EPIDEMIOLOGY OF FRACTURES IN THE AGED, ITS APPLICATION IN SINGAPORE

By P. C. N. Wong

INDRODUCTION

The rapid advances made in Medical Knowledge over the last two decades together with the elevation of the living standard have given many communities an increasingly aged population. Obviously on personal and humanitarian grounds this is not without its advantages, but at the same time a case to the contrary can also be made, in that this addition to a community has brought with it a variety of problems not the least of them being the ailments associated with increasing age—the degenerative cardio-vascular diseases, the strokes, diabetes, minor pyramidal lesions, paralysis agitans, osteoarthritis; and, of course, of importance to the orthopaedic surgeon those fractures which are commonly associated with the aged, *viz.* fractures of femoral neck, fractures of the proximal end and shaft of the humerus, bimalleolar fractures, fractures of the pelvis, and Colles fractures, all of which appear to be becoming increasingly more common.

Quantitative evidence of the magnitude of this latter problem first became available from the Eastern Region of Scotland where it was estimated by Steward (1955) that over the 23 year period, 1952 to 1975, the female population age 50 and above will have risen by 20% with the annual number of femoral neck fractures increasing by 50%. In Oxford, England, Buhr and Cooke (1959) have also found that over the period 1938 to 1956, the number of the same fractures admitted into the Radcliffe Infirmary in the last year was 6 times that of the first, but that there was only a 12% increase in the population over the same period.

In contrast to Dundee it has recently been estimated in Singapore that over a twenty year period 1962 to 1982 the age 50 and above population will have doubled itself and the annual number of fractures of the femoral neck will have increased by over 100%.

Obviously a proper understanding of the causes of fractures in this age group forms the basis for their prevention, and in the search for aetiological factors it has been found that the epidemiologic approach has an important place. (Bauer 1960, Alffram and Bauer 1962).

The term "fracture epidemiology" is of recent origin. Its introduction into orthopaedic surgery was by Goran Bauer in 1960, and was again used by the latter together with Alffram in 1962. But oddly enough on neither occasion was the term clearly defined, its meaning being merely implied.

In preventative medicine, epidemiology in its narrowest sense has been defined by Stallybrass as the science which considers infectious diseases—their courses, propagation and prevention. This is the definition of common usage. A more modern and comprehensive concept is by W. H. Frost who defines it as a science which considers the occurrence, distribution, and types of diseases of mankind in distinct epochs of time, at varying points of the earth's surface; and secondly will render an account of the relations of these diseases to inherent characteristics of the individual, and to the external conditions surrounding him and determining his manner of life. (Smillie and Kelbourne 1963).

Obviously, the first definition cannot be made use of in orthopaedic surgery but many of the facts from the second could apply equally well to fractures.

"Fracture epidemiology" may appropriately be defined thus; it is that part of orthopaedic surgery which considers fractures with regard to types, their occurrence, distribution and incidence according to sex, age and race; and it also considers the relationship between the fractures and both the health make-up and the environment of the individuals who have sustained such injuries.

THE PURPOSE OF FRACTURE EPIDEMIOLOGY

Such surveys enhance our knowledge of the characteristics of fractures obviously, but perhaps of a more immediate and practical import is that the epidemiological approach

