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Title: Workplace exposure to bioaerosols in Podiatry clinics

Objective: The aim of this study was to design and execute a pilot study to collect information on the personal exposure levels of podiatrists to microbial hazards in podiatry clinics; and also to assess health and safety knowledge within the sector using a questionnaire survey.

Methods: A self-report quantitative questionnaire dealing with health and safety / health issues was issued to 250 podiatrist clinics. Fifteen podiatry clinics were randomly recruited to participate in the exposure study. Concentrations of airborne bacteria, fungi, yeasts and moulds were assessed using a six stage viable microbial cascade impactor. Personal samples of total inhalable dust and endotoxin were measured in the breathing zone of the podiatrist.

Results: A questionnaire response rate of 42% (N= 101) was achieved. 32% of respondents indicated that they had a respiratory condition, asthma was the most prevalent condition reported. The most frequently employed control measures reported were; use of disposable gloves during patient treatments (73.3%), use of respiratory protective equipment (34.6%) use of protective aprons (16.8%), and eye protection (15.8%). 15.8% of respondents used mechanical room ventilation, 47.5% used nail drills with local exhaust ventilation systems, and 11% used nail drills with water spray dust suppression. The geometric mean concentrations of bacteria, Staphylococci, fungi and yeasts/moulds were 590 CFU/m³, 190 CFU/m³, 422 CFU/m³ and 59 CFU/m³ respectively. The geometric mean endotoxin exposure was 9.6 EU/m³. A significant percentage of all of the bioaerosols were in the respirable fraction were representative of yeasts and moulds (65 %) and Fungi (87%).

Conclusions: Even if statistical analysis of data is limited by low sample numbers, this study showed that the frequency of cleaning and use of RPE varied between clinics sampled, and it is likely that refresher health and safety training focusing on health and safety hazards inherent in podiatry work and practical control measures is warranted.

1

2 Introduction

3

4 Many studies have shown that occupational exposure to bioaerosols and organic
5 dusts can cause adverse health effects such as infectious and respiratory diseases, and
6 cancer (Lacey and Crook, 1988, Sigsgaard et al, 1994, Blair et al, 1992, Donham et al,
7 1986, Douwes et al, 2003, Thorne and Duchaine 2007). The medical and health sectors
8 have been identified as having an increased risk of contracting occupational infectious
9 diseases due to the potential for bioaerosol exposure within their work environment
10 (Douwes et al, 2003, Matheson et al, 2005). However, within the health sector
11 occupational exposures in podiatry practice have received little attention (Burrows and
12 McLarnon, 2006, Rees, 2008).

13 Podiatry is a healthcare profession that specialises in the management of disease and
14 disorders of the lower limb and foot. Podiatric treatments such as the reduction of thickened toe
15 nails, onychomycotic nails, foot calluses or corns have the potential to generate substantial
16 concentrations of organic dusts which could pose an occupational hazard to those exposed. It is
17 estimated that up to 3 grams of toe nail dust may be generated per day in a podiatry practice
18 (Davies and Ganderton, 1975). Studies of the morphology and particle size of toe nail dust
19 generated from podiatric nail drills, show that toe nail dust particles are plate like in shape
20 allowing them to remain airborne for long periods. Particles are largely respirable, with
21 greater than 80% of the particles within a 0.8 – 1.6 µm particle size range, thus once
22 inhaled these particles are capable of penetrating the lower lung (Abrahamson and
23 Wilton, 1985a, Donaldson, 2003). Toe nail dust has been shown to be a Type I Allergen
24 (Davies, 1984) rich in endotoxin and fungi species. Endotoxin is an amphiphilic
25 component of the outer cell wall of Gram negative bacteria, has strong innate immune
26 and pro-inflammatory properties and has been shown to be an important factor in the
27 etiology of lung diseases such as COPD and non allergic asthma (Hadina et al. 2008;
28 Douwes et al, 2003). Toe nail dust generated from the treatment of onychomycotic nails is
29 rich in fungi species such as *Trichophyton mentagrophytes*, and *Trichophyton rubrum*,
30 (Albert and Weis, 2004; Donaldson et al, 2003; English, 1972).

