Fontys Paramedic University of Applied Sciences

Programme Physiotherapy English Stream

The effect of nasal breathing on amateur runners

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Preface

I am happy to put the dot on the “I” with this bachelor thesis as the conclusion of my studies from the English stream program at Fontys University of Applied Sciences in Eindhoven, the Netherlands.

I would like to say thank you to Chris Burtin, my supervisor, who supported my choice of topic on nasal breathing. As an amateur runner, I was personally very interested in this topic and this made my research journey so much more enjoyable. Thank you for Tim Gerbrands, the supervisor of MART-lab, who came up with such a simple and ingenious way to test the posture of the runners.

I would also like to express my gratitude to everyone who decided to participate in my experiment and decided to try out nose breathing for four weeks. I would like to apologize to the ones who really did not like it.

A great thank you also goes out to everyone who peer-reviewed the progress of my thesis and to all my friends and family, who supported my work either directly or indirectly during the last weeks.

Orsolya Hegyi
30 May 2013, Eindhoven

Abstract

Background: Nasal breathing is a commonly used technique among runners. However, the scientific research available on the topic is limited. The aim of this study was to investigate the effect of nasal breathing on runners' posture, perceived exertion and the effect of practice.

Method: The participants, healthy amateur runners, performed two measured 20 minute treadmill runs, four weeks apart. During the four weeks, participants practiced nasal breathing during their runs. The average cervical lordosis and average thoracic kyphosis were measured with Codamotion-system: 3D gait analysis. The perceived exertion was measured on a 15-point Borg-scale. The heart rate was measured by the use of Oxiometer. Measurements were conducted after the first and the nineteenth minute of the treadmill run. The participants were asked to complete a questionnaire half-way and at the end of the experiment regarding their experience with nasal breathing. The data was analyzed in SPSS 17.0 by conducting a paired-sample t-test ($p<0.05$).

Results: The measured average cervical lordosis was statistically significantly greater during oronasal breathing than during nose breathing both at the measurement after one minute ($M_{oronasal}$=-35.96^{o}, M_{nasal}=-28.97^{o} sig=0.038) and also at minute nineteen ($M_{oronasal}$=-39.5^{o}, M_{nasal}=-30.37, sig=0.033). No statistically significant results were observed with regards to thoracic kyphosis, heart rate or perceived exertion. A significant increase was observed in the self-reported length of time the runners were able to maintain nasal breathing during their trainings in the course of the experiment.

Conclusion: The posture of the neck remained in a position closer to vertical or neutral during nose breathing. Nasal breathing did not decrease the perceived exertion of the runners. Participants commonly mentioned that they experienced a relaxation effect during nose breathing, which might be a result of increased breathing control. One's ability to breathe through the nose during physical exertion seems to be subject of improvement with practice.

Introduction

The popularity of running has been steadily increasing over recent years. In 2010, running became the quickest growing sport in The Netherlands.[18] The same trend can be observed in the United States, where the number of road race finishers almost tripled between 1990 and 2011.[1] In accordance with these trends, a substantial amount of information became available on various running techniques. Nasal breathing is a breathing technique which is a cornerstone of several books promising effortless training for runners, such as Body, Mind and Sport, ChiRunning, Gentle Running and Born to Run. According to internet fora, articles and blogs several athletes are using this technique with great success, while others find it impossible to maintain a high level of training with nose breathing only. Surprisingly, the amount of scientific research available on the topic of nasal breathing during physical exertion is limited.

Mammalians, including humans, are considered to be 'preferred nose breathers'.[20] Thus the nose is supposed to be the main source of inhaled air at rest in case of most healthy persons. This is also illustrated by the fact that newborn babies are almost obligate nose breathers and under great distress when they are unable to breathe through their nose.[8] Under normal circumstances, the oral cavity only interferes with respiration at rest when inspired air through the nose is insufficient. This primarily occurs due to nasal obstruction (e.g. allergy, infection).[2] The nose plays a crucial role in protecting the lower airways. It filters the inhaled air and thus prevents the penetration of particles and harmful gases to the lower respiratory tract. It also humidifies and warms the inspired air to near body temperature and 98-100% relative humidity before it enters the lungs.[3] The mouth is able to partially take over these functions, but since it is not primarily meant for breathing its work will be less effective.[8]

Ventilation significantly increases due to exercise. The resting ventilation of 4 l/min can increase to 120 l/min during maximal physical exertion.[22] Breathing through the nose provides approximately twice the resistance compared to breathing through the mouth.[8] Most people who typically breathe through their nose at rest will switch to oronasal breathing during exercise, thus try to supply the increased level of oxygen consumption by also breathing through the mouth. Bennett et al.[3] found that nasal contribution to breathing is decreasing as the level of exertion is increasing. The level of ventilation where a switch from nasal to oronasal breathing happens is the so-called 'oronasal switching point'. The switch is suspected to be determined by the nasal resistance to airflow, but the exact physiological reasons are not clearly understood.[3]

Morton et al.[16] were comparing the effect of nasal, mouth and oronasal breathing on oxygen consumption. They found a 35.1% and 35.0% reduction in VO_2max when breathing through the nose compared to breathing through the mouth plus nose and breathing only through the mouth respectively. This is in line with the findings of other studies, who also reported decreased VO_2max due to nose breathing. Morton et al. also reported decreased breathing frequency during nose breathing. The

ventilation during nose breathing was significantly reduced compared to other modalities of breathing. However the reduction in ventilation was proportionally larger than the reduction of the maximal oxygen consumption. This is suspected to be due to increased oxygen extraction and utilization during nose breathing.[16] The theory of improved use of oxygen during nose breathing may be supported by the high concentration of nitric oxide in the nose that is known to be a powerful bronchodilator.[5] The different running techniques applying nose breathing are also based on this argument. Typically they state that after a couple of weeks of practice, athletes can get used to nasal breathing and since it is a more efficient way of breathing, it will result in a decreased level of perceived exertion.[9] No officially published paper was located that researched the effect of nasal breathing following a practice period with this breathing technique.

