Postgraduate Medical Journal (June 1971) **47**, 320–325.

Metacarpal bone dimensions in young and aged South African Bantu consuming a diet low in calcium

ALEXANDER R. P. WALKER D.Sc.

B. F. WALKER

B. D. RICHARDSON M.Sc.

M.R.C. Human Biochemistry Research Unit, South African Institute for Medical Research, Johannesburg, South Africa

Summary

Groups of South African Bantu boys and girls of 14 years, compared with local Caucasian children, have lower cortical thickness, cortical score, and cross-section and volume scores for second metacarpal. Yet, when these parameters on groups of aged Bantu men and women, 70–79 years, are compared with published values on corresponding Caucasians, there are no significant differences. Further, aged Bantu have lower prevalences of hip fracture and severe collapse of vertebral bodies. Since a low calcium intake, and in aged Bantu women numerous pregnancies and long lactations, are compatible with satisfactory bone data, it is questioned whether the present insistence on a high calcium intake is justified.

Introduction

Over 99% of body calcium is contained in bone. Hence, a habitually low absorption or retention of the element would be expected to affect composition and dimensions of bone. The most plausibly influential factor is level of calcium ingested. Almost invariably, daily intake is less in underprivileged than in sophisticated populations. Yet studies on particular bones in Indian, Bantu, Ugandan and Caucasian subjects have indicated that calcium concentration is fairly constant (Nicholls & Nimalasuriya, 1939; Walker & Arvidsson, 1954; Dickerson & John, 1969). We therefore decided to investigate *dimensions* of cortex of bone (in the present instance second metacarpal) in two populations accustomed to a low calcium intake, Bantu school-children and aged people, in rural and urban areas. Additionally, in a region where dental fluorosis is marked, calcium intake and bone size were correspondingly investigated. For comparison, mean values for cortical thickness, cortical index, cross-sectional area and volume indices of second metacarpal are available, or have been extrapolated, from publications on Caucasian subjects (Barnett & Nordin, 1960; Nordin, MacGregor & Smith, 1966; Morgan *et al.*, 1967; Smith *et al.*, 1969; Hossain, Smith & Nordin, 1970; Dequecker, 1970; Exton-Smith *et al.*, 1969b; Exton-Smith, 1970). Such data, of course, relate to persons used to a relatively high calcium intake.

Subjects

School-children

Pretoria. In 1962–65, interracial studies on school-children were carried out by the National Nutrition Research Institute, Pretoria. Considerable care was taken to obtain representative groups (Fellingham, 1966). At 14 years, the age chosen for this investigation, mean daily calcium intakes of the groups studied were: Bantu (seventeen boys, seventeen girls) 296±262 mg and Caucasians (twenty-seven boys, twenty-two girls) 833 ± 410 mg (Lubbe, 1968). For the radiology studies, tube distance was 100 cm. X-rays of both hands, undertaken by Dr H. H. Christ, primarily for bone chronology studies (Christ, 1961), were carried out at Pretoria General Hospital. Measurements of second metacarpal were made as described below.

Kruidfontein and Saulspoort (rural areas). At Lessetlheng Community School, Kruidfontein (135 miles west of Johannesburg), severe fluorosis, manifested by extensive brown stain with pitting of enamel, was present in 92% of pupils. Drinking water contained 5–14 parts fluorine per million. Eighteen boys and twenty-four girls aged 14 years were examined. Calcium intake was 275 ± 210 mg *per diem.* At Moruleng Higher Primary School, Saulspoort, 6 miles distant, fluorosis was far less marked. Drinking water contained 1–3 parts fluorine per million. Sixteen boys and twenty-one girls of 14 years, showing either no relevant teeth lesions or only slight chalky patches, were examined. Calcium intake was 210 ± 195 mg *per diem.* X-ray studies were made at George Stegmann Mission Hospital, Saulspoort. Tube distance was 60 cm; bearing in mind the position of second metacarpal on the X-ray plate, the angle subtended is small and distortion slight.

Aged Bantu

Johannesburg. In the lower middle-class Bantu suburb of Zola North-West, there are twenty-three men and thirty-four women aged 70–79 years. All were X-rayed at Mofolo South Clinic, Soweto (Johannesburg City Health Department). Tube distance was 110 cm. Calcium intake was 320 ± 265 mg *per diem*. On an average the women had given birth to 6·3 children, and three quarters had breast fed 5·1 children for 6–12 months.

