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Analysis of the dermatophyte species isolated in the British Isles between 1980 and 2005 and review of worldwide dermatophyte trends over the last three decades

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Infections of the skin, hair and nails by dermatophyte fungi are common in developed and developing countries alike. However, the species involved and the resulting clinical entities vary both geographically and with time. We have surveyed 15,333 dermatophytes obtained from primary isolations at the Mycology Reference Laboratory, Bristol, UK from 1980 through 2005. Several striking trends in dermatophyte prevalence were apparent over this period. The relative frequencies of isolations of *Microsporum canis* (cat and dog ringworm), *Trichophyton verrucosum* (cattle ringworm), *T. mentagrophytes var. mentagrophytes* (rodent ringworm) and *Epidermophyton floccosum* (a cause of human groin and foot infections) all decreased by 90%. Conversely, the contributions of *T. tonsurans* and *T. violaceum* (two anthropophilic scalp-infecting species) to total dermatophyte isolations increased by 1000% over the same period. Finally, *T. rubrum* and *T. mentagrophytes var. interdigitale*, the two common causes of foot infection comprised 80% of all dermatophytes isolated in 1980 and 90% of isolations in 2005. Similar trends in dermatophyte prevalence were evidenced throughout the British Isles, based on the voluntary reporting of isolations from a large number of British laboratories at 5-yearly intervals over the same period. The implications of these changing patterns of dermatophyte species, and the clinical entities they produce are discussed in the context of a review of worldwide dermatophyte isolations over the last three decades, with emphasis on the causal agents of tinea capitis.

Keywords dermatophyte prevalence, anthropophilic, tinea capitis, British Isles, dermatophytosis

Introduction

The dermatophyte fungi comprise about 30 species of keratinophilic moulds causing infections of the skin, nail, and hair of mammals and feathers of birds. The resulting infections, termed dermatophytosis or ringworm, range from mild erythematous rashes on the skin to severe kerion- type lesions with pus formation in micro-abscesses. Athlete's foot, nail dystrophy and scalp ringworm are particular manifestations of human dermatophytosis. Some infections are zoonotic, caused by the so-called zoophilic dermatophyte species that spread from animal hosts. Others are caused by anthropophilic species, which have apparently evolved on humans and are not normally seen in animals. A third group, the geophilic dermatophytes, are soil-dwelling organisms that rarely cause human disease, but can occasionally be contracted direct from soil or via animal infections.

The incidence of specific dermatophyte species in a particular location varies with time, due to factors

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including varying hygiene levels, population movements, the introduction of new therapeutic measures and even war. The many studies on the prevalence of dermatophytes worldwide have been reviewed by Philpott [1], Rippon [2] and more recently by Aly [3]. In the UK 100 years ago, as in many parts of Western Europe, scalp ringworm (tinea capitis) was the principal dermatophytosis, and over 90% of scalp infections were due to *Microsporum audouinii*, with smaller numbers of *T. tonsurans* [4]. Both are anthropophilic species most frequently seen in hair invasion. However, by the late 1960s, the anthropophilic species causing athlete's foot (*T. rubrum* and *T. interdigitale*) were solidly established, and tinea capitis had become a relatively rare infection, predominantly caused by the zoophilic species *M. canis* and to a lesser extent *T. verrucosum* [5,6].

Here we present a detailed analysis of the frequencies of isolation of various dermatophytes for the years 1985 through 2005 from the UK Mycology Reference Laboratory (MRL) catchment area, which covers a substantial region of the southwest of the UK. All the significant trends observed in this local analysis were also evident in voluntary reports of dermatophyte prevalence submitted to the MRL at 5-yearly intervals from laboratories across the whole of the United Kingdom. We discuss these trends and attempt to integrate them into the changing worldwide patterns of dermatophytosis over the last 30 years.

Materials and methods

Yearly analysis of dermatophyte isolations at the Bristol Regional Mycology Laboratory (which became the National Mycology Reference Laboratory from 1992)

Figures for the numbers of isolations of dermatophytes were collected each calendar year from 1980 to 2005. Numbers of isolations included only primary isolates obtained at the Mycology Reference Laboratory (MRL) from dermatology specimens during its routine diagnostic activity of suspected dermatophytosis cases in the MRL catchment area. We estimate that greater than 80% of specimens were submitted from primary care sources. The MRL catchment area has been enlarged by the inclusion of several adjacent NHS areas over the study period (notably in 1997). However, these changes have impacted only on the total number of isolations, and have not significantly influenced the frequencies or spectrum of dermatophytes isolated (see Table 1 and Results). In 2005, the MRL catchment area included North Somerset, West Wiltshire and South Gloucestershire. To avoid bias towards unusual dermatophyte species, all isolates sent to the MRL as cultures for identification as part of its reference activities were excluded from the analysis.

Samples of skin, hair, or nail fragments collected from patients with suspected dermatomycosis were examined both directly after digestion in 20% KOH, and after culture on Sabouraud media (glucose-peptone agar containing 0.05 mg per ml of chloramphenicol) with and without actidione. Fungal growth was examined after 1 and 2 weeks incubation at 30°C. Identification was based on macroscopic and microscopic morphology of resulting colonies according to the guidelines used by the MRL in its publications [7]. The involvement of a non-dermatophyte in onychomycosis was only judged clinically significant in the presence of positive direct microscopy and isolation of the non-dermatophyte mould in pure culture from a significant proportion of the clinical sample. The taxonomic nomenclature adopted throughout this study is that recommended by the MRL in its publications [7]; (see Table 1).