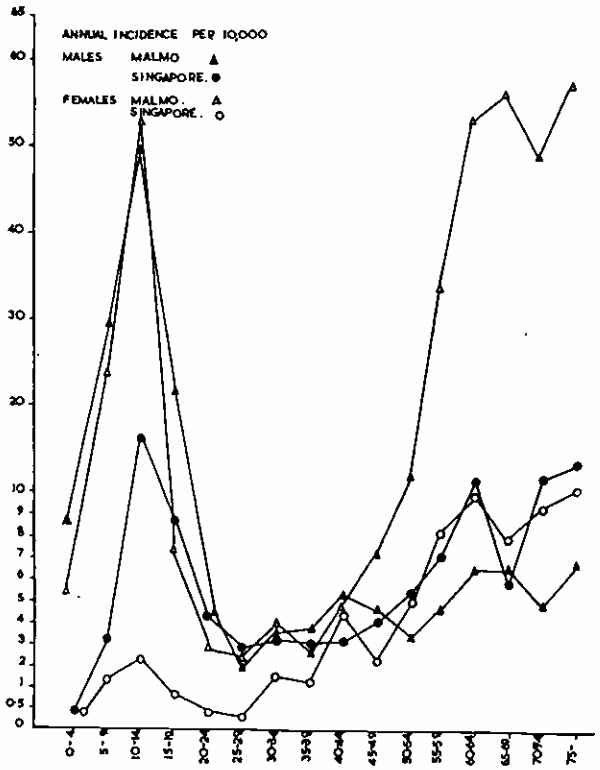

Fig. 1. Fragility curves of the distal forearm for the Singapore population considered as a mixed community. The corresponding curve for Malmo is superimposed.
Annual age specific rates are plotted against their corresponding age specific groups.

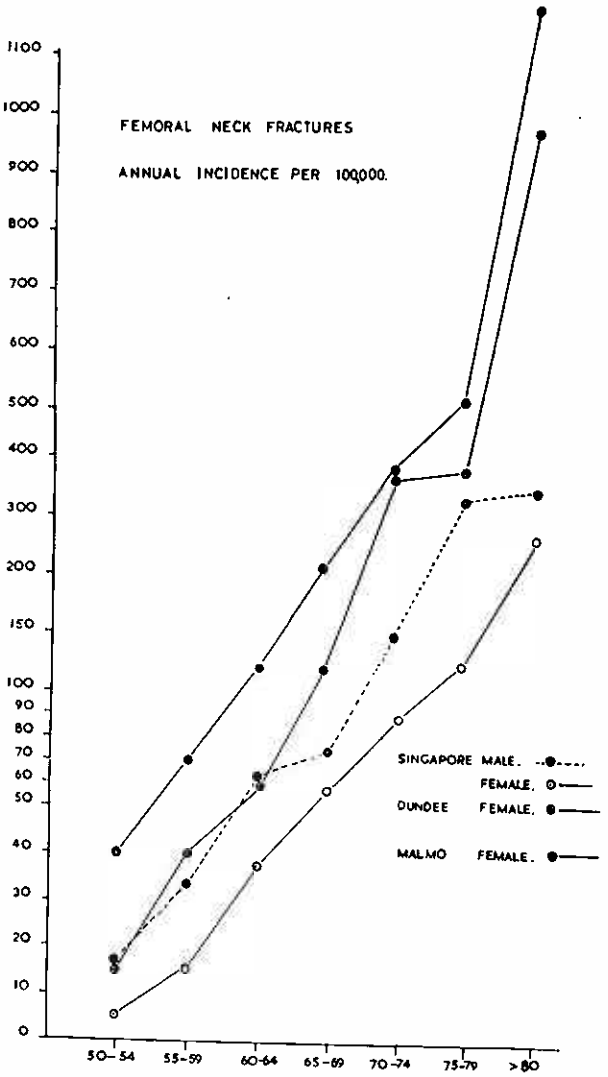

Fig. 2. Fragility curve of the proximal femur for the Singapore population considered as a mixed community. The corresponding curves for Malmo and Dundee are superimposed.

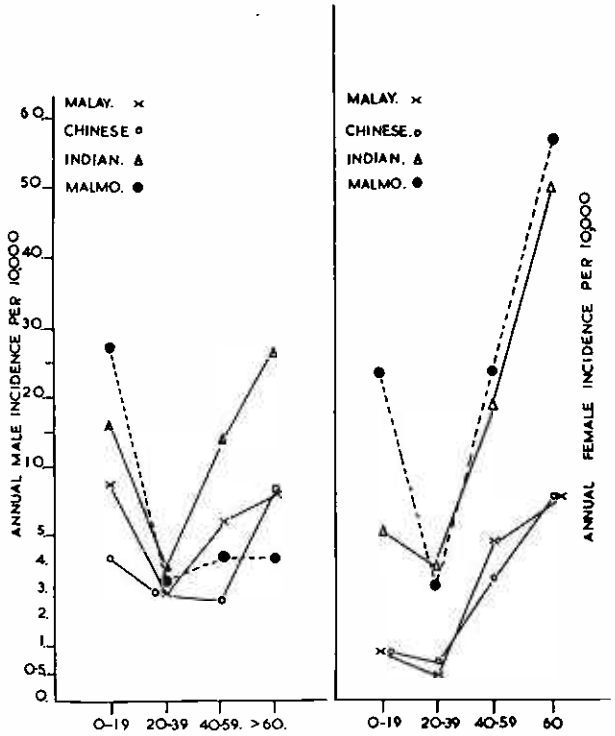

Fig. 3. Fragility curves of the distal forearm for both sexes among the major races in Singapore. The curves for Malmo are superimposed.

