



RESEARCH PAPER

Does maternal knowledge and parent education affect blood phenylalanine control in phenylketonuria?

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Abstract

Background Metabolic control in phenylketonuria (PKU) may be influenced by parental ability because dietary treatment involves complex food choices. This is an observational study to compare maternal carer (MC) knowledge and parental education with phenylalanine concentrations in children with PKU.

Methods Children ($n = 46$; 26 boys) aged 1–10 years (median age 6 years) on dietary treatment were recruited. Their median lifetime and median phenylalanine concentrations in the year prior to study were estimated. MC completed a questionnaire to assess dietary knowledge.

Results Overall maternal knowledge on most aspects of diet was good and there was a correlation between annual median blood phenylalanine concentrations, but at the age of 5–6 years of age only, and higher maternal carer scores on PKU knowledge ($r = -0.646$; $P < 0.0001$). Three of only four children (12%) with median phenylalanine concentrations above $500 \mu\text{mol L}^{-1}$ in the year prior to study had both parents leave school without educational qualifications. Children who had median phenylalanine concentrations ($n = 3$; 7%) over the recommended ranges at 3 years of age or earlier continued to have poor control.

Conclusions Blood phenylalanine control within the first 3 years of age, poor parental educational achievement at school level, and unsatisfactory maternal dietary knowledge may all influence longer-term blood phenylalanine control in children.

Conflict of interests, source of funding and authorship

The authors declare that they have no conflict of interest.

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AM conceived and designed the study; analysed and interpreted data; and drafted the paper. PD performed statistical analysis of data and critically reviewed the content of the paper. AD, VH, SKH, CH and AC critically reviewed the content of paper. All authors approved the final version submitted for publication.

Introduction

The quality of blood phenylalanine control in phenylketonuria (PKU) is influenced by the quantity and periodicity of prescribed protein substitute administered, the amount of natural protein eaten, and the adequacy of energy intake from a wide range of low phenylalanine foods (MacDonald *et al.*, 1996). In children, all of this is dependent on parental ability and discipline to continually apply and supervise this specialist dietary regimen. This in turn is likely to be influenced by the parents' understanding of the low phenylalanine diet, motivation, organizational skills, family cohesion, social support, and overall coping ability.

In PKU clinics, there is usually no formal documented system or structure for defining parent education needs, updating knowledge, or for monitoring education programmes and their effects. Parental understanding of diet therapy and its application has been rarely studied. In many chronic conditions, adherence to treatment regimens declines over time and the documented increase in blood phenylalanine concentrations with age demonstrates that PKU is no exception (Walter *et al.*, 2002). Poor dietary control is often associated with increasing noncompliance by older children, but it could also be due to a more relaxed dietary approach by parents and increasing dietary errors.

Consequently, it is possible that deteriorating dietary control in children with PKU may be

associated with poor carer knowledge of diet, decreasing motivation, inability to cope with the diet or a combination of all three factors. The aims of this cross-sectional, observational study in children with PKU were to compare maternal knowledge and carer/parental education with the effectiveness of blood phenylalanine control in a group of 1 to 10-year-old children with PKU.

Materials and methods**Subjects**

All children with PKU ($n = 46$), aged 1–10 years (median age 6 years), and living within the West Midlands and attending Birmingham Children's Hospital, were recruited. There were 26 boys and 20 girls. All were white Caucasian children ($n = 45$) with the exception of one child of Pakistani origin. There were three inclusion criteria: (i) children with PKU aged 1–10 years on dietary treatment; (ii) parental consent and child assent (age and understanding appropriate); and (iii) children living within the West Midlands boundary. There were two exclusion criteria: (i) children with PKU less than 1 year or over 10 years of age and (ii) children with mild PKU not on dietary treatment.

The local ethics committee approved the study. Informed consent was obtained from the parents and assent from all competent children.