Five-year voluntary reporting of dermatophyte isolations across the UK and the Republic of Ireland

Figures of numbers of isolations were solicited by the National MRL on a voluntary basis from any hospital pathology laboratory in the UK or Republic of Ireland (see Acknowledgments for participating laboratories). Only records of true dermatophyte species (members of the genera *Trichophyton, Microsporum* and *Epidermophyton*) were collated. The number of laboratories participating in the five quinquennial surveys was 25 (1980), 55 (1985), 61 (1990), 76 (1995) and 70 (2000). Some laboratories presented data to each of the surveys, whilst others participated less often. Similarly, several laboratories moved sites over the intervening years, merged, or changed catchment areas or referral policies. The identifications of fungal taxa submitted by the participating laboratories were taken at face value, but it proved necessary to combine some names to unify nomenclature. Given the degree of confusion surrounding the taxonomically complex *Trichophyton mentagrophytes* group in some laboratories, all reports of *T. mentagrophytes, T mentagrophytes* variety *interdigitale* and *T. interdigitale* were combined under the umbrella *T. interdigitale* for analysis of this data (see Table 2). Unfortunately, reports of the occurrence of *T. interdigitale* in tinea pedis are thus combined with *T. mentagrophytes* in animal-derived infections. However, from our own MRL data we know that the numbers of infections due to *T. mentagrophytes var. mentagrophytes* are so small that this should not have a significant impact on the overall trends.

Table 1 Dermatophytes isolated at the MRL from 1985 through 2005, expressed as total numbers of isolations (upper panel) or as percentage of total isolations (lower panel). Significant trends are highlighted in italics (declining relative incidence) or in bold text (increasing relative incidence). T.rubr., *T. rubrum*; T.int, *T. interdigitale*; T.tons, *T. tonsurans*; T.erin, *T. erinacei*; T.soud, *T. soudanense;* M.aud, *M. audouinii*; T.verr, *T. verrucosum*; T.equi, *T. equinum*; M.gyps, *M. gypseum*; M.pers, *M. persicolor* E.flocc, *E. floccosum*; T.ment, *T. mentagrophytes;* T.viol, *T.violaceum*.

Year	T.rubr	T.int	T.tons	T.viol	T.erin	T.soud	M.aud	T.verr	T.equi	M.canis	M.gyps	M.pers	E.flocc	T.ment	Total
1985	343	78	0	0	1	0	0	13	1	24	0	0	50	6	516
1986	288	63	0	1	0	4	0	21	0	20	0	0	41	6	444
1987	318	76	1	0	0	0	0	13	0	28	0	0	30	6	472
1988	297	88	0	1	1	0	0	13	0	9	1	0	15	10	435
1989	318	85	1	1	3	0	0	6	0	11	1	0	11	5	442
1990	309	51	0	0	0	2	0	6	0	16	0	0	7	3	394
1991	288	73	0	0	0	0	0	3	0	2	1	0	8	2	377
1992	334	59	11	0	0	0	0	3	1	14	0	0	12	13	447
1993	288	68	14	0	0	0	0	7	0	14	0	0	12	2	405
1994	314	78	29	1	0	0	0	3	0	6	1	0	9	2	443
1995	276	87	20	2	1	0	0	1	0	5	0	0	7	1	400
1996	272	84	34	1	2	0	0	0	0	11	1	1	8	0	414
1997	594	178	61	5	0	0	0	5	0	8	0	4	9	9	873
1998	606	188	72	5	3	0	0	4	0	12	0	0	9	4	903
1999	619	193	78	2	3	2	1	4	1	10	2	0	14	6	935
2000	706	218	37	4	2	1	0	2	0	4	0	0	10	3	987
2001	690	231	46	1	3	2	0	3	0	9	0	0	7	1	993
2002	686	320	54	5	2	0	2	1	0	9	0	0	5	5	1089
2003	907	384	72	19	1	6	2	5	0	6	0	4	5	5	1416
2004	995	347	67	9	2	2	0	6	0	2	2	0	6	4	1442
2005	1058	316	68	25	0	6	0	4	0	9	1	1	16	2	1506
Total	10506	3265	665	82	24	25	5	123	3	229	10	10	291	95	15333

