# Foot Ulcer Risk Is Lower in South-Asian and African-Caribbean Compared With European Diabetic Patients in the U.K.

## The North-West Diabetes Foot Care Study

Caroline A. Abbott, phd[1]
Adam P. Garrow, phd[2]
Anne L. Carrington, phd[1]
Julie Morris, phd[3]
Ernest R. Van Ross, frcp[2]
Andrew J. Boulton, md[1]

**OBJECTIVE** — To determine *1*) foot ulcer rates for European, South-Asian, and African-Caribbean diabetic patients in the U.K and *2*) the contribution of neuropathy and peripheral arterial disease (PAD) differences to altered ulcer risk between the groups.

**RESEARCH DESIGN AND METHODS** — In this U.K. population–based study, we screened 15,692 type 1 and type 2 diabetic patients in the community health care setting for foot ulcers, foot deformities, neuropathy, and PAD plus other characteristics. In total, 13,409 were European (85.5%), 1,866 were South Asian (11.9%), and 371 were African Caribbean (2.4%).

**RESULTS** — The age-adjusted prevalence of diabetic foot ulcers (past or present) for Europeans, South Asians, and African Caribbeans was 5.5, 1.8, and 2.7%, respectively ($P < 0.0001$). Asians and African Caribbeans had less neuropathy, PAD, and foot deformities than Europeans ($P = 0.003$). The unadjusted risk of ulcer (odds ratio [OR]) for Asians versus Europeans was 0.29 (95% CI 0.20–0.41) ($P < 0.0001$). PAD, neuropathy, foot deformities, and insulin use attenuated the age-adjusted OR from 0.32 to 0.52 (0.35–0.76) ($P < 0.0001$). African-Caribbean versus European ulcer risk in males was attenuated from 0.60 to 0.71 by vibration sensation.

**CONCLUSIONS** — South Asians with diabetes in the U.K. have about one-third the risk of foot ulcers of Europeans. The lower levels of PAD, neuropathy, insulin usage, and foot deformities of the Asians account for approximately half of this reduced foot ulcer risk. Lower neuropathy is the main contributor to the reduced African-Caribbean ulcer rate, particularly in men. The reasons for these ethnic differences warrant further investigation.

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There are striking differences in the prevalence of type 2 diabetes among migrant populations of South-Asian and African-Caribbean populations compared with Europeans in the U.K. (three and fourfold higher, respectively) (1,2). As the worldwide prevalence of diabetes continues to increase dramatically due to an increasing elderly and obese population, people from minority ethnic groups will be at particular risk (3,4). Estimating rates of, and risk factors for, diabetes complications in minority ethnic groups is therefore important for us to plan health care effectively, improve our understanding of disease natural history, and target therapeutic interventions for patients with diabetes.

South-Asian people in the U.K. appear to be protected from diabetes-related amputation, with rates being one-quarter that of Europeans with diabetes (5), as was recently confirmed in a population-based case-control study (6). For diabetic patients of African descent, data from the U.S. show a two- to threefold elevation in risk of amputation compared with U.S. whites (7,8), possibly due to the inequalities in access to health care. In the U.K., however, amputation risk was reduced in diabetic African-Caribbean men by about two-thirds compared with U.K. whites (9).

Two previous studies (10,11) reported that foot ulceration is markedly lower in South-Asian diabetic patients compared with their Europid counterparts. Despite peripheral neuropathy being the single most important contributor to diabetic foot ulceration and amputation (12–14), there are very limited data available of the prevalence of neuropathy in ethnic populations. The U.K. Prospective Diabetes Study alone has demonstrated that fewer newly diagnosed South-Asian and African-Caribbean diabetic patients have abnormal vibration perception threshold compared with their Caucasian counterparts (15). Two recent reports (6,9) implied that the reduced amputation rate of both these ethnic groups is, in part, associated with a lower level of neuropathy for these patients.

In this population-based analysis we aimed to determine *1*) how rates of foot ulcers, neuropathy, and peripheral arterial disease (PAD) differ between European, South-Asian, and African-Caribbean diabetic groups in northwest England; *2*) what factors contribute to ethnic differences in foot ulcer rates; and *3*) to what level do the

From the [1]Department of Medicine, Manchester Royal Infirmary, University of Manchester, Manchester, U.K.; the [2]Disablement Services Centre, Withington Hospital, Manchester, U.K.; and the [3]Department of Medical Statistics, Withington Hospital, Manchester, U.K.

