Occasional Survey

EFFECT OF DIETARY FIBRE ON STOOLS AND TRANSIT-TIMES, AND ITS ROLE IN THE CAUSATION OF DISEASE

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Summary Certain diseases are absent or rare in countries that have been little affected by industrialisation. Here diets containing the natural amount of fibre are eaten and result in large, soft stools that traverse the intestine rapidly. By contrast, the refined low-fibre foods of the economically developed countries produce small firm stools which pass through the gut slowly. This paper records over a 1000 transit-times of various ethnic groups at home and abroad, together with the weight of stool passed daily. It is suggested that dietary fibre has a role in the prevention of certain large-bowel and other diseases which have become prevalent in Western countries.

INTRODUCTION

WHILE proteins, fats, and carbohydrates have been studied extensively the unabsorbable fibre portion of our food has almost been ignored, probably because it is "indigestible" and of negligible nutrient value.[1] Fibre is lost when carbohydrates are refined, and it has been argued on historical and epidemiological grounds that fibre deficiency causes diverticulosis coli and appendicitis.[2-4] Both diseases followed changes in the British diet that occurred after 1870. Although previously stonegrinding had removed much bran from flour, the daily consumption of bread was often as high as 600 g., so that more fibre was then eaten than is ingested today when, at the most, only 200 g. of white bread is eaten daily and this contains the merest trace of fibre. In 1875, fat and sugar contributed 15–20% of calories, and this has risen to 55–60%. Only in the two wars was the fall in fibre consumption halted.[5-9] Table I shows that the greatest change in the British diet that has occurred in the past hundred years is the relative decrease in the intake of cereal fibre. This change is proportionately greater than the increase in the consumption of refined sugar.[10-14]

We have determined the amount of stools passed by various groups of people and the speed of transit of food residues through their intestinal tracts to see if their stools and the behaviour of their gut differed. We also looked at the prevalence of certain diseases in

TABLE I—APPROXIMATE DAILY CONSUMPTION OF FIBRE IN THE U.S.A. (g./person/day)

	1880		1970		Changes in fibre intake
	Food	Fibre	Food	Fibre	
Starches:					
Cereals	480	3·2*	120	0·3	−90%
Potatoes	300	1·1	120	0·5	−45%
Legumes	60	1·0	60	1·0	None
Starchy fibre	..	5·3	..	1·8	−66%
Fruit and vegetables	275	2·8	325	3·3	+20%
Total fibre	..	8·1	..	5·1	−37%

* Assumed fibre content of bread 0·7 g. per 100 g. (i.e., about 85% extraction; roller mills had only just started in U.S.A.).
Prepared by Dr. H. C. Trowell from material of Antar et al.[10]

TABLE II—TRANSIT-TIMES AS SHOWN BY HINTON'S METHOD

Subjects	Country	Race	Type of diet	No. of subjects	Time of appearance of first pellets (hr.)		Transit-time (hr.)		Weight of stools passed per day (g.)		Comments
					Range	Mean	Range	Mean	Range	Mean	
Naval ratings and wives	U.K.	White	Refined	15	22–110	45·7	44–144	83·4	39–223	104	Shore-based personnel (compare Steigman [17])
Teenage boarding-school pupils	U.K.	White	Refined	9	18–103	57·4	35–120	76·1	71–142	110	Institutional diet together with cakes, sweets, and so on from school shop
Students	South Africa	White	Refined	100	13–54	30·5	28–60	48·0	120–195	173	These ate more fruit than is usual in the U.K.
Nurses	South Indian	Indian	Mixed	13	9–34	27·6	23–64	44·0	..	155	Less refined diet than that of Western world
Urban school-children	South Africa	African	Mixed	500	9–40	28·5	24–59	45·2	120–260	165	Partly Europeanised diet
Manor House Hospital patients	U.K.	White	Mixed	6	15–24	22	27–48	41·0	128–248	175	U.K. diet plus wholemeal bread and added bran
Senior boarding-school pupils	Uganda	African	Mixed	27	4–54	27·6	22–118	47·0	48–348	185	Traditional Ugandan diet plus refined sugar, white bread, jam, butter
Vegetarians	U.K.	White	Mixed	24	8–49	22·0	18–97	42·4	71–488	225	Note similarity of values to those of African groups
Rural school-children	South Africa	African	Unrefined	500	5–28	12·8	20–48	33·5	150–350	275	..
Rural villagers	Uganda	African	Unrefined	15	4–32	19·8	19–68	35·7	178–980	470	Villagers not yet supplementing their diet with processed foods of Western type

various parts of the world to see if their incidence bore any relation to the type of stool passed and to the fibre content of the local diet.

