

# The impact of socio-economic deprivation on access to diabetes technology in adults with type 1 diabetes

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## Abstract

**Background:** With advances in technology, there is an emerging concern that inequalities exist in provision and diabetes outcomes in areas of greater deprivation. We assess the relationship between socio-economic status and deprivation with access to diabetes technology and their outcomes in adults with type 1 diabetes.

**Methods:** Retrospective, observational analysis of adults attending a tertiary centre, comprising three urban hospitals in the UK. Socio-economic deprivation was assessed by the English Indices of Deprivation 2019. Data analysis was performed using one-way ANOVAs and chi-squared tests.

**Results:** In total, 1631 adults aged  $44 \pm 15$  years and 758 (47%) women were included, with 391 (24%) using continuous subcutaneous insulin infusion, 312 (19%) using real-time continuous glucose monitoring and 558 (34%) using intermittently scanned continuous glucose monitoring. The highest use of diabetes technology was in the least deprived quintile compared to the most deprived quintile (67% vs. 45%, respectively;  $p < 0.001$ ). HbA<sub>1c</sub> outcomes were available in 400 participants; no association with deprivation was observed ( $p = 0.872$ ). Participation in structured education was almost twice as high from the most deprived to the least deprived groups (23% vs. 43%;  $p < 0.001$ ). Adults with white or mixed ethnicity were more likely to use technology compared to black ethnicity (60% vs. 40%;  $p < 0.001$ ).

**Conclusions:** Adults living in the most deprived quintile had less technology use. Irrespective of socio-economic status or ethnicity, glycaemia was positively affected in all groups. It is imperative that health disparities are further addressed.

## KEYWORDS

continuous glucose monitoring, diabetes technology, health inequalities, socio-economic deprivation, structured education, type 1 diabetes

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## 1 | INTRODUCTION

Type 1 diabetes management has been revolutionised by devices supporting self-management to optimise glycaemia, reducing diabetes-related complications, minimising disease burden and improving quality of life.<sup>1</sup> Continuous subcutaneous insulin infusion (CSII) is particularly beneficial in those with an elevated baseline HbA<sub>1c</sub>, and frequent, severe hypoglycaemia.<sup>2</sup> Real-time continuous glucose monitoring (rtCGM) improves glycaemia and reduced exposure to hypoglycaemia,<sup>3</sup> particularly those with impaired awareness.<sup>4,5</sup> Intermittently scanned continuous glucose monitoring (isCGM) systems (Freestyle Libre, Abbott) may reduce HbA<sub>1c</sub>,<sup>6</sup> and reduce exposure to hypoglycaemia in people with insulin-treated diabetes.<sup>7</sup>

Despite an abundance of data supporting type 1 diabetes technology, there are disparities in terms of access to and use of technology.<sup>8</sup> Widening health inequalities within the socio-economic gradient and social determinants of health are considered to be the main contributors.<sup>9</sup> High-risk lifestyle activities including smoking, poor diet, lack of physical activity and alcohol use are more pervasive in areas of deprivation, with the prevalence of these factors perpetuating health inequalities.<sup>10</sup> Accessibility and experiences within the healthcare setting may also be affected by socio-economic status. Adults from less deprived areas are more likely to know and exercise their rights, therefore are often prioritised for treatment.<sup>11</sup> Medical staff may be more cautious of disappointing individuals from more socio-economically advantaged backgrounds due to a higher chance of legal recourse.<sup>12</sup>

In type 1 diabetes care, inequalities in treatment and disparities in glycaemia have been associated with acute and long-term complications,<sup>13</sup> including diabetic ketoacidosis<sup>14</sup> and reduced life expectancy.<sup>15,16</sup> Lower socio-economic status and identifying as minority ethnic are associated with glycaemic control above target.<sup>17</sup> This has been attributed to the strong link between social deprivation and poor health behaviours that contribute to worse diabetes complications,<sup>10</sup> but may also reflect barriers for underprivileged groups to access diabetes technology. Barriers to technology adoption may include cost and education. For example, rtCGM companion technologies such as a smartphone and access to Internet data may be required to achieve ideal outcomes.<sup>10</sup> Furthermore, the optimal use of technology requires a high level of numerical and technical literacy, which could also pose barriers to adoption.<sup>9</sup> The National Diabetes Insulin Pump Audit 2019/20 highlighted a lower percentage of those using an insulin pump in the most deprived quintile (15%) compared to the least deprived (23%).<sup>18</sup>

