

Poor numeracy skills are associated with glycaemic control in Type 1 diabetes

S. Marden, P. W. Thomas^{*}, Z. A. Sheppard^{*}, J. Knott, J. Lueddeke[†] and D. Kerr.

Bournemouth Diabetes and Endocrine Centre, Royal Bournemouth Hospital NHS

Foundation Trust, Bournemouth, ^{*}Dorset Research and Development Support Unit,

School of Health and Social Care, Bournemouth University, Bournemouth and

[†]Brockenhurst College, Brockenhurst, UK.

Correspondence to:

Name Sarah Marden

Post Diabetes Dietitian

Address Bournemouth Diabetes and Endocrine Centre
Royal Bournemouth Hospital NHS Foundation Trust
Bournemouth, United Kingdom BH7 7DW

Phone 01202 704929

Email sarah.marden@nhs.net

Abstract

Aims

To assess the numeracy and literacy skills of individuals with Type 1 diabetes and determine if there was a relationship with achieved glycaemic control independent of socio-economic factors.

Methods

112 patients (mean age 43.8+/-12.5 years, 47% male, mean duration of diabetes 22.0+/-13.2 years) attending Bournemouth Diabetes and Endocrine Centre were randomly selected from the Centre's diabetes register and invited to participate in the study. The Skills for Life Initial Assessments were used to measure numeracy and literacy. These indicate skills levels up to Level 2, equivalent to the national General Certificate of Secondary Education grades A*-C. HbA_{1c} was also measured. Pearson's correlation was used to measure the correlation of numeracy and literacy scores with HbA_{1c}. T-tests were used to compare mean HbA_{1c} between those with or without Level 2 skills and multiple linear regression was used to investigate whether any differences were independent of demographic and socio-economic factors.

Results

Literacy was not associated with achieved HbA_{1c}. In contrast, participants with numeracy skills at Level 2 or above achieved a HbA_{1c} lower than those with numeracy skills below Level 2 (p=0.03). Although higher socio-economic status was associated with lower mean HbA_{1c}, the relationship between numeracy and HbA_{1c} appeared to be independent of socio-economic factors.

Conclusion

Low numeracy skills were adversely associated with diabetes control. Assessment of numeracy skills may be relevant to the structure of diabetes education programmes.

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Keywords

Numeracy, literacy, education, HbA_{1c}, Type 1 diabetes

Abbreviations

NICE, National Institute for Health and Clinical Excellence; T1DM, Type 1 diabetes mellitus; SES, socio-economic status; HbA_{1c}, glycated haemoglobin; GCSE, General Certificate of Secondary Education; NVQ, National Vocational Qualification; PASW, Predictive Analytic Soft Ware.

Introduction

In the UK, the National Institute for Health and Clinical Excellence (NICE) recommends that all individuals with Type 1 diabetes (T1DM) should be invited to participate in quality-assured, structured group education [1] to be trained in the nuances of carbohydrate counting and insulin dose adjustment [2]. A fundamental component of these programmes requires skill with handling numbers to allow individuals to be confident and accurate in determining their insulin doses according to the carbohydrate content of food. Numeracy is the ability to understand and use numbers in daily life and having appropriate numeracy skills is important for health in general and specifically for diabetes care [3]. Difficulty in reading, writing and listening will impact on the ability to learn about diabetes and understand and manage the treatment. Previously we have reported that information provided for patients with diabetes often had suboptimal readability, requiring literacy skills well above the UK average for adults [4].

The UK has high numbers of adults with low levels of literacy and numeracy compared with other developed countries [5]. In a 2008 House of Commons Public Accounts Committee report (page 5), the UK government stated “*that large numbers of the adult population of England remain functionally illiterate and innumerate*” [6]. In the United States, almost 2 in 3 adults cannot perform the most rudimentary of quantitative skills and numeracy may be an overlooked factor contributing to racial disparities in glycaemic control [7].