Year	T.rubr	T.int	T.tons	T.viol	T.erin	T.soud	M.aud	T.verr	T.equi	M.canis	M.gyps	M.pers	E.flocc	T.ment
1985	66.47	15.12	0.00	0.00	0.19	0.00	0.00	*2.52*	0.19	*4.65*	0.00	0.00	*9.69*	*1.16*
1986	64.86	14.19	0.00	0.23	0.00	0.90	0.00	*4.73*	0.00	*4.50*	0.00	0.00	*9.23*	*1.35*
1987	67.37	16.10	0.21	0.00	0.00	0.00	0.00	*2.75*	0.00	*5.93*	0.00	0.00	*6.36*	*1.27*
1988	68.28	20.23	0.00	0.23	0.23	0.00	0.00	*2.99*	0.00	*2.07*	0.23	0.00	*3.45*	*2.30*
1989	71.95	19.23	0.23	0.23	0.68	0.00	0.00	*1.36*	0.00	*2.49*	0.23	0.00	*2.49*	*1.13*
1990	78.43	12.94	0.00	0.00	0.00	0.51	0.00	*1.52*	0.00	*4.06*	0.00	0.00	*1.78*	*0.76*
1991	76.39	19.36	0.00	0.00	0.00	0.00	0.00	*0.80*	0.00	*0.53*	0.27	0.00	*2.12*	*0.53*
1992	74.72	13.20	**2.46**	0.00	0.00	0.00	0.00	*0.67*	0.22	*3.13*	0.00	0.00	*2.68*	*2.91*
1993	71.11	16.79	**3.46**	0.00	0.00	0.00	0.00	*1.73*	0.00	*3.46*	0.00	0.00	*2.96*	0.49
1994	70.88	17.61	**6.55**	0.23	0.00	0.00	0.00	*0.68*	0.00	*1.35*	0.23	0.00	*2.03*	0.45
1995	69.00	21.75	**5.00**	0.50	0.25	0.00	0.00	0.25	0.00	*1.25*	0.00	0.00	*1.75*	0.25
1996	65.70	20.29	**8.21**	0.24	0.48	0.00	0.00	0.00	0.00	*2.66*	0.24	0.24	*1.93*	0.00
1997	68.04	20.39	**6.99**	**0.57**	0.00	0.00	0.00	0.57	0.00	*0.92*	0.00	0.46	1.03	1.03
1998	67.11	20.82	**7.97**	**0.55**	0.33	0.00	0.00	0.44	0.00	*1.33*	0.00	0.00	1.00	0.44
1999	66.20	20.64	**8.34**	**0.21**	0.32	0.21	0.11	0.43	0.11	1.07	0.21	0.00	1.50	0.64
2000	71.53	22.09	**3.75**	**0.41**	0.20	0.10	0.00	0.20	0.00	0.41	0.00	0.00	1.01	0.30
2001	69.49	23.26	**4.63**	**0.10**	0.30	0.20	0.00	0.30	0.00	0.91	0.00	0.00	0.70	0.10
2002	62.99	29.38	**4.96**	**0.46**	0.18	0.00	0.18	0.09	0.00	0.83	0.00	0.00	0.46	0.46
2003	64.05	27.12	**5.08**	**1.34**	0.07	0.42	0.14	0.35	0.00	0.42	0.00	0.28	0.35	0.35
2004	69.00	24.06	**4.65**	**0.62**	0.14	0.14	0.00	0.42	0.00	0.14	0.14	0.00	0.42	0.28
2005	70.25	20.98	**4.52**	**1.66**	0.00	0.40	0.00	0.27	0.00	0.60	0.07	0.07	1.06	0.13

Table 2 Figures for voluntary dermatophyte reports from the UK by 5-year period, expressed as total isolations (upper panel) and percentage of total isolations (lower panel). To unify taxonomic usage, reports of *T. mentagrophytes* and *T. interdigitale* have been grouped under the header *T. interdigitale* (see Materials and Methods). Trends in relative incidence are highlighted in *italics* (declining incidence) or in bold text (increasing incidence). Organisms are abbreviated as in Table 1.

Year	T.rubrum	T.int	T.tons	T.viol	T.erin	T.soud	T.verr	T.equi	M.canis	M.gyps	M.pers	E.flocc	M.aud	Total
1980	3132	918	17	50	14	0	184	0	366	7	5	371	9	5073
1985	2211	996	27	13	2	6	209	2	416	12	5	305	2	4206
1990	4533	1503	73	39	12	23	134	1	384	10	6	162	14	6894
1995	11497	3228	474	64	44	83	138	1	466	11	4	183	57	16250
2000	18726	6007	1227	88	43	89	77	4	332	7	3	168	54	26825

Year	T.rubrum	T.int	T.tons	T.viol	T.erin	T.soud	T.verr	T.equi	M.canis	M.gyps	M.pers	E.flocc	M.aud
1980	61.74	18.10	**0.34**	0.99	0.28	0	*3.63*	0	*7.21*	*0.14*	*0.10*	*7.31*	0.18
1985	52.57	23.68	**0.64**	0.31	0.05	**0.14**	*4.97*	0.05	*9.89*	*0.29*	*0.12*	*7.25*	0.05
1990	65.75	21.80	**1.06**	0.57	0.17	**0.33**	*1.94*	0.01	*5.57*	*0.15*	*0.09*	*2.35*	0.20
1995	70.75	19.86	**2.92**	0.39	0.27	**0.51**	*0.85*	0.01	*2.87*	*0.07*	*0.02*	*1.13*	0.35
2000	69.81	22.39	**4.57**	0.33	0.16	**0.33**	*0.29*	0.01	*1.24*	*0.03*	*0.01*	*0.63*	0.20

Results

Trends in the prevalence of various dermatophyte species isolated at the Bristol Mycology Reference Laboratory, 1985–2005

Between 1985 and 2005 a total of 15,333 dermatophytes were isolated from clinical material submitted to the MRL from patients with suspected dermatophytosis. This corresponded to a mean yearly isolation rate of 432 in the period 1985–1996. This yearly rate increased significantly from 1997 onwards (average 1127 isolates per year), due to substantial increases in the MRL catchment area, rather than any significant changes in the annual rates of positive cultures. In 2004 and 2005, the MRL received 5312 and 5137 dermatology specimens, respectively, of which 2321 (45%) and 2277 (43%) were positive by direct microscopy, 1538 (30%) and 1553 (29%) were positive by culture and 1430 (28%) and 1415 (27%) were positive by both microscopy and culture.

