Pitted-Ware Skeletons and Boreal Temperatures

BY TORBJÖRN AHLSTRÖM

Abstract

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In the following paper, adaptations to cold stress are discussed with respect to two osteological characters, the Nasal Index and the Crural Index. The Nasal Index measures the constriction of the nasal opening. The Crural Index measures the relative shortening of the distal segment of the lower extremity. Based on data supplied by Howells (1989) and Trinkaus (1981), the functional relationship between these osteological characteristics and Mean Annual Temperature was assessed. The empirical findings thus produced were confronted with data from archaeological contexts, in order to elucidate the climatological experiences that the prehistoric populations may have encountered. The results of the present analysis firmly suggest that the bearers of the Pitted-Ware tradition were adapted to cold stress, and that the populations buried in South Scandinavian collective graves, i.e. Middle and Late Neolithic populations, were not. Further, some of the implications of this finding are discussed, especially with regard to the diet of the Pitted-Ware tradition.

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Introduction

Humans require chemical energy obtained via a number of sources in the environment in order to maintain life. This chemical energy is converted into a number of useful metabolic by-products, but much of this energy will be converted into heat. Heat is needed in order to catalyse different chemical processes in the body. However, heat may be lost due to conductance if the temperature of the surrounding environment – ambient temperature – is lower than body temperature. Crucial for understanding heat loss is the lower critical temperature (LCT). The LCT of a naked human is 27°C (Feist & White 1989; Garland 1994), which can be considered quite high, and it reveals a tropical origin for *Homo*. The metabolic rate will increase in order to balance a fall in body temperature if the ambient temperature falls below the LCT. However, the increased metabolic rate can only be sustained for a limited period of time and eventually, the loss of heat will be fatal. Given the distribution of our species, it is obvious that *Homo* has encountered ambient temperatures far below the LCT of the human body at several locations around the world. In this respect, it can be mentioned that the LCT of the Arctic fox is –6°C (Davenport 1992, p. 10). And yet, there is ample evidence to suggest that during the later Pleistocene and Holocene, humans and Arctic foxes coexisted in the same environment: the tundra. This narrows down to the fundamental question why we find a tropical animal alongside non-tropical animals in non-tropical environments. Adaptation to low ambient temperatures probably represents one of the most fundamental challenges facing prehistoric humans. However, this is a much larger question than the one about to be addressed in the following paper.

Conspicuous traces of a Stone Age population has been unearthed at several locations in Southern Scandinavia during the last century. The material culture encountered has been labelled as the Pitted-Ware Culture, named after the characteristic pit decorations on the pottery. The majority of the Pitted-Ware dwelling sites are located on former shorelines of the Littorina Sea. The tradition has been dated within the timespan 5000 to 3500 BP (Åkerlund 1996). The emergence of this tradition has been one of the most intriguing issues presented to Scandinavian archaeology. The major reason for this is the distinct adaptation to maritime resources as evidenced by the archaeological record. Both animal bones and measurements of stable isotopes of human bones indicate a notable portion of marine protein in the diet (cf. Ericson 1989; Lidén 1995). The frequency of caries – which can be used as a rough indicator of the degree of carbohydrates in the diet – is zero in odontological materials from Pitted-Ware contexts (Holmer & Maunsbach 1957). The emergence of the Pitted-Ware tradition somewhat postdates the introduction of a Neolithic mode of existence in Scandinavia ca. 5200 BP (cf. Åkerlund 1996). Why the emergence of this hunter-gatherer mode of subsistence after the inception of an agro-pastoral economy in South Scandinavia? Several theories have been advanced to explain this fact (cf. Åkerlund 1996 for further references). Some scholars argue that there is a continuation between the Late-Atlantic foraging populations (i.e. the Ertebølle tradition) and the Sub-Boreal Pitted-Ware tradition. This is a salient feature of the models concerning Neolithization presented by Zvelebil (1996), that is, the long and continuous existence of hunter-gatherer populations in South Scandinavia. Other scholars argue that the Pitted-Ware Culture evolved via Neolithic agro-pastoral populations – the Funnel-Beaker and/or Battle-Axe traditions – without a direct relationship with the Mesolithic foragers. According to this model, the Pitted-Ware population can be regarded as an original agro-pastoral population re-adapting to a hunter-gatherer mode of existence due to a climatic deterioration during the Sub-Boreal chronozone. Finally, some scholars argue that the Pitted-Ware Culture represents a western section of the North-Eastern Comb-Ware Culture. Clearly, understanding the emergence of the Pitted-Ware Culture will undoubtedly be crucial for the understanding of Neolithization in the region. All the models presented above are based upon different aspects of the material culture. None of the models described incorporates the anthropological material.

