THE DISTRIBUTION OF CARRIERS OF *STREPTOCOCCUS PYOGENES* AMONG 2,413 HEALTHY CHILDREN

By MARGARET C. HOLMES, Ph.D.* and R. E. O. WILLIAMS, M.D.
Streptococcal Reference Laboratory, Public Health Laboratory Service, Colindale, N.W. 9

It is now generally agreed that rheumatic fever is in some unexplained way a complication of streptococcal infection, but until recently few have considered that the frequency of rheumatic fever at different ages, and in different social class groups, might be largely a reflexion of a differing experience of streptococcal infection. In Melbourne, Holmes & Rubbo (1953) found that carriage of streptococci is commonest in just those groups of the child population among whom acute rheumatic fever is also thought to be most common. This paper reports a survey of the frequency of carriage of *Streptococcus pyogenes* in the nose or throat of healthy children, undertaken to test the same association in London.

Within the limits of a short-term survey, there are two methods of comparing the frequency of streptococcal infection in different population groups—examination for carriage of the organism, or for an elevated antibody titre in the serum. Neither is very satisfactory, the carrier survey because it gives information on the present state alone, the antibody survey because it gives only an indefinite picture of the past. However, we considered that the carrier survey would be more practicable and more likely to yield useful results for our purpose than the antibody survey, although we realized that we could not be certain of the relation between the streptococcal carrier rate in healthy children and the incidence of manifest streptococcal infection in the population.

Previous surveys

It is hoped to present elsewhere a detailed review of the numerous published surveys of the distribution of streptococci in various populations. For the present it will suffice to give the principal results, particularly as most of the reports give figures for a limited age or social class group and do not therefore afford evidence on the differences between such groups.

Antistreptolysin and antihyaluronidase titres in newborn infants are equal to, or higher than, the maternal titres; they soon fall to a low level, reached at the age of about 6 months, after which there is little change until the start of schooling, when the average titre rises rapidly (e.g. Gordon & Janney, 1941; Rantz, Randall & Rantz, 1948; Friou, 1949). Similarly, Dick-conversion rates increase only slowly in pre-school life, but rapidly thereafter (Schwentker, Janney & Gordon, 1943). The throat carrier rate for haemolytic streptococci is generally higher in school-children than in older persons, but information on pre-school children is very meagre (Schwentker

* Australian National University Travelling Scholar.

et al. 1943; Pike & Fashena, 1946). From all these studies there is, therefore, an indication that it is at entry into school that the child is usually first seriously exposed to streptococcal infection.

There is less evidence on social class differences in infection rates. Coburn & Pauli (1932) found a higher carrier rate in five poor families than in five wealthy families observed for 2 years. Holmes & Rubbo (1953) swabbed children from schools in high, medium and low rental areas, and found a very much higher carrier rate (25·3 %) in the poor areas than in the wealthy ones (12·5 %). They concluded that the difference could be in part attributed to social class differences in the experience of tonsillectomy.

Both Mote & Jones (1941) and Hammon, Sather & Hollinger (1950), who classified their subjects into environmental or income groups, found high anti-streptolysin titres more frequently in the lower social classes.

The carrier rate is consistently lower in tonsillectomized subjects (e.g. Macdonald, Simmons & Keogh, 1940; London County Council, Health Department, 1947); this may reflect either a greater liability to infection, or a tendency for infection to persist longer in persons with tonsils than in those without (e.g. Keogh, Macdonald, Battle, Simmons & Williams, 1939; Rantz, Spink & Boisvert, 1947, but compare Kuttner & Krumwiede, 1944).

Many of the published surveys not only cover a restricted field, but are difficult to interpret because they give no measure of the interaction between different factors. For instance the carrier rate varies with tonsillectomy, and the tonsillectomy rate varies with age and social class; how much of the observed age and social class variation in carrier rate is attributable to the variation in tonsillectomy rates? This point was considered briefly by Pike & Fashena (1946) and by Holmes & Rubbo (1953), but not by other workers.

We attempted, therefore, to make our survey as comprehensive as was practicable, by including children of all ages from birth to 16 years, from three geographically distinct areas of north and north-west London, and from different social classes. We tried to relate carrier state to age and social class, tonsillectomy, sex, size and age of family and, for the younger children, attendance at a nursery or nursery school.