In 1985, in order of decreasing prevalence, *T.rubrum* (66.5%), *T. interdigitale* (15.1%), *E. floccosum* (9.7%), *M. canis* (4.7%), *T. verrucosum* (2.5%) and *T. mentagrophytes* (1.2%) accounted for virtually all cases of dermatophytosis (Table 1). Significantly, by 1995, the relative prevalence of *E. floccosum, M. canis*, *T. verrucosum* and *T. mentagrophytes* had all decreased by five- to ten-fold, with the result that *T. rubrum* and *T. interdigitale* now comprised over 90% of dermatophytes isolated. Towards the end of this same period, *T. tonsurans* (in 1992) and *T. violaceum* (in 1997) were first isolated in significant numbers from clinical samples at the MRL. These two anthropophilic agents of tinea capitis became steadily more prevalent over the last 10 years of this study, to the extent that they were the 3rd and 4th most frequently isolated dermatophytes (after *T.rubrum* and *T. interdigitale*) from 2002 onwards (Table 1). Indeed, by 2003, *T. tonsurans* and *T.violaceum* comprised 86% of isolations from cases of tinea capitis at the MRL. Unfortunately, the numbers of isolations of the other dermatophytes included in this survey (*T. erinacei, T. equinum, T. soudanense, M. persicolor, M. gypseum and M. audouinii*) were all so low that any trends in prevalence over the period were not statistically significant. Finally, it is clear from the data in Table 1 that changes in the MRL catchment area in 1996–97 (notably the inclusion of Bath and its surrounding area) did not impact noticeably on the range or proportions of different dermatophytes isolated.

Voluntary UK-wide reports mirror the changes in dermatophyte frequencies observed at the Bristol MRL

The figures for voluntary dermatophyte reports from the rest of the UK are summarized in Table 2. While some laboratories returned less than 10 isolations, others reported over 1000 organisms each time. The mean number of organisms reported per laboratory was 204 (1980), 77 (1985), 113 (1990), 218 (1995) and 386 (2000). A total of 59,449 dermatophyte isolations were reported during the survey. The overall trends in dermatophyte isolations were remarkably similar to those observed at the MRL over the same period. *T. rubrum* and *T. interdigitale* accounted for 80% or all dermatophytes isolated in 1980, and approximately 90% at the end of the survey period (Table 2). *T. tonsurans*, which represented less than 0.5% of dermatophyte isolations in 1980, increased significantly

in prevalence over the survey period, to nearly 5% of all isolations in 2000 (Table 2; absolute numbers of isolations 17 of 5073 isolations in 1980, 1227 of 26914 isolations in 2000). Indeed, in 2000 *T. tonsurans* comprised 83% of isolations of the causative agents of tinea capitis and was recorded by 63% of the reporting laboratories. Similarly, another agent causing anthropophilic tinea capitis, *T. soudanense,* became significantly more prevalent over the survey period (0 isolations in 1980; 89 in 2000). Conversely, the relative prevalence of anthropophilic *E. floccosum*, geophilic *M. gypseum* and the zoophilic organisms *M. canis*, *T. verrucosum* and *M. persicolor* all decreased between 5- and 10-fold over the same period (Table 2).

Analysis of evolving international patterns of dermatophytosis

Given the significant changes in the patterns of dermatophyte isolations in the UK over the last 30 years, we undertook a literature-based analysis of reports of dermatophyte isolations worldwide for the periods 1970–1990 and 1990–2005 (Table 3). Since it was unfortunately not always possible to retrieve reports by the same authors from the same country for the two periods, reports are grouped by continent, and this analysis is necessarily designed only to detect major epidemiological dermatophyte trends. Moreover, unless specific differentiation was made by the authors of each study, all reported isolates of *T. mentagrophytes* were assumed to be *T. interdigitale*. Nevertheless, several intriguing patterns of dermatophytes isolations are evident from this search.

Dermatophyte reports from Northern Europe (Finland, Switzerland) and most of Australia and Asia in both time periods agree quite well with the patterns of dermatophyte isolations from the UK, in that *T. rubrum* and *T. interdigitale* are the major dermatophytes isolated. Strikingly, in most of Central and Southern Europe (Spain, Italy, Greece, Malta, Poland, Croatia, Slovenia), *M. canis* was and has remained the principal dermatophyte isolated from human infections, with no evident reduction in prevalence over the last 3 decades. This predominance for *M. canis* in dermatophyte isolations is also seen in some, but not all, South American countries including Brazil and Peru, and in parts of the Middle East, principally Saudi Arabia. Conversely, in North America, *T. rubrum* and *T. tonsurans* are the principal agents of dermatophytosis, with recent surveys suggesting that *T. tonsurans* accounts for almost 50% of dermatophytes isolated in the USA (Table 3). In most of the Middle East, and in Africa and India a varied pattern of dermatophyte isolations is evident, with strong geographical associations for certain species. Thus, *T. violaceum* appears the principal agent of human dermatophytosis in Ethiopia, Libya and parts of India, *T. soudanense* predominates in recent surveys in Nigeria, and 5–8 different dermatophyte species are isolated with roughly equivalent frequencies from human infections in Iran and Turkey.