There is limited research surrounding the link between socio-economic status and inequalities in access

### What's New?

1. Inequalities exist in technology uptake between socio-economic groups; adults living in the most deprived quintile had less technology use.
2. Despite this, there were no overall differences in HbA<sub>1c</sub>-related outcomes, with glycaemia positively affected in all groups, suggesting that reducing inequalities in technology access may resolve the disparities observed in glycaemia.
3. Future work describing and addressing health-care professional, organisational, institutional and individual factors underpinning inequality and bias is urgently required.

to diabetes technology as highlighted in the Diabetic Medicine Position Statement (2021): Optimising the use of technology to support people with diabetes.<sup>19</sup> This study aims to assess the relationship between socio-economic status and access to diabetes technology and their outcomes in adults with type 1 diabetes.

## 2 | METHODS

### 2.1 | Study population

This is a retrospective observational analysis of all adults with type 1 diabetes attending the diabetes services across three hospitals (Charing Cross Hospital, Hammersmith Hospital and St Mary's Hospital) under the umbrella of Imperial College London NHS Trust. Imperial College London NHS Trust is a specialist diabetes referral centre for northwest London, providing services to a diverse urban population. Access to technologies for people living in catchment areas of multiple Clinical Commissioning Groups in and out of London were in line with NHS England London technology commissioning recommendations, which reflect the National Institute of Clinical Excellence (NG17, NG18 and TA151) and NHS England National guidance.<sup>20</sup>

All individuals attending diabetes services were identified from an automated search by the Information Technology team. NHS Research Ethics Committee review was not required.

Adults aged  $\geq 18$  years old with a clinical diagnosis of type 1 diabetes were included in the study. Excluded from data analysis were children, women who were pregnant or people with a diagnosis of type 2 diabetes or maturity onset diabetes of the young. Those without a recorded postcode were also excluded from the study due to lack

of sufficient information to determine socio-economic deprivation.

## 2.2 | Data collection

Hospital identity numbers of individuals were checked against electronic health records held on the Imperial College London NHS Trust electronic patient record (Cerner Corporation). Data are uploaded onto Cerner manually by health practitioners and administrators to record and store medical notes, prescribe and dispense medication, and store investigation results and clinic letters. Furthermore, Cerner is connected to the National Health Service Spine, which synchronises core demographic data.

Demographic (age, sex, self-reported ethnicity), clinical (date of diagnosis, technology use) and biochemical data (HbA<sub>1c</sub> pre-initiation and 1 year post-initiation) were collected for all eligible individuals. Information regarding participation in structured education for diabetes was also collected; the name of the formal course was recorded or 1:1 sessions with a diabetes educator.

## 2.3 | Measure of deprivation

Socio-economic deprivation was assessed by the English Indices of Deprivation 2019.<sup>21</sup> Deprivation deciles are based on the Index of Multiple Deprivation 2019 (IMD 2019). Decile 1 represents the most deprived 10% of neighbourhoods in England, while decile 10 represents the least deprived 10%. Using deprivation deciles, the data were divided into quintiles, as in the National Diabetes Audits.

## 2.4 | Statistical analysis

Baseline characteristics are presented as mean  $\pm$  SD for continuous data, categorical variables as number (percentage) of participants.

To assess the significance of categorical data (including technology use, structured education participation and ethnicity) across the quintile groups, chi-squared tests ( $\chi^2$ ) were performed. For continuous data, an ordinary one-way ANOVA was performed to assess for any significant difference across the quintiles. Post-hoc between group comparisons were made where applicable.

Differences in HbA<sub>1c</sub> were obtained pre-initiation for each form of diabetes technology and 1-year post-initiation. Changes in HbA<sub>1c</sub> were analysed using one-way ANOVA with post-hoc between group comparisons

assessed using Tukey's multiple comparisons test. For all tests, *p*-values of  $<0.05$  were deemed statistically significant. To assess change in HbA<sub>1c</sub>, individuals using only one type of technology were included, and if both pre- and 1-year post-technology initiation were recorded.

