STUDIES IN THE EPIDEMIOLOGY OF TINEA PEDIS

IV. SEED AND SOIL

BY

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Our survey of tinea pedis in day-school children in Bristol (English and Gibson, 1959a) showed that girls had a uniformly low infection rate, averaging 1.6%, while the average infection rate among boys was 6.6%, with a significant variation according to the district in which their schools were situated. This variation was associated with the degree of infection found on the floors of the local swimming-baths (English and Gibson, 1959b). Later it was shown that these children did not usually contract their infection in their homes (English and Gibson, 1960).

The present investigation attempts to throw some light on factors of "seed" and "soil" which could account for the foregoing observations.

The work of Vanbreuseghem *et al.* (1952) and Tritsmans and Vanbreuseghem (1955) suggested that the frequency with which swimming-baths were used might be of considerable importance in the epidemiology of the disease. We have therefore investigated the frequency with which the children swam at public baths and all other occasions on which they might go barefooted in places where infection could be contracted.

Strauss and Kligman (1957) have shown experimentally that moisture and warmth favour interdigital fungus infections, and common observation without, so far as we can find, strict mycological control supports this view. Therefore we have included in our survey a detailed study of the children's footwear.

The investigation was carried out in the same schools and, so far as possible, on the same children as the previous school survey, in order to obtain the greatest possible uniformity of conditions.

The Subjects

The children, who were between 11 and 15 years old, attended senior schools 1-12 of our first survey (English and Gibson, 1959a), which took place approximately one year before the present one. Children in their second, third, and fourth "school years," approximately 12, 13, and 14 years old, were chosen exclusively from pupils who had been seen at lower grades in the first survey. A few in their first year, approximately 11 years old at the time of the present survey, had been seen at the first survey while attending junior schools 13-16, and these were again chosen for this investigation; but most of the younger children were now seen by us for the first time.

Two groups of children were selected: in the first the footwear, swimming habits, etc., of infected and

uninfected children were compared; in the second the same comparisons were made for boys and girls.

The first group consisted of 67 boys infected with tinea pedis at the first survey who were still at school, together with one control each—namely, the next uninfected boy on the class register.

At the first survey the *interdigitale* type of *Trichophyton mentagrophytes* had been isolated from 57 of the 67 infected boys, *T. rubrum* from 3, *Epidermophyton floccosum* from 4, and 3 had unidentified fungi. At the present survey 47 of the boys were cured; 19 were still infected with *T. mentagrophytes* and 1 with *T. rubrum*.

Only 12 girls who had been infected at the first survey were still at school. These were examined together with two controls for each—namely, the next two girls on the class register. The number of girls was even then too small for any conclusions to be drawn on factors affecting incidence.

The second group was composed of approximately equal numbers of boys and girls drawn from each of the four "school years" and chosen without any bias which would affect bathing habits and footwear.

Twelve boys and two girls of the second group of children were currently infected with *T. mentagrophytes* (*interdigitale* type).

The survey was carried out during 1958.

Methods

The same questionnaire was used for both groups and was prepared in such a way that the replies could be used for punched-card analysis without further coding. As well as questions concerning the children's footwear and bathing habits, the type and condition of the foot, and any occasions on which contact with the fungi could take place were also noted. Interviews were held in the schools, the questioning being mainly carried out by one of us (M.D.G.) with help from another (M.P.E.).

Scrapings were taken from the toe-webs of all children, including those with no lesions, by one of us (M.P.E.) and submitted to mycological examination by the methods of the previous survey (English and Gibson, 1959a).

The statistical planning of the survey and the analysis of the results were the responsibility of the third author (E.H.L.D.).

Terminology.—The words "bathed" and "bathing" here refer to "going for a swim" *not* to "taking a bath."

Results

Comparison of Infected Boys with Uninfected Controls from the Same Form

Footwear.—The footwear of the infected boys and controls was almost identical.