METHODS

Earlier methods for measuring the time taken by food and its residues to pass through the intestine, such as timing the passage of millet seeds, carmine, or barium salts, have been superseded by the method of Hinton et al.[15] which we used because it gives reproducible results. Twenty-five radio-opaque plastic pellets about the size of rice grains, 2–3 mm. in length, are swallowed after a meal, and the next five or six stools are voided into numbered plastic bags and the time at which each stool is passed is recorded. The stools are then weighed and X-rayed. The time elapsing between swallowing and passing twenty of the pellets is calculated and called the transit-time. One or two pellets may stay in the bowel for many days, and the passage of twenty pellets gives reliable results. Stools can be sieved to retrieve the pellets, thus avoiding the need for X-rays.[14]

EFFECT OF DIET ON STOOL CHARACTERISTICS AND TRANSIT-TIMES

Table II shows the daily stool weight and transit-times in groups of various races in different countries. The range of values for a group often overlapped the results obtained from another group. This variation is probably due to the personal physical factors and personal dietary preferences which are indulged within the limits of the foodstuffs available locally. The possible consequence of these variations will be discussed later.

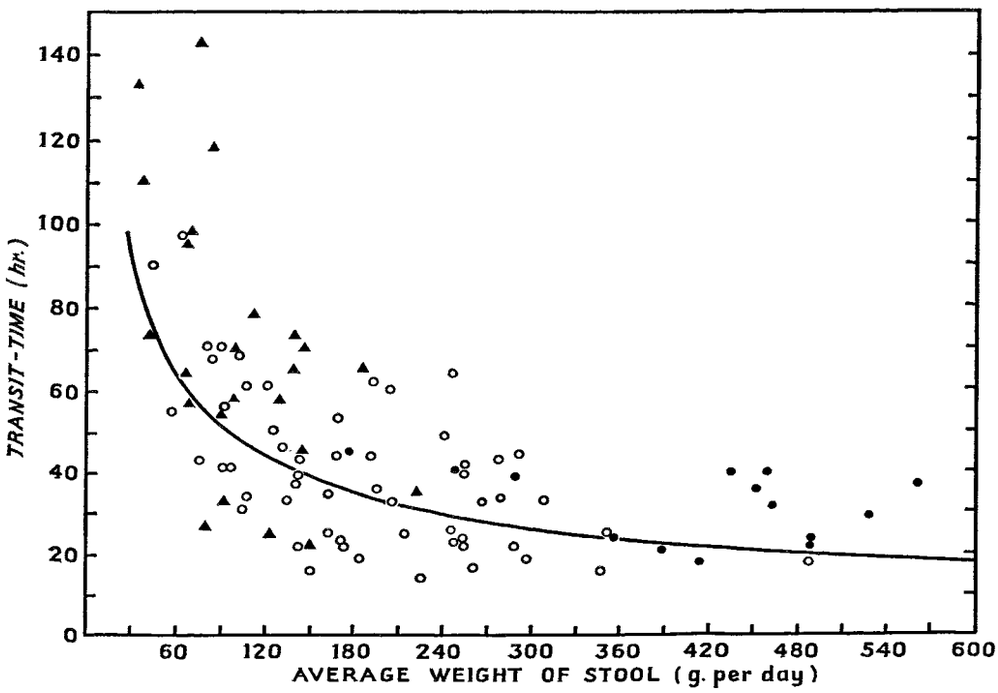
Despite this range of results it seems that the more refined is the diet the smaller the stool and the slower is the passage of the food residues through the intestine. By contrast, diets containing ample fibre produce stools which are bulky, soft, and traverse the gut rapidly. The fibre-deficient food residues of Western man may remain in the bowel for several days and yet be associated with a daily bowel movement. Thus there is evidence to support the truth of the old adage that a patient may be regular but five days late.

There is an inverse relationship between daily stool weights and transit-times (see fig.). The bulky stool containing more fibre weighs more and is propelled through the bowel faster. This is true regardless of race; for example, British vegetarians have stool weights and patterns of bowel behaviour that are essentially similar to those of Ugandan boarding-school pupils. Furthermore, the addition of bran fibre to the diet of British patients produced stools of about the same weight and resulted in transit-times which were similar to those of these two groups and which were shorter than those observed in English subjects eating refined food. This accords with the experience of Painter et al.,[16] who found that the addition of fibre to the diet of patients with diverticulosis makes defæcation regular and diminishes the need to strain at stool. Steigman [17] estimated that in North America the daily stool weighed between 100 and 200 g., with an average of 115 g. This was our experience in patients eating a refined Western diet, and these values are very different from those of rural Ugandans, who usually passed over 450 g. of fæces a day.