The principal aim of this paper is to broaden the context in which the Pitted-Ware tradition ought to be understood, this by reference to the anthropological record. In a recent paper, I have demonstrated that the mean Crural Index (see below) of skeletons attributed to the Pitted-Ware tradition is relatively low, comparable to recent populations of Saami and Inuit origins (Ahlström 1997). Following the results of Trinkaus (1981), this suggests that the population producing the Pitted Ware material culture was adapted to low ambient temperatures. This finding contrasts with the results from other South Scandinavian late Mesolithic and Neolithic (i.e. Funnel-Beaker and Late Neolithic) materials. These latter populations do not show any apparent skeletal indications of adaptations to low temperatures. My approach in the present paper is as follows: First I will discuss adaptations to cold stress from a general anthropological point of view. In the end, this discussion will narrow down to two osteological characteristics that convey information on cold stress: the aforementioned Crural Index and the Nasal Index. Next, I will carry out an analysis of intergroup differences with respect to these indices. This analysis will include anthropological material from Mesolithic, Funnel-Beaker, Pitted-Ware and Late Neolithic South Scandinavian contexts. Finally, this is followed by a discussion on the significance of the findings from an archaeological perspective.

Adaptations to cold

The empirical findings of over a century of research into the biological anthropology of man demonstrate a correlation between morphological variation and environment (So 1980; Ruff 1994). However, a strong correlation *per se* need not imply a causative mechanism. We cannot assume that a trait is adaptive just because it covaries with the environment. The adaptive value of a trait should be proved rather than taken for granted. Alas, proofs are in fact very difficult to obtain. In the following, the discussions on the specific osteological characteristics will be somewhat hampered by this fact. They can – in a broader sense – be considered as well-informed conjectures. The present study will use the comparative method in order to correlate morphological differences between recent human populations with Mean Annual Temperature as an ecological factor. These recent human populations have been sampled from different locations around the world. The reason for this is to reduce the risk of inferring causative relationships from populations that are morphologically similar due to an immediate common ancestry. Further, it is assumed that the morphology of these spatially distinct groups is a product of an evolutionary ancestral environment that is equivalent to the present geographical location. The relevance of this assumption will be discussed below. The findings from these analyses will be compared with the characteristics of Late-Atlantic and Sub-Boreal populations from Southern Scandinavia, in order to elucidate the climatological reality that these populations may have encountered. I will specifically address two osteological characteristics that have been demonstrated to convey information on adaptations to low temperatures: the Crural Index and the Nasal Index.

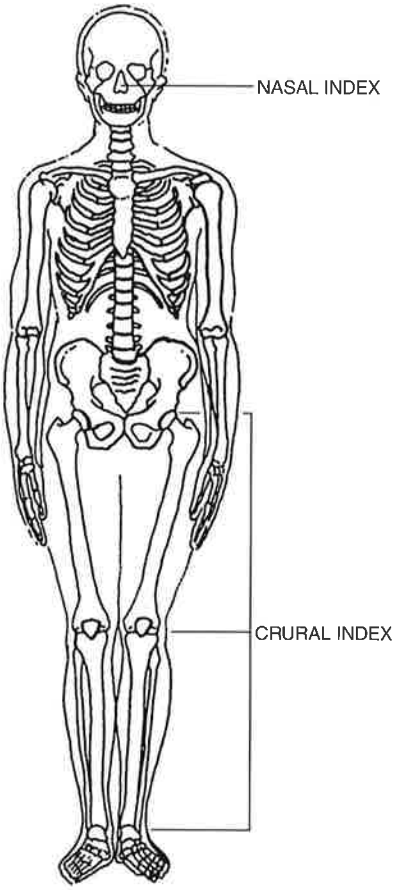

Fig. 1. Osteological characteristics that have been shown to covary with ambient temperature, the Nasal Index and the Crural Index.

Basically, the Crural Index measures the relative shortening of the length of the shin bone (tibia) compared with the length of the thigh bone (femur). The Nasal Index measures the constriction of the nasal opening. Before discussing these characters at length, I shall briefly introduce the biological theory that seeks to explain their covariation with temperature.

There are basically two options available upon encountering low ambient temperatures and cold stress: adaptation or escape. The adaptation governed by cold stress will include strategies for decreasing heat loss as well as increasing heat production (Feist & White 1989). In order to decrease heat loss, humans had to increase the physical and physiological insulation of the body. Culturally induced acclimations to increase insulation include hides for clothing, control of fire and sheltered dwellings. An adaptation to cold stress will also require alterations of the human morphology and physiology in order to improve insulation. The osteological consequences of this will be discussed at length below. Heat production may be increased by a diet proportionally rich in energy, i.e. diet-induced thermogenesis, the consequences of which will be discussed below.

