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ORIGINAL RESEARCH

Deficiencies in nutritional intake in patients admitted with diabetes-related foot complications

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Abstract

Aim: Adequate nutritional intake is an essential component for timely wound healing. The present research aimed to identify the frequency of inadequate dietary intake, including the specific nutritional elements most frequently lacking, in a group of patients admitted with diabetes-related foot complications.

Methods: Consecutive patients admitted to a diabetic foot unit underwent a dietary assessment, which included the retrospective collection of a seven-day food history for the period just prior to admission. The collected data were entered into FoodWorks, and comparisons were made with recommendations made by national guidelines.

Results: Thirty-five patients underwent nutritional assessment, 74% male and 26% having impaired renal function. Protein consumption was in excess of daily recommended intake, and although the overall fat intake as a percentage of total calories consumed was in keeping with national guidelines, the intake of saturated fat was inappropriately high. Of the 12 micronutrients assessed, niacin and vitamin C were appropriately consumed by all; average intake of potassium, phosphorus and thiamine approached recommended levels, while the intake of magnesium, calcium, zinc, riboflavin, folate and vitamin A all fell short of recommended daily requirements. No dietary differences were identified between individuals with normal and abnormal renal function, but deficiencies in calcium and iron were identified only in women.

Conclusion: Dietary deficiencies of macronutrients were not identified in individuals admitted with diabetes-related foot complications, but many patients were found to be consuming well below the daily recommended daily intake of one or more of the micronutrients deemed necessary for normal wound healing.

Key words: diabetes mellitus, food, foot disease, foot ulcer, nutrition.

INTRODUCTION

'Diabetes-related foot complications' is a generic term used to describe a group of pedal conditions, such as ulceration, cellulitis, wound infection, osteomyelitis, gangrene and Charcot joint, which have an increased prevalence in individuals with diabetes. The increased prevalence of foot complications in individuals with diabetes, and especially those with coexisting diabetic renal impairment, is caused by multiple factors but is mainly attributable to the presence of one or more of peripheral neuropathy, peripheral vascular disease, minor trauma and foot deformity.[1,2] These conditions are the leading cause of non-traumatic lower limb amputations and are responsible for more days of hospitalisation than any other diabetes-related complication.[3,4] There has been a growing realisation of the health and economic burden associated with this condition, and not surprisingly, a major research effort is being directed at determining the best management strategies for achieving timely and successful resolution of such complications.

In January 2005, a multidisciplinary diabetic foot unit (DFU)[5] was introduced to the Royal Melbourne Hospital (RMH). The fundamental philosophy of the DFU is to ensure that every patient undergoes a systematic examination and appropriate investigation and management for factors that either lead to the development of, or prevent the resolution of, the presenting condition. The approach aims to address the critical factors for wound healing, namely, to improve oxygenation, reduce pressure loading to the affected area, remove dead/non-viable tissue, manage infection and maximise glycaemic control. During the first 12 months following the establishment of the DFU, the average length of hospitalisation has decreased and total amputation rate has been reduced by 56%.

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Despite these impressive results, there is still potential for further improvements in clinical outcomes, especially with regard to the rate of wound healing and the percentage of patients achieving complete wound closure. It is known that adequate nutrition (protein, energy and specific vitamins and minerals) is important for the successful healing of pressure ulcers, amputation sites, skin grafts, lacerations and burns.[6–8] There are also data indicating that individuals with poor diets, those with chronic diseases, the elderly (especially those hospitalised), and individuals undergoing major amputations frequently have nutritional deficiencies.[9–12] In fact, studies have reported that 25–45% of hospitalised patients and 50% of general surgical patients have significant evidence of protein malnutrition.[13–16] Furthermore, there is a growing body of evidence to demonstrate the role of specific nutrients in wound healing.[17–19]

However, what is not clearly understood is the prevalence of nutritional deficiencies and which specific nutrients are subnormal in individuals who present with a diabetes-related foot complication. There have also been few studies investigating the possible role and extent to which nutritional deficiencies impact on wound healing in this particular population.[8,20,21] Therefore, as a first step towards better defining the role of nutrition in healing diabetes-related foot problems, we have studied the prevalence of nutritional deficiencies, as defined by dietary intake, in a clinical sample of this population. In particular, we aimed to determine which individuals are more likely to have inadequate dietary intakes and which nutritional elements are most frequently poorly consumed.