Address correspondence and reprint requests to Dr. Caroline A. Abbott, Diabetes Foot Clinic, Disablement Services Centre, Withington Hospital, Cavendish Road, Manchester, M20 1LB, U.K. E-mail: ca.abbott@btinternet.com.

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**Abbreviations:** NWDFCS, North-West Diabetes Foot Care Study; PAD, peripheral arterial disease.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

established risk factors of neuropathy and PAD contribute to the altered risk of foot ulcer between the ethnic groups.

## RESEARCH DESIGN AND METHODS

— The North-West Diabetes Foot Care Study (NWDFCS), a population-based investigation of diabetes-related foot problems in the community health care setting (13), provided the study population. This area of greater Manchester in the U.K. is particularly well represented by people of South-Asian descent (i.e., from India, Pakistan, or Bangladesh) and also, to a lesser extent, people of African-Caribbean descent (16).

In the NWDFCS, trained podiatrists examined a randomly selected cohort of diabetic patients attending primary and secondary health care clinics in six districts of northwest England over 4 years (13). The level of general practitioner involvement was calculated from three randomly selected districts, in which 53% of all patients were screened. The mean general practitioner response rate, from all general practitioner practices invited to become involved in the NWDFCS, was 68%. Of these practices, 60% of all listed diabetic patients were screened. This cohort, therefore, represents a large sample selection from the general diabetic population attending community health care clinics.

### Screening measurements

At baseline, various demographic, medical, and social variables were recorded for all patients (13). Ethnic group was defined as European, South Asian, African Caribbean, or other, according to the patients' appearance and parental origin. Details of past or present foot ulcers were documented via examination and assessment of the podiatry/medical notes. A foot ulcer was defined as a full-thickness skin break at least to Wagner stage 1 (17), occurring distal to the malleoli.

Peripheral neuropathy was assessed using various techniques, as previously described (13). A modified neuropathy symptom score was used to determine the severity of neuropathic symptoms (18). Signs of neuropathy in the feet were determined using the modified neuropathy disability score (18), derived from inability to detect pin-prick sensation (using Neurotip), vibration (using 128-Hz tuning fork), and differences in temperature sensation (using warm and cool rods) plus Achilles reflex (using tendon hammer). A score ≥6 indicated moderate to severe neuropathy (18). Cutaneous pressure perception was assessed using a 10-g monofilament at the first and fifth metatarsal heads and the heel on each foot by the forced-choice method (19). A six-point foot deformity score assessed small muscle wasting, hammer or claw toes, bony prominences, prominent metatarsal heads, Charcot arthropathy, and limited joint mobility; a combined score of ≥3 indicated significant foot deformities (13).

Peripheral arterial status was assessed by palpating the dorsalis pedis and posterior tibial pulses on both feet. Presence of two or fewer of the four pedal pulses, either with or without the presence of edema, indicated PAD. In addition, patients were questioned about any previous peripheral angioplasty or peripheral bypass surgery they had undergone to determine peripheral arterial history.

### Statistical analysis

Variables were stratified into normal and abnormal categories. Then, $\chi^2$ tests were performed for categorical data. Normally distributed continuous data were tested using one-way ANOVA with Tukey analysis, whereas nonnormally distributed data were first analyzed using Kruskal-Wallis, followed by a Mann-Whitney *U* test between all pair combinations of the ethnic groups.

Since Asians were younger, direct methods of standardization against the whole NWDFCS population were used to calculate age-adjusted rates of foot ulcers, neuropathy, and other variables in the ethnic groups (20). After obtaining 95% CIs, age-adjusted prevalence rate differences were evaluated between the ethnic groups (21). Asian and African-Caribbean groups were analyzed using logistic regression to obtain odds ratios (ORs) for ulcer risk compared with Europeans. Modifiers of the ORs were entered into the final logistic regression models to determine which risk factors may account for ulcer rate differences.