Apart from its olfactory function, the human nasal cavity contains anatomical structures to filter, humidify and heat inspired air – the turbinate bones. Although the turbinate bones are confined within the nasal cavity, there is ample evidence suggesting a correlation between the shape of the anterior nasal opening – the piriform aperture – and climate (Thomson & Buxton 1923; Davies 1932; Weiner 1954; Wolpoff 1968). In cold and dry climates the piriform aperture tends to be narrow, in hot and damp climates the piriform aperture tends to be broad. In the context of cold stress, it has been argued that the narrowing of the nasal opening reduces the inflow of cold air and prevents damage to the lungs. Further, the narrowing of the piriform aperture may enhance the recovery of heat from expired air (Franciscus & Long 1991). In order to elucidate the functional relationship between the shape of the nasal opening – as measured by the Nasal Index – and temperature, I have used the database on cranial metrics collected by W. W. Howells (1989).

Crucial for heat loss due to conductance is the volume of the body and its associated surface. Relatively larger objects will have relatively smaller surfaces, as the surface of an object increases disproportionally with an increase of volume. In this respect, the extremities of the human body have a relatively greater surface exposed to the environment than the core – or the trunk – of the body. Thus, extremities provides significant pathways for heat loss. One way to reduce the contrast in temperature between the body and the environment is to lower the temperature of the extremities, known as peripheral heterothermy (Feist & White 1989). Peripheral heterothermy implies that the extremities are relatively cold compared with the body core. Crucial for the establishment of this temperature gradient is peripheral vasoconstriction and countercurrent heat exchange (Bligh 1973; Feist & White 1989, Davenport 1992). Heat loss can be controlled by the sympathetic nervous system by diverting blood flow away from the surface of the body. This is accomplished by a contraction of blood vessels (vasoconstriction) close to the surface, which reduces blood flow. Countercurrent heat exchange implies that warm arterial blood leaving the core of the body gives up heat to the cold venous blood returning from the extremities. This system will level the differences with regard to temperature between the body core and the extremities and reduce heat loss. Both vasoconstriction and countercurrent heat exchange may be crucial for understanding the relative shortening of the distal segment of the lower extremity in cold stressed populations.

Trinkaus (1981) argued that decreased blood flow to the lower extremity due to vasoconstriction would truncate growth of the distal segment – i.e. the tibia – and produce a relatively short bone. This would explain the low crural indices associated with recent cold stressed populations. As bone growth demands a well-vascularized milieu, where blood supplies the growing tissues with both oxygen and nourishment, it would – superficially – seem to be a plausible explanation. Following Trinkaus (ibid.), the relative shortening of the distal segments of the lower extremity is a result of ecophenotypic plasticity (acclimation), induced by climate and not a result of natural selection (adaptation). However, there are drawbacks with this theory. Bass (1988) – originally from Stewart – published a chart comparing the growth of the femur for Inuits and Caucasians. As is evident from a mere inspection of this chart, the growth trajectories for the two populations are different, divergent already at birth. Now, this may not be of immediate importance to the problem presented here. There seems to be ample evidence to suggest that Inuit growth follows a slower tempo than that of Caucasians (Auger *et al.* 1980; Zammit *et al.* 1994). However, it is unlikely that this can be regarded as an acclimation to cold stress as the human foetus – reared within the warm body core of the female – obviously is secured from the effects of vasoconstriction and countercurrent heat exchange. If it can be demonstrated that the relative shortening of the distal segment of the lower extremity is present at birth among cold stressed populations, and not so among populations from warmer climates, I would suggest that this implies an adaptation via natural selection rather than an acclimation. However, at present, this question cannot be answered. One could speculate that the relative shortening of the distal segment of the lower extremity increases the effectiveness of countercurrent heat exchange among humans. As Lynch (1986) points out, if there is genetic variability and a selection pressure induced by cold stress is present, even small advantages will be selected. Trinkaus (ibid.) demonstrated a functional relationship between the relative shortening of the distal segment of the lower extremity and temperature, although the cause of this covariation may be discussed. For an application of the same principles to European Upper Palaeolithic and Mesolithic materials, see Jacobs (1985a,b).

Trinkaus also studied the Brachial Index, an index that measures the relative shortening of the distal segment (radius) of the upper extremity. He was able to establish an even stronger association between this index and Mean Annual Temperature compared with the Crural Index. However, he also demonstrated that this index is influenced by sexual dimorphism and should be studied separately with regard to sex. As the sexual determinations in the prehistoric database (see below) are varied with respect to the completeness of the individuals, methodology employed, and so on, I have felt reluctant to include the Brachial Index in the present study.

Material and methods

The recent samples of human populations used in order to elucidate the functional relationship between osteological characters and Mean Annual Temperature (MAT) are reported in Tables 1 and 2. The data on the Nasal Index was derived from the worldwide database collected by Howells (1989). The data concerning the Crural Index have been adapted by and large from Trinkaus (1981), although I have added some further data on circumpolar populations from Jørgensen (1953). Data on Mean Annual Temperatures (i.e. 1/2 (average max. temp. + average min. temp.)) were collected from Lamb (1973). The question whether the osteological characteristics depend on Mean Annual Temperature was assessed by means of a linear regression analysis (Sokal & Rohlf 1981).