The aims of this study were to assess numeracy and literacy skills based on the UK Adult Core Curriculum in a sample of individuals with T1DM and determine if there

was a relationship with achieved glycaemic control. A further aim was to determine whether any associations were independent of socio-economic status (SES).

Methods

After obtaining approval from the local Research Ethics Committee, a list of all patients with T1DM aged 18-65 years attending the Bournemouth Diabetes and Endocrine Centre was obtained from the Centre's computerised clinical information system (Diabeta 3) and randomly sorted using the random number generator in Excel. Starting from the top of the list, patients were sent an information leaflet containing details of the study followed up by a telephone call enquiring whether they had received and understood the information sent. Any additional questions or concerns were discussed. Patients agreeing to participate were invited to attend group sessions or individual appointments during the day or evening.

Recruitment continued until 112 numeracy and literacy assessments had been completed. A sample size of 112 was chosen so that the study would have 90% power, at the 2-sided 5% significance level, to detect a weak correlation of 0.3 between numeracy or literacy levels and achieved HbA_{1c} levels [8]. Figure 1 shows the patient selection pathway. The characteristics of the study sample were compared with an audit of the general T1DM population attending the Bournemouth Diabetes and Endocrine Centre to help assess whether any selection bias had been introduced by the recruitment process.

Figure 1

Assessments

The Literacy Initial Assessment and the Numeracy Initial Assessment are part of a range of resources to assess adult learners for the UK Skills for Life Programme [9]. Questions focus on everyday subjects and are not about diabetes per se. For example, the literacy assessment questions involved listening for detail, using correct basic grammar and spelling, identifying main points and obtaining specific information from text. For numeracy, questions involved understanding measures, performing calculations, extracting and interpreting information from lists, bar charts and diagrams as well as handling data. In total there were 40 questions for literacy and 25 for numeracy.

These assessments are designed to indicate approximate skill level up to, and including Level 2. Level 2 is equivalent to the General Certificate of Secondary Education (GCSE) grades A*-C or National Vocational Qualification (NVQ) Level 2. These are national qualifications required to progress into further education or skilled work. Level 1 equates to lower GCSE grades and Entry 1 to 3 corresponds to skills below those expected of 11 year olds on the national curriculum framework [10]. Table 1 shows where the Adult Skills for Life Literacy and Numeracy Levels relate to the National Curriculum and National Qualifications Frameworks for England, Wales and Northern Ireland.

Table 1

HbA_{1c} levels were collected from routine clinic visits providing these were within three months of undertaking the assessments; otherwise additional HbA_{1c} tests were taken. Whether they had attended structured education for T1DM was also recorded. Socio-economic information including the participants' age on leaving full

time education and postcode was collected from which the neighbourhood deprivation rank was obtained [11]. In England each postcode area has a total deprivation rank according to the level of deprivation, and for the purpose of this study, the ranks of the 32,482 neighbourhoods in England [11] were divided into three categories, the most deprived third, medium third and least deprived third.

Statistical analysis

Data were analysed using Predictive Analytic Soft Ware (PASW) Version 18. For significance tests a 2-sided 5% level was used. Total numeracy and literacy scores for each participant were derived by adding up the number of correct responses. Pearson's correlation coefficient was used to investigate the correlation between the total numeracy and literacy scores and HbA_{1c}. Literacy and numeracy scores were routinely categorised [9] into Entry 1 to 3 (numeracy score of 18 or less, literacy score of 28 or less), Level 1 (numeracy score between 19 and 22, literacy score between 29 and 36) and Level 2 (numeracy score of 23 or more, literacy score of 37 or more).

For some of the analyses, numeracy and literacy skills were categorised into participants with Level 2 skills and participants with skills below this level (i.e. Entry 1 - 3 and Level 1 were combined). This division enabled comparative analyses between participants with skills broadly equivalent to GCSE grade A*-C and those below this level. GCSE grade A*-C is not only regarded as a benchmark for UK government targets for educational achievement [12] but numeracy skills at Level 2 are also required to understand and implement the glucose management strategies taught in diabetes education.