MATERIAL AND METHODS

Selection of the population sample

The survey was carried out in the autumn of 1949 in three Middlesex boroughs, Enfield, Southgate and Willesden, referred to as E, S, and W. Three boroughs were sampled to allow for local epidemics, and for the possibility that the tonsillectomy rate varied markedly between different boroughs (Glover, 1938). Borough S was predominantly residential, while E and W contained industrial areas.

With the help of the Area Medical Officer of each borough and his staff, the clinics, nurseries and schools were allocated to three social classes, A, B, and C, according to the social standing of the districts which they served. Private and county grammar schools were all included in social class A; and day-nurseries, which cater almost exclusively for children of the poorer parents, in class C.

Two schools were chosen arbitrarily from each of the three social classes in each borough, and invited to co-operate. From each school two classes were chosen at random in each of the three departments—infant, junior and senior. Owing to the inability of some schools to take part the full number was not reached. The number finally included was forty-five of a possible fifty-four departments. In the private schools, where the classes were smaller, more than two classes were chosen from each department.

The parents of the school children were asked for permission to swab their child and for such particulars as the ages and history of rheumatic fever or growing pains in all children in the family, as well as for a history of measles and chickenpox in the child swabbed. At the clinics the mothers were asked individually whether they would allow their children, mostly babies, to be swabbed and were asked for details of family size and ages. At the nurseries these details were extracted from the records.

Assessment of social class

As rheumatic fever is thought to have a different incidence in different social classes, the social class classification of the population sample was important. The Registrar General's classification is based on parents' occupation, but for various reasons this was not generally available to us. We therefore had to rely on two other estimates. One was based on the general assessment of the schools by the Area Medical Officer. This was applicable to all the children, but whereas in each borough there was an obvious difference between A- and C-grade schools we could not be certain that the grades A, B, and C were the same in the three boroughs.

Another estimate was made by visiting the districts in which the children lived and arbitrarily classifying the housing into four standards. This method can give no more than a general grading, but it is of some use for purposes of comparison.

The social classes are referred to as A, B, C when the classification was based on the school classification, and *a*, *b*, *c* when based on the housing standard.

Technical methods

Plain cotton-wool swabs on metal applicators were used, those for the nose being moistened with saline containing 10% broth. The swabs were taken by one of us, or by our colleague Dr R. J. C. Hart. They were plated on horse-blood agar containing 1 in 500,000 crystal violet, within 6 hr. of collection, and the plates were incubated overnight, anaerobically, at 37° C. Beta-haemolytic colonies were subcultured and cultures resembling streptococci were grouped by Maxted's enzyme method (1948). Streptococci falling into Lancefield's group A (*Str. pyogenes*) were typed by agglutination and, when appropriate sera were available, by the precipitin method.

The condition of the children's tonsils was recorded as + when they were present but not enlarged, and either as + + or + + + when enlarged; in the small proportion of cases where there were obvious large tonsil remnants following excision, tonsils were recorded as present.

The collection of nose and throat swabs occupied 11 weeks, from 3 October to 16 December 1949. The order of swabbing was planned so that randomly selected representative units of each age-group, social class, and borough were swabbed at all stages of the survey, because it was anticipated that the incidence of streptococcal infection might change during such a lengthy period, and this in fact occurred. The mean nose and throat carrier rates rose between the first and last 4-week periods of the survey, from 1·6 and 15·1 % to 7·9 and 29·9 %.

Analytical methods

The results were analysed from the point of view of (*a*) the individual child, and (*b*) the community unit, i.e. the school class or nursery group. In the infant and junior schools, groups of children remain together during the whole day as 'classes' and so can justifiably be considered as 'community units'; the same is true in the nurseries where 'babies' (less than 1 yr. old), 'tweenies' (1 and 2 yr. old), and 'toddlers' (3 and 4 yr. old) occupy separate rooms. But in the senior schools the children in a class often separate into various groups for a greater part of the day, and they have been excluded from the second, community, analysis.

The results for children aged less than five who stayed at home and who were swabbed at clinics have been analysed separately from those who attended schools or day-nurseries.

