Working Paper

Breathing and Nasal Structures: Climatically Related Energetics

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Anthropologists have studied the relationship between nasal form and climate for more than 100 years, beginning at least as early as 1913 when Arthur Thomson read the paper “The Correlation of Isotherms with Variations in the Nasal Index” at the Anatomical Section of the International Medical Congress. Ten years later, Thomson and Buxton published an expanded version (Thomson and Buxton 1923). The preponderance of subsequent reports, if not all of them, have found, as Thomson and Buxton did, that tall, narrow nasal forms characterize cold, dry climates and short, broad nasal forms are found in hot, humid climates.

Thomson and Buxton offer anatomical descriptions of the internal nasal structures, including the conchae (or turbinates). These vary in size and placement, maximizing exposure of air to mucous membranes in tall, narrow noses and minimizing exposure in broad, short structures. The authors provide clear descriptions of how the nasal air-warming system works. Their statistical measures differ from those in papers today, as computer analysis offers modern scholars many advantages, but Thomson and Buxton’s samples, compared to most modern samples, are quite large. They use data in 153 samples of living people from all over the world, most with more than 30 subjects; and they have data from 98 cranial samples in diverse regions, most with 20 or more crania. Additionally, their paper is one of very few that discusses benefits of a broad nose in expelling hot moist air quickly.

Re-reading the paper in 2016, I found myself wondering why so many scholars, including myself, bothered to conduct additional studies. One answer is simply the appeal of the subject and another is that each new paper has offered a slightly different approach or has examined a different population; two recent excellent contributions are Fukase et al. (2016) and Butaric and Maddux (2016). The addition of genetic data from sampled populations contributes another dimension. Roseman and Weaver (2004) found, in comparing two genetically related populations that live in different climates, that the mid-facial area of the face (nasal structures) shows climatic effects while other cranial measures reflect ancestral connections. By comparing northern and mid-latitude samples of Athapaskan speakers who had separated 1,000 years ago, I determined that the nasal area of the southern sample had changed to reflect local conditions, while other cranial attributes had not, thus supporting findings of Roseman and Weaver (Hall

2006).

I’ve always been fascinated by noses and breathing, particularly by nasal shapes that vary in populations around the globe. In 1997, I began a study of nasal form in geographically diverse crania. After examining 518 crania housed at six different museums my general conclusions confirmed those that Thomson and Buxton reached and, as other anthropologists have done, I added a few new flourishes by using new measures and statistics, indicated by the titles of papers given at meetings; full information is listed in the References:

Metric Analysis of Non-Metric Traits Categorizing Nasal Form 1999
Intra-populational Variation in Nasal Morphology 2000
Human Biological Diversity: The Nose 2001
Narial Margin of the Piriform Aperture—Epiphenomenon or Forensic Indicator? 2003
How Does Nasal Morphology Respond to “In-between” Climates? 2005
Mid-Facial Climatic Adaptations of Indigenous Alaskans (Aleut, Inuit, and Northern Athapaskan) and People of the Northwest Coast 2006

Having become interested in energetics analysis in the reproductive system (Hall 2004), I became interested in exploring what lies behind the climate connection, that is, how climatic variation in nasal morphology manifests energetically in subjects. Breathing is the *sine qua non* of life as it brings oxygen in to provide energy. Adaptations of the lung and chest to low oxygen pressure have been studied in various high altitude regions for several decades, but, strangely, the nasal area, where air enters and is conditioned before it goes to the lungs, has not received a physiological analysis. Thus, I reasoned, it would be worthwhile to examine the morphologies of nasal structure that anthropologists presume natural selection has produced to adapt populations to particular environments, and learn what the energetic effects are. I decided to develop experiments using metabolic measures to determine the energy consumed by having deep, narrow nasal structures versus broad, short structures.

Research with other species has included physiological correlates of the morphology of breathing. Studies of mammal and bird metabolism show that these endotherms position turbinates (conchae) at the front of the nasal airway and that these turbinates conserve moisture and heat (Hillenius 1994; Geist 2000). In contrast, reptiles consume a tenth to a fifth of the energy of comparably sized birds and locate their turbinates where they benefit olfaction. It seemed time to examine variation in human nasal anatomy and compare outcomes metabolically under different climate conditions.

This is the type of study that Ted Steegman recommended when he wrote in Albert Damon's (1975) pioneering volume on physiological anthropology: "No physiological studies, to my knowledge, have been made of humidity, temperature, and disease or survival in the context of the nasal variation in a single population or in the whole species. Once again, these areas of distributional-physiological integration await simple but uncompleted experimentation" (Steegman 1975: 138).