Kgala. At this village (90 miles west of Johannesburg), seventeen men and twenty-one women were aged 70–79 years. All were X-rayed at Rustenburg Hospital. Tube distance was 100 cm. Mean daily calcium intake was 280 ± 255 mg. The women had had an average of 7·8 children, and had breast fed 6·3 for 9 months or more.

Kruidfontein. At this village (see above), where fluorosis is severe, twenty-four men and thirty women were aged 70–79 years. Of these, twenty-one men and twenty-seven women were X-rayed. Calcium intake was 340 ± 295 mg *per diem*. The women had produced an average of 7·3 children and had breast fed 5·9 for 9 months or more.

None of the children nor the aged Bantu had had calcium supplements.

Methods

Calcium intake

Among Pretoria children, calcium intake was estimated by the method of Burke & Stuart (1938) as modified locally by Lubbe (1968). Enquiry was limited to 7 days. Foods were chemically analysed.

For the rest, calcium intake was estimated by a recall procedure for 3 days. The South African food composition tables of Fox (1966) were used.

Radiographs

Hand radiographs (posterior–anterior) were made as described by Barnett & Nordin (1960) and by Exton-Smith *et al.* (1969a). At the mid-point of the second metacarpal of the right hand, measurements were made of external diameter (D) and internal diameter (d). The length (L) also was measured. With plates on the standard viewing box, measurements were made to 0·25 mm, a transparent rule and magnifying glass (× 3) being used. All measurements were made by two persons; mean differences between measurements of D, d, and L, were 1·5, 3·8, and 0·5%, respectively. Calculations were made of total cortical thickness $D-d$, cortical index $\frac{D-d}{D}$ as described by Barnett & Nordin (1960), cortical area/total area, i.e. $(D/2)^2-(d/2)^2/(D/2)^2$ as used by Hossain *et al.* (1970), cross-sectional area D^2-d^2 as used by Dequeker (1970), and bone volume index $\frac{D^2-d^2}{DL}$ as described by Exton-Smith *et al.* (1969b; Exton-Smith, 1970).

In the aged Bantu subjects, to secure data on the prevalence of fracture of the neck of the femur, and prevalence of obvious collapse of lumbar vertebrae, the following X-rays were taken—(1) anterior–posterior view of pelvis, and (2) lateral and anterior–posterior views of dorsolumbar spine.

Comments on results

Calcium intake and loss

The calcium intakes of both Bantu children and adults were less than half of those of Caucasians (Nordin *et al.*, 1966; Smith *et al.*, 1969). Regarding loss of calcium by old Bantu women, firstly, 30 g calcium per foetus was assumed (Widdowson & Spray, 1951). Next, since Bantu babies grow at the same rate as Caucasian babies for the first 6 months (Brock & Autret, 1952), a milk yield of 750 ml *per diem* (Wallgren, 1945) was assumed, containing 28 mg calcium/100 ml (Walker *et al.*, 1954). This flow, over 9 months, involves a loss of 57 g calcium. Hence, calcium loss for six children amounts to 522 g, probably equivalent to over half of the mother's total body calcium prior to child-bearing (Garn & Wagner, 1969). For Caucasians, loss of calcium for the pregnancy and lactation of three children for 3 months would be 147 g.

Bone data on children

For the boys, the scores for length, cortical thickness, cortical index, and cross-sectional area and volume indices, were all significantly lower in Pretoria Bantu than in Pretoria Caucasians ($P < 0·01$). This also applied for Bantu compared with Caucasian girls, save that the mean bone volume index of the Bantu girls was virtually identical to the extrapolated mean value for English girls studied by Exton-Smith *et al.* (1969b; Exton-Smith, 1970). The lower values in Bantu may be attributed in part to their slower rate of growth. Insufficiency of calcium *per se* is unlikely to be responsible (Walker, 1954; Garn, Pao & Rihl, 1964; Luyken & Luyken-Koning, 1969). In the Pretoria Bantu and Caucasian children, in each racial group the upper and lower quartiles, with respect to calcium intake, had mean cortical dimensions which did not differ significantly. The same type of finding (non-implication of level of calcium intake) has been noted for groups of U.S.A. Caucasian and oriental children (Garn *et al.*, 1964; Garn & Wagner, 1969), also for different racial groups of children studied in Surinam (Luyken & Luyken-Koning,