Certain 'community units' had high carrier rates, and in them a single type of streptococcus was usually predominant. This seemed to suggest that a single strain was spreading at the time of swabbing, or had recently spread, and that the unit was suffering from what may be called a 'carrier epidemic'. In this study a unit was considered to be suffering from a 'carrier epidemic' when the carrier rate for any one type within it significantly exceeded the overall carrier rate for that type among all the children in the survey.

Throughout the analysis standard statistical methods were used. A difference is considered 'significant' when the probability of its occurring by chance was less than one in twenty, and 'highly significant' when it was less than one in a hundred.

Some of the factors which were examined for their effect on the carrier rate were related, and this was allowed for in the analysis by adjusting the rates to those of one 'standard population' which was basically the same for all the analyses. The standard population comprised the 1894 children for whom all the necessary information was available. The factors taken into account in standardizing differed with the particular factor under study. For example, when the effect of tonsillectomy was being examined, the carrier rates were adjusted for borough (or geographical area), sex, and age-distribution, because the tonsillectomy rate varied with age and the incidence of tonsillectomy was different in each borough and for each sex. The standardized rates for children with and without tonsils, given in Table 2, are therefore the rates that children with and without tonsils would have experienced if the two groups had had the same proportion in the two sexes, in the various age groups and in the three boroughs, as were present in the standard population.

Since it is not legitimate to compute standardized rates when some of the ultimate cells of classification contain zero entries, we could not standardize, for example, both tonsil state and age together because none of the children aged less than 3 had had their tonsils removed. In some cases, therefore, the comparison has had to be based only on those children whose tonsils were still present, or on some other subgroup of the standard population.

A method for determining the significance of differences between these standardized rates was kindly provided by Dr P. Armitage of the M.R.C. Statistical Research Unit, and is reproduced as an appendix.

Composition of the population sample

The parents' response to the questionnaire varied widely, being generally best in social class C among the infants and in social class A among the older children. An average of 69 % of the children present in the class on the day of the visit were swabbed.

Nose and throat swabs were collected from 2413 children, 1173 boys and 1240 girls; 811 were from borough E, 806 from S, and 796 from W. There were 2150 'community children' who attended school or day-nurseries and for 1894 of these all data about housing, family size, etc., were known.

The children came from eighty-eight 'community units' of which twenty-two were in day-nurseries and sixty-six in schools. The average number on the roll for each unit was eight for babies, sixteen for tweenies, twenty-eight for toddlers and thirty-five for the school units.

The children were fairly evenly distributed over the ages and social classes, except that social classes A and B were poorly represented in the community group aged under 5 years, as no private kindergartens were included in the survey; there were no girls aged 5–15 swabbed from social class A or B in borough W. It may be noted that neither the highest nor the lowest levels of social class in London were represented in the survey.

The 'home' 0–4 age group differed from the 'community' 0–4 age group in having a disproportionately large number of babies.

Children aged less than 5 had, naturally, rarely had their tonsils removed; the tonsillectomy rate rose to a maximum of 37·5 % in those aged 11–15. Children in social classes A and B had had their tonsils removed at an earlier age than those in social class C, but the rate in the 11–15 age group was similar in all social classes. Enlarged tonsils were most frequently observed in social class C. The tonsillectomy rate was higher in boys than in girls.

RESULTS

Distribution of rheumatic fever

We were not able to demonstrate a significant difference in the incidence of rheumatic fever in the different social classes from the histories supplied by the parents. Histories relating to rheumatic fever were obtained from 1793 of the 1810 school children swabbed; histories were not obtained from the children (605) swabbed in day-nurseries or clinics or from seventeen school children. Histories of rheumatic fever were obtained from only thirteen (0·73 %) of the school children. Three (0·73 %) of those aged 5 and 6, one (0·14 %) of those aged 7–10, and nine (1·41 %) of those aged 11–15 had been affected. In school social classes A, B and C the rates were 0·38, 0·92 and 0·83 % respectively; these differences are not significant. From the histories of rheumatic fever in the children's siblings there was no suggestion that rheumatic fever had a higher incidence among the poorer families, the rates in the social classes being: A (855 children) 0·82 %, B (1194) 1·42 %, and C (1339) 1·05 %.

