# Socioeconomic deprivation is associated with reduced efficacy of an insulin adjustment education program for people with type 1 diabetes

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RESEARCH ARTICLE

# Socioeconomic deprivation is associated with reduced efficacy of an insulin adjustment education program for people with type 1 diabetes

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## Abstract

**Background:** The Dose Adjustment for Normal Eating (DAFNE) course teaches insulin dose adjustment to match dietary carbohydrates and improve glycaemic control in participants with type 1 diabetes mellitus (T1DM). We investigated the association between socioeconomic deprivation and reduction in HbA1c as a marker of sustained glycaemic control, after attending DAFNE education.

**Methods:** This retrospective observational study identified adults with T1DM who attended DAFNE training in NHS Lothian, South East Scotland. We extracted age, sex, postcode-based Scottish Index of Multiple Deprivation (SIMD) quintiles and annual HbA1c measurements available four years before and after course attendance. We calculated mean HbA1c before (baseline) and after attendance at DAFNE, across four annual measurements. Change in mean HbA1c (mmol/mol) was categorised into three groups: decrease ($\geq -2.5$), no change ($<\pm 2.5$), increase ($\geq +2.5$). We used multivariable ordinal logistic regression, with baseline mean HbA1c as a covariate, to investigate the association of SIMD quintile with reduction in mean HbA1c.

**Results:** 335 participants were included. Age and sex distribution were similar across SIMD quintiles (Mean age = 45, range 21–91, 59% women). Lower SIMD quintiles (greater deprivation) had higher baseline mean HbA1c (SIMD 1: 76.0, SIMD 5: 69.0). Higher SIMD quintiles (lower deprivation) were associated with lower odds of no change/increase in mean HbA1c (SIMD 5, odds ratio = 0.25, 95% confidence interval 0.10, 0.58, $p = 0.001$, multivariable analysis).

**Conclusion:** Socioeconomic deprivation was associated with higher baseline mean HbA1c and lower reduction in HbA1c following DAFNE education. Future research could explore causes and how best to support participants from deprived areas.

**Previous submissions:** This work has not been previously submitted to a journal.

Callum W.D. Innes and David E. Henshall are joint first authors

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**KEYWORDS**

diabetes mellitus, diabetes mellitus type 1, diet, glycated hemoglobin A, glycemic control, socioeconomic factors, DAFNE

## 1 | INTRODUCTION

Type 1 diabetes mellitus (T1DM) develops due to autoimmune destruction of insulin-producing pancreatic beta cells leading to insulin deficiency and marked hyperglycaemia requiring lifelong insulin replacement.[1] Approximately 1 in 20 people in Scotland have diabetes mellitus, with type 1 diabetes mellitus (T1DM) accounting for 10% of these diagnoses.[2]

The cornerstones of diabetes management are to reduce blood glucose to near physiological levels while limiting the risk of hypoglycaemic episodes. Tight glycaemic control minimises risk of both microvascular (retinopathy, neuropathy and nephropathy) and macrovascular (stroke and myocardial infarction) complications.[1] Achieving optimum glucose control relies on participant involvement in management; however, the associated practical aspects, such as counting carbohydrates and adjusting insulin doses can be challenging and reduce motivation to self-manage.[3]

In 1983, a team from Dusseldorf, Germany developed the Dose Adjustment For Normal Eating (DAFNE) course,[4] an intensive five consecutive day course which teaches small groups of participants on carbohydrate counting, insulin adjustments and their awareness and management of hypoglycaemia, with the aim of improving glycaemic control through increased participant confidence in self-management. A key message is that with appropriate insulin adjustment, people with T1DM do not need additional dietary restrictions compared to those without diabetes. Attendance at DAFNE courses is associated with improved glycaemic control (lower Hb1Ac) as well as psychological benefits.[3,5]

In Scotland, geographic areas are divided into five quintiles of deprivation that are postcode-searchable using the Scottish Index of Multiple Deprivation (SIMD) tool.[6] Whether socioeconomic background influences DAFNE outcomes has not yet been investigated.

The aim of this study was to investigate the association between socioeconomic deprivation, and reduction in HbA1c after attendance at the DAFNE course.