Percentages were calculated for categorical variables and measures of location and spread for continuous variables. Chi-squared tests were used to test associations between the dichotomous categories of numeracy and literacy and sex of the participant, and t-tests were used for comparing mean HbA_{1c} between dichotomous numeracy and literacy levels. Multiple linear regression was used to further investigate if any associations between HbA_{1c} and numeracy or literacy levels were independent of diabetes education, sex, age and SES (measured by age leaving full time education and neighbourhood deprivation). To do this, a staged approach was taken using the dichotomous levels for numeracy and literacy whereby, for example numeracy, model 1 included only numeracy skill level; model 2 also added literacy skill level and model 3 further adjusted for diabetes education. Model 4 additionally controlled for demographic factors (sex and age of the participant). Model 5 controlled for a measure of individual SES (age leaving full time education) and model 6 controlled for a measure of neighbourhood SES (categorised deprivation rank). The proportion of the variance explained was used to examine the influence of adding in each set of variables. The final parsimonious model included only the statistically significant variables.

Results

Of 650 randomly selected patients, 112 (17.2%) completed the assessments (Figure 1). The descriptive characteristics of the study sample (mean age 43.8 \pm 12.5 years, 47% male, mean duration of diabetes 22.0 \pm 13.2 years) were similar to the background population of 1112 patients with T1DM (mean age 41.6 \pm 12.2 years, 54% male, mean duration of diabetes 20.7 \pm 12.4 years). The mean HbA_{1c} of the study sample was 8.7 \pm 1.5% (72 \pm 17mmol/mol) and was comparable to the mean

HbA_{1c} of the background population at 8.7+/-1.7% (71+/-18mmol/mol) from 684 patients with recorded HbA_{1c}.

Figures 2 and 3 show that of the 112 patients with T1DM who participated in the numeracy and literacy assessments, 75% had literacy skills below Level 2 and 47% had numeracy skills below Level 2. This reveals a high proportion of participants with low level literacy and numeracy skills in the study sample, when adopting Level 2 (broadly equivalent to a GCSE grade A*-C) as the benchmark. National data for England suggest the situation is much worse than indicated in this study sample for numeracy skills with only 25% adults at Level 2 or above [13].

Figures 2 and 3

Pearson's correlation coefficient of HbA_{1c} with total numeracy and literacy scores was -0.17 (95% CI: -0.35, 0.02; p=0.07) and -0.08 (95%CI; -0.26, 0.11; p=0.41) respectively. Mean HbA_{1c} in those with numeracy skills of Level 2 or above was 8.4+/-1.2% (68+/-13mmol/mol) compared with 9.2+/-1.7% (77+/-18mmol/mol) for those with numeracy skills less than Level 2 (p=0.004). However, literacy skills were not associated with glycaemia. Mean HbA_{1c} in those with literacy skills of Level 2 or above was 8.6+/-1.3% (70+/-15mmol/mol) compared with 8.8+/-1.6% (73+/-17mmol/mol) for those with literacy skills less than Level 2 (p=0.56).

The numeracy assessment identified common difficulties using decimals, recognising and understanding fractions, using percentages, selecting relevant information from charts, converting units of measure as well as handling and comparing data. The literacy assessment also revealed that participants had difficulties with using correct grammar, spelling and punctuation along with listening and responding to spoken

information and inferring meaning from text. These difficulties were identified as study participants had more incorrect responses to questions on these skills compared to the other questions in the assessment. For example, in the numeracy assessment, there are five questions set at Entry 3. The study sample scored an average of 94% correct responses to these questions. One question requiring finding an equivalent fraction had only 87% correct responses. For example, in the literacy assessment there are eight questions set at Entry 3. The study sample scored an average of 93% correct responses to these questions. One of these questions caused difficulty with only 75% of the study sample responding correctly which required writing the correct verb tense into a sentence.