Methodology

The same dietitian visited each maternal carer at home on one occasion. Their children followed a strict low phenylalanine diet comprising: (i) a dietary phenylalanine allocation using a 50-mg phenylalanine exchange system (50 mg = 1 g protein); (ii) a phenylalanine-free protein substitute; and (iii) low phenylalanine foods (e.g. most fruits, many vegetables and special low protein products) or so-called 'free' foods permitted in unlimited quantities. The maternal carer's ability was assessed to: (i) calculate phenylalanine (1 g protein) exchanges estimated from protein analysis on food labels and (ii) estimate the number of phenylalanine exchanges from premeasured food

portions by eye. Questionnaires were used to gain information on demographic and educational background, and to review maternal knowledge of PKU. The median lifetime plasma phenylalanine of children was estimated.

Demographic background

The maternal carer completed a questionnaire on demographic background. This included information on ethnic origin, parental age, level of education, and employment status, type of housing (house owner/rented accommodation), household income, and number of siblings.

Maternal knowledge

A multiple-choice questionnaire was used to assess maternal knowledge of diet. Maternal knowledge was assessed because, in all cases, the main parental carer was the mother. The maternal carer completed this in the presence of the same researcher. Questions (using a list of predetermined potential answers) included defining 'what is PKU', identifying the effects of inadequate dietary treatment, defining a phenylalanine exchange, identifying weights of common phenylalanine exchanges, defining a 'free' food in PKU, naming brands of free sweets, explaining the function of protein substitute and how it should be administered, and identifying recommended reference ranges for blood phenylalanine concentrations.

Assessment of ability to calculate weights of food equivalent to one phenylalanine exchange from food labels

The researcher also assessed the maternal ability to calculate phenylalanine exchanges from protein analysis from food packaging labels. The maternal carer was asked to calculate the amount of food required to provide one phenylalanine exchange (50 mg of phenylalanine) based on the protein content given on the nutritional analysis table of food labels, from five different manufactured foods.

Estimating 50-mg phenylalanine exchanges by eye

Five common food items containing varying numbers of preweighed 50-mg phenylalanine exchanges were presented to maternal carers in

individual containers (phenylalanine exchanges were: Rice Krispies = two exchanges; chips = three exchanges; mashed potato = one exchange; sweet corn = two exchanges; and baked beans = three exchanges). They had to identify by eye only the number of 50-mg phenylalanine exchanges in each container. Maternal carers also identified how often they weighed 50-mg phenylalanine exchanges in practice.

Blood phenylalanine control

A retrospective analysis of each subject's median lifetime blood phenylalanine levels (excluding diagnostic phenylalanine levels) was conducted. In addition, the median plasma phenylalanine in the year prior to study was estimated for each subject.

Statistical analysis

The Wilcoxon signed rank test was used to examine changes in plasma phenylalanine control over time. Pearson's correlations were used to examine the relationship between blood phenylalanine concentrations, maternal knowledge scores, maternal ability to measure phenylalanine exchanges and demographic factors.

Results

Demographic background

Demographic factors such as maternal and paternal age, family size, parental employment, or household income did not affect median lifetime phenylalanine levels or blood phenylalanine control in the year prior to study (Table 1). Thirteen per cent ($n = 6$) of maternal carers and 15% ($n = 7$) of fathers left school with no formal educational qualifications. In three families, both parents left school without any formal educational qualifications.

Maternal knowledge of diet and PKU

Maternal knowledge of PKU was good and the median percentage correct answers from the multiple choice questionnaire were 70% (range 32–93%) (Table 2). Only two carers scored less

Table 1 Demographic background of the subjects' households

	Number	%
Demographic background		
Single parents	3	7
Paternal employment		
Full time	39	85
Unemployed	4	9
n/a	3	7
Maternal employment		
Maternal: working full-time	4	9
Maternal: working >26 h to > full-time	1	2
Maternal: working <26 h per week	22	48
Maternal: working full-time	19	41
Houseowners		
Yes	37	80
No	9	20
Annual income below UK national average for 2003–2004 (UK national statistics web site)		
Annual income > national average	29	63
Number of children in household		
1	9	20
2	17	37
3	16	35
4	2	4
5	2	4

n/a, not applicable.

than 50% correct answers. Maternal knowledge did not deteriorate with increasing age of the child. The majority of maternal carers (over 75%) could correctly define the term PKU, understood what was meant by a 'phenylalanine exchange', define recommended ranges for blood phenylalanine in PKU, and identify suitable low phenylalanine sweets. Between 50% and 75% of maternal carers could correctly define what phenylalanine and tyrosine were, knew the approximate protein equivalent of one 50-mg phenylalanine exchange, could explain what factors increased and decreased blood phenylalanine concentrations, and knew why protein substitute should be taken in equal, regular dosages throughout the day.