**Novelty Statement**

**What is already known?**

- Participants with higher HbA1c experience larger reduction in HbA1c after DAFNE. Deprivation is associated with higher HbA1c.

**What this study has found?**

- Greater socioeconomic deprivation is associated with reduced efficacy of DAFNE.

**What are the implications?**

- Future research should explore causes for this disparity and how best to support participants from deprived areas in managing their diabetic control.

## 2 | METHODS

### 2.1 | Study design and setting

This is a retrospective observational study of DAFNE attendees in South East Scotland. In NHS Lothian, DAFNE is delivered at three established centres to a predominantly white British population. This study includes two of these hospitals: the Western General Hospital and St John's Hospital—an urban and district general hospital, respectively.

Participants with T1DM voluntarily attended DAFNE following specialist referral. To be eligible, participants must meet all of the following criteria: established diagnosis of T1DM; age ≥ 18 years; availability to attend a 5 day course; motivation; willingness to inject/test >4 times daily; need for flexibility; numeracy skills; basal bolus insulin regimen; and the absence of end stage complications.

### 2.2 | Participants

We included all participants aged 18 years or above, meeting measurement criteria who completed a 5-day

DAFNE course between 2006 and 2017, at NHS Lothian. We excluded participants with missing demographic or HbA1c measurement data in their electronic health record.

## 2.3 | Clinical outcome

The primary outcome was the reduction in mean HbA1c as an index of improved glycaemic control, following attendance at DAFNE education. Mean HbA1c was calculated for each individual from HbA1c measurements taken at approximately yearly intervals up to 4 years before and after course attendance. Four annual measurements were used in preference to a single measurement, to assess evidence of sustained changes in glycaemic control.

A secondary outcome was commencement of an insulin pump (continuous subcutaneous insulin infusion) after attending DAFNE.

## 2.4 | Variable selection

Participants and their clinical information were identified using Scottish Care Information (SCI) Diabetes,[7] and the local electronic health record. Information was extracted on participant demographics (age, sex and postcode of address) and diabetic management (age at diagnosis, HbA1c, current insulin regimen and use and start date of insulin pump where applicable). SIMD quintiles (SIMD 1 being most deprived) were generated for individual participants from the postcode of home address at time of DAFNE attendance using the Scottish government website.[6]

## 2.5 | Statistical analysis

We summarised key characteristics of participants in SIMD quintiles in tables.

We assessed the normality of distribution of continuous variables (age and baseline mean HbA1c) using the visual inspection of histograms and the Shapiro–Wilk test. In our primary analysis, we performed an ordinal logistic regression to investigate the association of explanatory variables (age, sex, baseline mean HbA1c, SIMD) with change in mean HbA1c.

The explanatory variables, age and baseline mean HbA1c, were subdivided into groups of similar sizes to produce categorical variables. We decided to include baseline mean HbA1c in our analyses because of its expected, and observed, large association with reduction in mean HbA1c and its non-uniform distribution across SIMD quintile groups. Other explanatory variables of interest included sex and SIMD quintile. Explanatory variables were selected for multivariable ordinal logistic regression models based on their effects on model odds ratios and Akaike information criterion (AIC). Potential models were also compared using the likelihood ratio test for maximum likelihood estimation method.

The dependent variable of interest (change in mean HbA1c) was categorised into 3 groups: decrease ($\geq -2.5$ mmol/mol), no change ($< \pm 2.5$ mmol/mol) and increase ($\geq +2.5$ mmol/mol) to enable logistic regression analyses. We selected the value of 2.5 mmol/mol to its compatibility with existing published data for the reduction in mean HbA1c following attendance at other DAFNE centres.[5,8–11]

In secondary analyses, we assessed for change in mean HbA1c across all participants using paired two tailed t test. We performed two sensitivity analyses: (1) to assess robustness of findings to excluded individuals, we repeated our ordinal logistic regression inclusive of all participants with at least one HbA1c measurement from before and after DAFNE attendance, and (2) to assess robustness of findings to the regression method, we performed linear regression with the same explanatory variables with change in mean HbA1c.