Bathing.—Table I shows that infected boys began to attend swimming-baths at a significantly earlier age than their controls, and had therefore been exposed to the risk of infection from this source for longer. Almost all boys, whether infected or not, bathed regularly with their school. This entailed at the most one visit to the baths per week during term-time and it was not possible to show any relationship between these visits and infection. However, many of the boys also went swimming out of school hours, and there was a statistically

TABLE I.—Age at Which Bathing was Begun in Infected Boys and Controls

Category	No. of Boys	Age in Years							
		Under 7		7-9		10 and 11		12 and Over and Non-bathers	
		No.	%	No.	%	No.	%	No.	%
Infected	67	9	13	28	42	23	34	7	10
Control	67	1	1	25	37	23	34	18	27

$\chi^2=11.410$. Degrees of freedom=3. $P<0.01$.

TABLE II.—Use of Swimming-baths Out of School Hours by Infected Boys and Controls

Season	Category	No. of Boys	Frequency of Use of Baths					
			More than Once a Week		Once a Week or Less		Never	
			No.	%	No.	%	No.	%
Summer	Infected	67	26	39	35	52	6	9
	Control	67	15	22	34	51	18	27
Winter	Infected	67	14	21	37	55	16	24
	Control	67	8	12	30	45	29	43

Summer: $\chi^2=8.966$. Degrees of freedom=2. $P<0.25$.
 Winter: $\chi^2=6.134$. " " " " =2. $P<0.05$.

significant relationship between incidence of infection and frequency of out-of-school bathing both in winter and in summer (Table II). It would therefore seem reasonable to suppose that frequent bathing and infection are related. Moreover, children bathing out of school hours would be using the baths at a time when adults, who are probably more highly infected, were swimming, and therefore would run more risk of acquiring a fungus infection.

Other Factors.—21 infected boys had crowded toes and three had widely spaced ones; eight controls had crowded toes and 12 had widely spaced ones. The association of infection with crowded toes was statistically significant ($P<0.05$). No significant difference was found between infected and uninfected boys in their use of school or other showers, in the frequency with which they went bare-footed or wore sports footwear without socks, admitted to exchanging footwear, or washed their feet. The degree of sweating of the feet was estimated by combining the boy's estimate of this with observation of the condition of his socks. No association was found between heavy sweating and infection. Strauss and Kligman (1957) produced really severe maceration artificially and noted that it was incompatible with fungal growth: Cremer (1959) has reached the same conclusion.

Comparison of the Habits of Boys and Girls

Footwear.—Table III shows that there is a considerable difference in the shoes worn by boys and girls, both in winter and in summer. Nearly 80% of boys wore lace-up shoes during some part of the summer, compared with only 8% of girls. Most girls wore either slip-on shoes (light leather shoes without laces or straps and often low-cut) or sandals. The usual alternative to lace-up shoes for boys was gymnastic shoes (canvas shoes with rubber soles), which are notorious for overheating the feet. In winter, boots of some sort were widely worn by both sexes; but while 62% of girls wore slip-ons as an alternative, 97% of boys wore lace-up shoes. In girls the choice between sandals and slip-on shoes in summer, and between lace-up shoes and slip-ons in winter, was largely determined by age, the older girls preferring slip-ons at both seasons. Striking differences

between the hosiery fashions of boys and girls, especially in summer, are shown in Table IV; for 50% of girls discarded both socks and stockings during at least some part of the summer, whereas this practice was virtually non-existent among boys. The older the girl, however, the more continuously she tended to wear some sort of hose. Nylon socks were the most popular for both sexes in summer, but whereas the alternatives for girls were cotton socks or nylon stockings, boys more often chose woollen socks. In winter 76% of boys wore the latter compared with 31% of girls. The general picture given by these results is of the much lighter and cooler footwear worn by girls than by boys, especially in summer.

Bathing.—There was no significant difference in the age at which boys and girls first used swimming-baths, nor in the regularity with which they attended school swimming classes. However, as Table V shows, 25% of boys bathed more than once a week in their free time in summer, and 10% in winter, compared with 10% and 3% of girls; 42% of boys never bathed in winter compared with 60% of girls. These differences between boys and girls were statistically significant.

