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A pilot study of an integrated mental health, social and medical model for diabetes care in an inner-city setting: Three Dimensions for Diabetes (3DFD)

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What's new?

- There are few evidence-based models of diabetes care that include mental health and social care.
- The Three Dimensions for Diabetes (3DFD) model integrated social care, mental health and diabetes care into one service.
- This non-randomized, observational study, set in three diverse boroughs in London, UK, recruited adults with suboptimal glycaemic control and mental health and/or social problems.
- 3DFD was associated with clinically significant reductions in glycaemic control but because they were already a very expensive and high-risk group, there was no evidence of reduction in costs compared with the control.

Abstract

Aims We examined the effectiveness of a service innovation, Three Dimensions for Diabetes (3DFD), that consisted of a referral to an integrated mental health, social care and diabetes treatment model, compared with usual care in improving biomedical and health economic outcomes.

Methods Using a non-randomized control design, the 3DFD model was offered in two inner-city boroughs in London, UK, where diabetes health professionals could refer adult residents with diabetes, suboptimal glycaemic control [HbA_{1c} ≥ 75 mmol/mol (≥ 9.0%)] and mental health and/or social problems. In the usual care group, there was no referral pathway and anonymized data on individuals with HbA_{1c} ≥ 75 mmol/mol (≥ 9.0%) were collected from primary care records. Change in HbA_{1c} from baseline to 12 months was the primary outcome, and change in healthcare costs and biomedical variables were secondary outcomes.

Results 3DFD participants had worse glycaemic control and higher healthcare costs than control participants at baseline. 3DFD participants had greater improvement in glycaemic control compared with control participants [−14 mmol/mol (−1.3%) vs. −6 mmol/mol (−0.6%) respectively, $P < 0.001$], adjusted for confounding. Total follow-up healthcare costs remained higher in the 3DFD group compared with the control group (mean difference £1715, 95% confidence intervals 591 to 2811), adjusted for confounding. The incremental cost-effectiveness ratio was £398 per mmol/mol unit decrease in HbA_{1c}, indicating the 3DFD intervention was more effective and costed more than usual care.

Conclusions A biomedical, psychological and social criteria-based referral system for identifying and managing high-cost and high-risk individuals with poor glycaemic control can lead to improved health in all three dimensions.

<H1>Introduction

In the UK, around 4 million people have diabetes, costing almost £10 billion/year in direct costs alone, 80% of which is for complications [1]. Psychiatric morbidity, diabetes-related distress and social problems (e.g. debt, unemployment, isolation and poor housing) are common barriers to diabetes self-care and are associated with reduced self-management, which leads to suboptimal glycaemic control, increased risk of diabetes complications, premature mortality and increased healthcare costs [2–8]. National guidance recognizes that integrating social and psychological care with medical care could lead to better health outcomes [9].

Integrating the treatment of depression with diabetes care improves outcomes for both conditions and reduces costs [10,11], but studies that have attempted to integrate social welfare are almost non-existent. The highest prevalence rates of diabetes and the worst diabetes outcomes occur in inner-city settings [12,13]. Although there have been several interventions to intensify medical and educational interventions in inner-city settings to improve self-management and glycaemic control, there have been no interventions that address social problems with the aim of improving glycaemic control [14,15]. We found in a feasibility pre–post observational study design that integrating diabetes, mental health and social care into one service, the Three Dimensions For Diabetes (3DFD) model, was associated with improvements in biomedical, mental health, social and cost outcomes [16].

The primary aim of this pilot study was to further test whether 3DFD was associated with greater change in glycaemic control, other diabetes-related biomedical outcomes, and in healthcare costs compared with a control group receiving usual care over 12 months. Our secondary aim was to assess the change in psychological and subjective measures of healthcare use in the 3DFD group only from referral to 12-month follow-up.