The Mesolithic specimens used in this analysis derive from the cemeteries at Skateholm, Scania, Southern Sweden. This material, dated roughly to 6 000 BP, has been published by Persson & Persson (1988). The skeletal material attributed to the Middle Neolithic Funnel-Beaker Culture has been collected from Bröste *et al.* (1956). However, it should be emphasized that much of this material has not been securely dated by means of radiometric datings. Anthropological material from Pitted-Ware contexts derives from the cemeteries at Ire (Gejvall 1974; Sjøvold 1974), Fridtorp (Persson & Persson 1982), Visby (Dahr 1946; Gejvall 1974, Sjøvold 1974) and Västerbjers (Dahr 1943; Gejvall 1974; Sjøvold 1974). It should be remembered that the geographical distribution of these materials is highly localized to the island of Gotland. Finally, the Late-Neolithic material has been collected from Bröste *et al.* (1956).

Nasal shape was measured by the Nasal Index (NI) = nasal breadth x 100/nasal height. The

Table 1. Data on mean Nasal Index and temperature for 28 recent populations.

No.	Population	N	Mean	SD	MAT °C
1	Northern Europe, Norse, Oslo	110	49.2	4.0	5.8
2	Central Europe, Zalavar	98	50.2	4.2	10.8
3	Central Europe, Berg	109	50.5	4.8	9.8
4	East Africa, Teita	83	57.5	4.7	17.4
5	West Africa, Dogon	99	60.0	4.3	29.3
6	South Africa, Zulu	101	58.2	3.8	20.6
7	South Australia, Lake Alexandrina	101	56.4	4.1	17.2
8	Tasmania	87	60.2	5.4	12.5
9	Melanesia, Tolai	110	57.4	4.5	26.8
10	Polynesia, Mokapu	100	52.1	3.9	23.9
11	Polynesia, Easter Island	86	53.7	3.7	20.3
12	Polynesia, Moriori	108	48.6	4.1	12.3
13	North America, Early Arikara	69	50.3	3.4	2.6
14	North America, Santa Cruz	102	49.8	4.0	17.1
15	South America, Peru	110	50.3	4.4	13.0
16	N Japan, Hokkaido	87	50.0	4.5	5.7
17	S Japan, North Kyushu	91	51.0	3.7	16.8
18	China, Hainan	83	52.6	4.7	22.3
19	Taiwan, Atayal	47	53.9	4.6	22.1
20	Philippines	50	55.0	4.0	26.6
21	Guam	57	51.6	4.1	26.7
22	Bushman, San	90	61.4	5.3	17.0
23	Andaman Island	69	54.1	4.2	27.9
24	Ainu, Hokkaido	86	54.8	4.6	5.7
25	Siberia, Buriat	109	50.2	3.8	–7.4
26	Inuit, Inugsuk	108	45.1	4.1	1.8
27	S Maori	10	48.9	4.9	12.6
28	N Maori	10	51.3	3.8	12.6

Source: Howells 1989. MAT (°C) from Lamb 1973.

relative shortening of the shin bone was measured by the Crural Index (CI) = maximum length of tibia x 100/physiological length of femur. The majority of the texts cited above report the maximum length of the femur, rather than the physiological length of the bone. However, the physiological length of the femur is consistently smaller than the maximum length of the bone, and this difference amounts to approximately 4 mm. In the following, I have reduced the reported maximum length of the bones by 4 mm prior to the calculation of the Crural Index. Thus, the CIs reported in this text replace the ones reported in Ahlström (1997). It was not possible to calculate the CI on an individual basis for the Middle and Late Neolithic materials, as these derive from collective graves with disarticulated skeletal remains. However, as the mean of the CIs measured on an individual basis is equivalent to the CI derived from taking the ratio from the means of the lengths of the individual bones, this is not a major obstacle. In this context it is assumed that well-preserved disarticulated individuals are equally well-preserved with respect to the individual bones of the lower extremity.

Table 2. Data on mean Crural Index and temperature for 15 recent populations.

No.	Population	N	Mean	SD	MAT °C
1	Northern Europe, Saami	140	79.1	–	1.9
2	Inuit, Inugsuk[1]	74	78.7	–	1.8
3	Inuit, N.-East Greenland[1]	14	81.8	–	–4.0
4	Inuit, Kodiak Island	40	81.1	1.6	4.5
5	Southern Europe, Yugoslavia	39	83.7	2.5	11.8
6	Euro-Americans	30	83.1	2.4	9
7	Belgians	40	82.3	3.0	9.1
8	Amerindians, New Mexico	40	85.0	2.1	20.1
9	S. Africa, Bantus	30	86.7	2.6	16.1
10	Amerindians, Arizona	23	86.2	2.1	21.4
11	San, Bushmen	15	83.7	2.3	16.8
12	Melanesia, New Caledonia	29	85.2	–	26.8
13	Africa, Pygmies	23	84.8	–	20.2
14	Afro-Americans	40	85.4	2.2	26.5
15	N. Africans, Egypt	40	85.5	1.6	21.5

Source: Trinkaus 1981 except (1) from Jørgensen 1953. MAT (°C) from Lamb 1973.