Since one of the principal changes in patterns of dermatophyte isolations detected in the UK is the significant increase in the relative frequency of isolations of the anthropophilic agents of tinea capitis (*T. tonsurans* and *T. violaceum*), we also compiled data on dermatophytes isolated uniquely from cases of scalp infection worldwide over the last 30 years (Table 4). Once again, reports were grouped by continent. In the UK, USA, Jamaica and Brazil, *T. tonsurans* was by far the predominant cause of tinea capitis, and accounted for between 50–90% of dermatophyte scalp infections depending on the country. Conversely, in most of Central and Southern Europe, Puerto-Rico, and Saudi Arabia, *M. canis* was the most frequently isolated agent of scalp ringworm. Exceptions include Greece and Belgium, where *T. violaceum* (Greece), and *T. soudanense, M. audouinii* and to a lesser extent *T. violaceum* (Belgium) have been reported with significantly increased frequencies in recent years. These trends and other less dramatic ones in Italian adults have partly been linked with recent immigration from the Mediterranean and North Africa [8–11].

In the Middle East, Asia, Turkey, Rwanda and the Indian subcontinent *T. violaceum* apparently predominates as the agent of tinea capitis, although *M. canis* was also a significant contributor to total cases in the Middle East and Turkey. *T. soudanense* and *M. audouinii* are the major cause of scalp infections in a recent survey in the Ivory Coast, and *M. audouinii* also appears heavily implicated in tinea capitis in Rwanda. Thus it appears that the different geographical associations of certain dermatophytes with scalp infections are as striking as the differences in overall dermatophyte prevalence noted above.

Discussion

The changing incidence of dermatophytoses and their potential for spreading through population movements in the UK became clear after the two world wars. Children evacuated from large cities were instrumental in spreading *M. audouinii* tinea capitis to rural areas, and troop repatriation to Britain coincided with the large-scale introduction of *Trichophyton rubrum* from the Far East [2,12]. Similarly dramatic changes in dermatophyte flora were recently reported to have

Table 3 Worldwide distribution of dermatophyte species from published surveys, grouped by period and by continent. Predominant dermatophytes in a given region are highlighted in *italics* (greater than 10% of all isolations) or **bold** (greater than 20% of all isolations). Organisms are abbreviated as in Table 1. T.schoen, *T. schoenleinii*; a, *Trichophyton simii*; Switz, Switzerland.

Pre-1990	Northern Europe			Central/Southern Europe						Americas					Middle East		Africa		India	Australasia	
Reference	This Study	This study	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]
Region	SW UK	UK	Finland	Spain	Spain	Italy	Italy	Poland	Turkey	USA	USA	Mexico	Peru	PuertoRico	Iran	S.Arabia	S.Africa	Nigeria	India	Thailand	Australia
Year	1985	1985	82–90	59–86	<1991	85–93	<1981	84–95	1984	79–81	85–87	78–90	<1991	1982	86–91	88–90	80–88	83–86	72–73	<1988	66–82
Isolates	518	4212	3185	3351	158	N	N	1195	N	N	N	2397	N	97	7712	276	N	69	270	719	4353
T.rubrum	**66.5**	**52.5**	**66.0**	**24.6**	***10.7***	**27.0**	***10.3***	***14.7***	**26.0**	**53.7**	**54.8**	**45.0**	9.5	**79.3**	***16.5***		**27.0**	**24.6**	**32.6**	**66.0**	**35.3**
T.interdig	***15.1***	**23.7**	**26.0**	**21.4**	**22.7**	***10.6***	***17.8***	**42.1**	**21.0**	8.6	**6.0**	**23.7**	**35.7**	***10.3***	***14.6***		**23.0**		***17.0***	***15.0***	**26.5**
T.mentag	1.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.0		NA			NA	NA
T.tons.	0.0	0.6		3.9		0.2		4.6		**27.9**	**31.3**	**21.0**			**1.3**				4.8		***12.8***
T.viol	0.0	0.3		1.2		0.6		0.3	5.0		0.1				8.7	*14.5*	***18.0***		**33.7**		
T.verruc	2.5	5.0	1.5	3.1		0.1		1.3			0.2				***11.5***						
T.erin	0.2	0.0																			
T.soudan	0.0	0.1		0.1														***13.0***			
M.canis	4.7	9.9		**25.5**	**36.7**	**50.0**	**31.3**	**26.0**	9.0	3.7	4.0	7.0	**52.4**		***19.4***	**83.3**	***19.0***				8.4
M.gyps	0.0	0.3		5.2		2.3			5.0		0.6						1.0		0.8	6.0	
M.pers	0.0	0.1																			
M.aud	0.0	0.0		0.1						0.3	0.1							1.5			
E.flocc	9.7	7.2	6.0	***11.8***	***18.3***	9.3	**34.2**	***11.0***	***12.0***	4.4	2.0	2.5	2.4	9.3	***14.9***		***12.0***	1.5	6.7	***13.0***	***10.7***
T.schoen									10.0						5.5				0.4		
Others																5.5 a			1.5 a		