<H1>Material and methods

<H2>Design

We used a non-randomized control design in which we compared individuals who were referred to 3DFD with a contemporaneous control group receiving usual care [17]. The rationale for a non-randomized design was that the funding body had requested a control group but not a randomized controlled trial (RCT) as the results were to inform the commissioners as to whether there was any clinical and economic evidence to translate this model into routine care.

<H2>Setting

3DFD was set in Lambeth and Southwark, London, UK, which are adjacent inner-city boroughs with populations of 324 431 and 308 401 persons, and with high levels of ethnic diversity and significant socio-economic deprivation, as measured by the English Indices of Multiple Deprivation (IMD) 2010 [18]. The contemporaneous control group was set in Lewisham, a neighbouring borough with 275 900 residents and similar levels of ethnic diversity and deprivation. This borough did not have the 3DFD service or any diabetes-specific mental health or social care services, but shared the same diabetes clinical pathways as Lambeth and Southwark, and therefore had a comparable healthcare profile [19]. We invited all primary care practices in Lewisham to participate. The study was granted ethical approval by the East Kent Research Ethic Committee (Reference 13/LO/0101; NHS Research & Development number RJ113/N306) to collect data after informed consent for the 3DFD group and for the control group general practices to screen their registers for eligible individuals and generate anonymized diabetes-related data.

<H2>Participant selection

For the 3DFD group, we used a referral form with the following criteria of: (1) HbA_{1c} ≥ 75 mmol/mol (≥ 9.0%) and (2) the presence of psychiatric morbidity (including depression, psychosis, eating or anxiety disorder, substance misuse or diabetes adherence problems) and/or social problems (housing, debt, literacy problems, unemployment) as diagnosed and judged by the referring clinician as contributing to reduced self-management. We excluded individuals who were already registered under mental health services, because 3DFD aimed to identify participants with unmet or previously unidentified mental health or social needs or who did not meet the clinical criteria for mental health services. We did not distinguish between types of diabetes. Participants could be referred from any point on the care pathway from primary to secondary care [19].

For the control group, consenting practices collected sociodemographic and biomedical data from their electronic medical records to identify individuals who met the first 3DFD referral criterion, which was having a current HbA_{1c} ≥ 75 mmol/mol (≥ 9.0%).

<H2>Interventions

<H3>*Usual care*

This consisted typically of a diabetes multidisciplinary team (MDT), which included a general practitioner (GP), diabetologist, diabetes specialist nurse and dietitian in three settings of increasing severity: primary, intermediate and secondary care. The pathway in all three boroughs was aligned with the principles of the Diabetes Guide for London [19] in which there was no provision for mental health or social care.

<H3>*3DFD intervention*

The 3DFD team consisted of a full-time consultant liaison psychiatrist and two full-time community support workers from a third-sector (or non-governmental organization), voluntary organization, Thames Reach, that provided social welfare. Thames Reach helps homeless and vulnerable people to be rehoused and rebuild their lives (thamesreach.org.uk). This combination of specialists was selected based on our pilot study [16] which observed higher levels of severe psychiatric morbidity. The psychiatrist was also trained to deliver brief psychological therapies.

From 1 October 2012 to 30 September 2013, any professional from the diabetes MDT in Lambeth and Southwark (i.e. a GP, diabetologist, diabetes specialist nurse or dietitian) could refer adult individuals to 3DFD via a standardized online or paper referral form. Each referral was discussed and triaged at weekly 3DFD team meetings attended by the psychiatrist and community worker and allocated to: (1) the liaison psychiatrist (if the referral indicated pressing safety concerns or presence of multiple psychiatric morbidities) for a diagnostic assessment and initiation and monitoring of psychotropics; (2) assessment for psychological therapy; and/or (3) the community support worker if social problems were recorded. All individuals who were referred and met the criteria were included as participants. The 3DFD clinics were integrated into diabetes teams and clinics and the third-sector support workers delivered outreach work from their offices or participants' homes. The final follow-up took place on 17 June 2015.