Distribution of carriers of Streptococcus pyogenes

Of the 2413 children, 100 (4·2 %) were nasal carriers, and 496 (20·6 %) were throat carriers of *Str. pyogenes.*

Very much lower carrier rates were found in young children at home than in those of the same age who were attending schools or day-nurseries (Table 1); when the former were excluded the rates for the 2150 'community' children were 4·6 and 22·7 % respectively.

Table 1. *Nose and throat carrier rates in young children at home and in nurseries*

	Percentage carrier rates in children of					
	'Home' group			'Community' group		
Age	No. of children	Nose	Throat	No. of children	Nose	Throat
Less than 1 year	166	0·6	1·8	19	10·5	10·5
1 and 2 years	62	1·6	4·8	122	6·6	23·0
3 and 4 years	35	0	9·1	201	14·4	33·8

Factors affecting the carrier state in individual children

The carrier rates for different subgroups of the population are shown in Table 2, which is based on the results from the 1894 'community' children for whom all the necessary information was available (see p. 169). Unstandardized carrier rates are presented for comparison, but for reasons already stated discussion will be largely confined to the standardized rates.

Tonsils. The most striking difference was the significantly higher throat carrier rate for children with tonsils present (28·0 %) than for those without tonsils (7·9 %); this difference could not be accounted for by differences in borough, age, or sex distribution. Inclusion of social class, based on school or housing standard, in the standardization, did not alter the effect of tonsil state on carrier rate; the rates for children with tonsils became 31·0 and 27·3 % respectively and for those without tonsils 9·7 and 8·3 %.

Nose carrier rates were also significantly higher in children who had tonsils (3·8 %) than in those whose tonsils had been removed (1·6 %).

The throat carrier rate was higher in children with enlarged tonsils than in those whose tonsils were present but normal in size. Enlarged tonsils were not common

Table 2. *Percentage nose and throat carrier rates of children classified by borough, age, tonsils, etc.*

	Unstandardized carrier rates			Standardized carrier rates: Nose			Standardized carrier rates: Throat		
	No. of children	Nose	Throat	No. of children and basis of standardization†	Rate	P*	No. of children and basis of standardization	Rate	P
Tonsils Present	1398	5·2	28·3	1641	3·8	0·05–0·02	1641	28·0	< 0·001
Absent	496	1·8	8·1	$YZ; y$	1·6		$XYZ; y$	7·9	
Tonsil size +	516	3·7	22·3		4·7			23·3	
++	589	4·9	32·3	1398	4·7	> 0·1	1295	32·5	0·01–0·001
+++	293	8·2	30·7	$TYZ; t$	6·8		$XYZ; t(y)$	32·3	
Age < 3 years	103	6·8	20·4		4·8			18·6	
3 and 4 years	150	14·7	36·7		12·4			33·2	
5 and 6 years	393	4·3	25·4	1398	5·0	< 0·001	1398	28·3	> 0·1
7–10 years	669	3·0	19·3	$TXZ; t$	3·5		$TXZ; t$	26·5	
11–15 years	579	2·6	22·6		3·3			30·1	
Sex Male	920	3·9	25·5	1398	4·6	> 0·1	1894	25·6	0·01–0·001
Female	974	4·6	20·6	$TYZ; t$	5·8		TZ	20·5	
Borough E	645	4·2	27·6		4·8			33·6	
S	622	2·9	18·2	1398	2·8	0·05–0·02	1398	21·6	< 0·001
W	627	5·7	23·0	$TXY; t$	6·7		$TXY; t$	27·7	
Family size 1	517	5·2	22·0		3·3			17·5	
2	705	3·6	20·7	1151	3·6	> 0·1	1151	20·8	≃0·05
3	393	4·6	27·2	$TYZ; ty$	4·4		$TXZ; y$	25·7	
> 3	279	3·9	24·4		4·0			22·5	
School-age siblings	983	4·5	24·2	1398	5·0	> 0·1	1894	24·0	> 0·1
No school-age siblings	911	4·1	21·6	$TYZ; t$	4·3		TXZ	21·9	
History of measles	1515	4·3	22·8	933	7·5	0·05–0·02	933	30·8	> 0·1
No history of measles	379	4·2	23·5	$TXYZ; t((y))$	2·7		$TXYZ; t((y))$	26·5	
History of chickenpox	984	3·6	20·9	933	7·9	> 0·1	933	30·3	> 0·1
No history of chickenpox	910	5·1	25·2	$TXYZ; t((y))$	5·2		$TXYZ; t((y))$	29·4	