Less than half the maternal carers could identify the weight of a 50-mg phenylalanine exchange for four common exchange foods, and correctly identify the 'e' number for Aspartame (E951), an artificial sweetener that is a source of phenylalanine. Although 70% of maternal carers said they weighed their phenylalanine exchanges 50% or more of the time, the percentage of weighed phenylalanine ex-

Table 2 Maternal knowledge of phenylketonuria (PKU)

Questions on PKU	Number of correct answers (n = 46)	Percent correct answers
1 What is PKU?	38	83
2 What is missing in PKU?	35.5	77
3 What is an enzyme?	31.5	68
4 What is phenylalanine?	25	54
5 What happens if your child eats too much phenylalanine?	29	63
6 What is tyrosine?	31	67
7 What is an exchange?	40.5	88
8 How much protein is there in one exchange?	34	74
9 Why are some children/people with PKU allowed more exchanges than others are?	42	91
10 What should blood phenylalanine levels be?	45.5	99
11 What should the blood phenylalanine be of a person without PKU?	27.5	60
12 What makes blood phenylalanine levels go high?	32.5	71
13 What makes blood phenylalanine levels go too low?	33.5	73
14 Give the weight of one phenylalanine exchange for each of the following foods?	19.5	42
15 Which are free sweets?	35.5	77
16 What is the definition of a free sweet?	38.5	84
17 What is the definition of a free sauce?	5	11
18 What is a free food?	34.5	75
19 Why is aspartame not allowed?	42	91
20 If a food label states a food is 4.5 g/100 g protein. How much of that food can give for one exchange?	15	33
21 Why should protein substitute be given in at least three equal dosages throughout the day?	33	72
22 What is the E number for aspartame?	22.5	49

changes declines with the increasing age of the child ($r = -0.3185$; $P < 0.05$) (Fig. 1).

Assessment of maternal ability to calculate the weight of food equivalent to one phenylalanine exchange from food labels and by eye

Only 30% ($n = 13/43$) of maternal carers could accurately estimate the weight of food that would provide one phenylalanine exchange (1 g

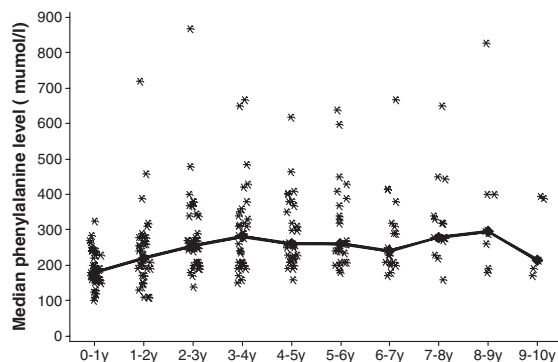


Figure 1 Lifetime median phenylalanine concentrations of group and individuals.

Table 3 Identifying the weight of a 50-mg phenylalanine exchange (equivalent to 1 g protein) using protein analysis from food labels

Number of manufactured food labels	Number of maternal correct answers (<i>n</i> = 43)	Percent correct answers
No foods	12	28
1 Manufactured food	2	5
2 Manufactured food	4	9
3 Manufactured food	3	7
4 Manufactured food	9	21
5 Manufactured food	13	30

of protein) from protein analysis from food labels (Table 3) from all the five food labels presented. There was no noteworthy correlation with ability to calculate weights of 50-mg phenylalanine exchanges (1 g of protein) from

the protein analysis on food labels with the level of maternal education, median lifetime blood phenylalanine concentrations and median blood phenylalanine concentrations in the year prior to study.

None of the maternal carers correctly identified by eye the number of 50-mg phenylalanine exchanges in all the preweighed food containers (Table 4). Only 36% (*n* = 16/44) were able to correctly recognize the correct number of 50-mg phenylalanine exchanges in three or more of the premeasured food portions (*n* = 5) presented.