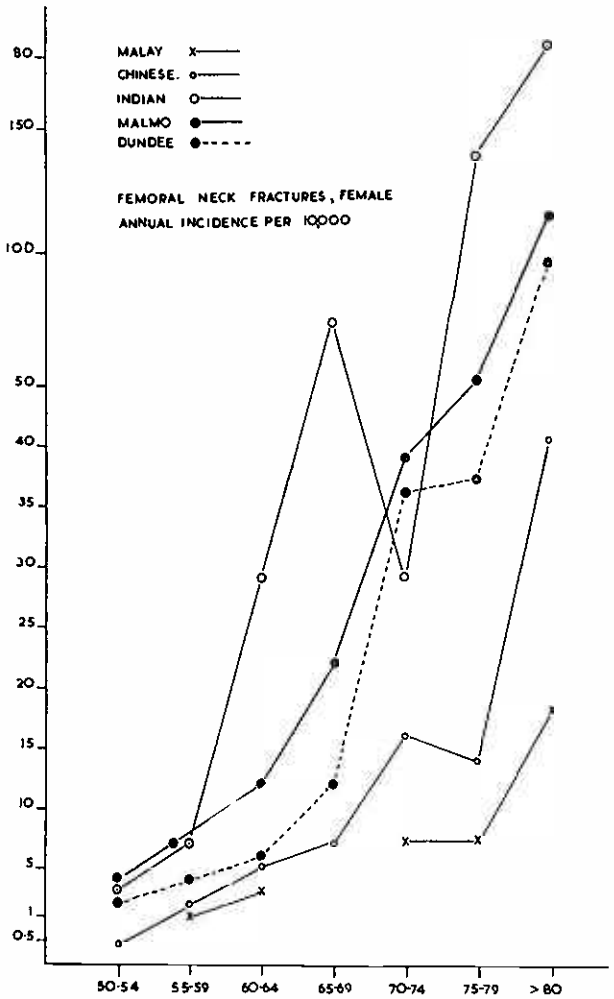

Fig. 4. Fragility curves of the femoral neck for Malay, Chinese, Indian, Malmo and Dundee females.

to them enables us to gain an insight into their aetiology and thereby forming the basis for their prevention.

It is also a part of such studies to apply present fracture rates to projected population estimates. By this means, expected cases in 5, 10, 15 or 20 years may be calculated. Its obvious application in future hospital building, planning and bed distribution requires no further amplification.

METHODS AND MATERIAL IN FRACTURE EPIDEMIOLOGY

It is an analysis of all of a particular fracture type collected over a defined period within a defined population. The methods used are few and simple; not a great deal of data is required. The only difficulty lies in their collection.

Broadly speaking the requirements may be classified thus:

1. A knowledge of the population at risk.
2. The nutrition and Health make up of the patient.
3. The environment of the patient.
4. The degree of trauma giving rise to the fracture.
5. The amount of displacement in a fracture.
6. The Biometrics of the collected fracture data.

The population at risk is given by the census, which gives accurate details of a population by race, numbers, sex and age distribution, and age specific groups.

Inquiry is made into the patient's nutritional state, and any constitutional disturbance from which he might have been suffering prior to the injury. (Bauer 1960, Alffram 1964).

The external conditions surrounding him and determining his manner of life are also looked into, and at the same time carefully ascertaining the circumstances which brought about, and the degree of trauma which actually caused the fracture.

The degree of trauma is classified as severe and moderate or minimal in nature. (Alffram and Bauer 1962).

In 1962 Alffram and Bauer introduced a further variable in their epidemiologic investigation of fractures of the forearm *i.e.* the amount of displacement.