Finally, CSII use per deprivation quintile at Imperial College London NHS Trust were also compared with data from the National Diabetes Insulin Pump Audit.<sup>18</sup>

Sample size estimation was not required due to the retrospective nature of this audit. All data analyses were performed using GraphPad Prism version 9.1.0.

## 3 | RESULTS

### 3.1 | Baseline characteristics

From a list of 3375 people, 1738 people were excluded due to diabetes subtype (i.e., did not have type 1 diabetes), 5 people were excluded due to insufficient clinical records and 1 person was excluded due to lack of information regarding postcode. In all, 1631 individuals with type 1 diabetes were included in this study.

The mean  $\pm$  SD of age was  $44 \pm 15$  years with 758 (47%) women. Baseline characteristics of the study population stratified by IMD 2019 quintiles are shown in [Table 1](#).

IMD quintiles within white and black ethnic background groups varied significantly. 62% of the least deprived quintile were of white ethnicity, compared to 41% of the most deprived quintile ( $p < 0.001$ ). 15% of the most deprived quintile identified as black ethnicity compared to 1.1% of the least deprived quintile ( $p < 0.001$ ).

### 3.2 | Use of diabetes technology

Overall, 904 (55%) people with type 1 diabetes attending specialist services used technology. In all, 391 (24%) used CSII, 312 (19%) used rtCGM and 558 (34%) used isCGM. There were significantly less people using technology in most deprived quintile compared to the least deprived quintile (45% in most deprived vs 67% in least deprived;  $p < 0.001$ ), with a linear increase in technology use across the quintiles (53% in 2nd most deprived, 56% in 3rd most deprived and 62% in 2nd least deprived). Greatest difference was observed with use of CSII ( $p < 0.001$ ; [Figure 1a](#)) than rtCGM ( $p = 0.032$ ; [Figure 1b](#)) and isCGM ( $p = 0.001$ ; [Figure 1c](#)).

For people using combined technology, similar trends were observed. Testing over all five quintiles, there was significant variance in use of CSII + rtCGM ( $p = 0.007$ ), and of CSII + isCGM ( $p = 0.027$ ).

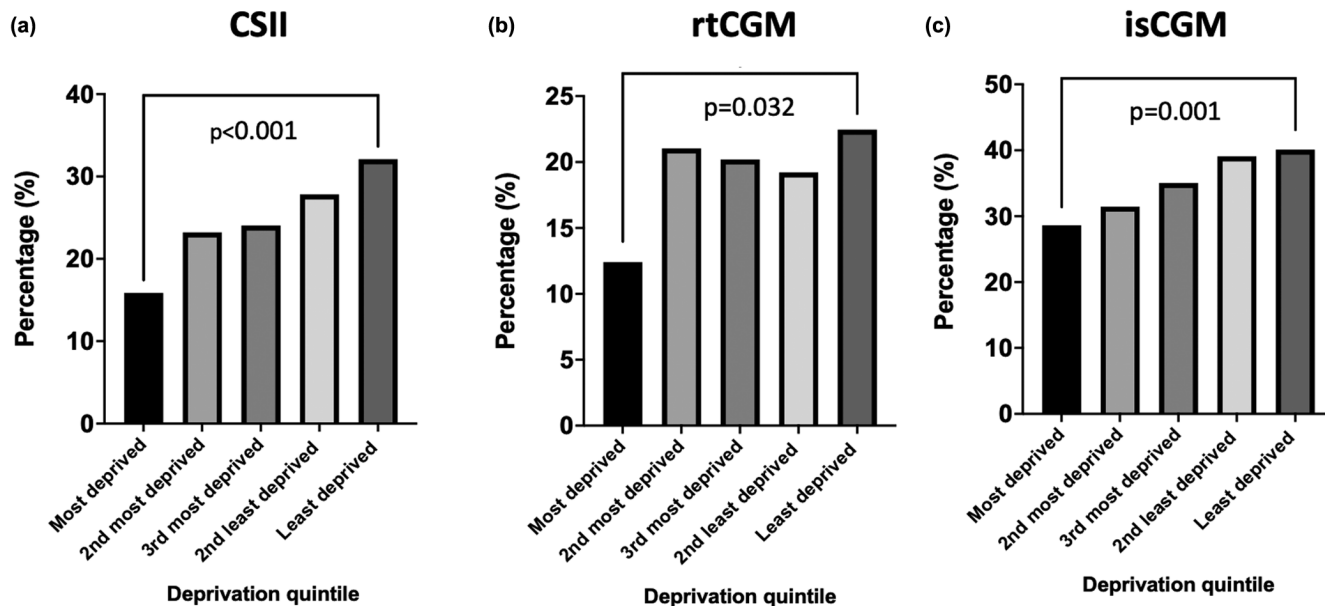
TABLE 1 Baseline demographics stratified by Indices of Multiple Deprivation 2019 quintiles (n = 1631)