TABLE 1. Metacarpal dimensions in Bantu children of 14 years compared with data on Caucasians (Means and standard deviations in mm)

Population	D	d	$D-d$	$\frac{D-d}{D}$	$\frac{(D/2)^2-(d/2)^2}{(D/2)^2}$	D^2-d^2	L	$\frac{D^2-d^2}{DL}$
Bantu boys								
Pretoria (urban)	7·50	4·13	3·37	0·45	0·70	39·07	61·82	0·084
SD	0·68	0·75	0·47	0·07	0·07	6·77	4·01	0·009
Saulspoort (rural)	7·39	4·11	3·28	0·45	0·69	37·80	60·03	0·084
SD	0·75	0·71	0·46	0·06	0·07	7·42	3·90	0·008
Kruidfontein (fluorosis)	7·37	4·37	3·00	0·41	0·65	35·22	58·03	0·081
SD	0·64	0·66	0·55	0·07	0·06	6·76	4·43	0·010
Caucasian boys								
Pretoria (urban)	8·16	3·57	4·59	0·56	0·81	54·06	65·70	0·100
SD	0·72	0·62	0·75	0·07	0·08	10·65	4·70	0·012
U.S.A. (Garn, 1961)	7·70	3·60	4·10	0·53	0·79	46·30		
England (Exton-Smith, 1970)								0·095
Bantu girls								
Pretoria (urban)	7·44	3·43	4·01	0·54	0·79	43·52	61·99	0·094
SD	0·56	0·66	0·39	0·06	0·08	5·64	4·53	0·010
Saulspoort (rural)	7·24	3·88	3·36	0·46	0·71	37·32	61·35	0·083
SD	0·63	0·64	0·47	0·06	0·07	6·22	3·14	0·007
Kruidfontein (fluorosis)	7·22	3·58	3·64	0·57	0·75	38·58	61·64	0·086
SD	0·44	0·94	0·71	0·10	0·07	5·49	3·34	0·010
Caucasian girls								
Pretoria (urban)	7·48	2·94	4·54	0·61	0·85	47·37	64·36	0·097
SD	0·65	0·55	0·47	0·06	0·08	7·97	2·08	0·008
U.S.A. (Garn, 1969)	7·20	2·70	4·50	0·62	0·86	44·60		
England (Exton-Smith, 1970)								0·095

D, external diameter; d, internal diameter; $D-d$, cortical thickness; L, length; $\frac{D-d}{D}$, cortical index; $\frac{(D/2)^2-(d/2)^2}{(D/2)^2}$, cross-sectional area index; D^2-d^2, cortical area index; $\frac{D^2-d^2}{DL}$, cortical volume index.

1969). The bearing of race on cortical thickness of metacarpal appears to be variable (Luyken & Luyken-Koning, 1969).

In the Bantu, values for boys at 14 years were slightly lower than those for girls ($P < 0·05$). This applied in certain respects to the Caucasian groups. A sex difference of this type has been noted by others (Morgan *et al.*, 1969; Garn & Wagner, 1969). In respect of excessive fluorine intake, the bone data were not significantly affected.

Bone data on adults

In the aged Bantu groups, mean bone data were either very close to, or lay within corresponding mean values reported for aged Caucasians (Nordin *et al.*, 1966; Morgan *et al.*, 1967; Smith *et al.*, 1969; Garn & Wagner, 1969; Hossain *et al.*, 1970; Dequeker, 1970; Exton-Smith, 1970).

In the fluorosis area, mean bone data on the aged Bantu did not differ significantly from corresponding data found in the non-fluorosis areas. This was unexpected (Srikantia & Siddiqui, 1965; Anonymous, 1970).

Among the total of sixty-four aged Bantu men and eighty-five women of 70–79 years examined, none had evidence of hip fracture. In the study of Solomon (1968) on urban Johannesburg Bantu, age-adjusted prevalence of hip fracture was only a tenth of such reported for corresponding Caucasians. With regard to obvious collapse of lumbar vertebral bodies, in the old Bantu, 6·3 and 11·7% of males and females respectively, were affected. A low prevalence, 6%, was noted in elderly indigenous inhabitants in Surinam (Luyken & Luyken-Koning, 1969). In contrast, in Caucasians in U.S.A., Bernstein *et al.* (1966) reported such collapse in 45 and 35% of males and females, respectively. In an interracial study undertaken in Durban on female groups of mean age approximately 70 years, Dent, Engelbrecht & Godfrey (1968) reported osteoporosis present in 3 and 2% of rural and urban Bantu, but in 14% of Caucasians. A lower prevalence of osteoporosis in U.S.A. Negroes compared with Caucasians has often been reported (Smith & Rizek, 1966). Unfortunately, in assessing the frequency of osteoporosis stigmata, different workers use different criteria; notwith-