HbA_{1c} in those with numeracy at Level 2 or above, after adjusting for demographic and socio-economic factors, remained statistically significant (Table 2). The percentage of variance in HbA_{1c} explained by the unadjusted model increased from 6% to 17% when adjusting for demographic and socio-economic variables.

Table 2

The final parsimonious model with only the statistically significant variables included numeracy level, age, and age leaving full time education and explained 18% of the variance in the data (Table 3). Participants with numeracy skills at Level 2 or above achieved a HbA_{1c} lower than those with lower numeracy skills ($p=0.03$). However, the models indicated that age was inversely associated with HbA_{1c}, as age increased the glycaemic control improved. The final parsimonious model also indicated that people leaving school after 18 years of age had HbA_{1c} lower than those leaving at 16 years.

Discussion

This study revealed a high proportion of participants with low level literacy and crucially poor numeracy skills as the latter appeared to negatively influence glycaemic control. Three-quarters of participants had literacy skills below the level of a good pass at GCSE and almost half had numeracy skills below this level.

Participants who demonstrated numeracy skills at Level 2 achieved a HbA_{1c} lower than those below Level 2 ($p=0.03$). It is recognised that a low level of literacy can make it difficult to function effectively in adult life, but it is often assumed that numeracy (i.e. being able to deal competently with numbers, tables and graphs) is less important than literacy [14]. However, this may not be appropriate for people living with T1DM.

Age was inversely associated with HbA_{1c} and further investigation to identify potential reasons behind this association is needed. Perhaps education is relevant with different teaching methods employed in schools with older participants learning the times tables and relying more on mental arithmetic rather than calculators. These skills may influence self management of diabetes. Another potential explanation could involve sample selection in that those with poorly controlled diabetes may be more likely to be ill, or die at a younger age, and unable to take part in the study.

Poor numeracy has been shown to have an economic, social and psychological impact including depression, low self esteem and the feeling of a lack in control over people's lives [14]. In employment, research has indicated that numeracy, even

more than literacy, has a powerful effect on earnings [5]. Our investigation suggests that the relationship between numeracy and HbA_{1c} was independent of socio-economic factors. However, age of leaving education had a significant association with HbA_{1c}; those participants leaving school after age 18 years had, on average, better glycaemic control compared to those leaving school at a younger age, again illustrating the importance of education. People with poor numeracy tended to leave full-time education at the earliest opportunity and usually without qualifications [15].

These findings are relevant to structured education programmes for T1DM. The aim of these programmes is for individuals to learn self management skills involving the assessment of the carbohydrate content of their food and making adjustments in insulin doses in relation to glycaemia. The required skills include being able to work up to and at Level 2 numeracy to understand and apply fractions, percentages, ratios and proportions as well as being able to handle data along with interpreting and calculating nutrients from food labels.

Educators need to examine the structure of education programmes and develop teaching strategies for individuals with poor numeracy skills to self manage their condition. They will need to investigate how teaching numeracy can be embedded into these programmes giving the potential of improved glycaemic control and health benefits. Identification and assessment of numeracy skills can maximise the learning potential of education programmes. A simple start would be asking an individual if they have achieved a qualification in mathematics then assessing the numeracy level they are currently working at when identifying their learning needs for diabetes

management. However, four times as many people were shown to have poor skills as those who acknowledged difficulties [16].

The numeracy initial assessment used in this study is designed to indicate approximate skill levels of an individual, up to and including Level 2. This assessment should be administered by a trained practitioner and is relatively short and quick. It helps to place individuals in education programmes at the right level. This approach may prove to be appropriate for individuals who need to enhance their skills and improve their confidence with numeracy. However, 6.8 million adults (21% population) in England lack basic Entry 3 numeracy, the level recognised by the government for functional competence for everyday living [5]. The numerical complexities of diabetes management are beyond their grasp and a significant proportion of patients may continue to have poor diabetes control because of a failure to appreciate the problem of poor numeracy in the adult population.