METHODS

Dietary intake assessments were completed on all patients at the time of their admission to the DFU. To be admitted to the DFU, patients required both a diagnosis of diabetes and the existence of a foot complication (pathological process below the level of the ankle) that necessitated inpatient care. A single dietitian, working as a member of the multidisciplinary DFU, performed all dietary assessments. All patients, except those unwilling to participate or unable to cooperate as a result of a coexisting medical condition (e.g. delirium, dementia or psychiatric condition), were included. Interpreters were used for patients who were unable to speak and/or comprehend English.

The dietary assessments involved the retrospective collection of a comprehensive seven-day food history for a period just prior to admission but excluding the period of acute illness. Patients were encouraged to detail their dietary intake, with extra information being elicited from family members and/or individuals preparing the meals. To improve data accuracy, extra information was obtained by the dietitian using a checklist specifically focusing on the intake of different food groups. All food groups were included in the checklist, as were cooking methods.

All dietary information was entered into FoodWorks, version 3.01.472 (Xyris software 2003 (Xyris Software, Highgate Hill, Qld, Australia), AusFoods version 5, AusNut version 16 databases), which calculated an estimated total daily intake of each specific nutritional component for each patient. On occasions when the specific food item consumed was not in the database, this item was substituted with the nearest available option. The FoodWorks program analysed the information with reference to the Australian Recommended Daily Intakes (RDIs) as specified by the National Health and Medical Research Council (NHMRC) guidelines.[22]

As the majority of the patients had underlying pedal sepsis, tissue necrosis and/or peripheral ischaemia, they were deemed to have elevated metabolic stress and thus a higher daily requirement for protein. Therefore, in order to enhance accuracy, an independent process was utilised to determine adequacy of total protein intake. Each individual had their ideal body weight (IBW) calculated (body mass index (BMI) 20–25 kg/m^2 if aged less than 65 years, and BMI 22–27 kg/m^2 if greater than 65 years of age) and was allocated a protein intake of 1–1.2 g of protein per kilogram of IBW. The upper level of this range was used as the RDI of protein, with which the individual's estimated intake was compared.

The results of the dietary assessments were analysed as the total group and according to two variables, gender and renal function. Each patient was categorised as either having normal renal function, with a glomerular filtration rate greater than 60 mL/minute/1.73 m^2, or renal impairment (which also included patients with renal failure requiring dialysis). The subanalysis according to renal function was undertaken because of the high prevalence of renal impairment expected in this population of patients and also because of reports in the literature which support higher amputation rates in individuals with diabetes, renal failure and foot complications.[23,24]

Statistical analysis was undertaken with Stata 3.0 (Stata Corporation, College State, TX, USA), with a *P*-value of <0.05 considered as statistically significant. Daily protein, fibre and kcal intake were calculated as a percentage of RDI, while median total fat intake was calculated as a percentage of daily total caloric intake. Micronutrient assessments were recorded as the percentage of individuals meeting their RDI. The Wilcoxson rank sum test was used to calculate *P*-values for continuous data (BMI, kcal, protein, fibre, fat and alcohol intake), while the Fischer's exact test was used in the analysis of the micronutrient data as these results were binary, in that patients either met or failed to meet RDIs. The study was approved by the Melbourne Health Human Research and Ethics Committee.

