Oral-nasal (ON)/ Nasal (N)	N° of shuttles	VO_2 peak	HR	BORG	RR	$ETCO_2$	SaO_2	BP
1	25/02	ON	9.2	43.9	152	4	-	47	97	138/79
2	25/02	N	5.5	31.8	156	4	-	34	99	170/95
3	25/02	ON	7.4	37.8	168	4	-	49	92	159/84
4	25/02	ON	8.7	41.8	145	3-4	22	48	94	195/88
5	25/02	N	8.0	40.5	152	7	16	50	91	170/86
6	25/02	ON	9.0	43.9	147	4	30	37	95	232/77
7	25/02	ON	6.0	33.6	153	3	23	54	94	188/90
8	25/02	N	7.4	37.8	158	3	15	51	93	225/90

Data collection session 2

Before

	Date	Oral-nasal (ON) or Nasal (N)	HR	RR	$ETCO_2$	SaO_2	BP
6	03/03	N	75	14	38	99	123/61
8	03/03	ON	82	5	49	100	157/84
9	03/03	ON	66	8	40	100	134/75
10	03/03	N	86	16	35	99	133/74
11	03/03	N	66	15	45	98	148/94
12	03/03	N	61	22	38	97	129/82
1	03/03	N	107	18	43	100	149/79

After

	Date	Oral-nasal (ON) or Nasal (N)	N° of shuttles	VO_2 peak	HR	BORG	RR	$ETCO_2$	SaO_2	BP
6	03/03	N	8.2	40.5	126	4	28	43	95	219/79
8	03/03	ON	8.2	40.5	125	1	14	42	96	180/88
9	03/03	ON	10.0	47.4	163	4	23	47	90	202/82
10	03/03	N	8.1	40.5	169	7	27	43	93	159/89
11	03/03	N	9.2	43.9	128	6	25	45	95	205/100
1	03/03	N	8.7	42.4	166	6	30	47	96	151/76
12	03/03	N	10.3	48.0	121	9	28	47	96	184/91

Date collection session 3

Before

	Date	Oral-nasal (ON) or Nasal (N)	HR	RR	$ETCO_2$	SaO_2	BP
2	10/03	ON	67	24	38	100	125/83
3	10/03	N	103	6	44	98	132/90
7	10/03	N	112	23	41	95	147/96
12	10/03	ON	64	20	41	98	144/82
5	10/03	ON	82	10	40	99	131/72
4	10/03	N	88	13	37	100	146/91
10	10/03	ON	79	23	34	96	124/78
9	10/03	N	69	9	45	98	144/78
11	10/03	ON	61	19	45	98	156/84

After

	Date	Oral-nasal (ON) or Nasal (N)	N° of shuttles	VO_2 peak	HR	BORG	RR	$ETCO_2$	SaO_2	BP
2	10/03	ON	6.3	34.3	118	3	28	32	100	146/85
3	10/03	N	6.5	35.0	161	3	14	14	99	152/82
7	10/03	N	4.4	27.6	170	3	19	19	90	195/97
12	10/03	ON	10.1	47.4	132	8	24	24	89	165/93
4	10/03	N	6.4	34.3	153	5	17	17	92	178/95
5	10/03	ON	12.5	55.4	160	8	20	20	85	161/79
9	10/03	N	4.2	26.8	126	2	15	15	94	198/92
10	10/03	ON	9.8	45.8	168	7	27	27	89	169/84
11	10/03	ON	12.0	54.3	164	8	25	25	96	204/97

Appendix 10: Reasons for stopping

Participant Number	Nasal breathing	Oral-nasal breathing
1	Could not get enough air in. Muscles were fine. Slight stitch maybe. Comfortable until level 7. Nose was running.	Breathlessness
2	Fire in my legs, lactic acid	'Timing' – keeping up with when BP was going. Could have kept going. Moderate SoB. No pain. No discomfort. Change in level unexpected.
3	Breathing – able to keep mouth shut afterward for CO2 monitoring better than when mouth breathing. Moderate SoB. Feeling hot. Felt comfortable. Problems with nose running but not blocked. Nose was limiting factor.	Didn't reach the line in time
4	The whole nose thing – could not get enough air in. Slightly SoB. No discomfort or pain. Makes you feel a bit weak generally. Running nose. Felt a bit more nervous and less confident.	Mainly heat and legs too short – could not stretch out to get the speed. No SoB.
5	Felt like one nostril was closing – could not get enough air. Like breathing in through a straw. Developed a slight headache.	Legs could not keep up, felt heavy. Breathing – ok while running. SoB when stopped. No discomfort. A bit light headed afterwards. Calf muscles felt tight afterwards.
6	Felt 'worse' than last week when mouth breathing. Was not getting enough air in. Legs felt fine. Tried to keep going better this week. Felt less tired than when mouth breathing.	Tired out, weakness – partly from breathing. Could not get enough air. A little dizzy afterwards. Legs felt a bit tired. No pain, just a little tight.
7	Looking and feeling hot and sweaty. Difficulty getting enough air in and build up in nose running. Nose not completely blocked. Not completely tired, could have done more. Just felt harder. Felt *a lot* harder. Nose was limiting factor.	Sweaty. SoB. Dry mouth. Heat. No pain.

8	SoB. Could have gone on for longer. Breathing quicker than normal. Could not get full breath. Calves uncomfortable. No dizziness. No pain. Sweaty.	Shin pain in both legs (had it last summer). Felt like needed to cough or sneeze. Felt phlegmy. Could have kept going by pain limited him. Did not get pain last week when nasal breathing.
9	When breathing hard, right nostril closed (due to deviated septum). Probably could have gone a bit more but feeling could not get enough air in. A little SoB at end. Not tired. No pain or discomfort anywhere. A REAL effort to keep mouth closed. Felt claustrophobic.	Tired legs – tibial on dorsiflexion. Could have pushed it more and breathed harder. Did not notice heat during test. Legs limiting factor.
10	Wanted to take a deep breath. Nose breathing was the limiting factor. Runny nose, but not limited by this. Feeling hot once stopped. No other symptoms.	Runny nose during run. Breathing limited and very hot. Struggling to get enough air in. Muscles fine. Sore throat. Nose breathing was more clearly limiting with breathing. Breathing limited.
11	Concentration at the turn made it difficult to keep mouth closed. Breathing was heavy but may have been able to keep going. Getting quite tired. Tightness in chest. SoB. Nose felt bunged up.	Leg speed limiting factor – turning and pushing off. Quite SoB as well. Some muscle tightness in hamstrings. No pain otherwise. Breathing easier this time and no chest tightness this time.
12	Nose hurting – stinging (was punched in the nose 2 weeks ago). Saliva in mouth hard to swallow. Legs starting to get sore generally. Nose running +++. No other symptoms.	Keeping up with beeps – found it harder. Leg muscles were tired (quads and calves). Some DOMS from previous day when played football. Very hot and sweaty. Not struggling to breath. Found it harder today. Touch of competitive element. Nose not ‘gushing’ today. Less ‘hazy’ this time, compared to last time.