31 Previous research carried out by McLarnon (2000) among podiatrists in the
32 United Kingdom found the prevalence of asthma among podiatrists to be 13% which is

1 higher than the UK's national average, and a high prevalence of eye irritation and respiratory
2 complaints has been reported in this occupational group. Podiatrists have also been shown to have
3 a higher prevalence of precipitating antibodies for *T. rubrum* compared to the general
4 public (Abramson and Wilton, 1985b, Davies, 1984). However the health implications of
5 inhaling toe nail dusts are inconclusive (Gately, 1991).

6 To the authors' knowledge there have been few studies which have characterized
7 the personal exposures of podiatrists, and few that have evaluated the use of exposure
8 controls and assessed the level of knowledge of occupational exposure hazards among
9 podiatrists. This information is required to adequately estimate the health risks of this
10 work, to aid the selection of appropriate exposure controls, and to develop appropriately
11 tailored hazard communication programmes for inclusion in educational podiatry
12 programmes.

13 The aim of the present study was to design and execute a pilot study to evaluate the
14 personal exposure of podiatrists to microbial hazards in podiatry clinics, namely airborne
15 bacteria, fungi, yeasts and endotoxin. A further aim of this study is to conduct a national
16 survey of podiatrists working in private practice in Ireland, to assess health and safety
17 knowledge and to evaluate the use of exposure controls within the sector. It is anticipated
18 that the results from this study will perform the basis for a larger study on occupational
19 exposures in podiatry.

20 21 22 23 24 25 Methodology

26 27 *Questionnaire survey*

28
29 A self-report quantitative questionnaire was employed in this study, and no medical
30 assessments were undertaken. The questionnaire consisted of twenty four closed
31 questions and one qualitative open-ended question designed to elicit information on the

1 practice of occupational health and safety in podiatry. The sub – scales contained within
2 the questionnaire were deemed appropriate for the objectives of this study.

3
4 As there is no single professional body/regulatory agency for podiatrists in Ireland, the
5 only direct method of identifying potential participants was through the National
6 telephone directory and School of Podiatry at NUI, Galway. A list of 250 podiatrists
7 practicing in Ireland was compiled utilizing an online telephone listing website.
8 Additional podiatrists were identified by a staff member in the School of Podiatry in NUI
9 Galway. Only podiatrists in private practice were included in this study. As this research
10 is exploratory, it was decided to conduct a full population survey. The questionnaire was
11 posted with an explanatory cover letter to all identified podiatrists and reminder phone
12 calls were used to follow-up with all non-responders.

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16
17 *Sampling methodology*

18
19 Fifteen podiatry clinics with between 1 and 3 podiatricians were randomly recruited to
20 participate in the exposure study. Exposure sampling was conducted over the Summer
21 Autumn period June – November 2010. All exposure sampling was completed by a
22 trained Occupational Hygiene research student, who stayed at the podiatry clinic for the
23 duration of the monitoring period. Prior to the survey each podiatrist was asked to
24 complete a short questionnaire which asked questions regarding their podiatry treatment
25 room, for example presence of exposure controls, room ventilation, cleaning regime etc.
26 Podiatrists were asked to complete a work diary at 30 minute intervals and asked to
27 indicate whether pre defined activities, likely to generate toe nail dust were performed.
28 They were also asked to indicate the number of patients treated over the sampling period.
29 Air-borne microorganisms were sampled by means of a six stage viable microbial
30 cascade impactor (TE-10-800, Tisch Environmental, Inc. USA) which was placed on the
31 podiatrists clinical unit, in between the podiatrist and the patient. The aerodynamic