RESULTS

Thirty-five consecutive patients, admitted with a diabetes-related foot complication during the first six months of 2005, underwent a dietary assessment. The mean age was 65 years (range 22–87), with 74% being male. (Table 1) Diabetes-related renal impairment was present in 26% of the cohort. BMI was normal in 23% of patients, 54% were overweight, 14% were either obese or very obese, and 9% were underweight.[25] Interestingly, 61% of men were overweight compared with 33% of women ($P = 0.14$), and 8% of

Table 1 Nutritional assessment according to total cohort, gender and renal function

	Total cohort (*n* = 35)	*Men* (*n* = 26)	*Women* (*n* = 9)	*Normal renal function* (*n* = 26)	*Renal impairment/failure* (*n* = 9)
Age (years)					
Mean	65.5	67.2	60.3 ($P = 0.76$)	68	58 ($P = 0.13$)
Range	22–87	29–87	22–87	22–87	29–77
BMI (kg/m^2)					
Median	26.5	26.0	29.5 ($P = 0.19$)	26.6	24.2 ($P = 0.12$)
Range	15.9–41.2	17.9–34	15.9–41.2	18–41.2	15.9–29.6
kcal (% of RDI)					
Median	92	93	85 ($P = 0.44$)	86	100 ($P = 0.06$)
Range	49–178	60–137	49–178	60–137	80–178
Protein (% of RDI)					
Median	197	189	205 ($P = 0.98$)	189	226 ($P = 0.31$)
Range	74–236	75–236	74–192	75–173	74–236
Fibre intake (% of RDI)					
Median	114	114	109 ($P = 0.45$)	109	121 ($P = 0.97$)
Range	31–138	43–138	31–106	31–84	53–138
Fat intake (% of daily total kcal)					
Total	31.0	30.8	33.6 ($P = 0.75$)	31.5	33.4 ($P = 0.78$)
SFA	13.7	14.2	12.8 ($P = 0.003$)	13.6	15.6 ($P = 0.18$)
MUFA	11.9	11.9	12.7 ($P = 0.72$)	12.6	11.3 ($P = 0.01$)
PUFA	5.4	4.7	8.1 ($P = 0.002$)	5.3	6.5 ($P = 0.85$)
Alcohol intake (g/day)					
Median	0	0	0 ($P = 0.23$)	0	0 ($P = 0.26$)
Range	0–38	0–38	0–8	0–38	0–14.4
% individuals meeting RDI for					
Potassium	94.2	96.1	88.9 ($P = 0.45$)	92.3	100 ($P = 1.0$)
Magnesium	74.3	73.1	77.8 ($P = 1.0$)	69.2	88.9 ($P = 0.39$)
Calcium	77.1	92.3	33.3 ($P = 0.001$)	73.1	88.9 ($P = 0.65$)
Phosphorus	97.1	100	88.9 ($P = 0.26$)	96.1	100 ($P = 1.0$)
Zinc	60.0	69.2	33.3 ($P = 0.11$)	61.5	55.5 ($P = 1.0$)
Iron	91.4	100	66.7 ($P = 0.01$)	88.5	100 ($P = 0.55$)
Thiamine	97.1	100	88.9 ($P = 0.26$)	96.1	100 ($P = 1.0$)
Riboflavin	85.7	92.3	66.7 ($P = 0.09$)	84.6	88.9 ($P = 1.0$)
Niacin	100	100	100	100	100
Vitamin C	100	100	100	100	100
Folate	82.8	84.6	77.8 ($P = 0.63$)	88.5	66.6 ($P = 0.16$)
Vitamin A	62.8	61.5	66.7 ($P = 1.0$)	65.4	55.5 ($P = 0.42$)

BMI = body mass index; MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid; RDI = recommended daily intake; SFA = saturated fatty acid.

men were either obese or very obese as compared with 33% of women ($P = 0.06$). Furthermore, of those patients with renal impairment, 44% had a BMI greater than 30 kg/m^2 as compared with 77% of those with normal renal function ($P = 0.07$)

The estimated median caloric intake for the total cohort was 92% of the RDI, but there was a large spread in the range of calculated values (Table 1). The estimated median values for caloric intake did not vary with gender, but there was a trend to greater caloric intake in those patients with renal impairment as compared with the group with normal renal function (100% vs. 86% of RDI, respectively, $P = 0.06$).