## RESULTS

— A total of 15,692 diabetic patients were assessed over 4 years. Of these, 13,409 were European (85.5%), 1,866 were Asian (11.9%), and 371 were African Caribbean (2.4%). Twenty-one individuals were of different ethnic origin, and ethnicity could not be ascribed in 25 patients; therefore, 15,646 case subjects were available for analysis.

Baseline demographic, social, and medical characteristics of the diabetic ethnic groups are given in Table 1. Asians were younger than Europeans and African Caribbeans (54.9 vs. 62.3 and 62.0 years, respectively, $P < 0.0001$), whereas diabetes duration was longer in African Caribbeans only (7.0 years, $P < 0.0001$) compared with Asians (5.0 years) and Europeans (5.0 years).

### Crude rates of foot ulcers, neuropathy, and PAD

The overall prevalence of active foot ulceration identified at screening was 1.3% (201 of 15,111). The median duration of these ulcers was 6 weeks (interquartile range 2–16 weeks), and median Wagner grade classification was one (1–1). The prevalence of past ulceration was 3.8% (573 of 15,111); therefore, overall foot ulcer history prevalence was 5.1% (774 of 15,111).

The crude prevalence of foot ulcer history was strikingly low in Asians (1.6% [30 of 1,824], $P < 0.0001$) compared with Europeans (5.5% [733 of 13,251]) or African Caribbeans (3.0% [11 of 365]). Active foot ulcers identified during screening were 2.3-fold less prevalent in Asians (0.6% [11 of 1,824], $P < 0.0001$) than Europeans (1.4% [186 of 13,251]), whereas past ulcers were 4.1-fold less common (1.0% [19 of 1,824] vs. 4.1% [547 of 13,251], respectively, $P < 0.0001$). Lower-limb amputation was also lower in Asians (0.6% [10 of 1,808], $P = 0.019$) than Europeans (1.3% [176 of 13,211]) or African Caribbeans (1.4% [5 of 361]).

Asians were much less likely than Europeans to have abnormal vibration sensation (10.6% [197 of 1,855] vs. 23.6% [3,154 of 13,385]), abnormal temperature sensation (5.7% [102 of 1,781] vs. 9.8% [1,296 of 13,159]), absent ankle reflexes (31.6% [581 of 1,836] vs. 37.6% [4,942 of 13,148]), and abnormal neuropathy disability score (13.8% [256 of 1,859] vs. 22.4% [2,995 of 13,385], all $P < 0.0001$). Conversely, Asians had slightly higher neuropathy symptom score (31.0% [572 of 1,847] vs. 24.9% [3,337 of 13,375]) and monofilament insensitivity (20.9% [368 of 1,764] vs. 16.5% [2,151 of 13,050]) compared with Europeans ($P < 0.0001$), whereas pin-prick sensation was unchanged (16.7%

**Table 1—*Baseline demographic, social, and medical characteristics of the diabetic ethnic groups***

| Variable | White European | South Asian | African Caribbean | *P* |
|---|---|---|---|---|
| *n* | 13,409 | 1,866 | 371 | |
| Male | 7,228/13,409 (53.9) | 1,002/1,859 (53.7) | 195/371 (52.6) | 0.877 |
| Age (years) | 62.3 ± 14.1 | 54.9 ± 11.8 | 62.0 ± 9.7 | <0.0001 |
| Duration diabetes (years) | 5.0 (2.0–10.0) | 5.0 (2.0–10.0) | 7.0 (3.0–12.8) | 0.42 WE vs. SA, 0.0001 SA vs. AC, 0.0001 WE vs. AC |
| Type 1 diabetes | 1,434/13,298 (10.8) | 133/1,833 (7.3) | 18/368 (4.9) | <0.0001 |
| Diabetes treatment | | | | |
| Diet only | 4,128/13,363 (30.9) | 430/1,845 (23.3) | 73/370 (19.7) | <0.0001 |
| Oral hypoglycemic agent plus diet | 6,201/13,363 (46.4) | 1,237/1,845 (67.0) | 232/370 (62.7) | |
| Insulin (with or without oral hypoglycemic agent) | 3,034/13,363 (22.7) | 178/1,845 (9.6) | 65/370 (17.6) | |
| Impaired renal function | 375/13,091 (2.9) | 50/1,782 (2.8) | 15/358 (4.2) | 0.328 |
| Impaired vision | 1,488/13,238 (11.2) | 173/1,814 (9.5) | 36/360 (10.0) | 0.078 |
| Live alone | 3,151/13,226 (23.8) | 147/1,831 (8.0) | 108/361 (29.9) | <0.0001 |
| Smoking history | | | | |
| Never smoked | 4,973/13,368 (37.2) | 1,346/1,852 (72.7) | 223/367 (60.8) | <0.0001 |
| Current smoker | 3,197/13,368 (23.9) | 318/1,852 (17.2) | 58/367 (15.8) | |
| Ex-smoker | 5,198/13,368 (38.9) | 188/1,852 (10.2) | 86/367 (23.4) | |
| Regular moderate alcohol consumption (>7 units/week) | 6,658/13,224 (50.3) | 164/1,839 (8.9) | 162/366 (44.3) | <0.0001 |