1 diameter range for each stage was as follows: Stage 1 > 7µm, Stage 2, 4.7-7.0µm, Stage
2 3, 3.3-4.7µm, Stage 4, 2.1-3.3µm, Stage 5, 1.1-2.1µm and Stage 6, 0.65-1.1µm. Air (28.3
3 l/min) was impacted for three minutes onto the agar plates. These contained supplier-
4 validated non-selective (for total viable aerobic microorganisms) or selective media the
5 latter of which subsequent to incubation supported the growth of staphylococci and fungi
6 (including moulds and yeasts). Each of the fifteen participating clinics were sampled for
7 one day and samples were taken in the morning before the first patient was admitted to
8 the clinic and again after the last patient had left. Duplicate samples were taken for each
9 of the 6 size fractions, and less than eight minutes elapsed between taking the second
10 sample. The mean of the two samples was used for further analysis, 90 samples were
11 collected in total, and 30 samples analysed for total bacteria, 30 samples analysed for
12 staphylococci and 30 analysed for fungi (including moulds and yeasts). It was only
13 possible to use the results from 72 samples, the remaining 18 samples were discarded as
14 the sample plates were either aseptically compromised during transport to the laboratory,
15 were statistically uncountable due to the proliferation of “spreading microorganism”, or
16 because of excessive medium drying during incubation.

17

18 Personal samples of total inhalable dust and endotoxin were collected in the breathing
19 zone of the podiatrist (sample cassettes were clipped onto the podiatrist’s lapel).
20 Sampling commenced in the morning before the podiatrist started work and continued for
21 the full work day, samples were collected at the end of the working day. Samples were
22 collected on to 25mm glass fibre filters (Pall Gelman Sciences) loaded into IOM
23 inhalable dust sampler cassettes (Institute of Occupational Medicine, Edinburgh, UK).
24 Filters were pre treated by heating at 200°C for 4hrs, cassettes and holders were washed
25 with E-Toxa clean (soaked in 1% E-Toxa clean overnight, rinsed 10 times with tap water,
26 5 times with DI water, one time with nanopure water and dried on room temperature).
27 Personal air sampling pumps (SKC Inc.), with the volumetric flow rate constant at 2
28 litres per minute, were used to draw air through the filters. Flow rates were checked
29 before and after sampling using a Primary Air Flow Calibrator. Three podiatrists refused
30 to participate in the personal sampling, In total 12 personal measurements were collected
31 sampling times ranged from 210 to 420 minutes.

1

2 *Sample analysis*

3 All samples were transported back to the laboratory in a chilled box at 4°C, where
4 possible within 1 hour after sampling. Samples of Total Bacteria (Total Viable Aerobic
5 count: TVC) were collected and enumerated using nutrient agar (NA: Oxoid, UK)
6 incubated at 30°C for 3 days. Samples of Fungi (including moulds and yeasts were
7 collected and enumerated using lactic acid-adjusted Malt Extract Agar (MEA: Oxoid,
8 UK) incubated at 22°C for 5 days. Samples of Staphylococci were collected and
9 enumerated using egg-yolk tellurite emulsion supplemented Bair-Parker medium (Oxoid:
10 UK) which were incubated at 37°C for two days. Samples of dermatophyte fungi were
11 collected using the settle plate technique on Dermasol Agar (Oxoid UK) and incubated at
12 22°C for 2 to 4 weeks. Dermasol agar plates were monitored over the 4 week period and
13 microscopy was used to identify the presence of *T. rubrum* or other dermatophytes grown
14 on the agar, results were expressed as presence or absence of dermaphytes. Using positive
15 hole correction tables (Macher, 1989) the concentrations of total bacteria, fungi, yeasts
16 and moulds were calculated and expressed as colony forming units per m³ of air
17 (CFU/m³).