Characteristics	All (n = 1631)	Most deprived (n = 290)	2nd most deprived (n = 461)	3rd most deprived (n = 391)	2nd least deprived (n = 302)	Least deprived (n = 187)	p value
Age, year	44 ± 15	43 ± 14	44 ± 15	43 ± 15	45 ± 16	47 ± 17	0.923
Sex							0.836
Men	873 (54%)	160 (55%)	246 (53%)	205 (52%)	167 (55%)	95 (51%)	-
Women	758 (47%)	130 (45%)	215 (47%)	186 (48%)	135 (45%)	92 (49%)	-
Ethnicity							<0.001
White (British, Irish, any other white background)	828 (51%)	118 (41%)	228 (50%)	200 (51%)	166 (55%)	116 (62%)	-
Black (African, Caribbean, any other black background)	130 (8.0%)	42 (15%)	54 (12%)	26 (6.6%)	6 (2.0%)	2 (1.1%)	-
Asian (Chinese, Indian, Pakistani, Bangladeshi, any other Asian background)	91 (5.6%)	13 (4.5%)	28 (6.1%)	28 (7.2%)	15 (5.0%)	7 (3.7%)	-
Mixed (White and Black, White and Asian, any other mixed background)	37 (2.3%)	11 (3.8%)	17 (3.7%)	2 (0.5%)	5 (1.7%)	2 (1.1%)	-
Any other ethnic group	148 (9.1%)	48 (17%)	42 (9.1%)	26 (6.6%)	24 (7.9%)	8 (4.3%)	-
Not known/not stated	397 (24%)	58 (20%)	92 (20%)	109 (28%)	86 (29%)	52 (28%)	-
Technology use							
Any technological device used	904 (55%)	129 (45%)	245 (53%)	218 (56%)	186 (62%)	126 (67%)	<0.001
CSII <sup>a</sup>	391 (24%)	46 (16%)	107 (23%)	94 (24%)	84 (28%)	60 (32%)	<0.001
rt-CGM <sup>a</sup>	312 (19%)	36 (12%)	97 (21%)	79 (20%)	58 (19%)	42 (23%)	0.032
isCGM <sup>a</sup>	558 (34%)	83 (29%)	145 (32%)	137 (35%)	118 (39%)	75 (40%)	0.001
CSII + rtCGM	157 (10%)	16 (5.5%)	42 (9.1%)	43 (11%)	34 (11%)	22 (12%)	0.007
CSII + isCGM	177 (11%)	19 (6.6%)	53 (11%)	43 (11%)	35 (12%)	26 (14%)	0.027
Structured education	531 (33%)	68 (23%)	144 (31%)	129 (33%)	110 (36%)	80 (43%)	<0.001
T1D course	404 (76%)	47 (69%)	114 (80%)	97 (75%)	84 (76%)	62 (78%)	<0.001
1-1 Structured education	127 (24%)	21 (31%)	30 (21%)	32 (25%)	26 (24%)	18 (22%)	0.316