Some people breathe through the mouth not only during physical exertion. Habitual mouth breathing is a condition affecting about 20% of the population. It indicates a habit to breathe through the mouth at rest despite of the patency of the nose. Such a habit may seem innocent and is often overlooked, but has serious consequences on one's health.[12] It can have negative impact on facial growth, dental health, sleeping disorders and cognitive development.[13] There is a consensus among authors that chronic mouth breathing will result in postural adaptations. The most commonly seen pattern of adaptation is the forward head posture with an extension of the head and the neck to facilitate airflow through the mouth.[7, 17, 23] The question is whether this adaptation also happens as a result of oronasal breathing due to physical exertion and whether this effect could be reduced as a result of nose breathing during running.

For this reason, the main aim of this study is to research the effect of nasal breathing on the cervical lordosis and thoracic kyphosis, thus the posture of the runners during physical exertion. It will be also examined whether nasal breathing produces a decreased level of perceived exertion and heart rate after a period of training. Furthermore it will be investigated whether one's ability to breathe through the nose during physical exertion can be improved with practice.

Method

Subjects and ethical considerations

Subjects were recruited via email and the message board of the English Stream Physiotherapy study of Fontys University of Applied Sciences. The inclusion criteria of the subjects were specified as follows: healthy recreational runners between the ages of 18 and 40 years old, who are training regularly – at least twice a week - and able to complete the distance of at least 5km.

Runners who had a history of specific back pain, any conditions causing nasal obstruction, respiratory disease and cardiovascular problems or were familiar with the nasal breathing technique were excluded from the experiment.

The participants were provided with information on the aim of the research, the intervention to be carried out, the assistance expected from them and the measurements to be conducted. The application of the subjects was voluntary, based on the interest and willingness of the person to take part in the study. They were given the choice to stop the experiment any time if they wanted to do so. All participants were provided with an electronic version of the Informed Consent Form (Appendix I.) before the start of the experiment via email and they were asked to sign the form upon arrival to the first measurement. The participants were provided with the opportunity to ask questions about the experiment, the procedure or the breathing technique either during the measurements or later any time during the course of the experiment

Study Design

The participants were required to attend the MART-lab at Fontys University of Applied Sciences, in Eindhoven twice. The first measurement was carried out in Week 1. It provided the base line measurement. The participants were running on the treadmill without any intervention for 20 minutes. The measurements were conducted after the first and the nineteenth minute of the treadmill run in order to measure changes in posture, heart rate and the level of perceived exertion during running. The average cervical lordosis and average thoracic kyphosis were measured with Codamotion-system: 3D gait analysis. The perceived exertion was measured on 15-point Borg-scale. Heart rate was measured by the use of Oxiometer.

At the end of the first measurement session participants were provided information on the nasal breathing technique and they were given instructions on how to train nasal breathing. (See Appendix I. - Informed Consent Form – What do you need to do as a participant?) The participants were asked to practice the

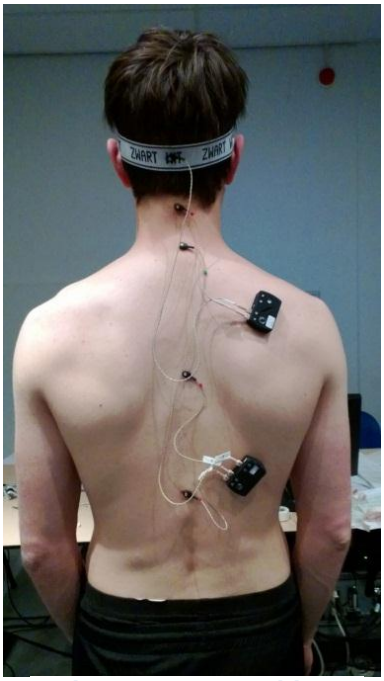
breathing technique during the following four weeks twice a week during their runs. No direct supervision was provided on the training. Regular contact was held with the participants to ensure their compliance and provide help when necessary. In the beginning of Week 3 all the volunteers of the experiment received a questionnaire to get an overview on their progress and experience with nasal breathing up to that point. (Appendix II.) The second measurement was carried out in Week 6 in the MART-lab. The participants were asked to breathe through the nose only during the 20-minutes-long treadmill run. All other conditions (running speed, treadmill elevation, running time etc.) and measurement procedures were kept stable in comparison to the first measurement. The participants were asked to indicate if they were not able to maintain nose breathing anymore and wanted switch to oronasal breathing. In that case all measurements were made at that point and the duration of the run was noted.

In the end of the experiment the test subjects were asked to fill in a questionnaire to provide information on their experience with nasal breathing during the last four weeks. (Appendix III.)

Measurement

Upon arrival the participants received information and explanation on the measurement process and the devices to be used.