We used Cox proportional-hazards to test for differences between SIMD quintiles in the time to commencement of insulin pump after attending DANFE.

All analyses were performed using R version 4.1.2, using the following packages for statistical analysis: tidyverse, finalfit, broom and dplyr.

Results are reported in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) checklist.[6]

# 3 | RESULTS

## 3.1 | Participant demographics

Four hundred seventy-one participants attended and completed a five-day DAFNE course. Of these, 136 participants were excluded due to incomplete/inadequate data in their electronic health record leaving 335 participants for inclusion (Table 1). Participants with missing data did not appear to differ from those with complete data (Table S1).

The mean age at the time of study (early 2018) was 45 years old. More women attended than men (59% versus 41%). There were fewer participants in SIMD 1 (most deprived) than other quintiles.

Mean age at diagnosis with T1DM was 22 years old. Mean HbA1c levels prior to attending DAFNE were usually above recommended targets for diabetic control (mean 72 mmol/mol (8.7%), 321 participants (96%) above

**TABLE 1** Characteristics of 335 people with T1DM in Southeast Scotland who attended a DAFNE course between 2006 and 2017

| | Overall | Scottish Index of Multiple Deprivation (SIMD) Quintile | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| | | Most deprived | | | | Least deprived |
| Included participants | 335 (100%) | 36 (11%) | 67 (20%) | 60 (18%) | 80 (24%) | 92 (27%) |
| DAFNE site attended | | | | | | |
| St John's Hospital | 245 (73%) | 27 (11%) | 57 (23%) | 44 (18%) | 58 (24%) | 59 (24%) |
| Western General Hospital | 90 (26%) | 9 (10%) | 10 (11%) | 16 (18%) | 22 (24%) | 33 (37%) |
| Demographics | | | | | | |
| Current age (range) | 45 (21–91) | 42 (22–71) | 44 (21–91) | 45 (24–70) | 47 (21–74) | 47 (23–76) |
| Sex | | | | | | |
| Men | 139 (41%) | 17 (12%) | 25 (18%) | 29 (21%) | 31 (22%) | 37 (27%) |
| Women | 196 (59%) | 19 (9.7%) | 42 (21%) | 31 (16%) | 49 (25%) | 55 (28%) |
| Diabetes details | | | | | | |
| Age at diagnosis (range) | 22 (0–65) | 20 (3–52) | 21 (0–65) | 22 (4–55) | 23 (1–60) | 23 (2–59) |
| Baseline mean HbA1c in mmol/mol (range) | 72 (40–120) | 76 (47–110) | 74 (51–116) | 72 (45–98) | 70 (43–120) | 69 (40–107) |
| Baseline mean HbA1c in NGSP % units (range) | 8.7% (5.8–13.1%) | 9.1% (6.4–12.2%) | 8.9% (6.8–12.8%) | 8.8% (6.3–11.1%) | 8.6% (6.0–13.1%) | 8.5% (5.8–11.9%) |
| Insulin regime | | | | | | |
| Pump | 3 (0.8%) | 0 | 0 | 0 | 2 (67%) | 1 (33%) |
| Basal-bolus | 332 (99%) | 36 (11%) | 67 (20%) | 60 (18%) | 78 (23%) | 91 (27%) |

*Note*. Variables listed as mean with range, or number with percentages. SIMD quintile 1 is most deprived, quintile 5 is least deprived. Mean baseline HbA1c calculated from 4 annual measurements prior to DAFNE attendance. Pump = continuous subcutaneous insulin infusion.

current recommended target <48 mmol/mol (6.5%)).[12] 1% of participants used a pump (continuous subcutaneous insulin infusion) for insulin administration prior to attending DAFNE.

## 3.2 | Reduction in mean HbA1c following DAFNE

Across the groups, there was a reduction in the mean HbA1c after attending a DAFNE course, (mean difference 2.5 mmol/mol (0.2% in percentage units), 95% confidence interval (c.i.)1.1, 3.8, $p < 0.001$, df = 334, $t = 3.6$, paired two tailed t test).