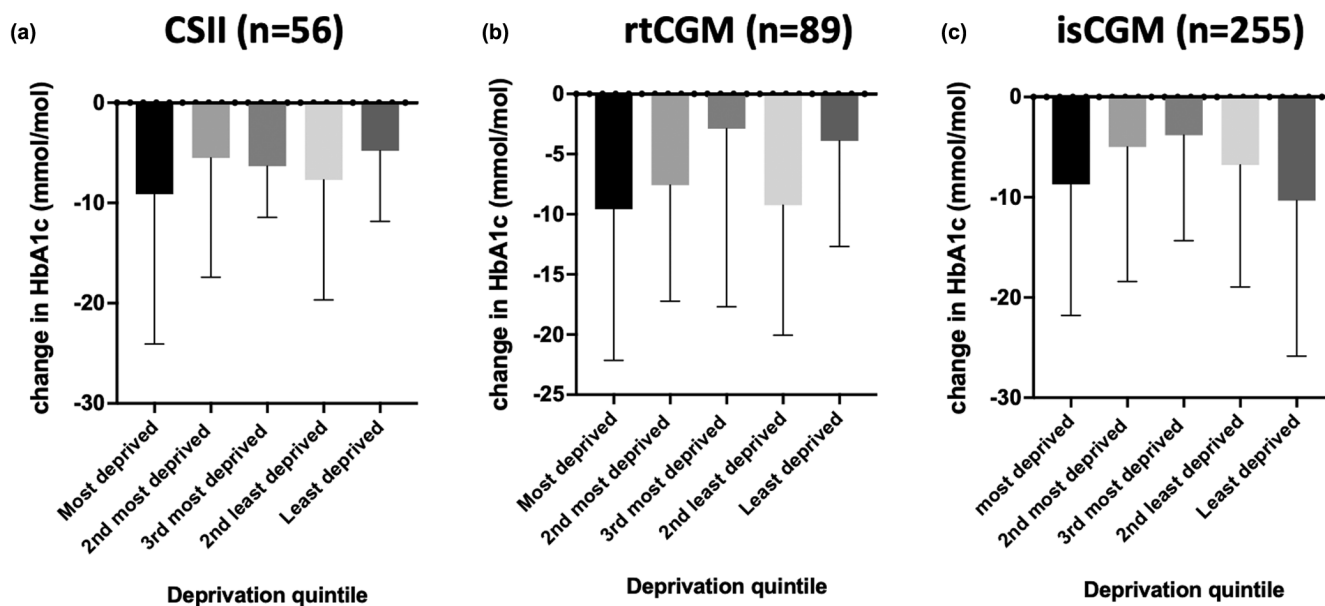
Note: Data shown are mean ± SD, n (%). P values are for a test of equal distribution across Indices of Multiple Deprivation 2019 quintiles.

Abbreviations: CSII, continuous subcutaneous insulin infusion; isCGM, intermittently scanned continuous glucose monitoring; rt-CGM, real-time continuous glucose monitoring; SD, standard deviation.

<sup>a</sup>Includes people using multiple devices (i.e., CSII + rtCGM or CSII + isCGM).



**FIGURE 1** Association between deprivation and technology use in adults with type 1 diabetes. Adults were grouped into deprivation quintiles based on Indices of Multiple Deprivation 2019 scores for (a) CSII ( $p < 0.001$ ), (b) rtCGM ( $p = 0.032$ ) and (c) isCGM ( $p = 0.001$ ). Data are shown as percentages (%). CSII, Continuous subcutaneous insulin infusion; rtCGM, real-time continuous glucose monitoring; isCGM, intermittently scanned continuous glucose monitoring.



**FIGURE 2** HbA<sub>1c</sub>-related outcomes with technology use across IMD deprivation quintiles. Bar charts demonstrate change in HbA<sub>1c</sub> (mmol/mol) from pre-initiation to 1-year post-initiation of people using (a) CSII alone, (b) rtCGM alone or (c) isCGM alone. Data are shown as mean  $\pm$  SD. No statistically significant difference in these changes was observed between the quintiles. CSII, Continuous subcutaneous insulin infusion; rtCGM, real-time continuous glucose monitoring; isCGM, intermittently scanned continuous glucose monitoring.

### 3.3 | Change in HbA<sub>1c</sub> 1-year post-initiation of technology

Data on HbA<sub>1c</sub> were available for 56 adults using CSII alone, 89 adults using rt-CGM alone and 255 adults using isCGM alone. There was no difference in the change in HbA<sub>1c</sub> from pre-initiation to 1-year post-initiation

across the deprivation quintiles for any of the technologies ( $p = 0.872$ ; [Figure 2](#)). CSII, rt-CGM and isCGM all showed overall beneficial outcomes with mean HbA<sub>1c</sub> reduction of  $-7 \pm 10$  mmol/mol ( $-2.8 \pm 3.1\%$  DCCT),  $-6.7 \pm 11.5$  mmol/mol ( $-2.8 \pm 3.2\%$  DCCT) and  $-6.4 \pm 12.8$  mmol/mol ( $-2.7 \pm 3.3\%$  DCCT), respectively. Although not reaching statistical significance,