Following a clinical psychiatric assessment using the International Classification of Disorders-10 (ICD-10) criteria for psychiatric disorders [20] and identifying the barriers to optimal diabetes control, the treatment options consisted of: diabetes-focused cognitive behaviour therapy (CBT) [21]; initiation and monitoring of psychotropics; and/or social interventions, which involved advocacy in housing, debt problems, childcare, domestic violence, immigration and/or signposting to employment training. These were integrated into their routine diabetes care by ensuring 3DFD clinics were co-

located with the diabetes MDT clinics via joint consultations with the key diabetes healthcare professionals or weekly feedback at the generic diabetes MDT meetings. The 3DFD liaison psychiatrist and/or community worker met the participant in weekly-to-monthly appointments, depending on their needs, for a period of up to 6 months. Separate weekly 3DFD MDT meetings provided an opportunity to discuss challenges in treatment and for supervision. Discharge into routine diabetes care was planned with the generic diabetes MDT.

<H2>Measures

At baseline and 12 months for all participants, we collected the following data from medical records: sociodemographic variables (age, gender, self-reported ethnicity, postcode for IMD 2010 score and decile), biomedical variables [HbA_{1c}, serum cholesterol, eGFR, albumin-to-creatinine ratio (ACR), BMI and BP], macrovascular and microvascular complications, and prescribed medications.

For both groups, the primary outcome was change in HbA_{1c} from baseline (time of referral for 3DFD group) to 12-month follow-up (i.e. 6 months after discharge from the 3DFD intervention). Secondary outcomes were the remaining biomedical outcomes (serum cholesterol, eGFR, ACR, BMI and BP). Service use was coded and costed as number of emergency department (ED) visits, inpatient admissions and outpatient visits, length of inpatient bed stays, and number of outpatient appointments offered and attended in the previous 12 months at baseline and follow-up. We calculated the cost of the intervention as £209 785.50, based on the salaries of one psychiatrist (£76 761/year), and one senior (£32 802/year) and one junior (£30 294/year) Thames Reach worker for the duration of the intervention's implementation (18 months).

We could collect self-report psychological, social and service use measures at baseline and 12 months in the 3DFD group only. These included: the Patient Health Questionnaire (PHQ-9), a nine-item questionnaire that screens for severity and number of depressive symptoms (range 0–27) with

a score of ≥ 10 representing case threshold for likely depressive disorder [22]; the Generalized Anxiety Disorder-7 (GAD-7) scale, a seven-item questionnaire for screening for the presence and severity of anxiety (range 0–21), with scores ≥ 10 indicating possible anxiety disorder [23]; and the Diabetes Distress Scale (DDS), a 17-item instrument for the assessment of diabetes-related emotional distress with a score of ≥ 40 representing clinical significance [24]. For social functioning, we used the Independent Living Star™, a multidisciplinary tool originating in the third-sector which has been since adapted and validated for measuring the outcomes of social and psychological interventions [25]. Participants rate eight areas of social functioning on a Likert scale, where higher scores indicate higher levels of functioning: (1) Where you live, (2) Looking after yourself, (3) Health, (4) Being treated with dignity, (5) Meaningful activity, (6) Social life, (7) Managing money, and (8) How you feel.

<H2>Power calculation

The power calculation was informed by the effect size observed in the earlier study [16], however, we anticipated a more conservative between-group difference. We estimated that the improvement in HbA_{1c} in the 3DFD group would be 4 mmol/mol greater than the control group (with a pooled standard deviation of 15 mmol/mol), corresponding to a small effect size of 0.25 (Cohen's *d*). At a power of 80% and two-sided significance level of 0.05, a per group sample size of 252 was required for comparing two means.