† The factors taken into account in standardization are indicated as follows: T = tonsils, X = sex, Y = age, Z = borough. Where it has been necessary to use restricted subgroups of the population (p. 169) these are indicated as follows: t = children with tonsils present, x = males, y = school-aged (5–15 yr.) children, (y) = aged 3–15 years, $((y))$ = aged 3–10 years; where none of these symbols is given the rate is based on all 1894 children. Thus the symbol $TYZ; t$ means that the data are standardized for tonsils, age and borough and are based on the children with tonsils present.

* P gives the probability that differences between the standardized rates at least as extreme as those observed, would have arisen purely by chance if this factor had no real effect on the carrier rate.

among the children aged 11–15 but it was in this group that the association between tonsil size and carrier state was most marked. Nasal carriers were not significantly more common among children with enlarged tonsils.

Age. On the crude rates, children aged 3 and 4 were much more commonly carriers than those in other age groups. The decrease in the throat carrier rate at ages over 4 seemed to be associated largely with the greater number of the older children whose tonsils had been removed, since the variation practically disappeared on standardizing for tonsil state. This was not so for the nasal carrier rate, which remained high in the 3- and 4-year-old children even after standardizing for borough, tonsils, and sex. The sharp rise in carrier rate in the 3- and 4-year-old children compared with younger children was still very marked in the standardized figures.

Sex. Boys yielded *Str. pyogenes* from throat swabs more often than girls, but there was no significant difference between the number with nasal carriage.

Borough. Children in the three boroughs had significantly different nose and throat carrier rates, evident in the crude rates and emphasized after standardization for age, sex, and tonsillectomy. The nose and throat carrier rates in borough S were considerably lower than in either of the others, even though boroughs E and S are adjacent.

Family size and structure. There was a suggestion that throat, but not nose, carriers were more common among the children from large families than among those from small. Children with school-age siblings were not significantly more often infected than those from families without other school children.

Previous infectious diseases. Although both the nose and throat carrier rates were higher in children who had had measles than in those who had escaped, only the difference in nasal carrier rates reached a significant level. However, since few of the children in the youngest age group had had measles, and very few of the oldest children had escaped, big differences in carrier rates were necessary for significance.

Little difference was found between the carrier rates in children who had, or had not had, chickenpox.

Social class. The crude carrier rates suggested that decrease in social class, on either school or housing assessment, was associated with an increasing nose and throat carrier rate. However, after allowance had been made for differences in the borough, sex, and age of the children, there were no differences in carrier rates between the social classes as judged by the school grading. The increased throat carrier rate associated with poorer housing conditions was still evident, but disappeared when tonsil state was included in the standardization (Table 3).

Carrier rates in 'home' group

The nose and throat carrier rates (0·8 and 3·0 % respectively) were too low in the 'home' group of children for us to calculate reliable standardized rates. From the crude rates it appears that the effects of social class, (measured by housing standard), family size and the possession of school-age siblings are worth further investigation (Table 4).

Table 3. *Effect of standardization on throat carrier rates in the different social classes*

	Unstandardized carrier rates				Standardized carrier rates, children aged 5–15. Throat carrier rates standardized by	
	All children		Children aged 5–15			
	No. of children	Throat carrier rate	No. of children	Throat carrier rate	Borough, sex	Borough, sex, tonsils
School social class A	469	19·4	462	19·4	23·7*	24·7
B	625	20·2	618	19·9	22·7*	22·7
C	800	27·2	561	26·0	24·3*	23·0
Housing social class *a*	613	19·9	587	19·8	17·2	18·2
b	875	22·4	748	22·4	21·7	21·6
c	406	28·8	306	24·8	20·4	19·0

* The standardized rates in school social classes A, B and C have been computed only for males as no females were swabbed in school social class C in borough W.