Table 3. Results of linear regression analysis.

Dependent variable	N	Correlation	Regression coefficient	Coefficient of determination	*t*-Ratio	*P*
Nasal Index	28	0.520	1.166	0.270	3.101	0.005
Crural Index	15	0.843	3.277	0.711	5.652	0.000

Results

The relationship between the Nasal Index, Crural Index and Mean Annual Temperature are shown in Figures 2 and 3. The results of the regression analysis are reported in Table 3.

The correlation between the NI and MAT (°C) is 0.520. The functional relationship between the NI and MAT (°C) can be written as MAT ± 7.9 (°C) = –46.447 + 1.166 x NI. The coefficient of determination is 0.270, implying that only 27.0% of the variation with regard to the NI can be explained by variation in Mean Annual Temperature. The regression coefficient, however, is significantly different from zero, implying that an increase in MAT (°C) is followed by an increase in NI: the warmer the climate, the broader the nasal opening. The correlation between CI and MAT (°C) is 0.843, suggesting a stronger causative relationship than was the case with the NI. The functional relationship between the CI and MAT (°C) can be written as MAT ± 5.3 (°C) = –260.000 + 3.277 x CI. The coefficient of determination is 0.711, implying that 71.1% of the variation with regard to the CI can be explained by variation in Mean Annual Temperature. The regression coefficient is significantly different from zero, implying that an increase in MAT (°C) is followed by an increase in CI: a warmer climate will be followed by a relatively longer shin bone. The results reported above are consistent with prior knowledge (Trinkaus 1981; Franciscus & Long 1991). These empirical findings will suffice as references as we vivisect

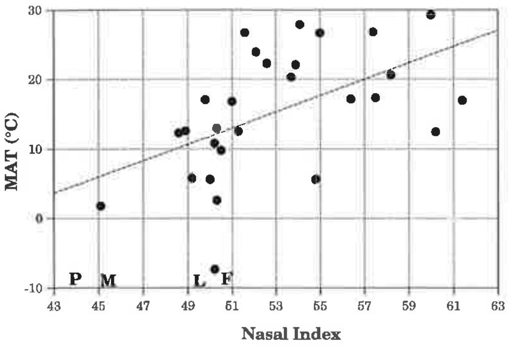

Fig. 2. Results of regression analysis of Nasal Index and Mean Annual Temperature. Data from Table 1. M = Mesolithic, F = Funnel-Beaker, P = Pitted-Ware and L = Late Neolithic (refer to Table 4).

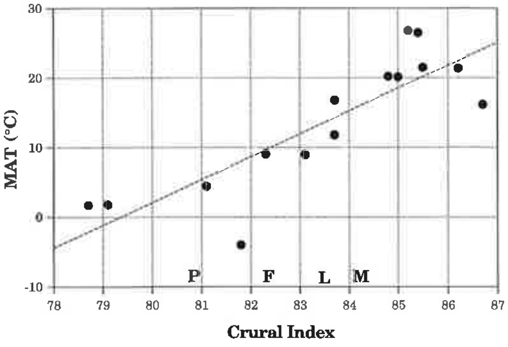

Fig. 3. Results of regression analysis of Crural Index and Mean Annual Temperature. Data from Table 2. M = Mesolithic, F = Funnel-Beaker, P = Pitted-Ware and L = Late Neolithic (refer to Table 4).

the bioanthropological variation present in Late-Atlantic and Sub-Boreal contexts from Southern Scandinavia.

As is evident from Table 4, there are differences between the various archaeological groups. With respect to the NI, the lowest values are associated with the Pitted-Ware Culture. In fact, the mean NI for this group is lower than any mean estimated from the recent database of Howells (see Table 2). Estimated MAT (°C) of the archaeological groups is presented in Table 5.