Illustrating the variables, degree of trauma and amount of displacement, these writers have found with reference to fractures of the shafts of the radius and ulna that "moderate trauma was the most common cause of fracture in children, but in men over the age of twenty severe trauma predominated, where as in women of the same age moderate and severe trauma were equally common. In children reduction was performed in 70% of the fractures, but in both men and women, displacement was negligible in about 50% of the cases."

Obviously the biometrics of the collected fracture material, *viz.* their analysis and interpretation by mathematical means, are essential procedures in fracture epidemiology, but experience both in Europe and locally has shown that more often than not such manouvres need proceed no further than the calculation of age specific rates, crude rates and their standardization.

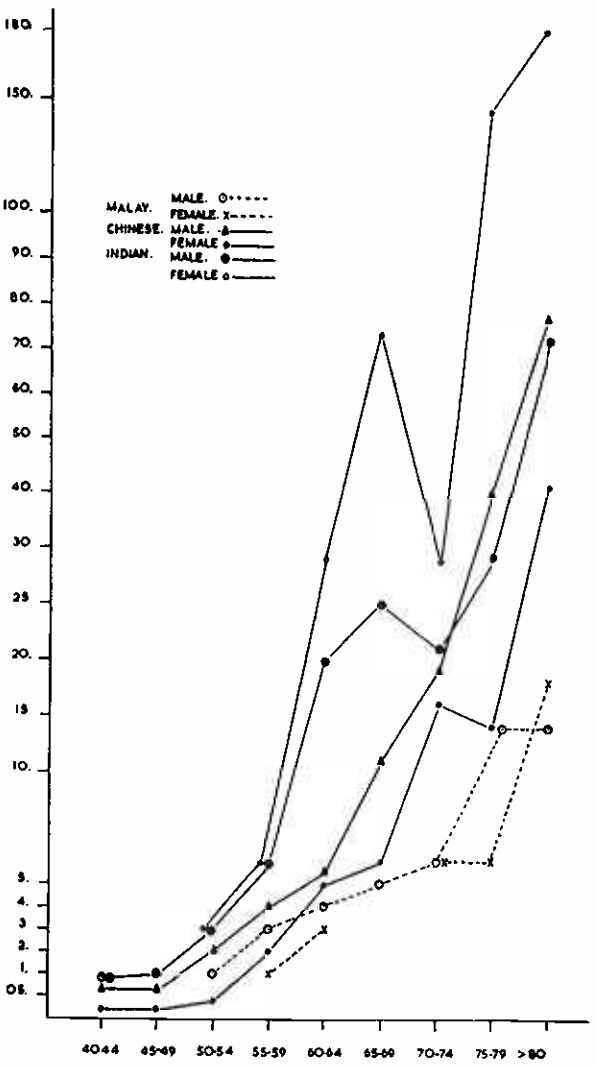

Fig. 5. Fragility curves of the femoral neck for the major races of Singapore.

The age specific rates, which are expressed as an annual estimate per ten or a hundred thousand of the poulation, are then plotted against their corresponding age specific groups.

In the studies among the local races, it has been found convenient to term the graph so obtained the "fragility curve" (Figs. 1, 2, 3, 4, 5).

THE AETIOLOGY OF FRACTURES IN THE AGED

The correlation and interpretation of data from fracture surveys conducted on European and Asian communities have enabled Stewart (1955), Buhr and Cooke (1959), Bauer (1960), Alffram and Bauer (1962), Alffram (1964) and Wong (1964) to come to a number of important conclusions as to some of the causes of fractures in the aged.

For convenience of description they may be considered under the following arbitrary headings.

1. Age and Sex
2. Exoskeletal
3. Endoskeletal
4. Heredity and Race.

Age and Sex

As long ago as 1882 Bruns, and more recently Buhr and Cooke 1959, and Bauer and Alffram 1960 and 1962 have pointed out that the study of the incidence and distribution of fractures according to sex, and age was of considerable aid in the evaluation of fracture aetiology. By this means alone it has been clearly established that fragility in cancellous bone increases with age.

Work on fractures of the distal forearm and proximal femur in Singapore give further support to this hypothesis. (Wong 1964).

Exoskeletal Causes

These are causes which are external to the patient, or which though internal to the latter are external to bone. They include such conditions as:

1. Accident proneness
2. Disabilities associated with old age
3. Accompanying medical ailments
4. Environment

Accident Proneness

Dunbar (1947) believes that the personal element in accidents is paramount and maintains that less than 20% are due to mechanical causes; she describes in detail the characteristics of the unstable, impulsive individual who is "accident prone". The extent to which this operates in the fractures of the elderly is probably small.