Table 4. *Unstandardized carrier rates for 'home children'*

	No. of children	Percentage carrier rate: Nose	Throat
Total 'home group'	263	0·8	3·0
Borough E	104	0	1·9
S	75	1·3	2·7
W	84	1·2	4·7
Sex Male	132	1·5	4·5
Female	131	0	1·5
Age <1 year	166	0·6	1·8
1 and 2 years	62	1·6	4·8
3 and 4 years	35	0	5·7
Housing social class *a*	95*	0	2·1
b	100*	1·0	4·0
c	45*	2·2	4·4
Family size 1	136	0	0·7
2	86	1·2	3·5
3	32	0	6·3
>3	9	(11·1)	(22·2)
No school-age siblings	197	0·5	1·0
School-age siblings	66	1·5	9·1

* Twenty-three not known.

Factors affecting carrier rates in 'community units'

The mean of the nasal carrier rates for the eighty-eight community units (see p. 168) was 5·9 %; forty-eight units had no nasal carrier and the maximum rate was 42·0 %. The mean of the throat carrier rates was 22·9 %, and the range from 0 to 75·0 % (Table 5).

Twenty of the units were suffering from 'carrier epidemics' as defined on p. 168; these units had mean nose and throat carrier rates of 13·7 and 45·7 %. The mean number of children infected with the epidemic type was 33 %. Although two of these units had a history of recent cases of scarlet fever, fifteen with high carrier rates had no such history, information not being obtained for the remaining three. Units where the nasal carrier rate was greater than 10 % or the throat rate greater than 40 % almost always had a sufficient prevalence of one type to be classed as having 'carrier epidemics' by our convention.

Table 5. *Distribution of carrier rates in 'community units'*

	No. of units	No. of units with carrier rate (%) 0	1–	11–	21–	31–	41–	51–	61–	71–80	Mean carrier rate
Nose. All units	88	48	28	5	2	4	1	0	0	0	5·9
'Epidemic units'	20	3	8	4	2	2	1	0	0	0	13·7
'Non-epidemic units'	68	45	20	1	0	2	0	0	0	0	3·2
Throat. All units	88	11	17	18	12	15	9	3	1	2	22·9
'Epidemic units'	20	0	0	0	2	5	7	3	1	2	45·7
'Non-epidemic units'	68	11	17	18	10	10	2	0	0	0	16·1

Table 6. *Carrier rates in 'community units'*

		No. of units	Mean of percentage carrier rates: Nose	Throat
Age group	Babies	5	(0)	(5·0)
	Tweenies	5	(2·9)	(16·8)
	Babies and Tweenies	3	(22·2)	(38·7)
	Toddlers	9	(15·2)	(35·4)
	Infants	31	5·5	25·2
	Juniors	35	3·0	19·8
School social class	A*	28	4·5	21·3
	B	20	1·8	21·3
	C	18	6·0	24·6
Borough	E*	23	3·2	25·3
	S	29	4·7	20·9
	W	14	4·7	20·0
Mean tonsillectomy rate (%)	0–15*	17	6·8	32·6
	16–30	26	3·2	23·6
	31 and over	23	3·2	13·3
Crowding (sq. ft. per person)	5–10*	11†	1·9	20·5
	11–15	20	5·4	24·5
	16 and over	25	4·2	21·8

* Infant and junior departments only.
† Information not known for 10 units.
( ) Based on less than 10 units.

The number of units was too small for differences in carrier rates associated with age, density, etc., to be statistically significant but some of the results were suggestive (Table 6).

As was to be expected, the units with the higher tonsillectomy rates had the lower throat carrier rates. High carrier rates were very frequent in the 'toddler' units in the day-nurseries; carrier epidemics were found in five of the nine units studied and only three had throat carrier rates of less than 20 %. The younger 'tweenie' groups were less often heavily infected and the 'babies' still more rarely.

DISCUSSION

Although numerous surveys for carriage of *Str. pyogenes* in healthy children have been reported in the literature, we have not found any sufficiently comprehensive to make it possible to examine the relative importance of various factors such as age, social class and tonsillectomy.