This reduction was consistent with a step change with sustained improvement in mean HbA1c from 4 years before (73 mmol/mol (8.8%), 72 (8.7%), 72 (8.7%), 71 (8.6%)) to 4 years after (69 mmol/mol [8.5%] for each of the subsequent years).

Baseline mean HbA1c was higher in lower SIMD quintiles (greater deprivation) (Table 1, Figure 1; Figures S1 and S2). Reduction in mean HbA1c was more apparent in higher SIMD quintiles (lower deprivation) following DAFNE (Tables 2 and 3), with mean reduction of 5.0 mmol/mol (0.5% in percentage units) in SIMD 5 (lowest deprivation). Mean HbA1c increased by 2.5 mmol/mol (0.3% in percentage units) in SIMD 1 and 0.5 mmol/mol (0% in percentage units) in SIMD 2. The standard deviation and glycaemic variability of HbA1c measurements were similar for SIMD quintiles before and after attending DAFNE.

## 3.3 | Socioeconomic deprivation was associated with lower reduction in mean HbA1c

On multivariable analysis SIMD quintile was associated with reduction in mean HbA1c (Table 4).

SIMD 5 (least deprivation) was associated with one quarter the odds of no change/increase in mean HbA1c as compared to SIMD 1 (most deprivation) (odds ratio = 0.25, 95% c.i. 0.10, 0.58, $p = 0.001$).

Higher baseline mean HbA1c was associated with reduction in mean HbA1c, with approximately one tenth the odds of no change/increase in the 80–120 group as compared to the 40–60 group (odd ratio = 0.12, 95% c.i. 0.05, 0.24, $p < 0.001$).

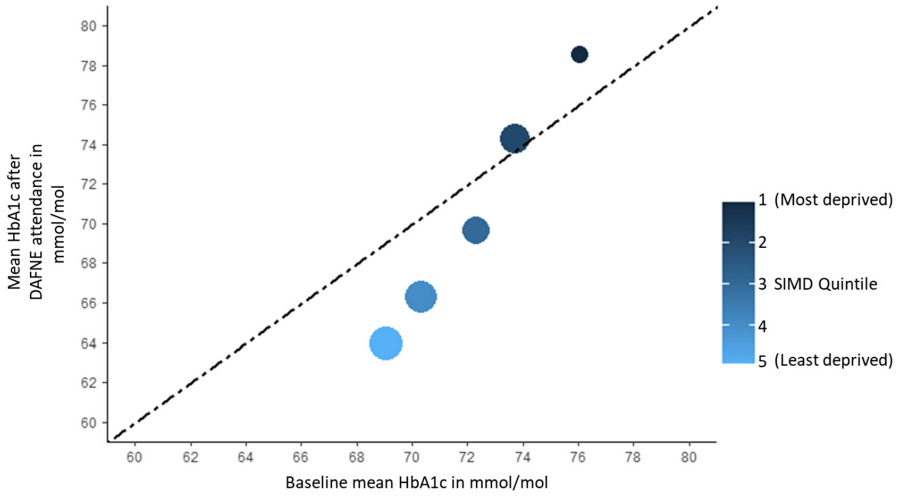



**FIGURE 1** Bubble plot of mean HbA1c of 335 people with T1DM before (baseline) and after DAFNE attendance for each SIMD quintile. Bubble plot of mean values for mean HbA1c before (x axis) and after attendance (y axis) at DAFNE course as calculated from four annual measurements in mmol/mol. Dotted reference line provided for no change in mean HbA1c. SIMD quintile 5 (least deprived) light blue, SIMD quintile 1 (most deprived) dark blue. Size of bubbles reflects number of participants in group, ranging from 36 (SIMD quintile 1) to 92 (SIMD quintile 5).