Of the macronutrients, the estimated median protein consumption was in excess of RDI, median fibre consumption was comparable with RDI, and median total fat intake was appropriate (Table 1). The median protein intake was in excess of RDI despite appropriate corrections for acute illness. Protein and fibre intakes were not influenced by gender or presence of renal impairment. Although the estimated total fat intake as a percentage of total calories approximated NHMRC recommendations, the intake of the individual fat components did not (Table 1). Whereas saturated fatty acids (SFA) should make up less than 10% of the total energy intake, patients in the present study had an intake that was approximately 14%.[26] SFA intake was significantly lower in women compared with men (12.8% vs. 14.2% of total daily energy intake, respectively, $P = 0.003$). Furthermore, intake of polyunsaturated fatty acids was significantly greater in women compared with men (8.1% vs. 4.7% of daily total energy intake, respectively, $P = 0.002$), and monounsaturated fatty acid intake was significantly less in individuals with renal impairment as compared with those with normal renal function (11.3% vs. 12.6% of daily total energy intake, respectively, $P = 0.01$).

The median consumption of alcohol was well within the RDI.[27] However, an examination of the range for daily alcohol intake showed that, while all female patients fell within the RDI for alcohol consumption, some male patients were consuming more than recommended given their age and coexisting medical conditions (Table 1).

Of the 12 micronutrients studied, only niacin and vitamin C were assessed to be consumed by all patients in adequate amounts.[22] The estimated intake of potassium, phosphorus and thiamine approached recommended levels (Table 1). The remaining micronutrients, magnesium, calcium, zinc, riboflavin, folate and vitamin A all fell short of daily requirements. Approximately 17%, 26% and 37% of all individuals had deficient intake of folate, magnesium and vitamin A, respectively. Forty per cent of individuals had an inadequate daily intake of zinc, with twice as many women having an inadequate intake compared with men (69% vs. 33%, $P = 0.11$). Deficiencies in calcium and iron intake were peculiar to female patients, as was a trend for lower riboflavin intake. There were no statistical differences in the micronutrient intakes between individuals with normal and abnormal renal function.

DISCUSSION

Wound healing is a complex process which is further complicated in individuals with diabetes because of the coexistence of confounding complications (peripheral neuropathy, peripheral vascular disease and impaired immune response). Glycaemic control may also play a direct role in rates of wound healing, but there are limited published data supporting this concept. Given that global and even specific nutritional deficiencies have been shown to impair wound healing in various different population groups, we hypothesise that nutritional deficiencies may also play a role in healing time or ability in individuals with diabetes-related foot complications.[8,9,11]

The results of the present study clearly demonstrate that although most subjects met their RDIs for energy and protein intakes, there were major deficiencies in micronutrient intake and fat ratios. Furthermore, although no significant difference was found between the intake of individuals with normal and abnormal renal function, there was a significant difference in the dietary intake of iron and calcium identified between male and female subjects.

Fat is an energy-dense macronutrient that is both directly and indirectly involved in glycaemic control, atheroma formation, and when consumed in excess, will contribute to weight gain. The results of the present study suggest that, on a whole, the cohort was mildly overweight, which is supported by the fact that the overall fat intake was in the realm of the recommended 30% of total energy intake. However, the less-than-ideal ratio of saturated to unsaturated fats raises concern. Given that it is well recognised that individuals with diabetes have increased rates of cardiovascular disease, including peripheral vascular disease,[28] it is recommended that such individuals lower their fat intake, with emphasis on improving the fat balance, by increasing the intake of unsaturated fats while decreasing saturated fats. Even though women consumed significantly less saturated fat than men, both groups were well in excess of the recommended daily saturated fat consumption of 10% of total kcal. This imbalance is likely to contribute to abnormalities in lipid profiles and more prevalent atherosclerosis, which presents clinically as peripheral vascular disease and consequently impaired wound healing ability.