Disabilities Associated with Old Age

A minor trauma of the order of the "fall" is of no consequence in the young but in the aged it is often the immediate causation of a fracture.

Sheldon (1948) has listed the common cause of such falls and included among others such disabilities as generalized muscle weakness failing eye-sight, defective hearing, slow reaction time and impaired co-ordination in the dark.

Accompanying Medical Conditions

58% of Stewart's (1955) material from Dundee, and 42% of Bauer's (1960) femoral neck fractures had pertinent medical diseases In Singapore in 128 cases of fractures of the proximal femur in which a knowledge of the State of health prior to injury was accurately known, no less than 46% had accompanying medical ailments of which well over one third were cases of pulmonary tuberculosis, and approximately 9% were diabetics. (Wong 1964

As predisposing factors to fractures in the aged such conditions have a strong claim in most and perhaps less and more obscure in others. Any ailment, and even age itself, which confines a person to his bed has deleterious consequences. It is a well known physiologic phenomenon that it only requires 2-3 weeks of immobilization to establish a negative nitrogen calcium and phosphorous balance due both to bone and muscle atrophy. The cycle becomes more vicious in the presence of sepsis and trauma (Buhr and Cooke 1959).

There appears no doubt that syncopal attacks and vertigo (common manifestations of degenerative cardio vascular diseases and hypertension) minor pyramidal tract lesions and paralysis agitans are the background of many of the falls which are the commonest immediate causation of fractures.

Calcium is lost from bone in healing tuberculosis. This is convincingly illustrated by the local femoral neck fractures where over 1/3 of the 46% of cases which had pertinent medical diseases were suffering from pulmonary tuberculosis (Wong 1964).

The discussion on the role of Malnutrition is being deferred to a later paragraph.

Environment

The external conditions surrounding the patient and determining his manner of life *i.e.* his environment, play no mean role in the aetiology of fractures in this age group.

The inter-departmental Committee of England, 1953, investigating the causes of home accidents found that 28% can be traced to defective designs or maintenance of stairs, hand rails, lighting and the like. Slippery floors and baths, obstacles in the house such as furniture, rugs, domestic pets also claim their victims.

No less than 22% of Bauer's material, 38% of our own femoral neck fractures were sustained as a result of severe trauma, many of which are due to hazards of the road, traffic accidents.

A considerable proportion of the fractures of the aged which can be related to environment could be reduced by attention to the dangers of the road and home, and by the improvement of their physical environment.

Endo-skeletal Factors

Endo skeletal factors are those which are responsible for bone atrophy. The steady decline after the age of 55 in the amount of bone in the body was first pointed out by Ingalls (1931).

This diminution in quantity and not quality has subsequently been proved both histologically and biochemically.

In the elderly it can be shown microscopically that the trabeculae of cancellous bone are of normal laminar structure but thinner, and in compact bone the reduction in volume is due to enlargement of the Haversion canals. The calcium and phosphorus contents of the remaining bone are normal. (Buhr and Cooke 1959).

Robinson (1942) also finds that the water content of the matrix of senile bone is less than that of the young.

Bone atrophy has variously been ascribed as due to:

1. Age itself—this is a process of which we have very little knowledge.
2. Immobilization—this has already been described at some length.
3. Nutrition.

It would seem natural to assume that if the skeleton was not supplied with the appropriate ingredients the latter would atrophy, or at least in some way be weakened. Yet oddly enough this apparently obvious relationship between osteoporosis, and therefore progressive cancellous fragility, and malnutrition is both controversial and little known. (Buhr and Cooke 1959).

Bauer (1960) is of the opinion that diet deficiency is not the cause of the progressive bone fragility as observed among the aged and instances the females at the menapause who show a dramatic rise in distal forearm fractures which could be as much as seven to eight times that of the males of a corresponding age.

This would certainly suggest factors other than nutrition. He also quotes Astley Cooper who practised in early 19th. century London at a time when food was deficient in calcium, and who encountered over a period of 30 years only two cases of fractures of the femoral neck in women less than 50.