Our survey was, we thought, comprehensive, but it suffered from two defects which should be considered, although we do not believe that they had a material effect on the results. First, the response to our invitation to the parents was much less satisfactory than we hoped. From examination of letters containing refusals, and from discussion with the teachers, we could not recognize any particular group that was unco-operative and we do not think that our sample was seriously open to bias. A personal approach to the parents would doubtless have reduced the number of refusals to a very low level, as it did in the clinics, but it would have been impracticable in a survey covering as big an area as we wished.

Secondly, we recognize that our assessments of social class were at best very rough, but we think that, certainly in any one borough, they represent a real trend in the standards and amenities of living. There was a highly significant correlation between school social class grading and housing standard, and between social class measured by parents' occupation and housing standard.

Our survey revealed a number of clear associations of streptococcal carriage, particularly with sex, age and tonsil state. We do not consider that these associations are likely to have arisen merely as a result of variation in the ease of swabbing: girls did not seem to be less co-operative than boys, nor were children 3–4 years old the easiest age group. The effect of tonsillectomy also seems unlikely to be due merely to efficiency of swabbing, and the fact that the tonsillectomized children had the lower nasal carrier rates seems to support the idea that these children in fact carried streptococci less often than those with their tonsils present.

It is far more difficult to judge how far all the associations that we have demonstrated reflect direct causation, and in particular how far the lower carrier rate in children with no tonsils results from the operation of tonsillectomy. So far as tonsil size is concerned, it might well be that the streptococcal infection produces the tonsillar enlargement observed to be associated with it. But it seems unlikely that all the difference between children with tonsils removed and those retaining their tonsils could be attributed to proliferation of tonsillar remnants in the carriers, even though such proliferation may have occurred in a few children and led to their transfer out of the tonsillectomized group.

However, even if it is admitted that children with tonsils present become carriers more often than those without, it might be held that both carrier and tonsil state reflected some correlated variable, such as the increased crowding associated with decrease in social class. It was the case that carriers were more common in the lowest social class than in the higher, but this was almost entirely due to the differences in the age, sex and borough (geographical) distribution of the population sampled in the three social classes. What little difference remained between the social classes after allowance for these three factors could be removed by adjusting for the tonsil state of the children in each social class. In fact, no residual 'social class factor' could be demonstrated. On the other hand, no allowance for age, borough, sex or social class affected the difference in carrier rate associated with tonsillectomy. We can reasonably conclude therefore that the relation between carrier state and tonsil state is a real one, rather than one secondary to some factor associated with social class.

Apart from the effect of tonsillectomy, a notable finding was the high nasal carrier rate for children aged 3 and 4 years. This seems to have been associated with the frequency with which the day-nurseries, where these children were swabbed, were suffering from carrier epidemics or, in one case, had recently suffered from an outbreak of scarlet fever. In such circumstances high nasal carrier rates were common. The figures suggest that extensive spread occurs frequently among 3- to 4-year-old children in communities.

From the results of a single swabbing it is impossible to tell whether the groups of children with higher carrier rates have such high rates because they become infected more often, or because they carry streptococci for a longer period when once infected. We are at present studying this problem elsewhere, but it may be noted that, even in school classes which were suffering from 'carrier epidemics' and in which it is reasonable to assume that the spread of the infection was probably recent, the children without tonsils were carriers less often than those with. This suggests that children with tonsils acquire the infection more readily than others.

The precise relation between rheumatic fever and streptococcal infection is unknown, so that we cannot tell whether the carrier rate in health is in fact a real measure of a rheumatic fever risk, but it is certain that rheumatic fever can follow some subclinical infections. Nor is it possible, on the present evidence, to judge whether an increased tendency to be a streptococcal carrier, as shown by children with their tonsils present, is correlated with a tendency to develop streptococcal sore throat or other illness. This problem is also being studied elsewhere.

There appeared to be real differences in the carrier rates, particularly throat, between children in the three boroughs studied. There was no undue incidence of any particular type of *Str. pyogenes* to explain the higher rates in two of the boroughs. Although significant differences were not found, the carrier rates tended to be higher in the larger families.