<H2>Statistical analysis

We included 3DFD participants who were accepted into the intervention and controls that were identified anonymously. We described the baseline characteristics as means (SD) for continuous variables and as counts (%) for categorical variables. Baseline characteristics of each group were

compared using Student's *t*-test or χ^2 test for continuous and categorial variables respectively. We compared the change in biomedical outcomes from baseline to 12 months between groups with *t*-tests. For the self-report measures collected in the 3DFD group only, paired *t*-tests were used to investigate changes from baseline to follow-up. Distributions of continuous variables were checked with histograms and QQ plots; skewed variables were analysed with non-parametric tests (i.e. Mann–Whitney *U*-test). We used Fisher's exact test for comparing IMD 2010 quintiles as some cells contained zero or almost zero observations.

Using linear regression models, our primary analyses compared the change in HbA_{1c} and the other biomedical outcomes in the 3DFD vs. control group. We adjusted for relevant potential confounders (age, gender, ethnicity, IMD 2010 score, type of diabetes and diabetes duration). Residual plots were visually checked to see if the regression models fit the data and if any assumptions were violated.

We recorded health service use (inpatient admissions, ED visits and outpatient clinic attendance) and calculated costs by estimating the cost per contact with the service based on staff and other expenditure data, overheads and activity levels. Other service costs were calculated by combining the data collected from hospital and primary care records with appropriate unit cost information [26].

For our economic analysis, we compared total follow-up healthcare costs between groups in a regression model, adjusting additionally for baseline costs and change in HbA_{1c}. We used a bootstrapped model with 1000 replicates, which makes no assumptions about the underlying data distribution, to estimate the 95% confidence intervals (95% CI) of coefficients, as regression analyses of cost data often result in non-normally distributed residuals [27]. We did not transform the data as this would distort the true spread of morbidity and costs. For 3DFD participants only, total follow-up costs included the per-participant cost of the intervention.

The incremental cost-effectiveness ratio (ICER) was calculated for the ratio of follow-up total costs to HbA_{1c}, adjusting for baseline values, as follows: $(cost_{3DFD} - cost_{control})/(HbA_{1c3DFD} - HbA_{1ccontrol})$. The ICER was bootstrapped with 1000 replicates, its 95% CI calculated, and uncertainty around the estimate was shown by plotting the replicates on the cost-effectiveness plane.

We performed a per-protocol sensitivity analysis as well because a small group of participants were recruited with HbA_{1c} < 75 mmol/mol (< 9.0%), as they had serious psychiatric and/or social problems. The above primary and cost analyses were redone excluding these participants.

<H3>Propensity score analyses

In addition to the regression analyses, we conducted a propensity score analysis (PSA) with stratification to investigate the effect of the 3DFD intervention on change in HbA_{1c} and total follow-up healthcare costs to reduce the potential bias in our estimation of the treatment effect due to the observational and non-randomized design. A PSA allows for the balancing of measured covariates between the control and treatment groups in an observational study [28]. An advantage of the PSA over multiple regression is that by matching by propensity scores we do not rely on the linearity assumptions between confounders and outcome as in multiple regression. However, PSA does not allow extrapolation and we may not be able to make inferences about certain groups.

Participants with complete data on the relevant variables were used for the PSA. Propensity scores for change in HbA_{1c} and healthcare costs were calculated by predicting treatment group status from five (age, gender, ethnicity, 2010 IMD score and baseline HbA_{1c}) and eight variables (additionally complications, type of diabetes and baseline total costs) respectively, in a logistic regression model. Participants were then stratified based on quintiles of the propensity scores to create five, relatively equal-sized groups. Treatment effects on change in HbA_{1c} and costs were estimated within each stratum and pooled across strata. We checked the balancing of covariates.

Data were analysed using SPSS for Windows (version 22) and, for the PSA and bootstrapped cost statistics, R (version 3.4.1).

<H2>Participant involvement

Thinkpublic, a social enterprise that supports qualitative research co-design projects in the community, conducted semi-structured interviews with participants after our pilot study to inform the content of the intervention for this project. They asked for participant feedback as to the key facilitators for improving their care and suggested improvements (report available from the authors) [16,29].