Five Infrared markers (Codamotion CX, Charnwood Dynamics, Ltd.) were placed on the back of each participant: at the level of C1, C7 and at a point exactly halfway between these two vertebrae; at level of T12 and at a point exactly halfway between C7 and T12. All participants were wearing a hairband which was secured at the base of the occiput at the level of C1 so that the marker could be placed there visibly to the camera. The vertebrae C7 and T12 were located by palpation. The distances between C1-C7 and C7-T12 were measured with the use of a measuring tape and noted; the distances halfway were marked. The infrared markers were placed at the indicated locations with the use of a double sided tape. The movement of the infrared markers was captured by one CX1 camera unit during the treadmill run and process by Codamotion Analysis software.



Picture 1: Test subject with the markers

The participants were given three to five minutes to warm up on the treadmill by walking or easy jogging. The test subjects were asked to select the speed they perceived feasible for the 20 minute run. It was decided to give the opportunity to the participants to select their own

speed as the aim was to achieve a submaximal exertion during the experiment that is closely related to the usual training conditions of the runners. There were considerable differences among the participants with regards to their running speed, running distance and physical condition so a fixed speed would not have provided the same level of exertion to everyone. A 1% elevation was set at the treadmill to equalize the energetic costs of treadmill run to outdoor running.[14]

The participants were asked to signal when they were ready to start the 20 minutes run on the treadmill. The time was measured by a stopwatch. The selected speed was noted. After 1 minute the heart rate of the participants was measured and noted with the use of an Oxiometer and the participants were asked to select a score for their current levels of exertion on the 15 point Borg scale, which was also noted. Then a 10 second long recording was made of the infrared markers placed on the back of the participants by the CX1 camera unit. Average values of the cervical lordosis and the thoracic kyphosis were noted. This procedure was repeated after 19 minutes.

Statistical Analysis

The data was analyzed in SPSS 17.0 with the use of paired-sample t-test. The results are expressed in mean (M) and standard deviation (SD). The significance level was set at $p<0.05$.

Results

Subjects

13 runners volunteered for the experiment – four females and nine males – between the ages of 22 and 29 (M=25, SD=3.18). Three runners out of the thirteen were training twice a week for 20 to 30 minutes, two runners trained twice a week for 90 to 120 minutes. The remaining runners were typically training twice a week for 45 to 60 minutes.

A male and a female participant had to be withdrawn from the experiment as it was not possible to find a suitable time to complete the second measurement. During the second measurement session, two values were lost for the average thoracic kyphosis and one for the average cervical lordosis as the markers fell off or came out of the socket. One value for oronasal breathing and two values for nose breathing for the heart rate were cleared from the statistical analysis as their correctness was regarded as highly unlikely. (Appendix IV.)

Posture

Statistically significant difference could be observed between oronasal breathing and nose breathing with regards to average cervical lordosis both at the measurement after one minute and also at minute nineteen. (Table 1)

Table 1: Average Cervical Lordosis (degrees)

	Oronasal breathing		Nose breathing		Significance
	Mean	Standard Deviation	Mean	Standard Deviation	
1 Minute	-35.96	9.33	-28.97	6.57	0.038
19 Minutes	-39.5	13.32	-30.37	5.78	0.033

The eta squared statistic at one minute (0.39) and also at minute nineteen (0.44) indicated a large effect size.

The differences with regards to average thoracic kyphosis between oronasal breathing and mouth breathing were statistically insignificant. (Table 2)

Table 2: Average Thoracic Kyphosis (degrees)

	Orsonasal breathing		Nose breathing		Significance
	Mean	Standard Deviation	Mean	Standard Deviation	
1 Minute	20.03	7.2	20.08	7.94	0.952
19 Minutes	18.09	7.46	17.87	7.27	0.796

No statistically significant change could be observed over time with regards to changes of average cervical lordosis and average thoracic kyphosis when comparing the minute one and the minute nineteen measurements at either breathing technique.

Perceived exertion and heart rate

No statistically significant difference could be observed in the average Borg-score (Table 3) and heart rate (Table 4) when comparing nose breathing to oronasal breathing either at the beginning of the run, neither at the end of the run.

Table 3: Borg Score

	Orsonasal breathing		Nose breathing		Significance
	Mean	Standard Deviation	Mean	Standard Deviation	
1 Minute	10.64	1.86	11.09	1.87	0.483
19 Minutes	13.73	1.8	14.36	1.96	0.172

Table 4: Heart rate

Heart rate	Orsonasal breathing		Nose breathing		Significance
	Mean	Standard Deviation	Mean	Standard Deviation	
1 Minute	155.18	11.55	155.91	8.67	0.843
19 Minutes	160.00	21.4	168.75	11.41	0.291

One participant needed to stop the measurement after 14 minutes, two after 15 minutes as they were unable to maintain nose breathing any longer. One participant had great difficulties to complete the 20 minutes of the run.

Seven out of the eleven participants reported in the questionnaires that they felt more relaxed or more in control of their breathing in response to the question inquiring whether they experienced any advantages from practicing nasal breathing during their runs.

The effect of practice on one's ability to maintain nasal breathing

A significant increase was observed in the self-reported length of time the runners were able to maintain nasal breathing when comparing their very first run with this breathing technique and at the end of the experiment. The test subjects were able to maintain nasal breathing during their first run for 18.18 minutes on average (SD=18.57) based on their responses in the questionnaires. This increased to an average of 33.91 minutes by the end of the experiment (SD=22.14).

Ten out of the eleven participants reported they had difficulty to maintain nasal breathing when running at a higher speed.

Discussion

The aim of this study was to investigate the effect of nasal breathing on runners with regards of posture, exertion and the effect of practice.