TABLE 2. Metacarpal dimensions in aged Bantu compared with data on Caucasians (means and standard deviations in mm)

Population	D	d	$D-d$	$\frac{D-d}{D}$	$\frac{(D/2)^2-(d/2)^2}{(D/2)^2}$	D^2-d^2	L	$\frac{D^2-d^2}{DL}$
Bantu males								
Zola (urban)	8·96	4·51	4·45	0·50	0·75	59·28	69·33	0·095
SD	0·80	1·11	0·68	0·09	0·08	8·34	3·63	0·010
Kgala (rural)	8·34	3·90	4·44	0·53	0·79	54·10	69·48	0·093
SD	0·54	0·73	0·56	0·07	0·07	6·66	4·30	0·008
Kruidfontein (fluorosis)	9·00	4·61	4·39	0·49	0·74	59·49	68·56	0·096
SD	0·66	0·85	0·66	0·08	0·08	9·38	3·20	0·010
Caucasian males								
U.S.A. (Garn, 1969)	8·60	3·80	4·80	0·56	0·80	59·50		
England (Morgan *et al.*, 1967)	9·70	5·10	4·60	0·47	0·72	68·10		
England (Exton-Smith, 1970)								0·097
Holland (Dequeker, 1970)						53·00		
Bantu females								
Zola (urban)	7·84	4·75	3·09	0·40	0·63	38·64	64·82	0·075
SD	0·60	0·78	0·64	0·08	0·07	7·86	3·36	0·012
Kgala (rural)	7·56	4·23	3·33	0·44	0·68	38·92	65·96	0·077
SD	0·40	0·72	0·63	0·08	0·07	6·17	3·34	0·010
Kruidfontein (fluorosis)	8·20	5·04	3·16	0·39	0·62	41·30	65·81	0·076
SD	0·46	0·83	0·75	0·09	0·08	8.35	3·50	0·013
Caucasian females								
U.S.A. (Garn, 1969)	7·60	4·25	3·35	0·44	0·69	39·70		
Scotland (Nordin *et al.*, 1966)				0·42				
Scotland (Smith *et al.*, 1969)				0·43				
Scotland (Hossain *et al.*, 1970)					0·64			
England (Morgan *et al.*, 1967)	8·10	4·95	3·15	0·39	0·63	41·10		
England (Exton-Smith, 1970)								0·082
Holland (Dequeker, 1970)				0·37		39·00		

standing, it would seem justifiable to conclude from our results that the prevalence of such stigmata was lower in Bantu than in Caucasians.

Discussion

Within the context prevailing, the salient finding is that in aged Bantu, a low calcium intake, and in the old women a very high drain of calcium, are both consistent with metacarpal bone dimensions and indices closely similar to those of Caucasians. Further, among the aged Bantu, also notable were absence of hip fracture and a lower prevalence of obvious collapse of lumbar vertebrae. It should be added that the diet of Bantu not only is low in calcium, but is high in phytic acid, and in the orthodox sense has an unfavourable calcium–phosphorus ratio; the diet, moreover, is frequently low in protein, especially animal protein (Walker, 1966).

Can data on metacarpal be regarded as representative of the bone situation in the body as a whole? It has been demonstrated that cortical dimensions of metacarpal, also humerus, correlate highly significantly ($P < 0{\cdot}001$) with mineral matter per unit volume (Virtama & Mahonen, 1960; Virtama & Tekkla, 1962). Although, as Virtama & Tekkla (1962) have emphasized, caution is necessary in extrapolating findings from one bone to another, it would seem reasonable to consider that there are no obvious differences in the skeletal stores of aged Bantu compared with Caucasians.