<H1>Results

<H2>Comparison of 3DFD and control groups

During the study period, we received 307 referrals of which 277 individuals met the 3DFD criteria. In the control group, the five largest general practices in Lewisham agreed to participate and 292 individuals were anonymously identified from the diabetes registers who met the first eligible criterion of $HbA_{1c} \geq 75$ mmol/mol (≥ 9.0%) (Fig. 1).

Table 1 presents baseline characteristics. The 3DFD group overall had greater morbidity and greater risk of diabetes complications. On average they were 10 years younger, more likely to be female or from an ethnic minority, and slightly less likely to be living in the most deprived areas. The 3DFD group had poorer glycaemic control, longer duration of diabetes and a higher proportion of participants with Type 1 diabetes. In addition, the 3DFD group had more Type 2 diabetes participants receiving current insulin therapy. The 3DFD group also had higher mean eGFR values but a lower mean BMI.

In the 3DFD group, 47 (17.0%) participants were offered all three dimensions of care (prescribed psychotropic medication, CBT, and social support). Seventeen (6.1%) participants were prescribed medication and offered social support, and 77 (27.8%) were offered CBT and social support. Ten (3.6%) participants were offered CBT only and 48 (17.3%) were offered social support only. Seventy-eight (28.2%) did not receive any of the 3DFD services.

Table S1 presents the unadjusted between-group difference in change in biomedical outcomes from baseline to 12 months; the mean reduction in glycaemic control in the 3DFD group was significantly greater than in the control group, with no other differences observed for the other biomedical outcomes.

<H3>Primary analyses

In the multivariate analysis adjusting for potential confounders, the change in HbA_{1c} was significantly greater in the 3DFD group compared with the control group (Table 2). Additionally, we observed that the 3DFD group had greater decreases in ACR values over time. Residual plots indicated that the models fit the data well. Low adjusted-R^2 values for the biomedical outcomes suggest that treatment status and the covariates explained very little of these variables' variance.

<H3>Economic analyses

Table 3 reports health service use and costs by group at baseline and follow-up. The mean baseline total costs were about three times higher in the 3DFD group than the control group. In both groups, the costs of diabetes care had increased; although the rate of increase in the 3DFD group appeared less than in the control group, the difference between the two groups remained significant at follow-up. In the multivariate analysis, total follow-up costs were significantly greater in the 3DFD group than in the control group (Table 2).

After adjusting for baseline values, the between-group differences in total follow-up costs and follow-up HbA_{1c} values were £1988 and 5 mmol/mol (0.6%) respectively, yielding an ICER of £398 per mmol/mol unit decrease in HbA_{1c}. In other words, every 10 mmol/mol (1.1%) decrease in HbA_{1c} costs £3980 in additional healthcare use, including the cost of the 3DFD intervention over 12 months, compared with usual care. The bootstrapped results almost entirely fell within the north-east quadrant of the plane (Fig. S1), strongly suggesting that the 3DFD intervention was more expensive and more effective.

<H3>**Sensitivity analyses**

For the per-protocol analyses, 58 participants were excluded for having a baseline HbA_{1c} < 75 mmol/mol (<9.0%), leaving 240 (37 excluded) participants in the 3DFD group and 274 (18 excluded) in the control group remaining. The baseline characteristics of each group were similar to those in the original sample. The results closely resembled the above results, namely that, compared with the control group, the 3DFD group from baseline to follow-up had a significantly greater reduction in HbA_{1c}, no statistically different changes in other biomedical variables, greater healthcare costs in absolute units, and statistically significant improvements in the psychological and social measures. The results of the sensitivity analyses are not shown but the data are available upon request.