Several limitations of the study should be noted. Despite the study sample seeming similar to the local population with T1DM with regards to age, sex, duration of diabetes and HbA_{1c}, the study sample may not be truly representative. Only 17% of people randomly selected from the patient register completed the numeracy and literacy assessments. The number of patients with low numeracy skills may be underestimated as 53% of the study sample had numeracy skills at Level 2 or above – a much greater proportion than suggested in national data where only 25% of adults have these skills [13]. Participants chose to attend the Diabetes and Endocrine Centre to undertake the assessments but patients lacking in confidence with numeracy and literacy may have declined to participate in the study.

Socio-economic barriers may also have prevented participation. The sample is from an area of relatively high SES and difficulty with transport, child care and work commitments were given as reasons for patients declining to take part. Given that numeracy has a powerful effect on earnings [5] participants with lower income and perhaps lower numeracy skills may be less likely to take time to participate. Future investigation should consider reimbursement for time and transport costs.

Although the current study included measures of both individual and neighbourhood level SES, household level data were not, so there is a need to collect such information in the future. More detailed socio-economic profiling is also necessary at the individual level including information on educational achievement, and occupational groups in line with the National Statistics Socio-economic Classification system [17]. Other measures of neighbourhood deprivation could also be investigated rather than the overall neighbourhood ranking. In particular, access to healthy food and physical activity facilities may play an important role as well as other potential mediating factors such as smoking. Therefore, although SES was found to be associated with HbA_{1c}, further investigation is needed to uncover whether it could also be an underlying factor behind the association between numeracy and glycaemic control. Future research should also include a detailed diagnostic assessment to identify individual strengths and weaknesses and to highlight any skills gaps appropriate for the management of diabetes.

Summary

This investigation reveals a high proportion of participants with low level literacy and numeracy skills. Although literacy was not significantly associated with glycaemic control, poor numeracy skills adversely and significantly influenced HbA_{1c}.

Participants with numeracy skills at Level 2 or above achieved a HbA_{1c} lower than those below this standard ($p = 0.03$).

Although SES was important, the relationship between numeracy and HbA_{1c} was independent of socio-economic factors. The assessment of numeracy skills of specific patient groups may be relevant to the structure of education programmes in many areas of chronic disease management. Further investigation is necessary to verify findings and to determine the true association between numeracy and achieved HbA_{1c}.

Word count 2936

Declaration of Competing Interests

Nothing to declare

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Table 1 How adult Skills for Life literacy and numeracy levels relate to the National Curriculum and National Qualifications Frameworks for England, Wales and Northern Ireland.

Adult Skills for Life literacy and numeracy level	Age in National Curriculum Framework	Examples of qualifications within National Qualifications Framework
Entry 1	6 years	
Entry 2	7 years	
Entry 3	8-10 years	
Level 1	11-13 years	General Certificate of Secondary Education (GCSE) grade D–G or National Vocational Qualification (NVQ) Level 1 to progress in skilled work
Level 2	14-16 years	GCSE grade A*–C or NVQ Level 2 to progress in education or skilled work
	16-18 years	A levels or International Baccalaureate to gain entry to university

Source: Adapted (with permission) from the national qualifications framework in the Adult Numeracy core curriculum. Basic Skills Agency, Department for Education and Skills 2001 [10].

Table 2 Summary of the model building process with adjusted unstandardised coefficients from the linear regression of HbA_{1c} (% and mmol/mol) in study sample of patients with Type 1 diabetes attending Bournemouth Diabetes and Endocrine Centre, 2008-9.