**TABLE 2** Patient characteristics and association with socioeconomic deprivation

| | Scottish Index of Multiple Deprivation (SIMD) Quintile | | | | |
|---|---|---|---|---|---|
| | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) |
| Variable | Most deprived | | | | Least deprived |
| Age | | | | | |
| 20–29 | 10 (28) | 13 (19) | 10 (17) | 9 (11) | 11 (12) |
| 30–39 | 6 (17) | 15 (22) | 10 (17) | 11 (14) | 15 (16) |
| 40–49 | 10 (28) | 17 (25) | 15 (25) | 25 (31) | 26 (28) |
| 50–59 | 4 (11) | 12 (18) | 19 (32) | 22 (28) | 22 (24) |
| >60 | 6 (17) | 10 (15) | 6 (10) | 13 (16) | 18 (20) |
| Baseline mean HbA1c in mmol/mol [NGSP % units] | | | | | |
| 40–60 [5.8–7.6%] | 4 (11) | 13 (19) | 10 (17) | 21 (26) | 24 (26) |
| 60–80 [7.6–9.5%] | 18 (50) | 33 (49) | 35 (58) | 39 (49) | 50 (54) |
| 80–120 [9.5–13.1%] | 14 (39) | 21 (31) | 15 (25) | 20 (25) | 18 (20) |
| Sex | | | | | |
| Men | 17 (47) | 25 (37) | 29 (48) | 31 (39) | 37 (40) |
| Women | 19 (53) | 42 (63) | 31 (52) | 49 (61) | 55 (60) |
| Change in HbA1c | | | | | |
| Decrease | 13 (36) | 17 (25) | 28 (47) | 41 (51) | 54 (59) |
| No change | 5 (14) | 18 (27) | 14 (23) | 14 (18) | 18 (20) |
| Increase | 18 (50) | 32 (48) | 18 (30) | 25 (31) | 20 (22) |

These findings were consistent with the sensitivity analyses performed. Findings were unchanged by the inclusion of individuals with incomplete data, that is those with at least one HbA1c measurement from before and after DAFNE course (see Table S2). Multivariable linear regression with age, baseline mean HbA1c and SIMD as

**TABLE 3** Patient characteristics and association with change in mean HbA1c

| | Change in mean HbA1c | | |
|---|---|---|---|
| Variable | Decrease (%) | No change (%) | Increase (%) |
| Age | | | |
| 20–29 | 19 (12) | 10 (15) | 24 (21) |
| 30–39 | 25 (16) | 11 (16) | 21 (19) |
| 40–49 | 53 (35) | 10 (15) | 30 (27) |
| 50–59 | 29 (19) | 27 (39) | 23 (20) |
| >60 | 27 (18) | 11 (16) | 15 (13) |
| Baseline mean HbA1c in mmol/mol [NGSP % units] | | | |
| 40–60 [5.8–7.6%] | 17 (11) | 20 (29) | 35 (31) |
| 60–80 [7.6–9.5%] | 80 (52) | 41 (59) | 54 (48) |
| 80–120 [9.5–13.1%] | 56 (37) | 8 (12) | 24 (21) |
| Sex | | | |
| Men | 56 (37) | 33 (48) | 50 (44) |
| Women | 97 (63) | 36 (52) | 63 (56) |
| SIMD quintile | | | |
| 1 (Most deprived) | 13 (8.5) | 5 (7.2) | 18 (16) |
| 2 | 17 (11) | 18 (26) | 32 (28) |
| 3 | 28 (18) | 14 (20) | 18 (16) |
| 4 | 41 (27) | 14 (20) | 25 (22) |
| 5 (Least deprived) | 54 (35) | 18 (26) | 20 (18) |

*Note*. Scottish Index of Multiple Deprivation (SIMD) quintiles were generated from the postcode of home address using the Scottish government website (SIMD 1 being most deprived).[6] Mean HbA1c before (baseline) and after attendance at DAFNE course, were calculated from up to four annual measurements. Age and baseline mean HbA1c, were subdivided into groups of comparable size. Change in mean HbA1c (mmol/mol) was categorised into three groups: decrease (≥ −2.5), no change (<±2.5), increase (≥ +2.5).

explanatory variables demonstrated similar trends (see Table S3).

### 3.4 | Initiation of pump use

Although very few participants were on an insulin pump (continuous subcutaneous insulin infusion) prior to attending DAFNE, over a quarter were using this method of insulin administration at the time of the study's completion (Figure 2). Pump use was not included in multivariate analyses due to low use rates.