EPIDEMIOLOGY OF BOWEL DISEASES

Information was obtained from more than two hundred hospitals in over twenty countries. Our inquiries confirmed that appendicitis, diverticular disease of the colon, and both benign and malignant tumours of the colon and rectum, which are common in the Western nations, are rare in the developing countries. Previous inquiries made over many years by letter or by working in or visiting various countries corroborate this statement.

All these diseases are very closely associated epidemiologically. They commonly afflict Western Europeans and both white and coloured Americans, although the American Negro was less prone to them only a generation ago. These diseases are still rare in developing countries and in rural Japan, where eating habits have changed but little, but they are all seen increasingly in Japanese who live in Hawaii and California and are increasing in Japan in those who have changed to a Western diet. In no country or region is one of these diseases common and the others rare save that appendicitis, which afflicts the young, appears about a generation before the other conditions.



Relation between fibre intake, transit-time, and stool weight.
○ = Vegetarians, vegans, and African boarding-school (mixed diet).
● = African villagers (high-residue diet).
▲ = English boarding-school and British Navy (low-residue diet).
The curve (which is based on more data than the points shown here) is:
log (time) = 2·81633–0·56057 log (weight).

TABLE III—TRANSIT-TIME OF DIGESTA AS REFLECTED BY FIRST APPEARANCE OF INGESTED CARMINE

Population	Ref.	Mean time of first appearance (hr.)
Whites, U.K., adults	Rothman and Katz [18]	40–48
Whites, U.K., adults	Mulinos [19]	28
Whites, South Africa, students	..	
Whites, U.K., adults	Wolman [20]	20
Whites, U.K., children	Mulinos [19]	28
Whites, U.K., children	Dimson [21]	26
Whites, U.K., children	Wolman [20]	20
Africans, Rhodesia, medical students	Holmgren and Mynors [22]	28
Africans, South Africa, urban children, Johannesburg	..	
Africans, Rhodesia, high-school teachers	Holmgren and Mynors [22]	20
Africans, Rhodesia, miners (unrefined diet)	Holmgren and Mynors [22]	14
Africans, South Africa, rural children, Johannesburg	..	

We found no community which consumed a high-fibre diet in which any of these bowel diseases was common, nor any community which had changed from a high to a low fibre diet which had not become increasingly subject to most, if not all, of these conditions within a generation, with appendicitis heralding the advent of its companion diseases.

EXPERIENCES OF OTHER INVESTIGATORS

Table III shows the results obtained by workers who used carmine markers. Rhodesian African miners on a high-fibre diet passed carmine within 14 hours of its ingestion, while in Rhodesian high-school teachers on a mixed or partly European diet this time was 24 and African medical students eating a more refined diet took 28 hours to pass the carmine.[22] White adults in the United Kingdom had transit-times of over 40 hours according to Rothman and Katz,[18] but Mulinos [19] and Wolman [20] recorded shorter times.

Hinton's method was used by Iswariah,[23] who found transit-times of 44 hours in Southern Indian nurses whose stools weighed on average 155 g. per diem. Very long transit-times were recorded by Brocklehurst and Khan [24] in British geriatric patients; they found that five out of eight patients studied retained the plastic pellets for 2 weeks. McCance and Widdowson [25] and Manoussos et al.[26] found that transit-times were increased by about 24 hours in patients eating white bread as opposed to brown bread.

DISCUSSION

Certain diseases that have become common in the past have so far affected only the Western industrialised nations to any marked degree. Their epidemiology suggests that they are the result of dietary changes. Our inquiries confirm that appendicitis, diverticulosis coli, and both benign and malignant tumours of the colon are always found together in populations who eat refined carbohydrates. We found fibre-deficient diets to be associated with prolonged transit-times and with a small daily stool that is usually voided only with effort. By contrast, populations who do not suffer from these diseases eat their traditional food rich in fibre and pass large soft stools which may be four times the weight of those of the Englishman. These soft stools traverse the gut faster and are voided without straining. The experience of other investigators is summarised in table III, and, when due allowance is made for their methods of study, their findings accord with ours.