Variables with categories	% study sample	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Numeracy skill level							
< Level 2 § (RC)	47%	-	-	-	-	-	-
≥ Level 2 §§	53%	-0.80** -8.79**	-0.83** -9.06**	-0.83** -9.09**	-0.84** -9.22**	-0.68* -7.42*	-0.66* -7.24*
Literacy skill level							
< Level 2 § (RC)	75%		-	-	-	-	-
≥ Level 2 §§	25%		0.10 1.03	0.10 1.09	0.17 1.81	0.41 4.44	0.49 5.35
Attended structured diabetes education							
No (RC)	52%			-	-	-	-
Yes	48%			0.06 0.60	-0.03 -0.28	-0.03 -0.34	-0.00 0.01
Demographic factors							
Female (RC)	53%				-	-	-
Male	47%				-0.23 -2.49	-0.13 -1.44	-0.11 -1.17
Age (years)	Mean=43.79 SD=12.51				-0.04** -0.39**	-0.04** -0.41**	-0.04** -0.44**
Age left education							
16 years (RC)	34%					-	-
18 years	18%					0.23 2.48	0.12 1.28

Post 18 years	48%						-0.70* -7.61*	-0.83* -9.07*
Neighbourhood deprivation category‡								
Most deprived (RC)	15%							-
Medium	42%							-0.40 -4.34
Least deprived	43%							0.03 0.35
Adjusted R²		0.06	0.06	0.05	0.13	0.17	0.17	

Model 1 included numeracy skill level only; model 2 additionally adjusted for literacy skill level; model 3 further added diabetes education, model 4 additionally controlled for demographic factors (sex and age); model 5 also controlled for age left education; model 6 finally added in categorised neighbourhood deprivation ranking.

RC = reference category

§ Less than GCSE grade A*-C (i.e. Entry 1 to 3 and Level 1)

§§ Level 2 is broadly equivalent to GCSE grades A*-C

‡ Derived from Indices of Multiple Deprivation (IMD) [11]

*p < 0.05

** p < 0.01

The first coefficient presented is for HbA_{1c} in % and the second is for HbA_{1c} in mmol/mol

Table 3 Adjusted unstandardised coefficients from the final parsimonious linear regression model of HbA_{1c} (% and mmol/mol) in study sample of patients with Type 1 diabetes attending Bournemouth Diabetes and Endocrine Centre, 2008-9.

Variables with categories	Unstandardised coefficient	95% confidence interval lower bound for unstandardised coefficient	95% confidence interval upper bound for unstandardised coefficient	p-value
Numeracy skill level				
< Level 2 § (RC)	-	-	-	-
≥ Level 2 §§	-0.63 -6.83	-1.18 -12.86	-0.07 -0.79	0.03
Demographic factors				
Age (years)	-0.04 -0.40	-0.06 -0.63	-0.02 -0.17	0.001
Age left education¶				
16 years (RC)	-	-	-	-
18 years	-0.25 2.76	-0.51 -5.62	1.02 11.15	0.52
Post 18 years	-0.60 -6.57	-1.23 -13.39	0.02 0.24	0.06
Adjusted R²	0.18			

Final parsimonious model included significant variables only.

¶ p=0.04 (using the F-test) for entering this variable into the model

RC = reference category

§ Less than GCSE grade A*-C (i.e. Entry 1 to 3 and Level 1)

§§ Level 2 is broadly equivalent to GCSE grades A*-C

The first coefficient presented is for HbA_{1c} in % and the second is for HbA_{1c} in mmol/mol

Figure 1The patient selection pathway.