The functional relationship between NI and MAT suggests that the Pitted-Ware tradition confronted a Mean Annual Temperature of about 4.2 ± 7.9°C. For both the Middle and the Late Neolithic groups, the evidence from the mean NI suggests a climatological regime with a MAT equal to 12.1 ± 7.9°C and 11.0 ± 7.9°C. The NI of the Mesolithic sample suggests a MAT of 6.1 ± 7.9°C. As the calculation of NI is based on a very modest number of specimens (7), this finding could very well be an effect of stochastic behaviour in the data. With respect to the CI, the mean of the Mesolithic sample suggests a MAT of 15.6 ± 5.3°C, distinctly higher than the case with the NI for this group. For both the Middle and the Late Neolithic samples, the mean CI of these groups suggests a MAT of 9.7 ± 5.3°C and 13.6 ± 5.3°C, more or less consistent with the findings for the NI. Finally, the estimates of the MAT from the mean CI for the Pitted-Ware tradition, 5.1 ± 5.3°C, are consistent with the results from the NI. In this respect, it can be noted that the Pitted-Ware tradition is grouped with Saami and Inuit groups.

Conclusion

Of the two osteological characters studied in the present analysis, the CI provides a somewhat better estimate of MAT (°C) than the NI, as judged by the standard error of estimates (± 5.3 and ± 7.9 respectively). By all means, these standard errors of estimates are rather large. The fact that the NI does not show a stronger association with MAT (°C) might imply that olfactory and respiratory functions counter-select the selection pressures induced by cold stress. There might be a restriction to the narrowing of the piriform aperture, as the nasal organs supply other functions crucial for the fitness of an individual. Another aspect that is crucial in the present context is the initial assumption made in the analysis. The basis for the assumption that the present geographical locations of the populations assembled in Tables 1 and 2 are equivalent to the evolutionary ancestral environments that shaped their morphology, may be questioned. Migrations

Table 4. Mean Crural Index and Nasal Index for prehistoric Scandinavian populations.

No.	Population	Nasal Index			Crural Index		
		N	Mean	SD	N	Mean	SD
1	Mesolithic Culture	7	45.1	2.9	29	84.1	2.5
2	Funnel-Beaker Culture	28	50.2	5.7	25	82.3	–
3	Pitted-Ware Culture	44	43.4	3.9	48	80.9	2.0
4	Late Neolithic Culture	37	49.3	4.6	76	83.5	–

may distort the picture and produce the residuals we see in Figures 2 and 3. Another fundamental question for which there is no answer at the moment, is how fast cold-induced stress would select for the anatomical rearrangements discussed in the present paper. Alas, we cannot estimate the selection coefficients associated with NI and CI with respect to cold stress. However, Livingstone (1969) did demonstrate that selection operating on polygenic traits could produce morphological changes relatively fast. He estimated that in the case of a characteristic determined by four loci and a fitness of 12%, it would take about 150 generations – or about 3500 years – for a morphological change to occur. In this case, Livingstone discussed the change from Neanderthal to modern man, and subsequently found that this change could be accomplished in a very short time. The osteological characteristics discussed in the present context are certainly not of that magnitude. But the fact still remains – as has been shown by the present statistical analysis – that the CI and NI do in fact covary with ambient temperature in a consistent manner.

The results of the present analysis firmly suggest that the bearers of the Pitted-Ware tradition were adapted to cold stress, and that the populations buried in South Scandinavian collective graves were not. For both CI and NI, the results suggest low estimates of MAT (°C) and are consistent for both indices. Based on recent populations, these results suggests that Pitted-Ware populations were adapted to Boreal conditions. The situation with regard to the Mesolithic sample from Skateholm is somewhat ambiguous. The results from the Nasal Index suggest cold stress, but the results from the Crural Index do not. Further data will clarify this issue. Given the fact that we can substantiate two divergent climatological experiences in the archaeological record during the Sub-Boreal chronozone, how should these be explained? The question still remains whether any of these groups are too "hot" or too "warm" given the contemporary palaeoecological circumstances.

Table 5. Estimated MAT (°C) for prehistoric Scandinavian populations.

No.	Population	Estimated MAT (°C)
1	Mesolithic Culture	NI = 6.1 ± 7.9 CI = 15.6 ± 5.3
2	Funnel-Beaker Culture	NI = 12.1 ± 7.9 CI = 9.7 ± 5.3
3	Pitted-Ware Culture	NI = 4.2 ± 7.9 CI = 5.1 ± 5.3
4	Late Neolithic Culture	NI = 11.0 ± 7.9 CI = 13.6 ± 5.3