School Showers.—80% of boys to whom school showers were available used them regularly, compared

TABLE III.—Comparison of Shoes Worn by Boys and Girls*

Shoes Worn in Summer					Shoes Worn in Winter				
Type of Shoe	Boys		Girls		Type of Shoe	Boys		Girls	
	No.	%	No.	%		No.	%	No.	%
Sandals	48	18	90	63	Gymnastic shoes	2	1	0	0
Gymnastic shoes	67	50	16	11	Lace shoes	131	97	65	46
Lace shoes	107	79	11	8	Gumboots	64	47	44	31
Gumboots	6	4	2	1	Fleecy-lined boots	2	1	50	35
Casuals (boys) or slip-ons (girls)	14	10	125	87	Other boots	9	7	3	2
Total children	135		143		Total boots	69	51	90	63
					Casuals (boys) or slip-ons (girls)	9	7	89	62
					Total children	135		143	

* The percentages in tables concerning footwear do not add up to 100 per cent because most children wore two or three different types.

TABLE IV.—Comparison of Hose Worn by Boys and Girls

Type of Sock or Stocking	Hose Worn in Summer				Hose Worn in Winter			
	Boys		Girls		Boys		Girls	
	No.	%	No.	%	No.	%	No.	%
Nylon socks	110	82	88	62	65	48	74	52
Cotton	21	16	54	38	12	9	32	22
Woollen	47	35	0	0	101	76	45	31
Other	13	10	1	1	9	7	1	1
Nylon stockings	—	—	21	15	—	—	40	28
Usually no hose	0	0	30	21	0	0	1	1
Occasionally no hose	0	0	42	29	0	0	15	10
Always with hose	134	99	71	50	132	98	123	86
Total children	135		143		135		143	

The discrepancy in the totals of the "boys" columns is due to omissions in filling in questionnaires.

TABLE V.—Use of Swimming-baths Out of School Hours by Boys and Girls

Season	Category	No. of Children	Frequency of Use of Baths					
			More than Once a Week		Once a Week or Less		Never	
			No.	%	No.	%	No.	%
Summer	Boys	135	34	25	69	51	32	24
	Girls	143	15	10	91	64	37	26
Winter	Boys	135	13	10	65	48	57	42
	Girls	143	4	3	53	37	86	60

Difference between boys and girls:
 Summer: $\chi^2=10.534$. Degrees of freedom=2. $P<0.01$.
 Winter: $\chi^2=11.647$. " " " " =2. $P<0.005$.

with 38% of girls. The floors of the showers of four boys' schools and one girls' school were sampled by Gentles's (1956) method immediately after they had been used, although we had no knowledge of the level of infection in the children last using them. Only one dermatophyte colony (*T. mentagrophytes*—*interdigitale* type) was isolated.

Other Factors.—60% of girls claimed that they washed their feet daily, compared with 20% of boys, but the appearance of the girls' feet did not support their statements. It is possible that the girls were more aware than the boys of the frequency with which their feet *should* be washed, and replied accordingly rather than with the strict truth. We considered it advisable, therefore, not to pursue this point any further. 16% of boys had crowded toes compared with 23% of girls; 19% of boys had widely spaced toes compared with 11% of girls. Statistically, the girls' toes were significantly ($P < 0.05$) more crowded than the boys. No other significant differences were found among those habits of the sexes which were investigated.

Discussion

School Showers

It was surprising that attempts to isolate dermatophytes from the concrete floors of five school showers produced only one colony, especially as for swimming-baths Gentles's method had been very successful in our hands. It must be observed, however, that almost all the indirect evidence obtained so far supports this result. In neither the first survey (English and Gibson, 1959a) nor the present one was any correlation found between infection and the use of showers by individual boys. Similarly, in the first survey there was no association between the infection rate in any school and the presence or absence of showers. The only contrary evidence is the far more consistent use of showers by boys than by girls, but there are sufficient other factors to explain in large part the different incidence of the disease in the sexes.