If the foregoing is valid, how is it accomplished? (1) The habitual meagre intake of calcium by Bantu must be very well utilized. There is adequate evidence that low intakes of the element are associated with a high absorption and relatively low excretion (Nicholls & Nimalasuriya, 1939; Luyken & Luyken-Koning, 1961; Begum & Pereira, 1969; Spencer *et al.*, 1969; Garn, 1970). (2) It is probably of relevance that old Bantu are far more active than Caucasians of the same age. All old Bantu studied still busied themselves in and around their dwellings; in rural areas some walk tremendous distances to their cattle posts (as much as 30 miles distant).

At a recent symposium, Whedon (1970) stated, 'Clearly now, *many* factors, hormonal, nutritional, physical and circulatory influence the rate of bone loss or bone preservation . . .' We question whether this is valid for communities. In each of the factors enumerated, our elderly Bantu groups differed markedly from Caucasian groups studied elsewhere. Yet, no significant interracial differences are apparent in mean data on metacarpal dimensions.

The whole situation will remain unsatisfactory until valid information is available on the lower limits of bone thickness and other indices which, in a community, are consistent with everyday good health and activity.

In the light of our findings, it would seem imperative that the reasons for the present insistence on high calcium intakes during growth, pregnancy and lactation, be critically re-examined. Equally, the continued addition of calcium salts to staple foodstuffs calls for renewed justification.

Acknowledgments

For facilitating or undertaking the X-ray observations at the hospitals at Pretoria, Rustenburg, Saulspoort, and Johannesburg (Mofolo), we are very grateful to Dr H. H. Christ, Dr F. Jooste, Dr G. H. Roux, and Mrs J. Richards, respectively. Miss M. J. Fick and Miss M. Wadvallah assisted with the cortical measurements.

References

ANONYMOUS (1970) Fluorides and human health. *World Health Organisation Chronicle*, **24**, 271.

BARNETT, E. & NORDIN, B.E.C. (1960) The radiological diagnosis of osteoporosis. A new approach. *Clinical Radiology*, **11**, 166.

BEGUM, A. & PEREIRA, S.M. (1969) Calcium balance studies on children accustomed to low calcium intakes. *British Journal of Nutrition*, **23**, 905.

BERNSTEIN, D.S., SADOWSKY, N., HEGSTED, D.M., GURI, C.D. & STARE, F.J. (1966) Prevalence of osteoporosis in high- and low-fluoride areas in North Dakota. *Journal of the American Medical Association*, **198**, 499.

BROCK, J.F. & AUTRET, M. (1952) Kwashiorkor in Africa. *Bulletin of the World Health Organisation*, **5**, 1.

BURKE, B.S. & STUART, H.C. (1938) A method of diet analysis. Application in research and pediatric practice. *Journal of Pediatrics*, **12**, 493.

CHRIST, H.H. (1961) A discussion of causes of error in the determination of chronological age in children by means of X-ray studies of carpal-bone development. *South African Medical Journal*, **35**, 854.

DENT, C.E., ENGELBRECHT, H.E. & GODFREY, R.C. (1968) Osteoporosis of lumbar vertebrae and calcification of abdominal aorta in women living in Durban. *British Medical Journal*, **4**, 76.

DEQUEKER, J.V. (1970) Parathyroid activity and post-menopausal osteoporosis. *Lancet*, **ii**, 211.

DICKERSON, J.W.T. & JOHN, P.M.V. (1969) The effect of protein–calorie malnutrition on the composition of the human femur. *British Journal of Nutrition*, **23**, 917.

EXTON-SMITH, A.N. (1970) Pattern of development and loss of bone with age. *Lancet*, **i**, 360.

EXTON-SMITH, A.N., MILLARD, P.H., PAYNE, P.R. & WHEELER, E.F. (1969a) Method for measuring quantity of bone. *Lancet*, **ii**, 1153.

EXTON-SMITH, A.N., MILLARD, P.H., PAYNE, P.R. & WHEELER, E.F. (1969b) Pattern of development and loss of bone with age. *Lancet*, **ii**, 1154.

FELLINGHAM, S.A. (1966) Statistical planning of the nutrition status surveys on Pretoria school children. *South African Medical Journal*, **40**, 228.

FOX, F.W. (1966) *Studies on the Chemical Composition of Foods Commonly Used in Southern Africa*. South African Institute for Medical Research, Johannesburg.

GARN, S.M. (1970) Calcium requirements for bone building and skeletal maintenance. *American Journal of Clinical Nutrition*, **23**, 1149.

GARN, S.M., PAO, E.M. & RIHL, M.E. (1964) Compact bone in Chinese and Japanese. *Science*, **143**, 1439.