Data are means ± SD, *n* (%), or median (25–75th percentiles). Categorical data were compared between the ethnic groups using the $\chi^2$ test. Normally distributed data were tested using one-way ANOVA. Nonnormally distributed data were first analysed using the Kruskal Wallis test, followed by the Mann-Whitney *U* test between all pair combinations of the ethnic groups. AC, African Caribbean; SA, South Asian; WE, white European.

[310 of 1,855] vs. 17.2% [2,295 of 13,378]). Significant foot deformities were only half as common in Asians (14.9% [276 of 1,856]) than in Europeans (32.3% [4,310 of 13,332], $P < 0.0001$). The most notable difference for the African Caribbeans, when compared with Europeans, was their lower rate of vibration abnormality (13.2% [49 of 370] vs. 23.6% [3,154 of 13,385], $P < 0.0001$).

Absent foot pulses were threefold lower in Asians (7.1% [132 of 1,862]) compared with Europeans or African Caribbeans (21.9% [2,927 of 13,387] and 20.3% [75 of 370], respectively, $P < 0.0001$). Twice as many Europeans (3.0% [385 of 12,921]) had a peripheral arterial surgical history compared with Asians (1.4% [25 of 1,773]) and African Caribbeans (1.4% [5 of 347], $P < 0.0001$).

### Age-standardized rates of foot ulcers, neuropathy, and PAD

The age-standardized foot ulcer history rate in the Asian group was threefold lower than the European group (1.9 vs. 5.5%, respectively, $P < 0.0001$), whereas the African-Caribbean rate (2.7%) was twice as low (Table 2).

Fewer Asians than Europeans had abnormal neuropathy disability score (17.6 vs. 21.8%, respectively, $P < 0.0001$), which also held true for abnormal vibration sensation (14.2 vs. 22.8%, $P < 0.0001$) and abnormal temperature sensation (7.8 vs. 9.7%, $P < 0.0001$). Abnormal pin-prick sensation, abnormal neuropathy symptom score, and 10-g monofilament insensitivity, however, were now worse in Asians compared with Europeans. No differences existed between Asians and Europeans for absent reflexes. Foot deformities were half as prevalent in Asians compared with Europeans (16.4 vs. 31.5%, $P < 0.0001$). African Caribbeans maintained their lower rate of vibration abnormality compared with Europeans (12.7 vs. 22.8%, $P < 0.0001$).

Age-adjusted PAD (absent foot pulses) was half as prevalent in Asians (10.4%) as Europeans or African Caribbeans (21.1 and 19.8%, respectively, $P = 0.003$). This pattern was also evident between Asians and Europeans for peripheral arterial history (1.3 and 2.9%, respectively, $P < 0.0001$).

The unadjusted risk of foot ulcer in Asians compared with Europeans was 0.29 (95% CI 0.20–0.41) ($P < 0.0001$, Table 3). Since Asians were younger than Europeans, age was used in multivariate models. When adjusting for younger age, the Asian risk reduction was minimally improved to 0.32 (0.22–0.46). Diabetes duration had an identical impact on the ethnic difference in risk of foot ulcer (0.32 [0.22–0.46]). A sex-stratified analysis was performed, and the Asian reduction in risk of foot ulcer was very similar in men (age-adjusted OR 0.33 [0.21–0.53], $P < 0.0001$) and women (0.30 [0.17–0.56], $P < 0.0001$). The sexes were therefore combined for subsequent analyses.