Adequate protein intake is essential for maintenance of muscle structure and turnover, and integrity of connective tissue, skin, hair and nails. It is generally recommended that healthy adults consume 15% of their total energy intake in the form of protein, but requirements are influenced by disease states, immune status, injury or insult. For example, less protein is required in states of chronic renal failure, while needs increase to almost twice RDI with severe sepsis or burns.[29,30] Even though we calculated for increased protein requirements resulting from sepsis and wound healing in our cohort of individuals, most subjects achieved their daily protein requirements. However, further assessment of the collected nutritional data demonstrated that the foods in which the protein was consumed were not the same for all subgroups. Even though this does not impact on the findings for daily intake of protein for the studied individuals, it does provide tantalising evidence on why specific micronutrients were deficient in certain groups.

Men were more likely than women to consume protein in the form of red meat as opposed to white meat (chicken, fish and pork). In fact, 73% of men consumed the recommended 3–4 serves of red meat per week as compared with 33% of women.[22] This variation in the type of meat consumed does not influence daily protein consumption, but it becomes significant when viewed from the perspective that red meat contains twice as much iron as white meats. Hence, the significant difference in daily consumption of iron between men and women is likely to be directly influenced by the types of meats consumed by the two genders. In comparison with meat-based sources of protein, consumption of plant-based sources of protein (nuts and legumes) was very low in all the subgroups studied.

The second major dietary difference documented between the genders was calcium intake. Given that dairy foods are a major source of dietary calcium, it was surprising to find that only one-third of women consumed the recommended three serves of dairy per day as compared with 73% of men.[22] Although the difference in dairy intake is likely to be the major cause of the significant difference in calcium intake between men and women, it should also be noted that no female individual was documented to consume dried fruits, another source of dietary calcium, as compared with approximately 20% of men.

Of the remaining micronutrients studied, zinc and vitamin A intakes were universally poor in all subgroups, riboflavin consumption was relatively low in women, and folate was relatively poor in all groups. This combination of micronutrient deficiencies likely relates to the poor intake of dairy products (zinc, riboflavin, vitamin A) and nuts (zinc) in women, but also suggests poor intake of yellow and green leafy vegetables (vitamin A, folate, riboflavin).

This prospective study has provided us with essential information regarding the nutritional intake of patients presenting with diabetes-related foot complications. However, we acknowledge that the present study has several limitations. First, the dietary histories were collected retrospectively and for only a seven-day period. As the present study was specifically addressing the area of nutrition in patients who developed a diabetes-related foot complication, and who subsequently required admission, it was necessary to study the dietary intake retrospectively, for the period of complication development and deterioration. Even though the recall period was for only seven days, the accuracy of the dietary histories was increased by patients being encouraged to provide fortnightly and monthly dietary trends, as well as the dietitian using a checklist to ensure that all dietary groups were being considered. A second limitation of the study was the inability of the FoodWorks program to account for special nutritional requirements, such as those that exist during periods of sepsis and acute illness. Although we attempted to account for this with regard to protein, it is likely that the FoodWorks program underestimated other dietary requirements, as we would expect individual requirements to increase as a result of acute wounds, tissue necrosis and sepsis.

In summary, the dietary histories revealed no evidence to suggest the presence of major macronutrient deficiencies; however, the results clearly demonstrate that there is a continuing need for education of patients regarding the ideal make-up of fat intake, to assist in lowering the prevalence of cardiovascular disease in this population. The study also suggests that many of the patients were consuming well below the RDI of one or more of the micronutrients that have been identified as being essential for wound healing. Of the micronutrients studied, vitamin A, zinc, magnesium and folate were poorly consumed by all individuals, while low intakes of calcium, riboflavin and iron were specific problems of female patients. There were no nutritional intake differences noted between individuals with normal and those with abnormal renal function. These findings raise two important questions. First, do the micronutrient intake findings translate into true serum deficiencies, and second, would there be any effect on wound healing rates if these micronutrient deficiencies were corrected? We plan to address these two pertinent questions in future studies.

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