<H3>**PSA**

There were 452 participants (3DFD group *n* = 203, 44.9%) with complete data on the variables for the PSA. Five strata were created, with sizes of 90 or 91 participants each, and a minimum of 20% participants from one group in each stratum. In the lowest, second and fourth strata, 3DFD participants had significantly greater decreases in HbA_{1c} (Table S2). When pooling across strata, the

3DFD treatment effect was also significant. When checking the balance diagnostics of the covariates, some group differences remained within strata: age (higher in control group in the top stratum), baseline HbA_{1c} (higher in control group in the third stratum), IMD 2010 score (higher in 3DFD group in the third stratum).

For the PSA comparing follow-up total healthcare costs, 556 participants across the two groups (3DFD group *n* = 270, 48.6%) with complete data on the relevant variables were included. Five strata were created, of 111–112 participants each, and a minimum of 16% participants from one group in each stratum. Within each and across all strata, follow-up costs were not different between groups (pooled estimate £212, 95% CI −302 to 727).

<H2>3DFD group only

On the self-report measures, 3DFD participants indicated experiencing high levels of psychological difficulties (Table S3). In the pre–post analysis in the 3DFD group, there were statistically significant improvements in each psychological and social outcome (Table S3).

<H1>Discussion

This study tested the potential effectiveness of a service that integrated mental health and social care into the diabetes care pathway. We found that individuals actively being identified by diabetes health providers referred into to the 3DFD service were at higher risk of diabetes complications and costing the health system three times more than using the HbA_{1c} cut-off of 75 mmol/mol (9.0%) alone as in the control group. We also found that the integrated 3DFD service was effective, but not cost-effective, in reducing glycaemic control after adjusting for baseline potential confounders compared with the control group. We also found in the 3DFD group only that measures of psychological and social functioning improved.

<H2>Strengths

We used a study design that allowed us to model a service innovation at a cluster level in the real-world setting of an inner-city with very high levels of socio-economic deprivation. The criteria were broad and simple to be inclusive to all types of mental health and/or social problems and to ensure that they were user-friendly by busy clinician referrers. This contrasts with other models of integrated care that focused only on depression in diabetes, thus limiting the generalizability of their findings to one comorbidity [10,11]. We also achieved high follow-up rates for our primary outcome, HbA_{1c}.

<H2>Limitations

The main limitation is the non-randomized design. An RCT was not appropriate as the service innovation was funded in only two boroughs. As an unexpected consequence, due to the non-randomized design, having a referral system in the intervention group led to recruitment of participants who were sicker than the control group; they had worse glycaemic control, were younger, more likely to have Type 1 diabetes and at greater risk of health disparities. Although we did not have psychiatric or social data for the control group, we appear to have selected a less sick group and we thus likely underestimated the cost-effectiveness of the intervention. For the 3DFD group, having a referral system that explicitly includes a mental health or social problems appears to encourage health professionals to select individuals for whom they had more concerns.

Second, we had a smaller number of practices agreeing to participate in the control borough and their diabetes population may have had better health status. We adjusted for the baseline differences between the 3DFD and control group in the multivariate analysis and used a PSA, and the effect of the 3DFD intervention on glycaemic control remained significant. A further limitation is that many 3DFD participants were missing outcome data on psychological measures at 12-month follow-

up because these data were being collected as participants presented routinely, potentially biasing our findings towards positive effects on mental health. Another limitation is that the inner-London setting is potentially different from other inner-city settings across the UK, for instance, in its ethnic and socio-economic diversity. We were not able to adjust for some potential confounders such as marital status. Finally, we conducted several statistical analyses with a relatively small sample size, thus some of our findings may be false positives. Overall, our findings are to be interpreted with caution and need further validation.

<H2>Interpretation

Although there have been many clinical trials of treating depression and diabetes distress in people with diabetes [10,30–32], there is almost no published literature evaluating the benefits on biomedical, psychological and social outcomes of integrating mental health and social care into a diabetes service [30]. The cost of diabetes is greater for those who are diagnosed earlier and therefore have a longer duration [33]. We observed this in our 3DFD group where costs before treatment were three times higher. The control group shows that the annual cost of diabetes increases rapidly and the 3DFD intervention suggests that it can slow down this inevitable year-on-year increase in costs.