1990–2005	Northern Europe			Central/Southern Europe							Americas			Middle East			Africa			India	Australasia			
Reference	This study	This study	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[14]	[46]	[47]	[48]	[49]	[50]	[51]	[52]	[53]	[54]	[55]	[56]	[57]	[58]	[59]
Region	SW UK	UK	Switz.	Spain	Spain	Malta	Greece	Croatia	Turkey	Slovenia	USA	Argentina	Brazil	Lebanon	Iran	Libya	Jordan	Nigeria	Ethiopia	Nepal	Malaysia	Singapore	Japan	Japan
Year	2000	2000	93–02	91–95	96–99	95–99	92–96	96–02	2004	95–02	93–95	1998	92–02	96–02	99-01	97–99	97–98	2003/4	<2005	2000	93–00	90–91	94–99	92–01
Isolates	1031	26914	4193	543	N	371	327	858	86	8286	N	1595	N	208	169	1160	199	65	364	N	N	139	1610	3795
T.rubrum	**71.5**	**69.6**	**62.5**	***18.6***	8.6	**32.6**	**44.4**	**21.5**	**43.0**	**36.7**	**41.3**	**52.7**	**48.7**	5.3	***18.3***	**24.0**	**28.6**		0.5	**45.7**	**53.8**	**58.3**	**57.7**	**79.4**
T.interdig	**22.1**	**22.3**	**24.5**	**31.4**	**27.1**	**21.6**	***14.4***	**24.8**	***19.8***	7.9	8.5	***19.4***	9.7	**24.5**	***17.2***	5.4	**32.7**	***12.3***		**26.6**	**36.1**	***15.1***	**40.4**	***19.5***
T.mentag	0.3	NA	NA	NA	NA	NA	3.4	NA	NA	4.9	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	6.5	NA	NA
T.tons	3.8	4.6		0.7		0.5		3.9		0.2	**44.9**	**8.3**	***13.8***	**54.8**					1.4	*11.7*				
T.viol	0.4	0.3		0.2	4.3	0.25	3.1	0.8	1.1	0.2					***16.6***	**45.0**	1.0		**84.0**	2.1	1.0		0.3	
T.verruc	0.2	0.3				0.5	1.8	4.0	7.0	0.9				4	4.7		2.0		9.6	1.1	0.2			
T.erin	0.2	0.2																						
T.soudan	0.1	0.3				2.7												**70.8**						
M.canis	0.4	1.2	5.0	**44**	**48.6**	**29.4**	**25.0**	**36.5**	***11.8***	**46.8**	3.3	***14.2***	**20.9**	7.7	6.5	*14.1*	***11.1***				3.1	2.9	0.5	0.7
M.gyps	0.0	0		1.4	1.4	7.3	0.3	3.0	9.3	1.3			2.5		4.1		0.5				0.3	0.7	0.6	0.1
M.pers	0.0	0				0.5																		
M.aud				0.2				2.0												8.4	1.1			
E.flocc	1.0	0.6		2.6	10.0	4.6	7.6	0.3	7.0	0.7	1.1		4.1		**31.4**	*11.4*	**20.1**			4.3	0.7	***13.7***	0.5	0.3
T.schoen								1.5									4.0			2.1				
Others																								

Table 4 Survey of the causative agents of tinea capitis worldwide, from published reports. Predominant dermatophytes in a given region are highlighted in *italics* (greater than 10% of all isolations) or **bold** (greater than 20% of all isolations). *Denotes figures for childhood infections only. Organisms are abbreviated as in Tables 1 and 3. M.aud/langer = *M. audounii*/*M. langeronii*.