HbA<sub>1c</sub> mean reduction was greater in the most deprived quintile of people for CSII and rt-CGM (−9 mmol/mol (−3.0% DCCT) and −10 mmol/mol (−3.1% DCCT), respectively) than in the least deprived quintile (−5 mmol/mol (−2.6% DCCT) and −4 mmol/mol (−2.5% DCCT), respectively).

### 3.4 | Structured education

Of the 1631 adults with type 1 diabetes, 531 (33%) had participated in diabetes structured education. There was a lack of information regarding structured education for 151 (9%) of people. Of the 531 that had participated, 404 (76%) had attended a structured education course, the other 127 (24%) had undergone 1:1 structured education sessions with a diabetes educator. The most commonly attended structured education course was DAFNE (Dose Adjusted for Normal Eating) ( $n = 188$ ; 47%). Other courses included ICICLE (Imperial College Insulin, Carbohydrate and Lifestyle Education) ( $n = 50$ ; 12%), CHARLIE ( $n = 24$ ; 5.9%) and BERTIE (Beta Cell Education Resources for Training in Insulin and Eating) ( $n = 3$ ; 0.7%). Of those that took part in a structured education course, there was no information regarding which programme was attended for 34% ( $n = 139$ ) of people.

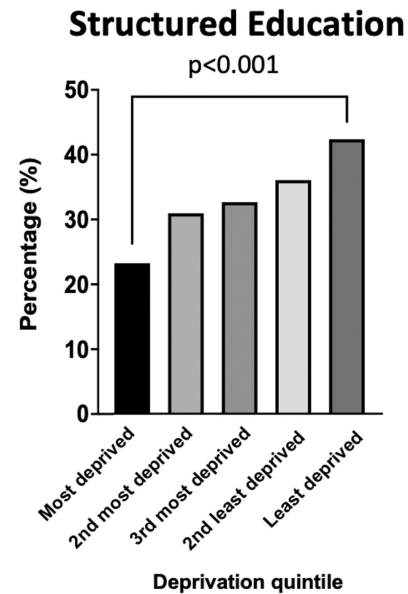
As deprivation status increased, adults were less likely to have participated in structured education (Figure 3;  $p < 0.001$ ). In the most deprived quintile, only 23% had completed education compared to 43% of those in the least deprived areas, showing almost a twofold increase.

### 3.5 | Ethnicity

Statistically significant differences between the percentage of adults in each ethnic group using technology were observed (Figure 4a;  $p = 0.006$ ). Subgroup analysis revealed statistical significance was reached for CSII ( $p < 0.001$ ) and rt-CGM ( $p = 0.013$ ) only. The ethnic group with the highest percentage of technology use was of 'mixed ethnicity' (60%), followed by white ethnicity (59%). The group with the lowest percentage of technology use were individuals of black ethnicity (40%). People of white ethnicity had the highest percentage using CSII (28%) and rtCGM (22%).

## 4 | DISCUSSION

Our study provides real-world evidence for difference in the use of diabetes technology across ethnicity and socio-economic deprivation with the lowest use in the most deprived quintile.



**FIGURE 3** Association between deprivation and participation in structured education ( $p < 0.001$ ). Participation included organised programmes or 1:1 sessions. Data are expressed as percentages (%).

Importantly, technology use improved HbA<sub>1c</sub> outcomes, irrespective of social deprivation and ethnicity.