Blood phenylalanine control

This group of subjects had good blood phenylalanine control (Fig. 1) and only 12% (*n* = 5) of subjects had an annual median plasma phenylalanine above their age related reference range (MRC Guidelines, 1993) in the year prior to study. Seven percent (*n* = 3) had a median lifetime phenylalanine concentration above their age-related reference range; and all these children had median phenylalanine concentrations over recommended ranges from 3 years of age or earlier. There was only a small (median 35 µmol L⁻¹) but significant rise in median blood phenylalanine in the year prior to the study compared with lifetime phenylalanine concentrations (*P* = 0.001). There was also a small but significant increase in median blood phenylalanine concentrations in the second year (by 25 µmol L⁻¹; *P* = 0.014) and third year of

Table 4 Maternal carer/parent estimation of phenylalanine exchanges by eye

Food	Number of 50-mg phe exchanges in each container	Number of maternal correct answers	%	Number of under-estimations of phe exchanges	%	Number of over-estimations of phe exchanges	%
Rice Krispies (<i>n</i> = 42)	2	17	41	12	29	13	31
Chips (<i>n</i> = 44)	3	14	32	22	50	8	18
Mashed potato (<i>n</i> = 44)	1	26	59	6	14	12	27
Sweet corn (<i>n</i> = 44)	2	17	39	7	16	20	46
Baked beans (<i>n</i> = 44)	3	18	41	14	32	12	27

life (by $45 \mu\text{mol L}^{-1}$; $P = 0.005$) compared to baseline values (age 0–1 year).

Correlations with maternal knowledge of PKU, parental education and blood phenylalanine control

Children whose maternal carers scored higher on the maternal questionnaire had better annual blood phenylalanine levels, although this did not quite reach statistical significance ($r = -0.278$, $P = 0.062$). Specifically, in children aged 5–6 years ($n = 26$), there was a negative correlation ($r = -0.647$; $P < 0.0001$) between the percentage of maternal correct answers and change in median blood phenylalanine concentrations after the age of 0–1 year, but this appeared to be strongly influenced by two mothers who scored less than 50% (Fig. 2). There was no correlation with any other age groups.

In the year prior to study, three of only four children with median blood phenylalanine concentrations above $500 \mu\text{mol L}^{-1}$ had both parents leave school without any educational qualification. By contrast, in all but one subject with median blood phenylalanine levels below $500 \mu\text{mol L}^{-1}$, there was at least one parent who attained some type of educational qualification. However, there was no correlation between the final level of educational attainment achieved of either or both parents combined and the median blood phenylalanine level in the year prior to study.

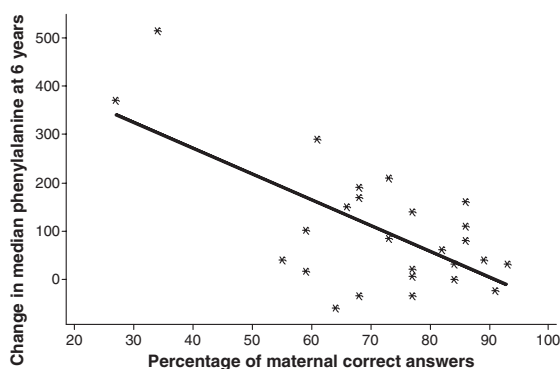


Figure 2 Correlation between median change in blood phenylalanine control between 0–1 year and 6 years of age and maternal knowledge of phenylketonuria.

Discussion

Identifying specific factors that influence dietary adherence (measured by plasma phenylalanine concentrations) is essential in supporting the family in more effective home management. Overall, this was a group of children who mainly achieved blood phenylalanine control within reference ranges, the majority of their maternal carers had adequate knowledge about diet and PKU, and one or both parents achieved educational qualifications. Children's blood phenylalanine concentrations were less well controlled if both parents left school without any educational achievements, if maternal carers scored less than 50% on diet and PKU knowledge testing, or if blood phenylalanine control was lost in the first 3 years of life.