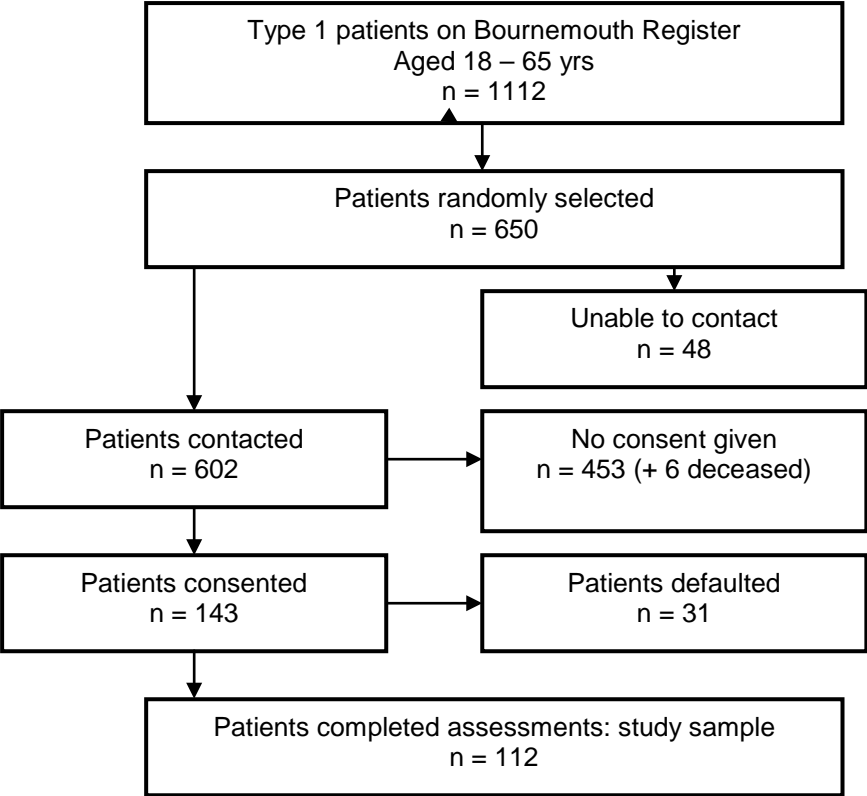
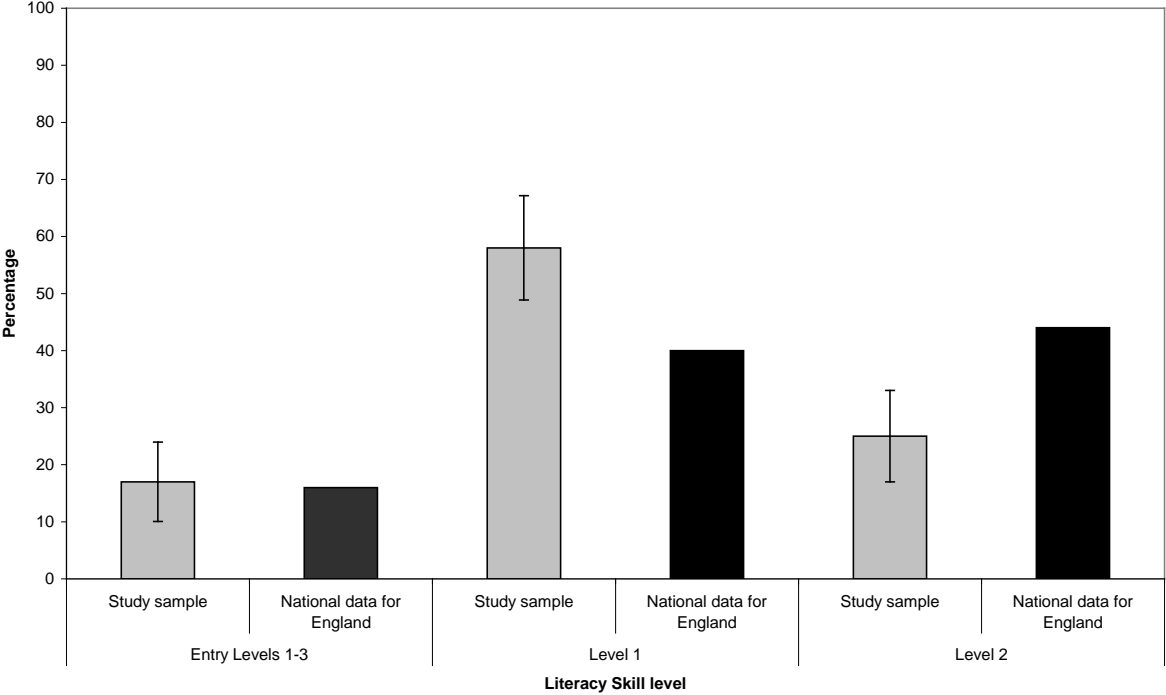


Figure 2 Literacy skill level with 95% confidence intervals of patients with Type I diabetes in study sample attending Bournemouth Diabetes and Endocrine Centre 2008-9 compared with national data for England.