Postural changes

The average cervical lordosis was found to be significantly higher in the case of oronasal breathing compared to nose breathing. The difference became apparent in the beginning of the run at the minute one measurement and increased further by the end of the run. The increased cervical lordosis during oronasal breathing seems to be the result of a natural adaptation of the body to increase airflow and to improve ventilation. Amis et al.[2] found decreased oral airway resistance with 45^{o}-50^{o} of head and neck extension, while oral airways resistance increased due to head and neck flexion. Haas et al.[11] found that endurance runners naturally adapted a position that favors ventilation; which was an 11^{o} forward angulation of the back and 35^{o} extension of the neck according to the observations of this study. It was found that this posture had a favorable effect on the maximum voluntary ventilation, peak expiratory flow and peak inspiratory flow of the test subjects.[11] Weber et al.[21] did not find any association between nasal airflow and extended head position, which could explain why the same adaptation could not be observed while the participants were breathing through the nose only during the treadmill run and the position of the neck remained closer to the vertical or neutral posture.

No statistically significant differences could be observed in the average thoracic kyphosis of the participants when comparing oronasal breathing with nasal breathing. It is unclear whether this resulted from similar adaptations in this area during both breathing methods or because the effect of physical exertion on the thoracic kyphosis is smaller.

Perceived exertion, heart rate and the learning effect

The outcomes Borg score and heart rate were used as measures for exertion. No statistically significant difference could be observed between the Borg scores given by the participants during oronasal and nasal breathing. This is in accordance with the findings of another graduation thesis project which recorded highly similar Borg scores for nasal and oronasal breathing during 20m Multi-stage Shuttle Test.[6] The greatest difference between the methods applied by the two graduation thesis is that the current thesis did not aim to test participants at their maximum level of performance. Furthermore, here a four weeks long learning period was included to test the claims of the running techniques promising decreased perceived exertion due to nasal breathing. The heart rate of the participants showed no statistically significant difference between oronasal and nasal breathing, which contradicts with the

findings of Morton et al.[16] who found significantly lower heart rate between nose only and mouth plus nose breathing during treadmill tests to volitional exhaustion. The difference might stem from the fact that the current experiment tested participants at a submaximal level of exertion. Based on these findings, the hypothesis can be rejected that nasal breathing would produce a lowered perceived level of exertion after the technique of nasal breathing has been trained for four weeks.

Contradicting the above mentioned findings, the responses of the participants from the questionnaires reflected they felt more relaxed or more in control of their breathing when they practiced nasal breathing during their regular runs. This was the most commonly mentioned benefit of this breathing technique. Two participants reported that when practicing nose breathing during running they did not get any side stitches - even when they were running at their normal speeds - which were previously an issue for them. This suggests that the participants were benefiting from an increased sense of breathing control due to nasal breathing what was probably providing the relaxation effect. The question is whether any other breathing technique would provide the same benefit.

The responses of the participants from the questionnaires indicate that an increased duration of running time could be maintained with nasal breathing as a result of practice. It is important to note, however, that substantial differences could be observed among runners. Two participants had no problem to maintain nasal breathing for the full duration of their first run, while two participants experienced great difficulties already in the very beginning and the improvements over the four weeks of the experiment were also rather limited in their case. This is in line with the findings of Fregosi and Lansing[10] who also reported great inter-subject differences with regards to the oronasal switching point. They theorized that the increased nasal resistance at higher level of ventilation and the associated or anticipated discomfort is responsible for either adjusting the activity of upper airway muscles, thus decreasing nasal resistance; or triggering the opening of the mouth, thus switching to oronasal breathing. They also suspect that one's behavior reflects a life-long learning or habit.[10] This theory provides support to the idea that the oronasal switching point during physical exertion can be delayed due to conscious effort and practice and one's ability to breathe through the nose can be improved.

Maintaining nasal breathing at higher speeds appeared to be a problem for almost all participants. This also reflected in the final measurement in the MARTlab. The four participants who were running at the highest speed were not able to or had great difficulty to complete the 20 minutes of the treadmill run with nasal breathing. This can probably be explained by the decreased VO_2max that among others Morton et al. reported due to nose only breathing.[16] Three out of the eleven participants, however, managed to achieve their normal running speed with nasal breathing by the middle or end of the experiment.

Limitations of the study

The two greatest limitations of this study are the lack of randomization and the low sample size. The same group of people was tested twice, once with their usual breathing pattern, and once with nose-only breathing. The chance that the adaptions that we see are a result of practice or training could have been lowered if a control group would have also been involved in the study and the test subjects were allocated randomly. Even if significantly lower perceived exertion was found at the end of the experiment due to nose breathing it would be highly doubtful whether it was the result of practice or simply the improved condition of the athletes due to the four weeks of training in-between. A higher number of participants would have also contributed to a greater statistical power.

With regards to the observed postural changes, a limitation is the placement of the marker at the level of C1. This marker can be deemed to be the least reliable as it was attached on a hairband and not on the vertebrae itself. It is also a point of consideration that the extended neck position could already be observed in the beginning of the run during oronasal breathing at the minute one measurement. The exact oronasal switching point - when the participants started to breathe through the mouth as well - was not noted, so it is possible that some participants were then still breathing nasally.

The measurement of the learning effect via the questionnaire can be considered to be suboptimal, as it was an estimation that the participants were providing. Furthermore the improvement that can be detected this way is limited by the actual running time of the participants. The study was not primarily designed for measuring this aspect of nose breathing. It can be considered to be an additional benefit.