We have stressed the use of standardized carrier rates in studying particular factors because only by this means can the effect of one factor be separated. For example, when the effect of age is to be studied we need to ensure that the populations at various ages are both representative of their age group and similar in all other material respects. Standardization is necessary to obtain a true measure of the effect of age when the different age groups may contain different proportions of children from boroughs with varying carrier rates. Standardization further indicates, in this example, that the differences in throat carrier rates between the age groups can be attributed largely to differences in tonsillectomy rate. However, since older children have had their tonsils removed more often than the younger, it is still a fact that older children carry streptococci less often than the younger.

Our findings thus confirm the Melbourne experience (Holmes & Rubbo, 1953) in showing that the increase in streptococcal carrier rate with lowering social class, which was revealed by the crude carrier rates, could be accounted for largely by correlated factors. We were unable to demonstrate any social class differences in a history of rheumatic fever in the children in our survey, but since factors revealed as affecting the carrier rate are unlikely to have changed, it seems reasonable to conclude that the streptococcal carrier rate is higher in those groups among which rheumatic fever has been found most prevalent in the past. It may also be noted that, apart from children attending day-nurseries, streptococcal carriage is first common at the age of entry to school—and rheumatic fever has been frequently noted as a disease which spares the younger, pre-school, children.

SUMMARY

Nose and throat swabs were collected from 2413 healthy children aged 2 weeks to 14 years and examined for *Streptococcus pyogenes*. The children came from different social levels in three boroughs in Middlesex.

Standardized carrier rates were used to compare the individual effects of age, borough, family age, family size, sex, social class and tonsils on the nose and throat carrier rates.

Community life appeared to facilitate the spread of streptococcal infection: young children aged less than 5 who attended nurseries had higher carrier rates than those of the same age who did not attend day-nurseries. The highest nasal carrier rates were found in the 3- and 4-year-old children attending the day-nurseries. The degree of crowding within the community units did not appear to affect the rates.

The three boroughs had significantly different carrier rates.

Boys were more often carriers than girls.

The unstandardized carrier rates were highest in the lowest social class but this could be explained by the differences in the age, sex and borough distribution of the children sampled in the three social classes, and by the fact that tonsillectomy was, on the average, undertaken later in the lower social classes than in the higher. When these factors were allowed for by standardization, there was no residual difference which could be attributed to social class or housing.

Children with tonsils were more often nose and throat carriers than children who had had their tonsils removed; this was true for all ages, for each of the three boroughs and in each social class.

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APPENDIX

Standardized carrier rates

Nose and throat carrier rates were standardized for population differences from a table of the following form:

Age 5–6		Tonsils	No tonsils	Standard population group	Pooled carrier rate
Borough A	Male	n_1p_1	$n_1'p_1'$	N_1	P_1
	Female	n_2p_2	$n_2'p_2'$	N_2	P_2
Borough B	Male	—	—	—	—
	Female	—	—	—	—
Borough C	Male	—	—	—	—
	Female	—	—	—	—
Age 7–10		—	—	—	—
Age 11–15		—	—	—	—

n = the number of children in the individual cell.
p = the carrier rate for the individual cell.
N = the number of children in the standard population group, i.e. the number with tonsils plus the number without tonsils.
P = the carrier rate in the standard population group, i.e. the rate on N.
$\mathbf{N}$ = the total standard population in all age, borough and sex groups.

The carrier rate for children with tonsils, standardized for differences due to age, borough and sex is given by the formula

$$R = \frac{N_1p_1 + N_2p_2 + \ldots + N_rp_r}{\mathbf{N}}.$$

This rate has a standard error S.E. (R), and a weight w:

$$[\text{S.E. } (R)]^2 = \frac{\dfrac{N_1^2P_1Q_1}{n_1} + \dfrac{N_2^2P_2Q_2}{n_2} + \ldots + \dfrac{N_r^2P_rQ_r}{n_r}}{\mathbf{N}^2},$$

$$w = \frac{1}{[\text{S.E. } (R)]^2}$$

For testing the significance of differences between rates

$$\chi^2 = \Sigma wR^2 - \frac{(\Sigma wR)^2}{\Sigma w}$$

on $k-1$ degrees of freedom, where k = the number of standardized rates being compared.

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