While fewer participants had insulin pumps in lower SIMD quintiles (more deprived areas), this was comparatively a greater proportion than areas of less deprivation. Cox proportional-hazards model did not demonstrate significant differences between the groups in the time to commencement of insulin pump after attending DANFE.

## 4 | DISCUSSION

### 4.1 | HbA1c and socioeconomic deprivation

In this retrospective observational study of 335 participants in South East Scotland, we found greater socioeconomic deprivation (lower SIMD quintile) to be associated with reduced efficacy of DAFNE course in reducing HbA1c. Participants in the least deprived group (SIMD 5) had one quarter the odds of no change/increase in mean HbA1c compared with the most deprived group (SIMD 1). Odds ratios decreased across increasing SIMD group, though there were overlapping confidence intervals.

Across the groups, attending DAFNE course was associated with reduction in mean HbA1c of 2.5 mmol/mol (0.2% in percentage units). This reduction is comparable with DAFNE audits in UK centres with reductions ranging from 0.2–0.6% (in percentage units) at 1 year.[5,9–11] Despite the improvement, the majority of participants (323, 96%) in this study remained above the NICE recommended target of <48 mmol/mol (<6.5%).[12]

On visual inspection of Figure 1, there appears to be exposure-response relationship between socioeconomic deprivation and HbA1c. Lower SIMD quintiles (greater deprivation) had higher mean HbA1c at baseline. An exposure-response relationship was also observed for socioeconomic deprivation and reduction in mean HbA1c after attendance at DAFNE course. While benefit was observed in the least deprived quintile with a mean reduction in mean HbA1c of 5 mmol/mol (0.5% in percentage units) in SIMD 5, this benefit was not apparent in the most deprived groups and mean HbA1c increased in SIMD quintiles 1 and 2. This suggests that socioeconomic deprivation is associated with reduced efficacy of DAFNE in reducing HbA1c.

The same relationships between socioeconomic deprivation and HbA1c were also observed on multivariable analysis. The strongest factor associated with reduction in HbA1c was baseline mean HbA1c, such that those with higher values received greater benefit. This is consistent findings from a larger DAFNE study in NHS Lothian.[13] While this may partly reflect regression to the mean, this finding supports existing DAFNE referral criteria based on high HbA1c levels. It is notable that despite having higher baseline HbA1c, reduction in mean value did not occur in more deprived groups (SIMD quintiles 1 and 2).

**TABLE 4** Association of socioeconomic deprivation with reduction in mean HbA1c after attendance at DAFNE, multivariable ordinal logistic regression

| Variable | | Decrease (%) | No change (%) | Increase (%) | Odds ratio univariable | Odds ratio multivariable |
|---|---|---|---|---|---|---|
| SIMD quintile | 1 (Most deprived) | 13 (36) | 5 (14) | 18 (50) | ref | ref |
| | 2 | 17 (25) | 18 (27) | 32 (48) | 1.66 (0.69, 4.00, $p = 0.255$) | 1.49 (0.59, 3.73, $p = 0.389$) |
| | 3 | 28 (47) | 14 (23) | 18 (30) | 0.65 (0.27, 1.50, $p = 0.313$) | 0.50 (0.20, 1.22, p = 0.135) |
| | 4 | 41 (51) | 14 (18) | 25 (31) | 0.54 (0.23, 1.19, $p = 0.133$) | 0.37 (0.15, 0.86, $p = 0.023$) |
| | 5 (Least deprived) | 54 (59) | 18 (20) | 20 (22) | 0.40 (0.18, 0.87, $p = 0.023$) | 0.25 (0.10, 0.58, $p = 0.001$) |
| Baseline mean HbA1c in mmol/mol [NGSP % units] | 40–60 [5.8–7.6%] | 17 (24) | 20 (28) | 35 (49) | ref | ref |
| | 60–80 [7.6–9.5%] | 80 (46) | 41 (23) | 54 (31) | 0.37 (0.19, 0.67, p = 0.002) | 0.31 (0.16, 0.58, $p < 0.001$) |
| | 80–120 [9.5–13.1%] | 56 (64) | 8 (9.1) | 24 (27) | 0.18 (0.09, 0.35, $p < 0.001$) | 0.12 (0.05, 0.24, $p < 0.001$) |