18 Personal inhalable air samples were analyzed for endotoxin as previously described
19 (Thorne 2000, Thorne et al. 2010). Briefly, sampling filters were extracted into 10 mL of
20 pyrogen-free LAL grade water (Lonza, Inc.) plus 0.05% Tween-20 (Fisher Scientific),
21 shaken for 60 min and centrifuged for 15 min at 600 x g and decanted. Extracts were
22 assayed for endotoxin activity using a modification of the kinectic chromogenic *Limulus*
23 amebocyte lysate (LAL) assay with a 12-point standard curve ($r^2 > 0.995$) ranging from
24 0.0249 to 50 EU/mL. Extracts were assayed at 4 dilutions in LAL water using a 37°C
25 microplate reader (SpectroMax 340, Molecular Devices) at 405 nm with readings taken
26 every 30 sec for 90 min. Four microplate wells served as assay blanks.

27

28 *Statistical analysis*

29 All statistical analysis was performed using SPSS (Version 18) and Minitab. The
30 normality of distribution of the bioaerosol concentrations data was checked using the
31 Shapiro–Wilk test. The distributions were lognormal distributed and so the data is

1 presented as geometric means, and geometric standard deviation (Table 3). Independent
2 student t-tests were used to compare concentrations of bioaerosols collected before the
3 first patient treatment with samples collected after the last patient treatment. Agreement
4 between bioaerosol concentrations and each of the following; the number of patients
5 treated, the number of onychomycotic nails treated (Fungi only), the total time using a toe
6 nail drill/grinder/nail file and endotoxin concentrations (Bacteria only) was assessed by testing
7 the significance of the Pearson correlation coefficient.

8

9

10 Results

11

12 *Questionnaire survey results*

13

14 A response rate of 42% (N= 101) was achieved to the questionnaire survey. The majority
15 of the survey respondents were female 87% (n=88) and 13% (n=13) were male. Most
16 respondents had been working in podiatry for a number of years, with 42% having
17 worked between 20-40 years, another 44% having worked in excess of ten years and the
18 minority (15%) had worked for less than 10 years.

19

20 As respiratory illness is the health outcome of most interest in this study, participants in
21 the questionnaire study were asked to indicate whether or not they had a work related
22 respiratory illness as diagnosed by their doctor. The questionnaire allowed respondents to
23 select more than one illness, and 32 out of the 101 survey participants indicated that they
24 had a respiratory condition (Table 1). Asthma was the most prevalent condition, with
25 eight podiatrists reporting this condition, followed by sinusitis (n=8), repeated chest
26 infections (n=6), persistent cough (n=5), nasal irritation (n=4) and bronchitis (n=2). The
27 data was analysed to assess the numbers of podiatrists suffering from individual
28 conditions only.

29

30 The questionnaire survey also investigated the use of exposure controls and protective
31 equipment in podiatry practice. Participants identified the frequency with which they
32 employed various control measures. From the self reported data it was found that the
33 most frequently employed control measures were; always wearing of disposable gloves

1 during patient treatments (73.3%); use of respiratory protective equipment (RPE) (34.6%)
2 was at a lower level; while consistent use of protective aprons (16.8%) and eye protection
3 (15.8%) were employed to a lesser degree (Table 2). The questionnaire did not require
4 respondents to provide detail regarding the protection factor of the RPE used.

5
6 The use of room mechanical ventilation systems, local exhaust ventilation, and dust
7 suppression systems, was also investigated in the questionnaire survey. Use of room
8 mechanical ventilation systems was very low (15.8% of respondents used mechanical
9 ventilation). Almost half (47.5%) of the respondents used nail drills with local exhaust
10 ventilation systems. However, the use of nail drills with water spray dust suppression was
11 far less common, with only 11% of respondents always using this equipment.

12 13 *Exposure assessment results*

14
15 The concentrations of airborne bacteria, fungi (including moulds) yeasts, Staphylococci,
16 and personal endotoxin exposures measured in podiatry clinics are presented in Table 3.
17 The geometric mean concentrations of bacteria, Staphylococci, fungi (including moulds)
18 and yeasts were 590 CFU/m³, 190 CFU/m³, 422 CFU/m³ and 59 CFU/m³ respectively.
19 The geometric mean endotoxin exposure was 9.6 EU/m³. The concentrations of bacteria
20 were much higher than the concentrations of fungi. Bioaerosol concentration data is
21 presented as CFU/m³ in Table 4 and the size distribution is plotted in Figures 1 and 2 as
22 bacteria CFU/m³/dLog *Dp* staphylococci CFU/m³/dLog *Dp*, fungi CFU/m³/dLog *Dp*,
23 yeasts and moulds CFU/m³/dLog *Dp*. dLog *Dp* is the Logarithmic width of the impactor
24 stage, presenting the concentration data as CFU/m³/dLog *Dp*, allows direct comparison
25 between the concentrations of different stages.