The most important factors that appeared to account for the Asian reduction in risk of foot ulceration were PAD (OR 0.38), neuropathy defined by abnormal vibration sensation (0.36), insulin use (0.39), and foot deformities (0.35) (Table 3). A combination of these four variables gave the highest attenuation of the Asian protection against foot ulcer, changing the age-adjusted OR from 0.32 to 0.52 (95% CI 0.35–0.76) ($P < 0.0001$). Adding smoking, alcohol, living alone, or any other variables into the model had no effect on improving this OR. No neuropathy measure, other than vibration sensation, had any impact on this OR.

The unadjusted risk of foot ulcer in African Caribbeans compared with Europeans was 0.53 (95% CI 0.29–0.97) ($P =$

0.040, Table 3). African Caribbeans and Europeans had similar ages, and no appreciable effect of age was found on reduced ulcer risk (OR 0.54). Diabetes duration, however, was significantly longer in the African Caribbeans and was used in the multivariate model. When a sex-stratified analysis was performed, the African-Caribbean reduction in risk of foot ulcer appeared greater for women (diabetes duration–adjusted OR 0.44 [0.16–1.19], $P = 0.104$) than for men (0.59 [0.28–1.27], $P = 0.178$); therefore, subsequent analyses were split according to sex (Table 3).

The combination of variables giving the highest attenuation of the African-Caribbean protection against foot ulcer in women was vibration sensation, foot pulses, and smoking, changing the OR from 0.44 to 0.58 (95% CI 0.21–1.59) ($P = 0.288$), whereas in men, vibration sensation alone provided the greatest effect (0.71 [0.33–1.55]) $P = 0.392$). Adding any other variables had no impact on improving this OR value further.

**CONCLUSIONS** — We have demonstrated in this population-based cohort that the prevalence of diabetic foot ulcers (past or present) in Asians (1.8%) and African Caribbeans (2.7%) was significantly lower (threefold and twofold, respectively) than for Europeans (5.5%), even after adjusting for differences in age. Our epidemiological findings confirm and extend results from previous smaller studies (10,11) that, although not population-based, have indicated that foot ulcers are at least half as prevalent in Asian people with diabetes compared with their white European counterparts. We further showed in Asians that the lower rate is consistent for men and women and is not affected by their younger age. The much lower level of PAD and neuropathy found in Asians, plus their fewer foot deformities and lower insulin usage, accounts for approximately half of the reduction in risk of foot ulcers found in Asians, with the risk reduction being attenuated from approximately one-third to over one-half of the risk observed in Europeans. Diabetic foot ulcer rates have not been previously reported for African Caribbeans. Although ulcer numbers are relatively small in this group, we have shown that ulcers are generally half as prevalent in African-Caribbean diabetic patients compared with Europeans, and women have the slightly greater protection. In African-Caribbean men, neuropathy alone accounted for the majority of their overall protection.

From population estimates, the overall proportion of Asians in the six northwest districts selected is ~3.6%, whereas for African Caribbeans it is ~1.3% (16). Migrant populations of African-Caribbean and Asian descent to the U.K. have a prevalence of type 2 diabetes that is three- and fourfold higher, respectively, than the general population (1,2). Thus, we estimated that ~11% of the adults with diabetes in the study area would be Asian and ~3% would be African Caribbean. The actual screened population of 11.9 and 2.4%, respectively, has therefore an ethnic distribution pattern typical of the general diabetes population (i.e., this very large cohort of patients is suitable and valid for study). We cannot report here on provision of primary health care services, such as diabetes miniclinics, podiatric care, and referrals for special footwear for the health care districts, although variable quality of health care may possibly affect ulcer outcomes. Our active ulcer prevalence rate of 1.3%, however, is very comparable to that of other U.K. populations (22,26) and is therefore a representative sample.