The lack of direct supervision during the four weeks of training time with nose breathing can also be considered to be a limitation. The participants were trusted to comply with the agreed training schema but it was not possible to regularly check whether their interpretation or practice was correct.

Implications and recommendation for future research

Considering the findings of this paper, nasal breathing seems to provide some benefits but it is not necessarily suitable for everyone. Based on the above mentioned results this breathing technique might be beneficial to some amateur runners, who train at lower-levels and have problems to maintain a regular breathing pattern. Learning this breathing technique is very simple, although its application may take some persistence. Further research would be needed to determine whether other breathing techniques would provide a similar effect with regards to relaxation and breathing control.

The results of this study suggest that nasal breathing during running might help to maintain a good alignment of the head and the neck, which is crucial to a good running posture.[15] For future research, it would be interesting to include the average lumbar lordosis in the measurements as well to see whether any changes or adaptations could be observed in that region in response to the breathing technique. This would provide better insight in how the overall posture of the runners is affected and what the possible benefits of this breathing technique may be. Measuring the average thoracic kyphosis of the participants at rest or during easy walking would provide important base-line values for better interpretations of the results. The measurements in this case were carried out after a training period of four weeks with nose breathing. It is an important consideration for future research whether similar changes would also be visible straight away, when participants are running with the technique of nasal breathing for the very first time.

Even though no significant postural changes were observed over time in case of either breathing technique during the 20 minutes of the treadmill run, the question remains how this would change at a higher level of fatigue similar to the demands of for example a 10k race, a half-marathon or a marathon and whether nose breathing would provide the same effect in that case as well.

It remains unclear whether everyone is capable to apply this breathing technique during physical exertion. It is possible that some people are simply not able to breathe enough air in through the nose to supply the increased ventilation during physical exertion. For similar experiments in the future, better structured and supervised training would be needed to be able to draw any conclusions. Most of the participants adjusted well to this breathing technique and some were able to achieve their normal running duration and speed with nose breathing only. Nevertheless it remains unclear how far one's ability to breathe through the nose can be improved.

Since a certain trend could be observed from the responses of the participants which indicated an improvement of one's ability to breathe through the nose, it would be interesting to investigate whether this has an actual impact on the VO_2max during nose breathing.

Conclusion

Oronasal breathing resulted in increased cervical lordosis, supposedly as the body's normal adaptation process to improve airflow via the mouth. During nasal breathing the posture of the neck remained in a position closer to vertical or neutral. No significant changes were observed in the thoracic kyphosis of the runners as a result of the breathing techniques.

No significant difference in perceived exertion or the heart rate of the participants could be observed as a result of nasal breathing during physical exertion. Participants commonly mentioned that they experienced a relaxation effect during nose breathing, which might be attributed to increased breathing control.

The length of time participants could maintain nose breathing during their runs increased significantly over the four weeks of the experiment, suggesting that one's ability to breathe through the nose during physical exertion improves with practice.

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Appendix I. - Informed Consent form for research on nasal breathing

This Informed Consent Form is for recreational runners who would be interested to participate in my graduation project researching the 'Effect of nasal breathing on athletes'.

Introduction

My name is Orsi Hegyi, final year physiotherapy student (English stream) at Fontys University of Applied Sciences. The aim of my graduation project is to research the effect of nasal breathing on the posture and perceived exertion of recreational runners. Hereby I would like to invite you to participate in this research.

Purpose of the Research

Currently running is one of the fastest growing and most popular sports in the Netherlands that hopefully you are enjoying yourself as well on a regular basis. If you observe your breathing you will probably find that during rest you are breathing through your nose and during physical exertion you are breathing through your mouth. Nasal breathing is a widely-used, popular technique, applied by many runners to improve their performance. There is plenty of information available on the internet about this technique; however its actual effect has not been widely researched. The aim of this study is to find out more about the long-term effects of this breathing technique.

What is nasal breathing?

The underlying idea behind nasal breathing is very simple. Basically you keep breathing through your nose during exercise. In the beginning it is not easy. Research shows that maximal performance decreases due to the use of nasal breathing in the short-run. Its effect has not been researched in a controlled environment in the long-run. I am asking your help to do so during my graduation thesis. Nasal breathing during physical exertion is a skill that can be easily learnt. Runners are supposedly able to condition themselves to keep breathing through their nose during exercising. This seems to have several benefits, including protection of the airways, improving the efficiency of gas exchange and helping to maintain a good posture.

What do you need to do as a participant?

If you decide to participate you would need to try using nasal breathing for a period of 5 weeks. Basically all you need to do is to do your usual weekly running training **at least twice a week**, but you try to avoid switching to breathing through your mouth and try to keep breathing through your nose. In the beginning it will not be easy and you will experience that you are unable to complete your usual distance with pure nasal breathing. If you feel that you can not get enough air in through your nose you can either slow your pace down or switch to oral breathing. You will notice it that during each training the distance you can comfortably complete with nasal breathing gets longer. After a couple of weeks you will probably able to

complete your normal running distance with nasal breathing. If you have questions or in doubt during any point of the research and the training period you can always contact me for more information and I will try to provide guidance on the technique to the participants to my best knowledge.

Measurements

As a participant of this study you will need to complete two measurements at the so-called Gait-lab of Fontys Hogescholen (Ds.Th. Fliednerstraat 2, 5631 BN Eindhoven). You will be asked to run on the treadmill for 20 minutes during these measurements. Codamotion motion capture and movement analysis system will be used to measure changes in the posture of participants during running. Four small infrared markers will be placed on your back and an infracamera will record your motion. Your heart-rate will be taken with the use of an oximeter (small-measurement tool that can be placed on the finger) and your experienced/perceived exertion will be also measured.