In direct contrast to Bauer, Duncan McKeever (1960) maintains "that many of the intertrochanteric fractures are really fatigue fractures, where the patients have long been laying the ground work for their occurrence, by among other factors poor nutrition which results in deprivation and loss of calcium from bone from the matrix of which there is also a lessening of protein.

The density of such bone is decreased to the point whereby even the taking of a step may result in a fracture. This may well explain the fleeting pain of varying intensity which these patients experience some time before the actual fracture."

Of the contrasting views, local data have produced considerable evidence in favour of Bauer's. This we shall elaborate upon later.

Endocrine

Both the ovary and testis have important effects upon bone metabolism. It has been clearly established by Reifenstein (1957) for people of European extraction that oestrogen and androgen levels in women fall rapidly at the climateric, but in men, the androgen decline with age is gradual, and oestrogen, which was low in the first instance, shows little change throughout life.

He correlates the decline of these anabolic steroids accompanying increase in age with the development of osteoporosis which not only occurs at an earlier age and more often in women but that it could be as much as 5 times more frequent in the latter than in men.

These facts are certainly borne out by Bauer's (1962) work on the epidemiology of fractures of the distal forearm where it has been found that about the age of 45 the ratio of female to male fractures rose dramatically, to 7 or 8 to 1 in favour of the women. Buhr and Cooke (1959) had come to this latter conclusion some years earlier. It will be shown later the Reifenstein hypothesis is not supported by the results from fracture surveys conducted in Singapore.

FACTOR OF HEREDITY AND RACE

Finley in 1956 had already suggested that osteopenia in the aged may have a hereditary basis, and Mildred Trotter and her associates (1960) have shown that there is a density difference between the skeleton of the American Negro and that of the American White.

As a corollary to this Gyepes et Al (1962) in an American Hospital found fractures of the proximal femur to be rare among Negroes. More recently, Alffram (1964) maintained that the differences in the proportion of cervical and trochanteric fractures between Swedish and British series may indicate biological differences between the two populations, and that the incidence of cervical fractures being twice as high in Sweden as it is in Britain may also indicate a hereditary factor.

RESULTS FROM LOCAL SURVEYS AND THEIR COMPARISON WITH EUROPEAN COMMUNITIES

Singapore with its mixed Community approximating one and a half million inhabitants, where accurate knowledge of their numbers, age, sex and race is available, like Malmo in Sweden, offers unique opportunities for epidemiological study of diseases in a well defined community. Such studies have recently been made on fractures of the proximal femur and distal radius using the methods already outlined. The results were compared with those from European communities. (Wong 1964).

Although all the races respected the law that fragility of cancellous bone increased with age, it was found that fractures of the latter exhibited variations which were either not observed or which were in considerable contrast to those of European Communities.

Thus compared with Europeans and our local Indian females, incidences of fractures of the femoral neck and distal forearm among Malay and Chinese females are very much lower, their increase with age considerably more gradual, and the final peak attained a great deal less, *viz.* although cancellous bone becomes progressively more fragile with increase in age it is to a far lesser extent among the Malays and Chinese females than among the Indian and European females, (Figs. 3 & 4).

The absolute rates for fractures of the distal forearm among Chinese and Malay women have been found to be very similar, those of the European and Indian females are also closely related. (Fig. 3). This has not been observed for fractures of the femoral neck.

From the age of forty years onwards the sex distribution of these two fractures differs considerably among the various races. Thus, among the Indians, it is analogous to European Communities *viz.* there is essentially a female predominance. Among the Chinese, however, male and female rates in fractures of the distal forearm are roughly similar, but in fractures of the femoral neck, male rates are in considerable excess of those of the female.

Incidences of the same fractures among Malay men and women are, in the main, approximately equal wherever comparisions could be made (Figs. 3, 5).

It would appear from the study of the local fracture incidences (femoral neck, distal forearm) and their comparision with those of European Communities, considerable support has been given to the hypothesis which contends that, with reference to fractures involving cancellous bone, each race exhibits a charac-

teristic fracture pattern which is different from that of another race. *Viz.* cancellous fragility trend is strongly influenced by heredity and race.