National data is from Skills for Life Survey [13]

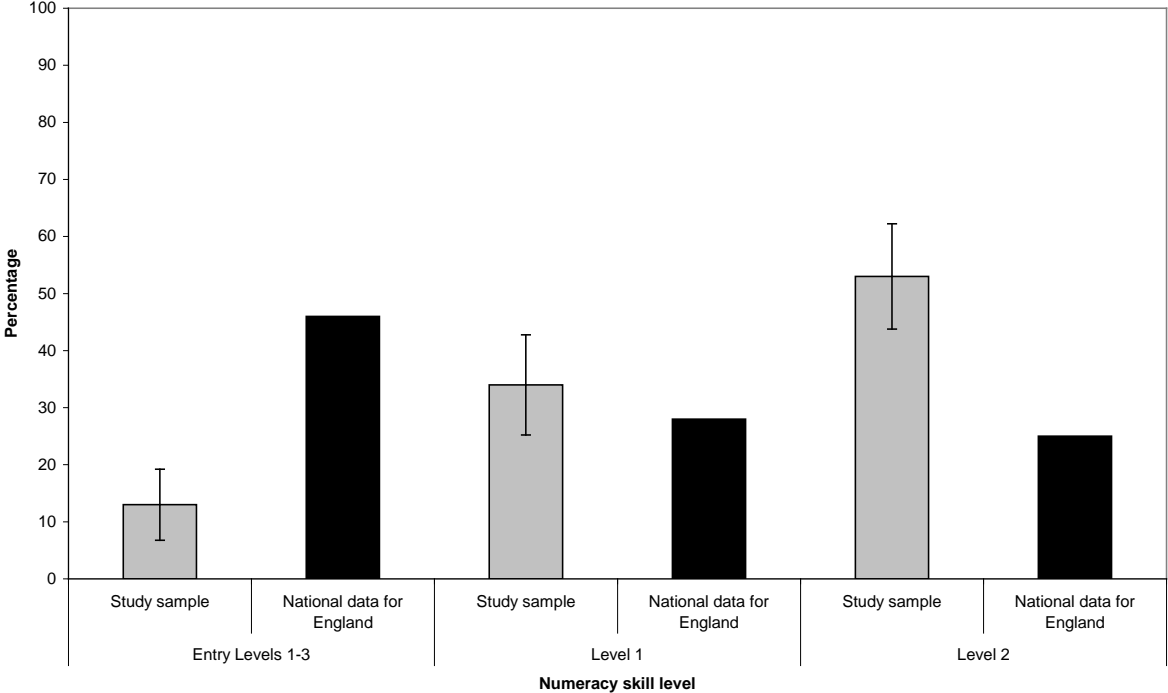
Entry levels (E1-3) equate to skills below those expected of 11 year olds on national curriculum framework

Level 1 is broadly equivalent to GCSE grades D-G

Level 2 is broadly equivalent to GCSE grades A*-C

Note: The adult basic skills tests used in the Skills for Life national survey did not include the assessment of listening skills

Figure 3 Numeracy skill level with 95% confidence intervals of patients with Type I diabetes in study sample attending Bournemouth Diabetes and Endocrine Centre 2008-9 compared with national data for England.



National data is from Skills for Life Survey [13]

Entry levels (E1-3) equate to skills below those expected of 11 year olds on national curriculum framework

Level 1 is broadly equivalent to GCSE grades D-G

Level 2 is broadly equivalent to GCSE grades A*-C

Note: Percentages do not add up to 100% due to rounding.