The first measurement will take place **between 1-5 April**. This will be followed by a 5-week-long training period during which you will try to condition yourself to breathe through your nose.
Then the second measurement will be completed between **13-17 May** on the above mentioned way and the results of the two measurements will be compared to see if nasal breathing had any influence on your posture or perceived exertion. The measurement will take up a maximum of one hour of your time.
Several dates and time periods will be available to accommodate your own schedule.

Benefits

Participating in this research provides you with the opportunity to learn about a popular breathing technique. Due to the measurements that will be carried out you will gain a better understanding on how your body reacts to physical exertion that can greatly benefit your training. You will be also provided guidance by an almost fully qualified physiotherapist.

No financial reimbursements are offered to the participants of this experiment.

Who can participate?

The participants of this study need to be healthy recreational runners between the age of 18 and 40 years old, who are training regularly – at least twice a week - and able to complete the distance of at least 5km.
Unfortunately you can not participate in this research if you have a history of specific back pain (herniation, spinal stenosis, tumor etc), any conditions causing nasal obstruction, respiratory disease, cardiovascular problems or have any previous experience with nasal breathing.
Your participation in this research is entirely voluntary. You may change your mind later and stop participating even if you agreed earlier.

If you have any question about the procedure or any part of the information is unclear please do not hesitate to contact me for more information.

Risks

No side-effects of nasal breathing are known. The risks involved in the participation of this study is not greater than participating in any kind of physical exercise. In order to decrease the chance of any possible health complications you will need to fill in a short questionnaire screening for possible health risks.

Confidentiality

The information that will be collected from this research will be kept confidential, only myself and my school supervisors will have access to it. You will receive the data from your own measurement.

Sharing the Results

You will receive an electronic copy of the final research product. You can always contact me for more information on the preliminary results of the research.

Who to contact?

If you have any questions please feel free to contact me via email: orsolyahegyi@gmail.com or via phone on the number: 0681499239.

Certificate of consent:

I have read the foregoing information. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant of this research.

Print Name of Participant:

Signature of Participant:

Date:

Appendix II. - Questionnaire – Nasal Breathing – Week 3

I hope you are progressing well with nasal breathing during your running routine. I would appreciate it if you could take a couple of minutes to answer some questions so I can see how you are getting on with nasal breathing.

1. ***How many times a week do you practice nasal breathing during your run?***
2. ***How long do you normally run?***
3. ***How long could you maintain nasal breathing for the first time during your run?***
4. ***How long are you able to maintain nasal breathing now during your run?***
5. ***Does nasal breathing affect your running technique?***

   Yes/No

   - If yes: Could you please specify how?

6. ***Do you experience any difficulty during nasal breathing?***

   Yes/No

   - If yes: Could you please specify what your difficulty is?

7. Do ***you experience any benefits from nasal breathing?***

   Yes/No

   - If yes: Could you please specify what benefit you experience?

8. ***Do you have any additional remarks concerning nasal breathing that you would like to share?***

Appendix III. - Questionnaire – Nasal breathing – End of experiment

Name:

How long are you currently able to maintain nasal breathing during your run?

What was your overall experience with nasal breathing?

Will you continue with nasal breathing after the experiment?

Yes/No

Appendix IV. – Measurement results

Table I. - Measurement result oronasal breathing

Subject no.	Running speed	Heartbeat 1 min	Borg 1min	Heartbeat 19 min	Borg 19 min	Kyphosis average 1min (degrees)	Kyphosis average 19min (degrees)	Cervical lordosis average 1 min (degrees)	Cervical lordosis average 19 min (degrees)
1	9	145	11	128	12	25.14	26.63	-53.38	-56.5
2	11.1	160	14	167	16	11.14	11.37	-32.45	-35.3
3	8	136	8	161	13	23.79	24.14	-43.11	-38.39
4	9.8	132	9	113	12	7.62	8.04	-52.61	-66.1
5	12	159	10	178	14	30.01	31.61	-22.53	-26.78
6	8	140	7	161	13	18.76	16.08	-32.02	-44.56
7	10	155	11	173	16	21.41	20.88	-33.99	-33.9
8	9.2	161	9	150	12	11.29	8.32	-34.91	-43.61
9	13	170	12	180	15	24.99	24.49	-32.41	-34.64
10	10.5	160	12	167	15	25.38	26.61	-28.03	-28.52
11	10	167	11	176	11	19.36	20.38	-36.11	-27.38
12	8.9	158	11	160	15	25.19	25.61	-37.14	-26.21
13	7.8	133	13	150	11	19.88	18.91	-52.06	-62.41

Table II. - Measurement results nasal breathing

Subject no.	Running speed	Heartbeat 1 min	Borg 1min	Heartbeat 19 min	Borg 19 min	Kyphosis average 1min (degrees)	Kyphosis average 19min (degrees)	Cervical lordosis average 1 min (degrees)	Cervical lordosis average 19 min (degrees)
1	9	138	11	160	11	29.75	29.39	-25.27	-28.93
2	11.1	155	13	166	16	11.68	11.72	-22.39	-28.38
3									
4	9.8	161	11	173	13	9.64	10.07	-36.97	-35.93
5	12	161	13	91	14	30.6		-21.23	-20.93
6	8	155	11	155	13	12.23	11.23	-43.12	-38.35
7	10	150	8	166	17	20.42	19.93	-27.68	-29.44
8	9.2	150	8	155	15	10.35	10.79	-32.67	-37.04
9	13	167	11	180	17	25.8	24.7	-29.73	-23.22
10	10.5	150	14	85	16	24.33	24.69	-23.32	
11	10	167	11	188	13	19.69	18.27	-28.82	-33.42
12	8.9	161	11	167	13	26.36		-27.52	-28.1
13									