There are very few existing reports of diabetic neuropathy in ethnic minorities, in particular for migrant South-Asian populations. In the U.K. Prospective Diabetes Study, South-Asian people with newly diagnosed diabetes had lower rates of impaired vibration sensation than Europeans (4% compared with 13%, respectively) (15). In the Indian subcontinent, differing prevalence rates of peripheral neuropathy (3–25%) have been reported (23,24), but as methods of neuropathy detection vary so widely it is difficult to know how these rates compare to European populations. The U.K. Prospective Diabetes Study found that prevalence of abnormal vibration sensation in African-Caribbean patients with newly diagnosed diabetes was slightly lower than for Europeans; this neuropathy difference was also highlighted in a case-control study of medical records from African-Caribbean and European diabetic amputees (9).

We showed that neuropathy is much lower in Asians compared with Europe-



**Table 2—*Age-adjusted rates of foot ulcers, amputation, peripheral neuropathy, and PAD in the diabetic ethnic groups***

| | White European | South Asian | African Caribbean | WE-SA (95% CI) | *P* | WE-AC (95% CI) | *P* |
|---|---|---|---|---|---|---|---|
| Foot ulcer history | 5.48 | 1.85 | 2.68 | 3.63 (3.29–3.97) | <0.001 | 2.80 (2.44–3.16) | <0.001 |
| Lower-limb amputation | 1.32 | 1.16 | 1.03 | 0.16 (−0.01 to 0.33) | 0.07 | 0.29 (0.11–0.47) | 0.002 |
| Foot deformities (≥3) | 31.47 | 16.35 | 25.59 | 15.12 (14.42–15.82) | <0.001 | 5.88 (5.18–6.58) | <0.001 |
| Neuropathy disability score (≥6) | 21.77 | 17.55 | 19.56 | 4.22 (3.59–4.85) | <0.001 | 2.21 (1.58–2.84) | <0.001 |
| Abnormal vibration sensation | 22.79 | 14.15 | 12.68 | 8.64 (8.02–9.26) | <0.001 | 10.11 (9.48–10.74) | <0.001 |
| Abnormal temperature sensation | 9.68 | 7.80 | 9.71 | 1.88 (1.42–2.34) | <0.001 | −0.03 (−0.50 to 0.44) | 0.90 |
| Abnormal pin-prick sensation | 16.97 | 19.10 | 16.99 | −2.13 (−2.72 to −1.54) | <0.001 | −0.02 (−0.61 to 0.57) | 0.94 |
| Abnormal ankle reflexes | 33.95 | 34.00 | 34.64 | −0.05 (−0.78 to 0.68) | 0.90 | −0.69 (−1.42 to 0.04) | 0.06 |
| Insensitivity to 10-g monofilament | 16.11 | 24.51 | 17.52 | −8.40 (−8.99 to −7.81) | <0.001 | −1.41 (−1.99 to −0.83) | <0.001 |
| Neuropathy symptom score (≥6) | 24.88 | 31.46 | 24.11 | −6.58 (−7.26 to −5.90) | <0.001 | 0.77 (0.10–1.44) | 0.025 |
| PAD (≤2 pedal pulses) | 21.13 | 10.44 | 19.82 | 10.69 (10.08–11.30) | <0.001 | 1.31 (0.69–1.93) | 0.003 |
| Peripheral arterial history | 2.94 | 1.30 | 1.81 | 1.64 (1.38–1.90) | <0.001 | 1.13 (0.86–1.40) | <0.001 |

Data are the rate per 100 person-years, as directly compared with the standard population (ages available for $n = 15,589$). AC, African Caribbean; SA, South Asian; WE, white European.