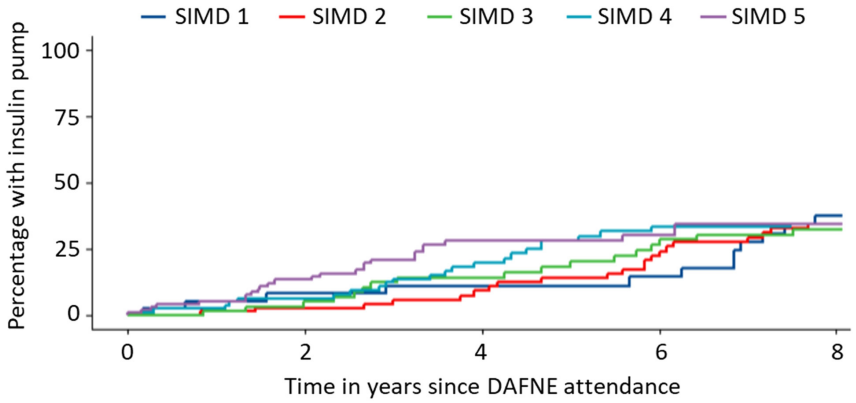
*Note*. Baseline mean HbA1c and SIMD quintiles were included in the final model. Inclusion of other explanatory variables (age or sex) did not improve model parameters. Odds ratios are presented with 95% confidence intervals. Model details: number of participants in model = 335, Akaike information criterion (AIC) = 419.7, C-statistic = 0.72, The Hosmer-Lemeshow goodness of fit test = Chi-squared 2.54 ($p = 0.96$).

Socioeconomic deprivation was also associated with reduction in mean HbA1c following DAFNE on multivariable analysis. While the root causes of this association are unknown, we suggest that differences in education may play a role. DAFNE is an intensive five consecutive day course, covering a large volume of information and several potentially new concepts such as glycaemic indexes (the relative ability of foods containing carbohydrates to raise blood glucose levels). It requires users to understand, recall and change their existing insulin administration habits in line with course recommendations during that working week so that the changes can be sustained. Several aspects, such as adjusting insulin and carbohydrate counting rely heavily on numeracy skills. In addition to the general aim of lowering blood glucose, a large focus is placed on avoiding hypoglycaemia (lowering blood glucose too much) due to its potentially life-threatening effects. It seems possible that those less confident in their numeracy skills may be more conservative in their estimates for insulin administration. Attendees from areas of greater socioeconomic deprivation may achieve a less complete understanding or be less able to apply course content, have lower confidence in numeracy related changes, and accordingly receive less benefits to glycaemic control. The disparities observed could raise questions regarding the delivery of DAFNE education itself and whether it is pitched at level that is appropriately accessible.

In addition to differences in health literacy, there are many recognised factors that exacerbate socioeconomic disparities in glycaemic control. These may relate to diet (such as access to fruit/vegetables versus fast food outlets), exercise (such as availability or access to spaces for physical activity), or financial stability (such as affordability of medication/devices, or stability of housing).[14] It is recognised that these systemic factors can make it challenging for those from areas of greater deprivation to avail of new technologies or health education.[15] Considering this, it seems unlikely that education alone can address disparities in glycaemic control if other socioeconomic barriers remain.

## 4.2 | Initiation of pump use

NICE recommend the initiation of an insulin pump (continuous subcutaneous insulin infusion) for participants who experience frequent episodes of disabling hypoglycaemia, or HbA1c >69 mmol/mol (8.5%) despite multiple daily injection of insulin and a high level of care.[16] While very few participants were on an insulin pump prior to their attendance at DAFNE, over a quarter of participants had changed to this method of administration by the time of study completion. While some of this may be accounted for by time bias due to their only recently being funded by the National Health Service (available privately for ~£2000 for 4–8 years use),[17] this may also reflect the failure to achieve more optimal control in our participant population despite having attended DAFNE. Interestingly, while greater deprivation may be negatively associated with insulin pump use in paediatric populations,[18] in our study, pump use was proportionally higher in more deprived groups, perhaps reflective of their higher HbA1c.