	Northern Europe				Central/Southern Europe								Americas			Middle East				AFRICA			INDIA		
Reference	This study	This study	[60]	[8]	[18]	[61]	[62]	[9]	[14]	[44]	[63]	[16]	[64]	[65]	[66]	[67]	[68]	[69]	[70]	[72]	[73]	[74]	[75]	[76]	[77]
Region	SW UK	SW UK	Germany	Belgium	Italy	Italy *	Spain	Greece	Slovenia	Croatia	Turkey *	USA	Trinidad	Puerto-Rico	Brazil	S.Arabia	Iraq	Libya	Libya *	IvoryCoast	Rwanda	Nigeria	Pakistan	Pakistan	Nepal
Year	2003	2000	1998	1-Feb	73–94	86–95	77–97	81–95	95–02	96–02	2005	86–93	<1993	79–89	99–02	<1993	94–95	90–00	97–99	98–99	1993	97–98	<1994	<1999	2005
Isolates	30	29	377	122	17	336	190	35	326	268	149	186	N	36	136	237	143		584	217	100	154	180	100	69
T.rubrum	3.3		*14.7*					8.5	2.8	1.9		3.8	1.4	*19.4*	4.4	0.2									5.1
T.mentag	**70.0**	**86.2**	3.8	3.3	**23.5**	*17.3*	**30.0**	5.7	4.0	6.7	8.1	1.6		*19.4*	1.5	0.2	5.6		5.5			**16.7**	1.7	5	**15.4**
T.tons	*16.7*	*10.4*	6.1	*18.3*	**23.5**		0.5	2.8		5.2		**90.9**	**52.9**	2.8	**54.4**							**10.5**	**16.7**	8	**12.8**
T.viol		3.4	8.1		5.9		1.6	**54.5**		0.8	**43.6**	0.5				*13.9*	**38.5**	**49.4**	**64.4**		**64.6**		**69.4**	**82**	**48.7**
T.verruc							0.5																		
T.soudan	6.7			**28.6**							4.8			2.8		0.2	**28.7**	7.8		**63.6**		**20.2**	**10**	5	
M.canis	3.3		**54.8**		**47.1**	**82.7**	**60.4**	*14.3*	**91.1**	**73.9**	**37.9**	3.2	**20**	**38.9**	**39.0**	**82.3**	**26.5**	**38.6**	**24.7**						7.7
M.gyps									0.3	2.2			1.9	*13.9*	0.7		0.7		1.0			1.8			5.1
M.pers																									
M.aud/ langer				**39.4**			0.5			3.7			*18.6*			2.2				**31.3**	**35.4**		2.2		2.6
T.schoen							0.5	5.7		3.7												**28.1**			
T.yaoundii																						4.4			
M.gallinae																						**18.4**			

resulted in Croatia from war-associated population movements [13].

This survey supports other observations of the continuing dominance of the anthropophilic species *T. rubrum* over all other species in the UK. Typically a disease of the feet, sometimes spreading to the groin and the hands, and the most common cause of tinea unguium, *T. rubrum* infection often becomes chronic, lasting for months or even years. Interestingly, the next most prevalent dermatophyte, *T. interdigitale*, is also principally a causative agent of disease of the feet. Although the exact reasons for the predominance of these two organisms remain unclear, their increased prevalence and continued dominance may relate to genuine changes in lifestyle, including increased urbanization and ready access to communal sports facilities. It has also been speculated that the fungistatic nature of many of the currently employed antifungal drugs used to treat athletes foot may contribute to the chronic nature of the infection. Whatever the precise reasons, with the exception of regions of central and southern Europe (see below), *T. rubrum* appears to be a major etiological agent of dermatophytoses in most developed countries. The proportion of the zoophilic *T. mentagrophytes* included in the data under *T. interdigitale* in the quinquennial study is unknown, though it is unlikely to be large, as general experience shows this species to be relatively rare. For example, the Bristol Laboratory figures for clinical specimens revealed a total of 95 isolates of *T. mentagrophytes* compared with some 3265 isolates of *T. interdigitale*.

The current survey has also demonstrated that the two common zoophilic species, *M. canis* and *T. verrucosum*, have dwindled considerably in relative importance over the same period in the UK. The decline in *M. canis* has previously been attributed at least in part to the introduction of griseofulvin therapy [12]. Conversely, in most of central and southern Europe *M. canis* is the principal dermatophyte isolated from human infections, to the extent that notification of *M. canis* infection is compulsory in certain countries [14]. Anamnestic data, where available, link the majority of such infections with domestic cats, and highlight the problems in controlling stray cat populations, which are thought to be the primary reservoir of infection [14]. In the case of *T. verrucosum*, it is unlikely that the introduction of effective vaccines against cattle ringworm have contributed to the decline in prevalence observed in the UK. Although this is certainly the case in those European countries where the vaccine has been heavily used [15], the available UK data suggest that as few as 0.5% of the estimated six million UK cattle are vaccinated (personal communications from Intervet

UK Ltd, Milton Keynes, UK. and Dr Tim Jones, University of Bristol, Langford, UK). Alternatively, it is possible that partial eradication of *T. verrucosum* in the UK is linked to the significant decline of the agricultural industry over the last two to three decades, and to altered farming practices which involve less human–animal contact.

For a species once thought to be almost eradicated in the British Isles, the re-emergence of *T. tonsurans* is a remarkable finding and mirrors reports of establishment of this species in the United States (see Table 3 and 4), where it comprises up to 50% of dermatophyte infections and 90% of cases of tinea capitis. In the UK at least, the re-introduction and continued rise in prevalence of this organism has been closely linked to increased population movements from the West Indies and the Caribbean. The reasons why this disease is seen predominantly in Afro-Caribbean populations are unknown, although it has been suggested that special hair-care practices, including braiding, may play some role in infection spread [16]. It seems clear that race alone cannot explain the distribution of *T. tonsurans*, since epidemic increases in prevalence have also been reported in Australian children over recent years [17]. Immigration, particularly from the Mediterranean and North Africa, has also been implicated in dramatic increases in prevalence of the anthropophilic agents of tinea capitis *T. soudanense, T. violaceum* and *M. audouinii* in Belgium [8], and *T. violaceum* in Greece [9] and Italy [18].