Table III. – Summary of responses from questionnaire

Subject no.	Duration of time participants could maintain nose breathing (min)			Difficulty at higher speed	Relaxing	Continue
	1st time	Middle	End			
1	15	20	20	yes	yes	maybe
2	45	45	45	yes	yes	yes
3						
4	60	90	90	yes		yes
5	2	5	15	yes	more control	maybe
6	4	10	18	yes		no
7	10	15	30	yes	yes + more control	yes
8	5	10	20	yes		yes
9	15	20	30	yes	yes	yes
10	4	6	15	yes		no
11	25	35	45	no	no side stitches	no
12	15	45	45	yes	yes, less exhaustion + no side stitches	yes
13						

Appendix V. – Approval Project Plan

Fontys Paramedische Hogeschool

B4 Assessment form project plan

Name: Orsi Hegyi Student no:

Date: 12-03-2013

Title: The effect of nasal breathing on athletes

General	
- The project plan is according to format	yes /
- Spelling and language are correct	yes /
Problem description and problem definition (introduction)	
- The problem description is sufficiently clearly formulated	yes /
- The problem description reflects social and paramedical relevance	yes /
- A concrete and relevant research question (or questions) can be formulated based on the problem definition, including possible sub questions	yes /
Objective	
The objective is:	
- Sufficiently clearly and concretely formulated	yes /
- Relevant for a selected target group within the (paramedical) professional practice	yes /
- Practically feasible	yes /
- Achievable within the set time	yes /
Project product	
The project product:	
- Is in line with the problem definition, research question and objective	yes /
- Is usable for the selected target group	yes /
- Is in line with the client's wishes	yes /
- The product requirements are accurately described	yes /
Activities/method	
Sufficient insight is given into the type of activities and types of sources for the performance of the research and the realization of the product	yes /
Time schedule	
- The time schedule gives a global phasing and time investment for the project as a whole and for the coming weeks an increasingly detailed schedule	yes /
- Important moments are recorded in the table (typographically noticeable) (e.g. contact moments, handing-in moments)	yes /
- The time schedule gives a global task division of the planned activities	yes /

Fontys Paramedische Hogeschool

Estimated costs

Clear insight is given in:

- The costs to be expected concerning money and hours yes /
- The division of these costs (project leader, student, programme) yes /

Literature

- Used and planned literature is specific and mentioned to a sufficient extent yes /
- Relevant and recent literature is referred to yes /
- Literature references, in the text and in the literature list, are made according to the Writer's Guide (Wouters 2012) yes /

Comments:
The measurement of the angles should be better described in the methods.
Is there any influence of the treadmill on these angles?
Same speed during both measurements?
Is training supervised or unsupervised?

All points under B3.1 up to and including B3.8 must be answered with a 'yes' in order to receive a GO for the project. The supervisor discusses with the student which points need adjustment.

GENERAL: **GO /**

Name assessor: Date + Signature

12-03-2013

Chris Burtin

Steven Onkelinx

Appendix VI – Conveyance of Rights Agreement

AGREEMENT

Pertaining to the conveyance of rights and the obligation to
convey/return data, software and other means

The undersigned:

1. Mr/Ms Orsolya Hegyi [*full name as stated in passport*], residing at 5612MH, Eindhoven [*postal code, place of residence*] at the Loondermolen 29 [*street and house number*], hereinafter to be called "**Student**"
   and
2. Fontys Institute trading under the name Fontys University of Applied Sciences, Rachelsmolen 1, 5612 MA Eindhoven, hereinafter to be called "**Fontys**"

CONSIDERATION

A. Student is studying at the Fontys Paramedic University of Applied Sciences in Eindhoven and is performing or will perform (various) activities as part of his/her studies, whether or not together with third parties and/or commissioned by third parties, as part of research supervised by the lectureship of Fontys Paramedic University of Applied Sciences. The aforesaid activities will hereinafter be called "**Lectureship Study Activities**". At the time of the signing of this Statement, the Lectureship of Fontys Paramedic University of Applied Sciences supervises in any case the studies listed in Appendix 1, but this list is not an exhaustive one and may change in the future.

B. It is of essential importance to Fontys Paramedic University of Applied Sciences that (the results of) the Lectureship Study Activities can be further developed and applied without any restriction by Fontys Paramedic University of Applied Sciences and/or used for the education of other students. Fontys wishes in any event – but not exclusively – (i) to be able to share with and/or convey to third parties (the results of) the Lectureship Study Activities, (ii) to publish these under its own name, where the Student may be named as co-author providing that this is reasonable under the circumstances, (iii) to be able to use these as a basis for new research projects.

C. In case intellectual ownership rights and/or related claims on the part of Student will be/are attached to (the results of) the Lectureship Study Activities, parties wish – taking into account that which was mentioned under (B) – Fontys Paramedic University of Applied Sciences to be the only claimant with regard to said rights and claims. The Student therefore wishes to convey all his/her current and future intellectual property rights as well as related claims concerning (results of) the Lectureship Study Activities to Fontys, subject to conditions to be specified hereafter;

D. Student furthermore wishes to enter into the obligation – again taking into account that which was mentioned under (B) – to convey all data collected by him/her as part of the (results of) the Lectureship Study Activities to Fontys and not to retain any copies thereof, and also to return all data, software and/or other means previously provided by Fontys as part of (the results of) the Lectureship Study Activities, such as measuring and testing equipment, to Fontys without retaining copies thereof, all the above being subject to conditions to be specified hereafter.