26 The highest concentration of bacteria and fungi (including moulds) occurred in stage 5
27 (1.1-2.1µm), followed by stage 4 (2.1-3.3µm). Highest concentrations of yeasts occurred
28 in stage 2 (4.7-7.0µm) followed by stage 4 (2.1-3.3µm). A significant percentage of all of
29 the bioaerosols were in the respirable fraction, ranging from 65 % (yeasts and moulds) to
30 87% (Fungi). There was no significant difference between the concentrations of

1 bioaerosols collected in the morning, prior to the first or second patient treatment
2 compared with samples collected in the evening, after the last patient treatment.

3 Correlations between bioaerosol concentrations (bacteria or fungi) and the number of
4 patients treated, total time using a toe nail drill/grinder/nail file, were all not significant
5 ($p>0.05$). Similarly there was no correlation found between fungal concentrations and
6 number of onychomycotic nails treatments within the clinics ($p<0.05$).

7
8 Endotoxin concentrations (expressed as 8 hour TWA) ranged from 0.5 to 32.6 EU/m³.
9 The highest endotoxin exposures were recorded in Clinic 7. Correlations between
10 endotoxin concentrations and total bacterial concentrations, total number of patients
11 treated, the total time using a toe nail drill, or the total time using a nail file or pumice
12 stone were not significant ($p<0.05$).

13 14 Discussion

15
16 Concentrations of total viable bacteria, fungi, yeasts/moulds and personal endotoxin
17 exposures were measured in podiatry clinics. To the authors knowledge there have been
18 no other studies reported concerning bioaerosol concentrations and endotoxin exposures
19 in podiatry.

20 The geometric mean concentrations of bioaerosols reported in this study are higher than
21 values reported for other clinical settings such as dentistry and hospital environments
22 (Monarca et al, 2000; Bennett et al, 2000; Kim and Kim, 2007), and lower than those
23 reported for residential dwellings (Nasir and Colbeck, 2010; DeKoster and Thorne,
24 1995). In the present study concentrations of bacteria were highest, followed by fungi
25 (including moulds) and yeasts. There were no visible signs of fungal or mould growth in any
26 of the clinics sampled. The maximum concentrations of all bioaerosols (apart from yeasts
27 and moulds) were isolated from Stage 5 (1.1 – 2.1 μm) (Figures 1 and 2). The size
28 distributions of bacteria and fungi (72 – 79%, 87% respirable) are comparable to those
29 reported for residential homes in the UK Nasir and Colbeck 2010, and the USA DeKoster
30 and Thorne, 1995, but slightly higher than those reported by Kim and Kim, 2007 for
31 hospitals environments. In this study the high fraction of respirable bioaerosols could

1 largely be due to microbial laden dust originating from the use of grinding tools used for
2 podiatric treatments within the clinics. Studies of toe nail dust particle size and
3 morphology on dust collected from toe nail drills have shown that toe nail dust is highly
4 respirable (Abrahamson and Wilton, 1985; Donaldson et al, 2002). Nine of the clinics
5 sampled in this study used a toe nail drill during the survey. Some clinics reported
6 spending up to 1.5 hours per day reducing the thickness and distortion of onychomycotic
7 nails using a toe nail drill or nail file. Highest concentrations of yeasts were found in
8 Stage 2 (4.7 – 7 μm).