**Table 3—*Risk of foot ulcers in South Asians versus white Europeans and African Caribbeans versus white Europeans with adjustment for covariates***

| Asians versus Europeans | OR (95% CI) | *P* |
|---|---|---|
| Unadjusted | 0.29 (0.20–0.41) | <0.0001 |
| Adjustment for different duration of exposure to time-related variables | | |
| Age | 0.32 (0.22–0.46) | <0.0001 |
| Duration of diabetes | 0.32 (0.22–0.46) | <0.0001 |
| Models with age adjustment and univariate associations with other risk factors | | |
| Age + sex | 0.32 (0.22–0.46) | <0.0001 |
| Age + PAD | 0.38 (0.26–0.55) | <0.0001 |
| Age + abnormal vibration sensation | 0.36 (0.25–0.52) | <0.0001 |
| Age + abnormal temperature sensation | 0.32 (0.22–0.47) | <0.0001 |
| Age + abnormal neuropathy disability score | 0.34 (0.23–0.49) | <0.0001 |
| Age + foot deformities | 0.35 (0.24–0.51) | <0.0001 |
| Age + smoking history | 0.33 (0.23–0.48) | <0.0001 |
| Age + insulin use | 0.39 (0.26–0.56) | <0.0001 |
| Age + regular alcohol | 0.32 (0.22–0.47) | <0.0001 |
| Age + living alone | 0.33 (0.22–0.47) | <0.0001 |
| Multivariate models | | |
| Age + PAD + abnormal vibration sensation | 0.42 (0.29–0.62) | <0.0001 |
| Age + PAD + abnormal vibration sensation + foot deformities + insulin use | 0.52 (0.35–0.76) | <0.0001 |

| African Caribbeans versus Europeans | OR (95% CI) (male, female) | *P* (male, female) |
|---|---|---|
| Unadjusted (all) | 0.53 (0.29–0.97) | 0.040 |
| Unadjusted (sex stratified) | 0.60 (0.28–1.29), 0.44 (0.16–0.20) | 0.189, 0.111 |
| Adjustment for different duration of exposure to time-relate variables | | |
| Age | 0.60 (0.28–1.28), 0.47 (0.174–1.29) | 0.182, 0.142 |
| Duration of diabetes | 0.59 (0.28–1.27), 0.44 (0.16–1.19) | 0.178, 0.104 |
| Models with duration adjustment and univariate associations with other risk factors | | |
| Duration + PAD | 0.54 (0.25–1.16), 0.48 (0.18–1.32) | 0.114, 0.155 |
| Duration + abnormal vibration sensation | 0.71 (0.33–1.55), 0.49 (0.18–1.33) | 0.392, 0.160 |
| Duration + foot deformities | 0.61 (0.29–1.32), 0.44 (0.16–1.20) | 0.211, 0.110 |
| Duration + smoking history | 0.59 (0.28–1.27), 0.47 (0.17–1.29) | 0.177, 0.144 |
| Duration + insulin use | 0.60 (0.28–1.30), 0.45 (0.17–1.22) | 0.146, 0.116 |
| Duration + renal impairment | 0.62 (0.29–1.34), 0.44 (0.16–1.19) | 0.223, 0.105 |
| Duration + regular alcohol | 0.61 (0.28–1.30), 0.44 (0.16–1.19) | 0.199, 0.106 |
| Multivariate model | | |
| Duration + abnormal vibration sensation + PAD + smoking | —, 0.58 (0.21–1.59) | —, 0.288 |

ans, even after adjusting for age. Interestingly, although vibration (large Aβ fibers) and temperature (small Aδ/C fibers) sensation was better in Asians than Europeans, pin-prick sensation (small Aδ/C fibers), monofilament sensitivity (large Aβ fiber), and painful symptoms were somewhat worse in Asians. For African Caribbeans, abnormal vibration sensation was twofold less prevalent than Europeans, although other neuropathy differences were generally less pronounced. Thus, variations in neuropathy prevalence occur between the ethnic groups dependent on the nerve fiber type tested, for reasons, as yet, unknown.

Nevertheless, abnormal vibration perception had the highest impact on both the Asian and African-Caribbean reduced ulcer risk. This not only reconfirms the well-known causative link between abnormal vibration perception threshold and ulcer risk (25–27) but also highlights its importance in contributing to ulcer development compared with other neuropathy measures such as temperature, pin-prick, or pressure sensation (2,15,28).

The much lower level of PAD in Asian diabetic patients compared with Europeans confirms our previous finding in a study (29) of diabetes-related amputation and also studies elsewhere, in both the U.K. (15,30,31) and from the Indian subcontinent (23,32,33). The contribution of PAD in general to foot ulcers is also well documented (13,34), and so the contribution of lower PAD in our Asian subjects to their reduced ulcer rate, though small, appears valid. Our data support observations elsewhere in the U.K. that atherosclerotic PAD is generally less prevalent in Asians and African Caribbeans than in Europeans, despite the "classical" risk factors (i.e., abnormal lipid patterns) being as prevalent (2,15,35).