Taking an evolutionary approach to human variation in breathing structures requires us to think about life in prehistoric societies where people do considerable amounts of physical work and food is not always readily available. Energy efficiency is important. Energetics theory as applied to nasal shape and structure posits that natural selection favors nasal adaptations that conserve energy in a population's native habitat. Because humans live in diverse climates, structures can be expected to vary.

My initial study employed 24 male and 26 female young adult subjects to test protocols. Our team did two sets of metabolic tests of subjects in three positions: resting; sitting up; and doing moderate exercise. Moderate exercise was operationally defined as cycling on a stationary cycle with a level of resistance that produced a heart rate 60% of expected maximal heart rate, based on age (Hall 2005). In one session we used a mask allowing only nose breathing, and in the second session we used a mask allowing only mouth breathing. Nasal breathing is advantageous because it facilitates conditioning air for temperature and moisture, and can remove small particles of dust and other pollutants, but intense exercise demands mouth breathing also.

Protocols worked well; other findings included that nose breathing in most individuals consumed less oxygen than mouth breathing. Lean body composition and male gender, which tend to co-occur, were equally strong in explaining VO2 values, as expected. We also interviewed subjects after each trial. Subjects reported that mouth breathing during exercise dried the throat whereas nose breathing was more comfortable. Exercise scientists normally have subjects breathe through their mouths because it is easier to attach the mouth to measurement devices and because breathing at high capacity requires mouth breathing. In a modern laboratory situation it is not difficult to replace lost moisture or soothe the throat after a test. However, these luxuries are not available to a prehistoric human doing daily activities at moderate levels under ordinary circumstances, and it is this experience that we wanted our experiment to represent.

Going to the next step in the project required either taking the research to varying habitats and testing subjects who live there or finding a laboratory substitute to do an experiment. John Halliwill of the Human Physiology Department at the University of Oregon agreed to be co-investigator on a pilot project in his lab using a climate chamber with temperature and humidity controls to simulate climatic conditions in other environments. We began work with each subject by testing for maximum VO2 using separate air tubes from the nose and mouth, in order to determine how each subject breathes naturally. We thus could learn how nose and mouth breathing changed as exercise on a cycle became increasingly intense. Subjects varied a great deal; the chart below shows the breathing by nose and mouth of one subject throughout his maximum VO2 test. He experienced cross-over from primarily nose-breathing to primarily mouth-breathing a little more than half way through his trial.

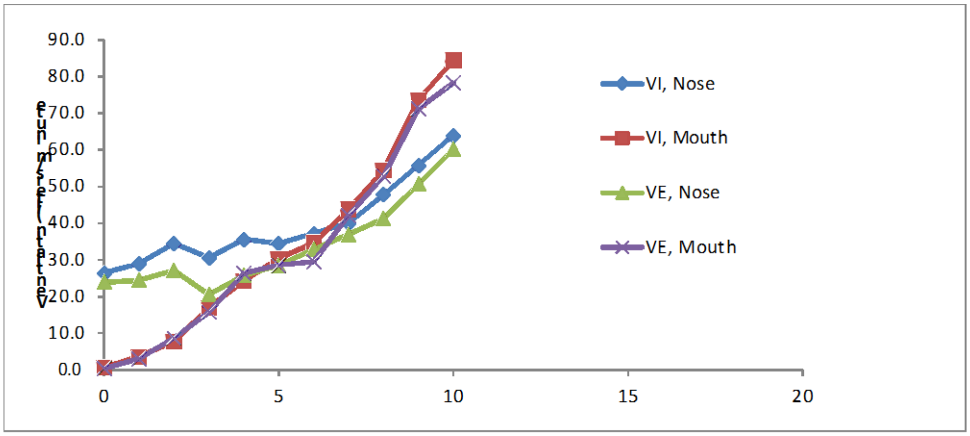


Chart of a subject’s nose and mouth breathing experience during a maximum VO2 test. VI blue shows nose inhaling; VE green shows nose exhaling; VI red shows mouth inhaling and VE purple shows mouth exhaling. Cross-over can be seen a little more than half way through the exercise at about seven and a half minutes.