There are several indications supplied from palaeoecology suggesting that the inception of the Sub-Boreal chronozone is marked by a climatic deterioration. Berglund (1991) lists several environmental parameters that changed during this time: an increased frequency of tree-pollen, expanding glaciers in Northern Scandinavia at 5000–4500 BP, distinctively retreating tree-lines at ca. 5000 BP, and, finally, a regression of the Littorina Sea at ca. 5000 BP (cf. Åkerlund 1996, p. 124). All this taken together implies lower temperatures compared with the Atlantic chronozone. But the question arises whether this climatic change was so drastic that it can account for a local Boreal adaptation on Gotland? Today, the gradient with regard to Mean Annual Temperature is deg. +0.4°C between Southern Scandinavia (7.3°C) and Gotland (6.9°C) (Ångström 1974). The results of the present analysis suggest a steeper temperature gradient than this. Now, I am not suggesting that the osteological characteristics discussed in the present paper can be used as independent methods for assessing palaeoecological conditions. But the contrasts with respect to the different groups are nevertheless clear. Although the climate during the beginning of the Sub-Boreal period deteriorated compared with the Atlantic period and produced a more continental climate, the climate was not significantly different from the present climate. Thus, it seems exceedingly unlikely that the climatological differences between Gotland and Southern Scandinavia were so radical that a local adaptation to cold stress was present on Gotland, but not so in Southern Scandinavia. Now, we do not know how fast a deteriorating climate would select for anatomical rearrangements as discussed in the present paper, but it is unlikely that the palaeoecological setting in Southern Scandinavia was so extreme that it could initiate a selection. I would argue that we have to look further north or east on the Eurasian continent in order to identify the evolutionary ancestral environment responsible for the cold stress experienced by the Pitted-Ware population.

One aspect of the Pitted-Ware Culture that becomes clearer if we subscribe to the theory that the Boreal zone was the evolutionary ancestral environment of the Pitted-Ware tradition is the diet. It has already been noted that the diet of the Pitted-Ware tradition is highly specialized towards marine protein and that clear indications of carbohydrates are lacking. Also, it has been noted that heat production may be increased by a diet proportionally rich in energy, i.e. diet-induced thermogenesis. Anthropologists have established that foraging populations living at high latitudes incorporate more hunting and fishing rather than hunting and gathering in their foraging behaviours (Kelly 1995). The proximal cause behind this foraging behaviour may have been a selection for diet-induced thermogenesis. Thus, an increased food intake may elevate the metabolic heat production. In this respect, meat is richer in energy than the products of gathering. Perhaps this is the cause of the "Arctic diet" that is shown by the Pitted-Ware tradition. This Arctic diet is brought to a lower latitude by this tradition during the Sub-Boreal period, even though the climatological situation in Southern Scandinavia *per se* probably never selected for it. Of all the models discussed in the introduction, which one seems most likely given the findings of the present analysis? It is hard to find evidence that the Pitted-Ware tradition represents a de-Neolithized agro-pastoral population, as the contrasts with respect to these skeletal indices are so marked between the these populations. At the moment, the differences between the Mesolithic foragers and the Pitted-Ware tradition is somewhat ambiguous. The Nasal Index may suggest a relationship, but the Crural Index does not. As the findings from the Crural Index are somewhat more secure than the findings based on the Nasal Index, I am more prone to conclude that there is not an immediate relationship. There is, of course, a significant chronological difference between these materials. However, a selection pressure for cold-induced stress was certainly not present in Southern Scandinavia during this time-span. The model that seems most likely is the model that links the Pitted-Ware tradition to north-eastern Neolithic foraging populations. The major finding of this paper is that the Pitted-Ware tradition ought to be understood in a circumpolar perspective.

References

Ahlström, T. 1997. *Den exogama gränsen: Kring interaktionen mellan jägar-samlare och bönder-boskapsskötare under mellanneolitisk tid.* Stockholm Studies in Archaeology (in press).

Åkerlund, A. 1996. *Human Responses to Shore Displacement: Living by the Sea in Eastern Middle Sweden during the Stone Age.* Diss. Stockholm.

Ångström, A. 1974. *Sveriges klimat.* Stockholm.

Auger, H., Jamison, P. L., Balslev-Jørgensen, J., Lewin, T., De Pena, J. & Skrobak-Kaczynski, J. 1980. Anthropometry of circumpolar populations. In Milan, F. A. (ed.), *The Human Biology of Circumpolar Populations.* Cambridge.

Bass, W. 1988. *Human Osteology.* Missouri.

Berglund, B. 1991. The Early Neolithic Landscape: Landscape, Land Use, and Vegetation. In Berglund, B. (ed.), *The Cultural Landscape during 6000 Years in Southern Sweden.* Ecological Bulletins 41.

Bligh, J. 1973. *Temperature Regulation in Mammals and Other Vertebrates.* Amsterdam.

Bröste, K, Baslev Jørgensen, J., Becker, C. J., Brøndsted, J. 1956. *Prehistoric Man in Denmark.* Copenhagen.

Dahr, E. 1943. Anthropologischer Bericht. In Stenberger, M., Dahr, E. & Munthe, H., *Das Grabfeld von Västerbjers auf Gotland.* Stockholm.

– 1946. Studier över kranier från en neolitisk boplats i Visby, tillvaratagna åren 1936–1939. *Fornvännen* 41.

Davenport, J. 1992. *Animal Life at Low Temperature.* London.

Davies, A. 1932. A Resurvey of the Nose in Relation to Climate. *Journal of the Royal Anthropological Institute* 62.