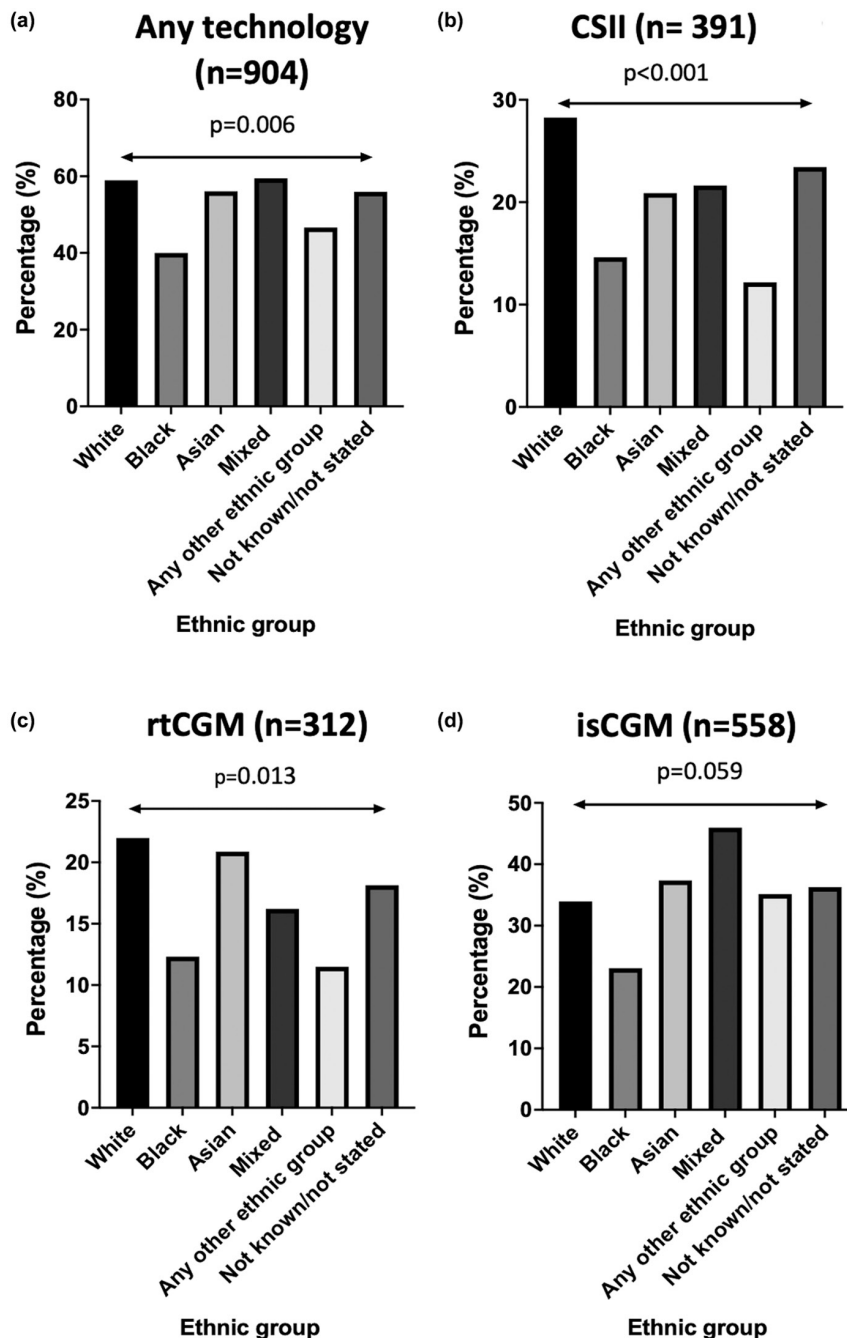
Our findings are comparable to previously published literature.<sup>22–24</sup> The greatest variation was observed with CSII use. A key reason may be the variation observed in structured education uptake; the percentage of people completing structured education in the least deprived group was almost double that of the most deprived group. Structured education and carbohydrate counting are important components of the CSII pathway to optimise the value of the technology. Extracting value from structured education programmes, like DAFNE, requires basic English literacy and numeracy skills.<sup>25</sup> Thus, cultural and language barriers, lower health literacy and confidence or the inability to take time off work may affect uptake.<sup>26</sup> Equally, potential clinician barriers may exist with assumptions based on which individuals may benefit or be suitable for referral.

In all deprivation quintiles, Imperial College London NHS Trust had a larger percentage of people using CSII than the national diabetes audit with a similar pattern across quintiles. No national data are available at present for rtCGM and isCGM.