Although other factors are likely to be involved, maternal knowledge of PKU and lack of parental educational achievement appear to be important in overall blood phenylalanine control. In the present study, those children aged 5–6 years with maternal carers who had more understanding of PKU particularly had better phenylalanine control. Also children's blood phenylalanine concentrations appeared to be less well controlled if both their parents left school without any educational qualifications, although the majority of children had median blood phenylalanine concentrations within recommended reference ranges. Demographic factors such as household income, parental age and family size had no bearing on overall control.

It could be argued that, although knowledge is necessary, it is not sufficient to bring about dietary improvement (Mackner *et al.*, 2001). Indeed, in patients with end-stage renal failure, dietary knowledge has been associated with worse compliance (Katz *et al.*, 1998). However, Fehrenbach & Peterson (1989) showed that parents of children who were more compliant with their children's treatments had higher quality verbal and written problem solving solutions to hypothetical diet-related dilemmas. Also, Bekhof *et al.* (2003) demonstrated in PKU that higher parental knowledge was associated with lower blood phenylalanine concentrations. Furthermore, Russell

et al. (1988) demonstrated that maternal carers with a high school education were more likely to adhere to dietary treatment in children with PKU.

Changing behaviour and attitude in any population is a difficult task; thus, it was reassuring that median annual blood phenylalanine concentrations in patients with well controlled PKU only slightly deteriorated with age, although small increases in blood phenylalanine between the aged of 1–3 years were observed. All of our families with PKU had been well supported by the Regional PKU team, maintained weekly to twice monthly contact with the dietitian, and all parents received an in-depth teaching programme in the first 12 months post-diagnosis. However, it appeared from this group of children that, if blood phenylalanine control was poor in the early years, it was irrecoverable in many cases. It was certainly difficult to try and motivate some carers because they believed they had a well child, and appeared to disregard any risk associated with nonadherence. Children with PKU do not experience obvious immediate symptoms with high blood phenylalanine concentrations, although some may report feeling tired, experience poor behaviour and lack concentration (Ievers-Landis *et al.*, 2005).

Weighing of phenylalanine exchanges became less common with increasing age. Generally, this study group of mothers had poor knowledge of the 50-mg phenylalanine exchange system and yet the vast majority of children still achieved excellent blood phenylalanine control. Many maternal carers had little knowledge of common food exchange weights, could not calculate the quantity of food that could be eaten to yield a specific quantity of protein from food analysis labels, and could not identify the protein content of premeasured portion sizes by eye. Maternal carers explained their lack of knowledge as being due to the fact their children ate the same type of foods from day to day, so they had no need to examine food labels or consider incorporating a wider range of foods into the diet. Many children ate repetitive, simple meals and maternal carers provided mealtimes using familiar foods, and admitted that they no longer had to think about shopping or menu planning.

Although this group of carers had received a comprehensive teaching programme in the early years, new strategies are required for the small sub-section of families who have the least knowledge of PKU and limited educational qualifications. A variety of approaches rather than any one type of teaching method is more likely to be effective. Any teaching programme must consider individual differences in capacity to process information and it should be supportive and inclusive of extended family members who commonly have an invaluable role to play in diet therapy. More practical training with tasks such as planning appropriate menus, food shopping, measuring ingredients and cooking low protein dishes (Waisbren *et al.*, 1997) may give carers confidence in their own ability to adhere to the treatment regimen. Others measures may include providing models of positive behaviour through working alongside other carers or even older patients with PKU (Sherman *et al.*, 2000).

The present study has several limitations. Only small numbers of subjects were studied but it did have a 100% participation rate, and all the patients had been taught by the same dietitian in the same systemized way. Carer motivation and ability to cope were not assessed. The data were also collected by the family dietitian. However, all the data were objective, collected in the same standardized manner and no help was given in completing the knowledge questionnaires or calculating the phenylalanine exchanges.

Inadequate maternal carer knowledge about diet and PKU and poor parental school educational achievement by both parents influenced the overall control of blood phenylalanine concentrations in PKU. The present study also indicated that, if blood phenylalanine control is consistently above target ranges in the first 3 years of age, recovery from this position is unlikely and so the initial education programme is of paramount importance. The early identification of any barriers to dietary intervention should accompany any intensive educational programme, so that the provision of realistic and acceptable solutions for family carers can be implemented.

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