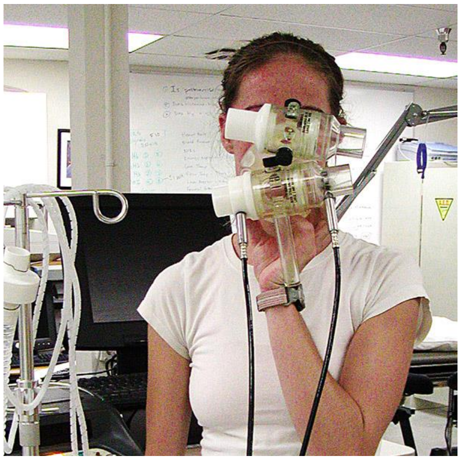
Doing the maximum VO2 test, which entails having a subject cycle at increasing cycling resistance until s/he cannot continue any longer, allowed us to base the level of moderate exercise on the subject’s own maximum heart rates. In our climate-based exercises, we used information from the maximum test and recorded data at three different resistance levels that corresponded, in turn, with 20%, 40%, and 60% of the subject’s maximum heart rates.

Halliwill added instruments to the exercise mask to measure the temperature and moisture levels of expired air during simulated climate experiments. Climate simulations were set to characteristics like those recorded in Calcutta, India (35 C, ~22 Specific Humidity), Wales, Alaska (-12 C, ~1 Specific Humidity), and our indoor lab (20 C, ~11.2 Specific Humidity). I chose Calcutta and Wales because these were extreme in terms of temperature and humidity and were sites from which I had samples of cranial data; the indoor lab measurements were used as a control. We referred to the indoor lab conditions as thermo-neutral, meaning a comfortable air temperature and humidity for ordinary indoor spaces. Someone growing up in a very different environment might have an argument with that, but at least all of the subjects that we worked with had experience in the western Oregon environment for some time and were accustomed to it. We completed a pilot project with 12 male University of Oregon students between the ages of 18 and 28.

Nasal area metrics included measurements to estimate the depth as well as height and breadth of internal nasal structures, measurements of the external fleshy nose, and a standard set of body measurements plus body composition. The subjects varied widely in all measures, including the VO2 max, implying that they varied in general aerobic fitness. To control for confounding variables such as subjects' body size, I made intra-individual comparisons of the heat and moisture of expired air under different climate simulations, i.e., I used the subjects as their own control. The concept was to compare how much a subject's energy use in each extreme location varied from his own energy use in the thermo-neutral trial. Making ratios of these for nose-only and mouth-only trials, I correlated the ratios with nasal metrics. (See the poster paper in this folder titled NasalMorphologyPhysiology.pdf; Hall, Halliwill, and Bridgmon 2012).

Correlations were intriguing but not definitive. Interviewing subjects after each trial revealed that subjects experienced more stress during the hot/humid trial than during the cold trials, and two failed to complete the hot trial at the 60% moderate exercise level. This observation convinced me that, as Thomson and Buxton had suggested, the selective value of a broad open nasal chamber in a warm and humid climate may be equally as important as that of a narrow chamber in a dry, cold climate.

Of course this was a pilot study and we could not test the nasal energetics hypothesis in a small pilot study and we knew we needed many more resources to continue. Clearly a large test involving subjects with greater morphological diversity than was available in Oregon is needed, perhaps involving two or three universities in diverse geographical regions. Testing using a mask, particularly when various sensors are added and when the subject is exercising and thus moving the mask to and fro, does pose complications. It is difficult during mouth breathing only, but even trickier when restricting breathing to the nose. Our cumbersome mask with sensors measuring heat and moisture going in and out made air-tight fitting questionable, even when using gel to attempt to provide a seal. Ideally, I would want to place a subject in an air-tight chamber with only the subject and necessary equipment inside and all air metabolically recorded. I found myself envying zoologists like Nicholas Geist (2000) whose subjects were birds. Room-sized chambers suitable for human subjects exist, but we did not have access to one.



I continue to think that such a test could provide a proof of concept. Such data could enable the project to receive support needed to fully test the nasal energetics hypothesis using experiments based on protocols such as those we developed. Irrespective of all the cultural adaptations invented to aid humans, breathing and adapting to the atmosphere where we live are still central to human existence as they are to other mammals. Practical applications of what is learned may be used to ameliorate health problems such as allergies, asthma, and sleep apnea. Research on this topic could perhaps be useful as humans attempt to adapt to atmospheric changes that may result from global warming. Regardless of applications, the purpose of this research is to understand how humans have responded to their environments in the past, and what mechanisms and principles govern adaptation in the future.

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