We have also assessed the potential role of non-dermatophyte moulds in skin and nail infections, again drawing on data for primary isolations of the organisms from clinical material submitted to the MRL (Table 5). Such infections have risen from 1% of all dermatophytoses in 1985 to 5% in 2005. Skin infections with *Scytalidium* spp. (previously *Hendersonula toruloidea*) were first noted in the MRL catchment area in 1994, and have continued to be reported at relatively low frequencies ever since. These organisms, which are well-recognized causes of skin and nail infections in tropical countries, are very likely to have been introduced into the UK through population movements [19]. The steady increase in frequency of nail infections by other non-dermatopytes, and especially *Fusarium* spp. and *Aspergillus* spp. is also of interest (Table 5). We have no concrete explanation for such an increase in prevalence. However, it is possible that this increase results from the continued predominance of *T. rubrum* in the UK, and that non-dermatophyte mould infections of nails are secondary infections which are actually masking chronic primary *T. rubrum* onychomycosis. Improving treatment regimens and recent press advertising has also encouraged larger numbers of individuals to seek treatment for fungal nail infections. Nevertheless, it is clear that non-dermatophyte

Table 5 Importance of non-dermatophyte moulds in human skin (*Scytalidium* spp. only) and nail infections, expressed in total numbers of isolations (left-hand panel) and percentage of all infections (right-hand panel). Acrem., *Acremonium* spp.; A.cand, *Aspergillus candidus*; A.vers, *Aspergillus versicolor*; Fusar., *Fusarium* spp.; Scop., *Scopulariopsis* spp.; Scyt., *Scytalidium* spp.

Year	Acrem.	A.cand	A.vers	Fusar.	Scop.	Scyt.	Moulds	Total
1985	0	1	1	1	3	0	6	522
1986	0	1	0	1	1	0	3	447
1987	5	0	0	1	2	0	8	480
1988	3	0	0	1	0	0	4	439
1989	2	0	0	1	2	0	5	447
1990	1	0	0	0	1	0	2	396
1991	0	0	0	4	4	0	8	385
1992	1	0	0	3	6	0	10	457
1993	1	0	1	2	4	0	8	413
1994	2	0	3	1	6	3	15	458
1995	0	0	0	2	5	2	9	409
1996	2	0	0	2	9	1	14	428
1997	4	0	3	6	16	3	32	905
1998	10	0	3	7	16	2	38	941
1999	6	1	4	13	10	3	37	971
2000	6	2	3	10	18	5	44	1031
2001	6	0	6	23	23	6	64	1057
2002	13	3	8	22	0	4	50	1137
2003	12	5	5	17	18	5	62	1431
2004	19	2	7	19	21	7	75	1517
2005	11	0	11	27	22	6	77	1532

Year	Acrem.	A.cand	A.vers	Fusar.	Scop.	Scyt.	Moulds	Total
1985	0	0.19	0.19	0.19	0.57	0	1.15	522
1986	0	0.22	0	0.22	0.22	0	0.67	447
1987	1.04	0	0	0.21	0.42	0	1.67	480
1988	0.68	0	0	0.23	0	0	0.91	439
1989	0.45	0	0	0.22	0.45	0	1.12	447
1990	0.25	0	0	0	0.25	0	0.51	396
1991	0	0	0	1.04	1.04	0	2.08	385
1992	0.22	0	0	0.66	1.31	0	2.19	457
1993	0.24	0	0.24	0.48	0.97	0	1.94	413
1994	0.44	0	0.66	0.22	1.31	0.66	3.28	458
1995	0	0	0	0.49	1.22	0.49	2.20	409
1996	0.47	0	0	0.47	2.10	0.23	3.27	428
1997	0.44	0	0.33	0.66	1.77	0.33	3.54	905
1998	1.06	0	0.32	0.74	1.70	0.21	4.04	941
1999	0.62	0.10	0.41	1.34	1.03	0.31	3.81	971
2000	0.58	0.19	0.29	0.97	1.75	0.48	4.27	1031
2001	0.57	0	0.57	2.18	2.18	0.57	6.05	1057
2002	1.14	0.26	0.70	1.93	0	0.35	4.40	1137
2003	0.84	0.35	0.35	1.19	1.26	0.35	4.33	1431
2004	1.25	0.13	0.46	1.25	1.38	0.46	4.94	1517
2005	0.72	0	0.72	1.76	1.44	0.39	5.03	1532

mould infections of nails are rare and follow nail trauma, and such a diagnosis requires positive direct microscopy and isolation of the non-dermatophyte mould in pure culture from a large proportion of the clinical sample.

The importance of dermatophytoses has been somewhat eclipsed in recent decades by the enormous increase in invasive fungal infection in immunocompromised patients. However, the contagious nature of ringworm fungi guarantees that they will continue to be of medical concern. The current study has uncovered a significant modification in the pattern of dermatophyte isolations in the UK over the 25 years, with the anthropophilic agents of tinea capitis re-emerging as significant pathogens in the UK. This study has also highlighted the dramatic worldwide variations in the relative prevalence of individual dermatophyte species. Given the ever-increasing magnitude of population movements it seems inevitable that the agents and sites of dermatophyte infection will continue to evolve, and that mycologists are likely to be confronted by an ever-increasing diversity of potential agents of dermatophytosis.

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