Our results here are completely at variance with those of Gentles and Holmes (1957) for miners. They found that where mines had pit-head baths there was a much higher incidence of tinea pedis among the men than in mines without baths. Gentles (1957) was able to isolate dermatophytes freely from the floors of pit-head baths. The explanation may lie in the different use made of showers by schoolboys and by miners. Schoolboys never use the showers more than three times a week, usually only once or twice, whereas miners use them daily: day-school boys are allowed only two or three minutes underneath and rarely wash systematically, whereas miners take time to scrub down, and their feet are often badly macerated and peeling (Gentles, personal communication). It has been pointed out, too, that we did not know the incidence of infection in the classes using the showers immediately prior to our visit. In addition, the infection rate in miners was very much higher (16% to 50% in pits with showers) than in any of our schools, where the highest level was 8.9%.

No doubt the use of showers has some small cumulative effect on the level of infection, but this would be masked by more important factors such as the use of swimming-baths, and would be demonstrable only in a much larger investigation than the present one.

Bathing and Footwear

The association we have shown for boys between duration and frequency of attendance at swimming-baths

and the incidence of infection is in complete agreement with the work of Tritsmans and Vanbreuseghem (1955) on Belgian swimmers, and also confirms the observations of Amrein (1953) in Switzerland. Marples and Chapman (1959), on the other hand, found no association between swimming and infection in a mixed school of 387 children in New Zealand. They suggest that this may be due to their comparatively small numbers and low infection rate. But their "frequent bathers" went to the baths "at least once a week," whereas our keenest children went once a week with the school and more than once in their own time—that is, a minimum of three visits a week. The New Zealand school also had its own swimming-bath, and only some of the children ever visited the municipal baths and came into contact with adult bathers.

Because of the more qualitative nature of the evidence, the correspondence we have shown between type of footwear and incidence of tinea pedis in the sexes is suggestive but not conclusive. Scheffler (1958) and Marples and Chapman (1959) found an almost equal incidence of tinea pedis in boys and girls. Scheffler's results cannot be compared strictly with ours, as *T. rubrum* was of much more frequent occurrence in his subjects and its epidemiology may differ from that of *T. mentagrophytes* (English and Gibson, 1959a, 1960). In the New Zealand school, however, where *T. mentagrophytes* was the predominant fungus, woollen socks and gymnastic shoes were the favourite footwear for both sexes in winter, when the survey was carried out. Though no figures are available for the summer, it was observed to be common practice for girls to wear cotton ankle-socks while boys wore no socks, and for both sexes to wear gymnastic shoes or sandals (Marples, personal communication). In these children, therefore, the slight difference that exists between the footwear of the sexes should tend to favour a higher incidence in girls.

In observations on different communities, Davies (1951, 1952), Copland (1952), and Nickerson *et al.* (1945) show that a number of skin conditions of the foot, including tinea pedis, were exacerbated by raised temperatures and heavy footwear, but the work was not mycologically controlled. Doupage (1957, and personal communication) found that tinea pedis occurred among Congolese soldiers wearing heavy boots and socks, but not among the native civilian population, who wore light socks and sandals or went barefooted. This observation is complicated, however, by the fact that the communal living conditions of the soldiers would, in themselves, undoubtedly be expected to increase the incidence.

This aspect of the epidemiology of tinea pedis has, however, been carefully investigated by Strauss and Kligman (1957) in their experimental work on a male prison population. In men with normal feet they were able, on 25% to 50% of occasions, to produce tinea pedis by occluding the toes on either side of massively inoculated interdigital spaces with a rubber condom, while in unoccluded, inoculated interdigital spaces infection was never obtained. On the other hand, the continuous wearing of a rubber boot for a week promoted infection in only one inoculated subject out of six. Similarly, when the normal interdigital spaces of men whose other toe-webs were naturally infected were occluded, the occluded spaces of five out of seven subjects became infected. The wearing of boots daily for up to a month also produced infections in three out

of five subjects under these conditions. Infection was never produced in toe-webs of uninfected feet similarly treated but not inoculated. The great majority of experimentally induced infections were spontaneously cured after the removal of the occlusive condom or boot, a foreseeable result, as the subjects must have included a number who were naturally resistant to the disease.