AGREE THE FOLLOWING

Conveyance of intellectual property rights

1.1 Student herewith conveys to the Fontys Paramedic University of Applied Sciences all his/her current and future intellectual property rights and related claims concerning (the results of) the Lectureship Study Activities, for the full term of these rights.

1.2 Intellectual property rights and/or related claims are understood to refer to, in any case – but not limited to – copyright, data bank law, patent law, trademark law, trade name law, designs and model rights, plant breeder's rights, the protection of know-how and protection against unfair competition.

1.3 The conveyance described under 1.1 shall be without restriction. As such, the aforesaid conveyance shall include all competences related to the conveyed rights and claims, and said conveyance shall apply to all countries worldwide.

1.4 Insofar as any national law requires any further cooperation on the part of Student for the conveyance mentioned under 1.1, Student will immediately and without reservation lend such cooperation at first request by Fontys Paramedic University of Applied Sciences

1.5 Fontys accepts the conveyance described under 1.1.

Waiver of personal rights

2.1 Insofar as permitted under article 25 'Copyright' and any other national laws that may apply, Student waives his/her personal rights, including – but not limited to – the right to mention Student's name and the right to oppose any changes to (the results of) the Lectureship Study Activities. If and insofar as Student can claim personality rights pursuant to any national laws notwithstanding the above, Student will not appeal to said personality rights on unreasonable grounds.

2.2 In deviation from that which was stipulated under 2.1, the Fontys Paramedic University of Applied Sciences may decide to mention the name of Student if this is reasonable in view of the extent of his/her contribution and activities.

Compensation

Student agrees that he/she will receive no compensation for the conveyance and waiver of rights as described in this Statement.

Guarantee concerning intellectual property rights

Student declares that he/she is entitled to the aforesaid conveyance and waiver, and declares that he/she has not granted or will grant in future, license(s) for the use of (the results of) the Lectureship Study Activities in any way to any third party/parties. Student indemnifies Fontys from any claims by third parties within this context.

Obligation to convey/return data, software and other means

5.1 At such a time as Student is no longer performing any Lectureship Study Activities and/or is no longer a student at Fontys, Student is obliged to convey to Fontys all data, in the widest sense of the word, collected by him/her as part of (results of) the Lectureship Study Activities, including – but not limited to – studies and research results, interim notes, documents, images, drawings, models, prototypes, specifications, production methods, process descriptions and technique descriptions.

5.2 Student guarantees not to have kept any copies in any way or form of the data meant under 5.1.

5.3 Student is obliged to return to Fontys all data, software and other means provided to him/her by Fontys as part of the Lectureship Study Activities, and guarantees not to have kept copies in any way or in any form, of the provided software and/or other means.

5.4 Student agrees that if he acts and/or proves to have acted contrary to the obligations mentioned under 5.1 up to and including 5.3, (a) he/she shall be liable for all and any damages incurred or to be incurred by Fontys, and (b) that this will qualify as fraud and that Fontys can apply the appropriate sanctions hereto. The sanctions to be applied by Fontys may consist of, among other things, the denying of study credits, the temporary exclusion of the Undersigned from participation in examinations, but also the definitive removal of the registration of the Undersigned as a student at Fontys.

Waiver

Student waives the right to terminate this Agreement.

Further stipulations

7.1 Insofar as this Agreement deviates from the Student Statute, this Agreement shall prevail.

7.2 This Agreement is subject to Dutch law. All disputes resulting from this statement will be brought before the competent judge in Amsterdam.

Student:	**Fontys Institute** **trading under the name Fontys Hogescholen** **Supervisor:**
Name: _____Orsolya Hegyi_____	Name: _____
_____	_____
(signature)	(signature)
Date:30/05/2013	Date:__/__/_____
Place: _____Eindhoven_____	Place: _____

I, Ms. M.H. de Waard, sworn translator for the English language registered at the Court in Groningen, the Netherlands, and registered in the Dutch Register of Sworn Translators and Interpreters (Rbtv) under nr. 2202, herewith certify the above to be a true and faithful translation of the attached Dutch document into the English language.

Groningen, 23 May 2012,

[M.H. de Waard]

Appendix VII. - Confidentiality statement

Name: Orsolya Hegyi Student No°: 2146045

Title: The effect of nasal breathing on amateur runners

_____

Content (description)**:**

1. By signing this Statement, the Fontys Paramedic University of Applied Sciences in Eindhoven commits itself to keep any information concerning provided data and results obtained on the basis of research of which is taken cognizance as part of the above practical research project and of which it is known or can be reasonably understood that said information is to be considered secret or confidential, in the strictest confidence.
2. This confidentiality requirement also applies to the employees of the Fontys Paramedic University of Applied Sciences, as well as to others who by virtue of their function have access to or have taken cognizance of the aforesaid information in any way.
3. The above notwithstanding, the student will be able to perform the practical research project in accordance with the statutory rules and regulations.

Student:

Name: ____Orsolya Hegyi_____

_____

(signature) Date: 30/05/2013

Supervisor:

Name: _____

_____

(signature) Date:__/__/_____

Coordinator: for receipt

Name: _____

_____

(signature) Date:__/__/_____