Clinically, the addition of fibre to a refined diet reverses the effect of food refining. The presence of fibre shortens the transit-times and increases the stool bulk. This was demonstrated in British patients on a high-fibre diet and is similar to the experience of Painter et al.,[16] who found that the addition of bran to the diet increased the frequency of defæcation and lessened the need to strain at stool. Both British patients eating bran and English vegetarians had stool weights and transit-times that were essentially the same as those of Africans who had modified their traditional unrefined diet by adopting certain European eating habits. Hence, these differences in the behaviour of the bowel seem due to dietary factors rather than to any characteristic of race. The astronaut makes use of the observation that food refining leads to fewer smaller stools. He is fed on a diet almost free of fibre, which results in constipation with five or six days elapsing between bowel actions.[27]

We conclude that the transit-times and stool weights of the villager in the developing countries, who still eats his traditional unrefined carbohydrates, are normal and that the small stiff stools and prolonged transit-times of the citizens of the Western world are abnormal. If this view is accepted, the following questions must be asked. If the removal of fibre from the diet has such a profound effect on the stools and on bowel behaviour, is the physiology of digestion modified by the presence or absence of fibre? If the addition of only a few grammes of bran to the diet can so alter the environment of the colon, could not fibre deficiency be responsible, at least in part, not only for the colonic disorders already mentioned but also for some of the other diseases of Western man?

In the West, coronary-artery disease, diverticulosis coli, appendicitis, and gallbladder disorders loom large on the clinical scene, while cancer of the colon is second only to lung cancer as a killing neoplasm.

This was not always so. Coronary-artery disease was rare in England until 1925; diverticulosis coli was a curiosity until 1900; appendicitis appeared towards the end of the 19th century; and gallbladder disease has increased fourfold in the Bristol region since 1940.[3,28–30] All these diseases became common after the introduction of improved milling techniques, lower consumption of bread, and increased use of sugar. The same process can be observed in the American Negro, whose diet changed later and who was less prone to coronary disease, to diverticulosis coli, and to appendicitis until a generation ago.[12,31–33] The Japanese seldom suffer from these diseases to this day, but all these conditions are very common in Hawaiian Japanese who have been reared on a Western diet.[34]

With regard to colonic diseases, fibre deficiency is of great importance. Diverticulosis is apparently caused

by a lack of dietary fibre [2,3] and its replacement relieves the symptoms of diverticular disease.[16,35] Short [36,37] suggested that appendicitis was the result of eating refined food, and extensive epidemiological studies support the view that the disease is due to fibre deficiency.[4] Likewise, constipation has become commoner in the last century. Today, £5 million is spent on laxatives in Britain annually besides 3½ million National Health Service prescriptions.[38] Constipation can be cured by bran.[39–41] and one of us (N. S. P.) can testify that fibre replacement in constipated patients produces a soft stool, reduces transit-times, and lessens the need to strain at stool.

Epidemiologically, benign and malignant tumours of the colon are always related to these diseases, and it has been shown that the bacteria in the colon of people eating a Western diet degrade bile to form the precursors of carcinogens.[42,43] These noxious compounds would remain in contact with the colonic mucosa for a longer time and in a more concentrated form if a fibre-deficient diet was eaten. It will be remembered that a wide range of values was obtained in each group as regards transit-times and stool weights. This may account for the fact that not all those who eat a refined diet suffer from these diseases. Perhaps personal susceptibility and choice of food may offer some protection against the long-term effects of a fibre-deficient diet. Nevertheless, at the age of sixty, no less than a third of our population have diverticulosis, and polyps and cancer of the colon are very common while in rural Africans these conditions are almost unknown.[14,44]

Trowell [45,46] has reported that the serum-cholesterol rises when fibre is removed from the diet. Eating a fibre-rich diet [47] or adding cellulose to the diet [48] lowers the serum-cholesterol. Diverticular disease and coronary disease are closely associated in patients [49] and a high-fibre diet increases the excretion of bile acids in the fæces.[30,50] Hence, it is possible that the removal of fibre from foodstuffs not only causes diverticulitis, which first appeared in the Registrar General's reports as a cause of death in 1923, but may also partly be responsible for the appearance of coronary-artery thrombosis in these reports in 1926 and for the increased incidence of gallstones containing cholesterol.

CONCLUSION

Some of the diseases that have become a common problem in Western countries in this century may be caused, at least in part, by the removal of dietary fibre from carbohydrate foods. The role of cereal fibre in the diet has attracted little attention, presumably because it has little energy value. Sufficient evidence is already available to show that fibre does not only provide " bulk " but also in some way affects the physiological processes which occur in the gut and the bacterial flora which inhabit it. Fibre deficiency has been shown to be an apparent cause of diverticulosis and so may be of great importance in the causation of other diseases associated with diverticular disease. Therefore, its role in human physiology deserves more attention.

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