Importantly, our data suggest that all adults with type 1 diabetes and access to technology achieve the same improvements in glycaemia, irrespective of socio-economic status or ethnicity. This is in keeping with a previous real-world study in the UK showing that CSII improves HbA<sub>1c</sub> irrespective of social deprivation and demographics.<sup>27</sup>

Despite the reimbursement of diabetes technology by the National Health Service for people with type 1

**FIGURE 4** Association between ethnicity and technology use. Bar charts demonstrate percentages for use of (a) any technology ( $p = 0.006$ ), (b) CSII ( $p < 0.001$ ), (c) rtCGM ( $p = 0.013$ ) and (d) isCGM ( $p = 0.059$ ). Data are shown as percentages (%). Abbreviations: CSII, Continuous subcutaneous insulin infusion; rtCGM, real-time continuous glucose monitoring; isCGM, intermittently scanned continuous glucose monitoring.



diabetes, financial barriers may also contribute to health disparities. These include the expenses of work absences, childcare and transportation that come with attending multiple hospital appointments, including pre-technology education, initiation and reviews.<sup>28</sup> Research has indicated that low socio-economic status is the highest predictor of multiple missed appointments and one reason for this is the financial burden of hospital appointments.<sup>29</sup>

Lack of knowledge of available technology may also act as a significant barrier to accessibility.<sup>30</sup> Only 12% of those in the least deprived socio-economic group were not aware of technology compared to 25% in the most deprived.<sup>30</sup> Furthermore, only 18% in the most deprived

cohort discussed technology at their clinician appointments, compared to 46% of the least deprived, demonstrating the significant disparity in the rate with which technology is discussed. People from more disadvantaged areas also report feeling worse engagement with healthcare professionals regarding their diabetes management,<sup>30</sup> which possibly leads to a perpetuating cycle of reduced engagement. As the most important source of information about diabetes technology were diabetes healthcare professionals,<sup>30</sup> this demonstrates the need for discussing technology with all individuals.

Lastly, ethnic differences also contributed to the significant difference in technology use. Individuals with black

ethnicity had the lowest percentage of technology users. These findings support previous literature stating that racial and ethnic minorities are less likely to use health-related technology.<sup>8,24,31</sup>

Our study has several strengths and is one of few studies to specifically report on the impact of social deprivation on pre- and post-rtCGM and isCGM HbA<sub>1c</sub>. Furthermore, this study consisted of a large multi-ethnic cohort living across a wide range of different deprivation quintiles, providing a prime representative population to evaluate deprivation-based health disparities.

Limitations include the observational retrospective nature of the study, lack of information about hypoglycaemia and percentage times in ranges, discontinuation rates as well as psychological outcomes. Furthermore, IMD scores may not necessarily represent individual factors, such as income, education and lifestyle.<sup>32</sup> Additionally, there were limited ethnicity data with almost a quarter of the cohort not available. HbA<sub>1c</sub> data were not available for all of the population treated exclusively by just one technology.

It is imperative that health disparities are recognised and addressed. Qualitative research evaluating structural, policy, healthcare professional and individual reasons for differences in technology use with deprivation would provide a deeper insight into the causes for social inequalities in health and uncover areas for potential interventions to prevent these.<sup>19</sup>

Suggestions for future development include education courses directed at different ethnic minority groups, education programmes adapted for those with a lower health literacy or financial reimbursement for the costs that come with hospital appointments and education programmes. For example, the Diabetes Education and Self-Management for Ongoing and Newly Diagnosed (DESMOND) structured education course for T2D has been specifically adapted for providing culturally specific education and is delivered in different languages. Finally, research evaluating the most effective strategies that are economically feasible and significantly improve management are needed. Improving experience of care for less advantaged people with type 1 diabetes could be addressed by raising awareness and educating healthcare professionals on the differences in access to healthcare across deprivation levels. Furthermore, routine data collection with easily available outcomes, as part of national audits particularly for CGM, will be important in driving change and reducing inequality.

To conclude, our study emphasises the presence of discrepancies in technology uptake between socioeconomic groups. Despite this, in the 400 people with HbA<sub>1c</sub> outcomes, there were no overall differences in these outcomes, and glycaemia was positively affected in all groups. This suggests that reducing inequalities in

technology access may resolve the disparities observed in glycaemia. Reduced participation in structured education from people living in the most deprived quintile could be a potential driver for poorer health outcomes. Future work describing and addressing healthcare professional, organisational, institutional and individual factors underpinning inequality and bias is urgently required.

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