The reasons for the generally lower level of neuropathy and PAD in Asians is unclear, especially when established risks factors are considered. Hyperglycemia, for example, is consistently the strongest risk factor for both diabetic peripheral neuropathy (36,37) and PAD (38), yet glycemic control in Asians is, paradoxically, either similar to or worse than Europeans (31,39). Similarly, Asian lipid profiles are also worse than Europeans (2), yet dyslipidemia predicts incidence of diabetic PAD and neuropathy (38,40). Other risk factors for diabetic neuropathy in multivariate analyses include increasing age, height, male sex, type of diabetes, heart rate, smoking, alcohol intake, insulin resistance, BMI, and severity of microvascular disease (40–42); however, none is superseded by glycemic control. The low risk of neuropathy in South-Asian di-

abetic patients cannot obviously be explained by the main conventional risk factors thus far explored. We were constrained from measuring blood parameters or BMI in this study due to large population size; therefore, we were unable to perform a full risk factor assessment. While smoking rates and alcohol intake are substantially lower in the Asian group, their relative weakness as risk factors indicates that they cannot fully explain the low Asian rates of neuropathy. Speculatively, ethnic differences in neuropathy may also be partially attributable to genetics or circulating biochemical factors directly affecting nerve function or indirectly via vascular mechanisms; however, this deserves further investigation.

Our data indicate that the lower smoking rate in the Asian group has little, if any, effect on their low ulcer rate, whereas the effect of smoking is marginal in African-Caribbean women. Elsewhere (34,43,44), the evidence to support smoking as a risk factor for ulcers is mixed. Lower smoking levels in Asians with diabetes, however, is causative to their reduced lower-limb amputation rate (6), probably linked to the mainly vascular etiology of most amputations. Although high alcohol intake has been linked to foot ulcer risk (45,46), the relatively low alcohol consumption of our Asian population has had no effect on their ulcer rate here.

The marked contribution of foot deformities to the reduced Asian ulcer risk here supports conclusions by others that certain deformities (i.e., small muscle wasting, hammer or claw toes, prominent metatarsal heads, and Charcot arthropathy) are associated with increased plantar pressures and, subsequently, are precursors of foot ulceration (13,34,47–49). Our African Caribbeans also have fewer foot deformities than Europeans, complementing other U.S.- and U.K.-based studies' findings of better joint mobility and lower plantar pressures in this ethnic group (49,50). In contrast to the Asians, however, the African-Caribbean protection against foot ulcers is not linked to foot deformities.

The impact of lower insulin usage in the Asian group on reduced foot ulceration verifies the finding of insulin as a predictive risk factor for foot ulcers in diabetic veterans (34). This relationship may possibly reflect severity of metabolic disturbance, as concluded elsewhere when insulin use predicted high plantar foot pressures (47), neuropathy (42), and lower-limb amputation (14) in diabetes. However, as diabetes control is often worse in Asians (15,28), as discussed earlier, this effect appears unlikely.

In conclusion, we suggest that lower levels of PAD, neuropathy, foot deformities, and insulin use appear to be the main factors accounting for the threefold-reduced Asian diabetic foot ulcer risk compared with Europeans; however, these factors can account for only half of the Asian protection. Indeed, PAD and neuropathy, which are two major risk factors for ulcers (13,44,48,49,51), are relatively minor contributors to this protection.

African Caribbeans have a twofold-reduced ulcer risk compared with Europeans, yet, by contrast, there is a sex influence: the lower PAD, neuropathy, and smoking habits of African-Caribbean women play a small role in protection, whereas lower neuropathy levels in African-Caribbean men provide a greater benefit.

It will now be of value to determine *1*) why rates of neuropathy and PAD in Asians are so low, *2*) why neuropathy status is different between different ethnic groups, and *3*) the other, as yet, unknown risk factors that account for Asian and African-Caribbean reduced ulcer rates.

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