GARN, S.M. & WAGNER, B. (1969) The adolescent growth of the skeletal mass and its implications to mineral requirements. In: *Adolescent Nutrition and Growth* (Ed. by F. P. Heald), p. 139. Appleton, Century & Crofts, New York.

HOSSAIN, M., SMITH, D.A. & NORDIN, B.E.C. (1970) Parathyroid activity and post-menopausal osteoporosis. *Lancet*, **i**, 809.

LUBBE, A.M. (1968) A survey of the nutritional status of white school children in Pretoria: description and comparative study of two dietary survey techniques. *South African Medical Journal*, **42**, 616.

LUBBE, A.M. (1970) Personal communication.

LUYKEN, R. & LUYKEN-KONING, F.W.M. (1961) Studies on the physiology of nutrition in Surinam. VIII. Metabolism of calcium. *Tropical and Geographical Medicine*, **13**, 46.

LUYKEN, R. & LUYKEN-KONING, F.W.M. (1969) Studies on physiology of nutrition in Surinam. XII. Nutrition and development of muscular, skeletal, and adipose tissues in Surinam children. *American Journal of Clinical Nutrition*, **22**, 519.

MORGAN, D.B., SPIERS, F.W., PULVERTAFT, C.N. & FOURMAN, P. (1967) The amount of bone in the metacarpal and the phalanx according to age and sex. *Clinical Radiology*, **18**, 101.

NICHOLLS, L. & NIMALASURIYA, A. (1939) Adaptation to a low calcium intake in reference to the calcium requirements of tropical populations. *Journal of Nutrition*, **18**, 563.

NORDIN, B.E.C., MACGREGOR, J. & SMITH, D.A. (1966) The incidence of osteoporosis in normal women; its relation to age and the menopause. *Quarterly Journal of Medicine*, **35**, 25.

SMITH, D.A., HARRISON, I., NORDIN, B.E.C., MACGREGOR J. & JORDAN, M. (1968) Mineral metabolism in relation to ageing. *Proceedings of the Nutrition Society*, **27**, 201.

SMITH, R.W. & RIZEK, J. (1966) Epidemiological studies of osteoporosis in women of Puerto Rico and South-eastern Michigan with special reference to age, race, national origin and to other related or associated findings. *Clinical Orthopaedics*, **45**, 31.

SOLOMON, L. (1968) Osteoporosis and fracture of the femoral neck in the South African Bantu. *Journal of Bone and Joint Surgery*, **50 B**, 2.

SPENCER, H., LEWIN, I., FOWLER, J. & SAMACHSON, J. (1969) Influence of dietary calcium intake on Ca^{47} absorption in man. *American Journal of Medicine*, **46**, 197.

SRIKANTIA, S.G. & SIDDIQUI, A.H. (1965) Metabolic studies in skeletal fluorosis. *Clinical Science*, **28**, 477.

VIRTAMA, P. & MÄHÖNEN, H. (1960) Thickness of the cortical layer as an estimate of mineral content of the human finger bones. *British Journal of Radiology*, **33**, 60.

VIRTAMA, P. & TELKKA, A. (1962) Cortical thickness as an estimate of mineral content of human humerus and femur. *British Journal of Radiology*, **35**, 632.

WALKER, A.R.P. (1954) Does a low intake of calcium retard growth or conduce to stuntedness? *American Journal of Clinical Nutrition*, **2**, 265.

WALKER, A.R.P. (1966) Nutritional, biochemical and other studies on South African populations. *South African Medical Journal*, **40**, 814.

WALKER, A.R.P., ARVIDSSON, U.B. (1954) Studies on human bone from South African Bantu subjects. Part 1. Chemical composition of ribs from subjects habituated to a diet low in calcium. *Metabolism*, **3**, 385.

WALKER, A.R.P., ARVIDSSON, U.B. & DRAPER, W.L. (1954) The composition of breast milk of South African Bantu mothers. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **48,** 395.

WALLGREN A. (1945) Breast milk consumption of healthy full-term infants. *Acta paediatrica,* **32,** 778.

WHEDON, G.D. (1970) In: Osteoporosis: The state of the art. A Symposium report. *American Journal of Clinical Nutrition,* **23,** 839.

WIDDOWSON, E.M. & SPRAY, C.M. (1951) Chemical development *in utero*. *Archives of Disease in Childhood,* **26,** 205.