9 All personal endotoxin exposures are less than the Dutch exposure standard limit of 90
10 EU/m³ for airborne endotoxin DECOS (2010)). Concentrations are highly variable (range
11 0.5 – 32.68 EU/m³), but within the range of exposure concentrations reported for similar
12 clinical settings such as dentistry (Singh et al, 2010), or for indoor environments such as
13 office buildings and rural households (Thorne and Duchaine, 2007).

14 One of the most commonly performed treatments at the podiatry clinics during the survey
15 involved the drilling or filing of onychomycotic nails. As onychomycotic nails are caused by
16 dermatophytic fungi, the number of onychomycotic nail treatments performed should be one of
17 the main sources of airborne fungi within the clinic. There was, however, no dermatophytes
18 identified and there was no significant correlation ($p>0.05$) between the number of
19 onychomycotic nail treatments, or total time using a nail drill and total fungi concentrations. In
20 addition there was no significant correlation ($p>0.05$) between bioaerosol or endotoxin
21 concentrations and number of patients treated, even though previous studies have identified
22 building occupancy as a factor influencing bioaerosol concentrations in domestic settings (Nasir
23 and Colbeck, 2010).

24 Podiatrists indicated that they use a variety of disinfectants for cleaning, however the
25 frequency of cleaning varied between clinics. Two of the clinics reported cleaning the
26 immediate work area; patient chair, clinical unit, and podiatrists' chairs once per day, the
27 remaining 10 clinics reported cleaning the immediate work area between each patient
28 treated. 75% of clinics sampled reported cleaning the treatment room once per week, and
29 a small number reported using a household floor brush or vacuum cleaner. An endotoxin
30 exposure concentration of 32.6 EU/m³ (8 hr TWA) was recorded in one clinic, where the
31 podiatrist reported using a household vacuum cleaner to clean the work area between
32 patient appointments. This was the highest endotoxin exposure value recorded in the

1 study. The use of a household brush or vacuum cleaner for cleaning is likely to generate
2 high concentrations of bioaerosols, by re-suspension of settled microbial laden dust from
3 work surfaces.

4 Microbial laden respirable dust has the potential to deposit deep in the alveolar region of
5 the lung, and could have significant health implications for workers with respiratory
6 diseases such as asthma. During the field study it was observed that many of the
7 podiatrists sampled in this study wore gloves while treating a patient, however rarely
8 used respiratory protective equipment. When respiratory protective equipment was used,
9 surgical dust masks, without assigned protection factors, were typically worn. Similar
10 results were reported in the questionnaire survey, only 35% of podiatrists reported using a
11 dust mask and as many as 70% reported not having a mechanical ventilation system.

12 8% of the podiatrists who participated in the questionnaire survey, confirmed that they
13 had been diagnosed with asthma, this rate is 1% lower than the Irish National average
14 (Asthma Society of Ireland). Only 9% of questionnaire respondents suffered from nasal
15 irritation, significantly lower than the value of 57%, which was reported by Gately in
16 1991. A possible explanation for the large discrepancy in the two figures is that the
17 majority of the podiatrists who participated in Gately's study were using toe nail drills
18 without extraction. Nowadays most of the toe nail drills available include an extraction
19 unit, and in this study 47% of the questionnaire respondents reported using nail drills with
20 dust extraction.

21 Given that this was a small study with 12 - 15 podiatry clinics participating, a larger scale
22 study is necessary, building on the findings of this pilot project, to better understand
23 occupational exposures within this under studied sector. Some conclusions can be made
24 from this initial study. The inconsistent cleaning and use of exposure control measures
25 observed in this study may be explained by a number of contributory factors; such as lack
26 of awareness of health risks posed by inhalable dusts. Given that most of the participants
27 in this study had been practicing for a number of years, and that there is no Regulatory
28 Podiatry body in Ireland, health and safety knowledge on topics such as infection control
29 and personal protective equipment may have been forgotten in the absence of any re-
30 fresher training. A starting point to address this gap could be the implementation of a
31 targeted health and safety guidance tool for practitioners to raise awareness of health and

1 safety hazards inherent in podiatry work incorporating practical control measures to
2 minimise risk.

3

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5

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