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# Polynesian body size: an adaptation to environmental temperature?

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A computer simulation of exposure at sea in the tropical Pacific supports the hypothesis that humans colonising this region have been subject to strong directional selection for a large muscular body. This is advanced as an explanation for the typical Polynesian phenotype, and suggestions are made linking this phenotype with the metabolic disorders of gout and non-insulin dependent diabetes mellitus.

## Introduction

With passage east across the Pacific, from relatively large-islanded Melanesia to small-islanded Polynesia, there is a change in human phenotype from rather slight to distinctively muscular. The evidence is that the muscular phenotype was also prevalent in Micronesia in the past, but major population change in historic time has much altered the picture there. Within Melanesia, more muscular and robust physiques are found on the coast and slighter physiques inland. Scrutiny of patterns of disease (particularly malaria) and of nutrition, and consideration of the secular trend, suggests that none of these factors explain the phenotypic variation[1].

Recently we have suggested that the basis for the phenotypic variation has been climatic: the geographically tropical Pacific was frequently a very cold place for Neolithic Homo Sapiens, with a resulting strong directional selection for a large muscular physique[2,3]. These studies examined survival of different Pacific physiques under a specific set of environmental conditions (exposure to a 16 kph wind at temperature 14.5°C) taken to approximate common exposure to wet wind-chill conditions in the tropical Pacific. While the advantage of a large muscular physique for survival over several hours exposure was shown, no indication could be given as to just how often something close to such a set of conditions was likely to have occurred. However the factors involved are favourable for use in a computer simulation, and the results of such a simulation are presented here.

## Materials and Methods

The variables are meteorological and biological.

*Meteorological variables.*

World Meteorological Organisation weather data were obtained from 22 small-island weather stations through the South Pacific covering a period of two years. Each weather station reports (approximately every three to six hours) the wind speed, ambient temperature, eighths of cloud cover, and, sometimes, rainfall.

*Biological variables.*

The data for body weight and surface area were the means for males and females of a representative range of Pacific groups. Maximum heat production by an "individual" was taken as five times basal, augmented by up to 20% depending on the amount of sunshine. In the simulation, this was given by the equation:

maximum heat production (kJ/hr) = B*M* 4.6

where B = multiple of basal energy produced/kg body weight; M = mass in kg; 4.6 is basal heat production in kJ/kg/hour.

Heat loss was based on ambient temperature and wind speed, using the wind-chill equation:[4]

heat loss (kJ/hr) = 1.16 * (10 * sqrt(V) + 10.45 - V) * (33-T) * 3.6 * S

where V = wind speed in metres per second; T = ambient temperature in degrees Celsius; S = surface area of individual in square metres; sqrt = square root function.

The crew became wet if wind speed reached 15 knots (about 27 kph) or if it rained persistently. Heat loss was then taken to increase by 60%. Body temperature change is given by the equation:

body temperature change (°C) = E/(3.5*M)

where E = energy debit or credit in kJ/hour; M = mass of person in kg; 3.5 is the specific heat of body tissues.

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**Table 1.** Survival proportions for ten-day periods of exposure in summer and in winter. The results for the extremes of Pacific physique, Karkar (small) and Hawaiian (large), are given, and those for a group of intermediate physique, the Lau of Malaita in the Solomon Islands.

| | Karkar | | Lau (Malaita) | | Hawaii | |
|---|---|---|---|---|---|---|
| Latitude | Female | Male | Female | Male | Female | Male |
| **Summer** | | | | | | |
| 10 | 0.48 | 0.54 | 0.64 | 0.73 | 0.80 | 0.80 |
| 15 | 0.23 | 0.23 | 0.40 | 0.44 | 0.59 | 0.62 |
| 22 | 0.05 | 0.06 | 0.06 | 0.11 | 0.16 | 0.18 |
| **Winter** | | | | | | |
| 10 | 0.44 | 0.47 | 0.53 | 0.60 | 0.66 | 0.71 |
| 15 | 0.02 | 0.02 | 0.04 | 0.08 | 0.11 | 0.17 |
| 22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

A person was deemed dead when body temperature fell below 32°C.

Several other parameters were considered in the simulation. For example studies on several animal species show huddling to be an effective method of reducing heat loss by up to one-third for each animal in the huddle up to a maximum of three, compared with that of a solitary animal[5] and this doubtless was done, compatible with the demands of keeping afloat. Heat loss from the respiratory tract was not allowed for.

Each simulation assessed which members of the "crew" survived the "voyage". When repeated with other sets of weather data from the same station, the different physiques each survived a particular proportion. If a particular physique survived in 76 of 100 simulations then the survival rate is 76/100 = 0.76. For most weather stations at least 100 simulations were run for summer (November to February) and winter (May to August).

**Results and discussion**

Results from simulations of ten day periods of exposure in summer and in winter are presented (Table 1) using, for clarity, only the results for three groups - the two extremes of physique, being Hawaii (large) and Karkar island (off the north-eastern coast of New Guinea, small) and an intermediate group, the Lau of Malaita in the Solomon Islands.

For most station data at least a hundred simulations were run. For each simulation there were only two possible consequences for any member of the crew, survival or death. Survival was scored as 1 and death as zero. All series of simulations were adjusted to 100 for ready comparison. Thus, for a given physique, sex and season, a result in the table of 0.48 indicates that out of 100 simulations, survival resulted 48 times and death resulted 52 times.

The simulations are likely to present a rather gloomier picture of survival than the reality because human judgement is not allowed for: craft push off and take whatever weather the computer throws out, whereas in reality, experience and judgement on favourable and persisting weather patterns would be significant in determining when a voyage would start. However, being based on human biological parameters, it seems unlikely that these results paint a significantly distorted picture.

The results support the hypothesis that exposure would have been a major problem for Neolithic voyagers in the Pacific, and the likelihood of strong direction selection for a muscular phenotype. The survival proportions for all groups were less than anticipated. For example survival proportions in summer for males of intermediate physique across a range of latitudes from 12°S to 25°S are 62, 56, 19, 5 and zero. For all groups, whatever their range of survival, there is a rapid decline in survival beyond 15° latitude, and this association of survival with latitude was, in statistical terms, highly significant. For any group there is an approximately 5% decline in survival for each degree movement away from ten degrees of latitude, with an average male/female difference in survival of 5% in summer and 3% in winter, to the advantage of the males.

The inference is that the impressive Polynesian muscularity has evolved not for locomotor purposes but as a metabolic heat source. The particular muscle fibre type predominantly involved in shivering (an isometric contraction) is Type IIb, or fast twitch[6,7,8]. We suggest that people of Polynesian ancestry are likely to show a genetically-determined preponderance of this muscle fibre type, and currently we are obtaining muscle biopsies to assess this.

There are clinical studies showing a strong association between muscle mass and abnormalities of uric acid metabolism[9,10]. Other studies have shown an association between a predominance of Type IIb fibres and obesity, and between Type IIb fibres and disturbances of glucose metabolism and insulin response[11-14]. It is hypothesised that some major metabolic health problems of modern-day Pacific peoples thus derive from their evolutionary background. However this background differs from that usually invoked as explanation for high incidences of NIDDM, and we suggest that for these Pacific people it is questionable whether the concept of a "thrifty" genotype is relevant.

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