The experimental conditions in this work are obviously much more severe than the mere wearing of thick socks and shoes in hot weather by schoolboys, combined with intermittent exposure to small pieces of infected skin shed at swimming-baths and other places. On the other hand, the experiments were of comparatively short duration, while our schoolboys bathed several times a week and persisted in the use of unsuitable footwear for years on end. The relevance of our purely observational evidence of the great difference in the normal footwear of boys and girls, especially in summer, to the epidemiology of tinea pedis, does receive some support from these experiments of Strauss and Kligman.

Table VI summarizes and compares our results for both groups of children. Observations 1 and 2 are concerned with the exposure to infection of the children ("seed"); observations 3-5 would affect the suitability of the "soil" for the growth of this seed.

TABLE VI.—*Summary of Results*

Habit or Characteristic	A. Infected Boys and Uninfected Controls		B. Boys and Girls	
	Boys	Controls	Boys	Girls
1. Age of starting bathing	Early	Later	Moderately early	Moderately early
2. Spare-time	Frequent	Moderate	Frequent	Moderate
3. Footwear in winter	Heavy	Heavy	Heavy	Light
4a. " " summer	Always	Always	Always	Often without
4b. Socks or not	Tendency to crowding	Tendency to wide spacing	Tendency to wide spacing	Tendency to crowding
5. Toe spacing				

In section A, the infected boys had been exposed to greater risk than the uninfected by virtue of the frequency and long duration of their attendance at swimming-baths. But all the boys wore equally hot and heavy footwear. This suggests that where the soil in any group tends to be favourable for infection the actual infection rate will depend on the extent of contact with the inoculum.

In section B, where boys are compared with girls, there was less difference between risk of infection, for though girls swam less often than boys, they started just as early. On the other hand, there was a very striking difference in the footwear of the sexes, especially in summer, which might be expected to be the critical season (Strauss and Kligman, 1957). This could mean that where soil conditions are limiting these alone can keep the level of infection low. However, a complicating factor is that, simply because the infection rate in girls is so low, they never expose each other to as heavy an inoculum potential in their changing accommodation (English and Gibson, 1959b) as do boys. It will be noticed that though infected boys had more crowded toes than uninfected boys, girls, with a low infection rate, had more crowded toes than boys. This contradictory finding suggests that crowded toes are of importance in the epidemiology only when other factors are also favourable.

In this investigation we have been unable to take host resistance to tinea pedis into account because of lack of knowledge of the subject. That some persons of both sexes are resistant is a matter of common observation (Vanbreuseghem *et al.*, 1952; Baer *et al.*, 1955; Gentles and Holmes, 1957; English, 1957; Strauss and Kligman, 1957). That we have been able to demonstrate marked differences in the behaviour of infected and uninfected groups of children despite this would seem to add to the significance of our results. On the other hand, we have no proof that the different levels of infection in the sexes is not wholly or partially due to some resistance factor inherent in the female sex. This would be an interesting field for further work.

Summary

An attempt was made to study the infectivity of, and susceptibility to, tinea pedis in school children.

It was shown that infected boys started to attend their local swimming-baths at an earlier age than uninfected ones, and also used them more frequently. Most boys wore hot and heavy shoes and socks all the year round. The frequency and duration of the use of school showers was limited and no relationship could be shown between infection and their use.

In a group of boys and girls chosen without bias affecting their bathing habits or footwear there was no significant difference in the age at which bathing was begun, but boys bathed more often out of school hours. Girls' footwear was shown to be much lighter and cooler than boys, especially in the summer.

It is suggested that where, as in boys, badly ventilated footwear renders the feet a suitable soil for fungal growth the infection level in a community will depend on the extent of exposure to infective particles, the seed. On the other hand, the well-ventilated footwear of girls may be the limiting factor which keeps their infection rate low. The possibility of resistance in girls due to sex has yet to be investigated.

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