Ericson, P. G. P. 1989. Säl och säljakt i Östersjöområdet under stenåldern. In Iregren, E. & Liljekvist, R. (eds.), *Faunahistoriska studier tillägnade Johannes Lepiksaar.* Institute of Archaeology, Report series 33. Lund.

Feist, D. D. & White, R. G. 1989. Terrestrial Mammals in Cold. In Wang, L. C. H. (ed.), *Advances in Comparative and Environmental Physiology* 4. *Animal Adaptation to Cold.* Berlin.

Franciscus, R. G. & Long, J. C. 1991. Variation in Human Nasal Height and Breadth. *American Journal of Physical Anthropology* 85.

Garland, H. O. 1994. Altered Temperature. In Case, R. M. & Waterhouse, J. M. (eds.): *Human Physiology: Age, Stress and the Environment.* Oxford.

Gejvall, N.-G. 1974. Description of the Human Skeletons from the Graves and Some Associated Animal Bones. In Janzon, G., *Gotlands mellanneolitiska gravar.* Stockholm Studies in North-European Archaeology 6.

Holmer, U. & Maunsbach, A. B. 1957. Odontologische Untersuchung von Zähnen und Kiefern des Menschen aus der Steinzeit in Schweden. *Odontologisk tidskrift* 64.

Howells, W. W. 1989. *Skull Shapes and the Map. Craniometric Analyses in the Dispersion of Modern Homo.* Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University 79.

Jacobs, K. H. 1985a. Evolution in the Postcranial Skeleton of Late Glacial and Early Postglacial European Hominids. *Zeitschrift für Morphologie und Anthropologie* 75.

– 1985b. Climate and the Hominid Postcranial Skeleton in Würm and Early Holocene Europe. *Current Anthropology* 26.

Jørgensen, J. B. 1953. *The Eskimo Skeleton: Contributions to the Physical Anthropology of the Aboriginal Greenlanders.* Meddelelser om Grønland 146:2.

Kelly, R. L. 1995. *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways.* Washington.

Lamb, H. H. 1973. *Climate: Present, Past and Future* 1. *Fundamentals and Climate Now.* London.

Lidén, K. 1995. *Prehistoric Diet Transitions.* Diss. Stockholm.

Livingstone, F. B. 1969. Evolution of Quantitative Characteristics Which Are Determined by Several Additive Loci. *American Journal of Physical Anthropology* 31.

Lynch, C. B. 1986. Genetic Basis of Cold Adaptation in Laboratory and Wild Mice, *Mus domesticus.* In Craig, H., Heller, H. V., Musacchia, X. J. & Wang, L. C. H. (eds.), *Living in the Cold, Physiological and Biochemical Adaptations.* Amsterdam.

Persson, O. & Persson, E., 1982. Det mellanneolitiska skelettmaterialet från Fridtorp, Gotland. In Englund, S. (ed.), *Stenåldersboplatsen vid Fridtorp – En presentation av gravarna.* RAGU 1982:1.

– 1988. Anthropological Report concerning the Interred Mesolithic Populations from Skateholm, Southern Sweden. Excavation Seasons 1983–1984. In Larsson, L. (ed.), *The Skateholm Project* I. *Man and Environment.* Stockholm.

Ruff, C. B. 1994. Morphological Adaptation to Climate in Modern and Fossil Hominids. *Yearbook of Physical Anthropology* 37.

Sjøvold, T. 1974. Some Aspects of Physical Anthropology on Gotland during Middle Neolithic Times. In Janzon, G., *Gotlands mellanneolitiska gravar.* Stockholm.

So, J. K. 1980. Human Biological Adaptation to Arctic and Subarctic Zones. *Annual Review of Anthropo-*

logy 9.

Sokal, R. E. & Rohlf, F. J. 1981. *Biometry.* New York.

Thomson, A. & Buxton, L. H. D. 1923. Man's Nasal Index in Relation to Certain Climatic Conditions. *Journal of the Royal Anthropological Institute* 59.

Trinkaus, E. 1981. Neanderthal Limb Proportions and Cold Adaptation. In Stringer, C. (ed.), *Aspects of Human Evolution.* London.

Weiner, J. S. 1954. Nose Shape and Climate. *American Journal of Physical Anthropology* 12.

Wolpoff, M. H. 1968. Climatic Influence on the Skeletal Nasal Aperture. *American Journal of Physical Anthropology* 29.

Zammit, M. P., Kalra, V., Nelson, S., Broadbent, B. H., & Hans, M. G. 1994. Growth Patterns of Labrador Inuit Youth: II. Skeletal Age. *Arctic Medical Research* 53.

Zvelebil, M. 1996. The Agricultural Frontier and the Transition to Farming in the Circum-Baltic Region. In Harris, D. R. (ed.), *The Origins and Spread of Agriculture and Pastoralism in Eurasia.* London.

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