The Chinese in Singapore are people essentially of a Mongoloid Composition, the Malays are said to be predominantly so. The Indians and Europeans are people of Caucasoid origin. (Del Tufo 1947). The common factor of racial origin may well explain the close similarity in forearm fracture incidences between the Chinese and Malay females on the one hand, and that between the Indian and European females on the other.

Exoskeletal causes such as accident proneness, disabilities associated with the aged and accompanying medical ailments probably play no greater part in the aetiology of fractures among the local aged than anywhere else. However it is known that the homes of the average aged in Singapore present more hazards than those of Europeans, and it is also known that the dangers of the local roads claim more femoral neck fractures than Malmo.

The average daily diet per capita for the Federation of Malaya and Singapore has been given by May and Jarcho (1961) as having a value of 2555 calories. It is below the recommended values both in proteins and calcium. The authors also caution that the given figure is an average of which the prosperous is responsible for a considerable share. That portion of the population among whom fractures are rife, therefore, is almost certainly consuming a diet which is considerably less. It is aslo known that in the family unit "the husband and children get a higher intake of every thing because they eat more of every thing, and the best morsels are kept for the husband first, children next, and the wife last" (Llewellyn-Jones 1962).

Of the three races the Chinese are the best provided for, followed by the Malays and then the Indians.

If diet alone is considered the all important aetiological factor in the progressive weakening of bone with age, it is difficult to explain why of the three local races only the Indian female fracture rates exceed those of the Malmo and Dundee, with which the rates of the Malay and Chinese females are not even comparable.

From 40 years onwards femoral neck fractures among the Chinese males considerably exceed, and distal radial fractures are comparable to those of their females. Again if inadequacy of diet alone determines the fragility of bones, and therefore fracture rates, it would be nearer the expected results if the sex ratio of femoral neck fractures among the Chinese was reversed, and the distal forearm ones in a proportion at least 7 or 8 times to 1 in favour of the females. Among the Malays the sex ratio of equivalent injuries approximate unity where again a female predominance is expected if deficiency of diet is considered an important factor in fracture aetiology. Contrasting with the Malays and Chinese, the Indian female fracture rates in general exceed those of their males.

Thus of the three races only the fracture results from the Indian population support opinions that bone weakening may in part be explained in terms of nutritional deficiency.

Atrophy of bone with aging among women is an increasing osteoporosis which accompanies the sudden decline of anabolic steroid hormones at the menopause and thereafter. It is a process which operates to a far lesser extent among men. (Reifenstein 1957). The post climateric preponderance of fractures among women as compared with males of quivalent ages among European and Indian peeople provide ample clinical evidence of the validity of Reifenstein's work.

Lugg and Bowness (1957) investigating the urinary anabolic steroid hormones, 17 keto steroids, among the local males, which also include Europeans, were of the opinion that "any ethnic group differences in the excretion of such substances by these subjects could be conveniently regarded as reflections of differences in weight."

Might it not be inferred from this that the hormonal environment and therefore the anabolic steroid osteoporosis relationship of the post menopausal Malay and Chinese females also follow that of their Indo-European counterparts? There appears no basis for any opinion to the contrary.

Fracture abnormalities as produced by the Malays and Chinese must thus be regarded as further evidence of the lack of correspondence between fracture incidence and osteoporosis incidence, a fact which has previously been observed by Bauer (1962), and thereby lending additional support to the latter's

suggestion that osteoporosis and cancellous fragility may be separate entities.

CONCLUSION AND SUMMARY

A definition for "fracture epidemiology" has been proposed, and the methods and data used in its investigation have been outlined. The possible aetiological factors determining the progressive fragility of cancellous bone in the aged are also discussed.

The results of epidemiologic surveys of fractures of the proximal femur and distal forearm on the major races of Singapore are analyzed and compared with those of European Communities. The Major conclusions drawn are:—

1. Cancellous bone of all races become progressively more fragile with age but the trend which the latter takes is strongly influenced by heredity and race.
2. In races of Mongoloid origin cancellous bone in the aged male is equally or more fragile than that of their female.

Chinese and Malay Female fracture trends

1. Support opinions that diet is unimportant in the progressive weakening of cancellous bone with age.
2. Further indicate the lack of correspondence between osteoporosis incidence and fracture incidence, thereby lending support to suggestions that bone fragility and osteoporosis may be different entities.

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