| Quintile | Number at risk | | | | |
|---|---|---|---|---|---|
| SIMD 1 | 36 | 32 | 28 | 26 | 19 |
| SIMD 2 | 67 | 65 | 56 | 46 | 38 |
| SIMD 3 | 59 | 55 | 43 | 36 | 19 |
| SIMD 4 | 78 | 68 | 49 | 39 | 0 |
| SIMD 5 | 91 | 71 | 48 | 22 | 1 |

| SIMD Quintile | Hazard Ratio | P value |
|---|---|---|
| 1 (Most deprived) | ref | ref |
| 2 | 0.88 (0.45, 1.71) | 0.702 |
| 3 | 0.88 (0.43, 1.80) | 0.726 |
| 4 | 1.11 (0.56, 2.21) | 0.758 |
| 5 (Least deprived) | 1.38 (0.70, 2.70) | 0.352 |

**FIGURE 2** Survival plot of commencement of insulin pump after attending DAFNE course across SIMD quintiles. Percentage using insulin pump over time, across the Scottish Index of Multiple Deprivation (SIMD) quintiles after attending DAFNE. Those without insulin pump were receiving basal-bolus insulin regime. Cox proportional-hazards model did not demonstrate differences between the groups.

### 4.3 | Strengths, limitations, and other considerations

A strength of our study is the inclusion of all eligible participants across two centres encompassing a population of diverse socioeconomic background. This yielded a sample of sufficient size for analyses that is representative of DAFNE attendees in NHS Lothian, and based on reduction in HbA1c, is comparable with other UK DAFNE centres.[5,9–11] However, there fewer participants from the most deprived areas, which is consistent with data from other centres.[19] This may reflect the local geographical distribution of deprivation[20] or differences in referral patterns or attendance. While deprivation has been previously associated with poorer glycaemic control (higher HbA1c),[21] this is the first study to explore its association with glycaemic control after attending DAFNE.

Glycated haemoglobin (HbA1c) is an effective measure of the average serum glucose of individuals across approximately 3 months[22] and hence is useful for monitoring trends in glycaemic control. Other measures of glycaemic control such as daily or continuous capillary blood measurements could provide further information on the day-to-day glycaemic variability and enable assessments of associations with hypoglycaemia. Future research could explore association with complications such as diabetic ketoacidosis or life-threatening hypoglycaemia, and psychological benefits from DAFNE.

SIMD quintiles group participants on postcode associated deprivation. While this is a frequently used instrument it may not accurately represent deprivation at the individual level. As it does not use individual specific measures, for example income, individuals in the same quintile are not necessarily at the same risk of deprivation. This variability may mask true associations with economic deprivation and decrease the power of analyses.

## 5 | CONCLUSION

Higher baseline HbA1c was associated with a greater reduction in mean HbA1c following attendance at DAFNE, validating this as an important clinical indication for referral. Lower SIMD quintile (greater deprivation) was associated with higher baseline HbA1c values; however, despite this, these groups had limited reduction in HbA1c after DAFNE. We found socioeconomic deprivation to be associated with lower reduction in HbA1c with greatest benefit being observed in higher SIMD quintiles (lower deprivation). Future research should examine whether this association generalises to the rest of the UK and could use qualitative or mixed methods to explore causes of this differential benefit, identify barriers to lowering HbA1c and how best to support people with T1DM from areas of greater deprivation.

## AUTHOR CONTRIBUTION

**Callum W.D. Innes:** Conceptualization, methodology, investigation, formal analysis, writing—original draft, review & editing. **David E. Henshall:** Methodology, formal analysis, writing—original draft, review & editing. **Blair Wilson:** Formal analysis. **Michael Poon:** Formal analysis, writing—review & editing, supervision. **Steven D. Morley:** Writing—review & editing, supervision. **Stuart A. Ritchie:** Conceptualization, methodology, resources, supervision. Manuscript submission approved by all authors.

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## CONFLICT OF INTEREST

No conflicts of interest declared.

## ETHICS STATEMENT

The study received local ethical approval from the University of Edinburgh. The study conforms to standards of research involving human participants as per the Declaration of Helsinki.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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