The cost of 3DFD was £757.35 per person over 12 months and was associated with a reduction of 10 mmol/mol (1.1%) in HbA_{1c}. This is favourable compared with adding a second or third diabetes drug, for instance, adding liraglutide 1.8 mg/day for 12 months would cost the NHS an additional £1433.24 per person [34]. However, as well as knowing the cost of pharmacological interventions, we would also need to establish their effectiveness in comparison with 3DFD because healthcare decisions cannot be made on the basis of cost alone.

The added value of integrating mental health and social care into patient management seems to result in multidimensional improvements in outcomes and of a larger magnitude than those observed in clinical trials of collaborative care [35]. Referral processes and pathways of care that include an assessment of mental health and social problems encourage clinicians to identify a group of much higher risk individuals, rather than using poor glycaemic control alone as an indicator of psychological or social distress or greater healthcare utilization. Another added value is that 3DFD crossed organizational boundaries from primary care to specialist diabetes services, overcoming many communication barriers. There are very few similar models to compare with 3DFD. The Rapid, Assessment, Interface and Discharge (RAID) model is a specialist multidisciplinary mental health service for rapid discharge of mentally ill individuals presenting in ED settings and was associated with significant cost savings, and despite lacking the RCT gold-standard evidence, has been widely disseminated [36]. A recent pragmatic cluster RCT of integrated psychological and biomedical approach to multi-morbidity in primary care did not lead to improved quality of life, possibly because social factors were not included [37]. Our findings suggest there is now a need for a cluster RCT to test the effectiveness and cost-effectiveness of integrated psychiatric and social care in diabetes services.

<H1>Conclusions

In summary, a biomedical, psychological and social criteria-based referral system for identifying and managing high-cost and high-risk individuals with poor glycaemic control can lead to improved health in all three dimensions. The cost of the intervention was lower than second-line diabetes drugs.

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Competing interests

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Data are available upon reasonable request to the corresponding author.

Author contributions

KI with CG developed the 3DFD model of care, supervised the study, supervised the analysis and manuscript development. KR contributed to the data collection. EB conducted the study and data collection and preliminary analyses. RF contributed to data collection. DS contributed to the statistical analyses. KS contributed to the statistical analyses and writing of the manuscript. PM contributed to the economic portion of the study. CG with KI developed the 3DFD model of care, implemented and supervised the study. AMD led the delivery of 3DFD and supervised the data collection and initial manuscript draft. All authors commented on and contributed to the manuscript development.

References

1 Hex N, Bartlett C, Wright D, Taylor M, Varley D. Estimating the current and future costs of Type 1 and Type 2 diabetes in the UK, including direct health costs and indirect societal and productivity costs. *Diabet Med* 2012; **29**: 855-862.

2 Gonzalez JS, Peyrot M, McCarl LA, Collins EM, Serpa L, Mimiaga MJ *et al*. Depression and diabetes treatment nonadherence: a meta-analysis. *Diabetes Care* 2008; **31**: 2398–2403.

3 Ismail K, Winkley K, Stahl D, Chalder T, Edmonds M. A cohort study of people with diabetes and their first foot ulcer: the role of depression on mortality. *Diabetes Care* 2007; **30**: 1473–1479.

4 Fisher L, Polonsky WH, Hessler DM, Masharani U, Blumer I, Peters AL *et al*. Understanding the sources of diabetes distress in adults with type 1 diabetes. *J Diabetes Complicat* 2015; **29**: 572–577.

5 Lustman PJ, Clouse RE. Depression in diabetic patients: the relationship between mood and glycemic control. *J Diabetes Complicat* 2005; **19**: 113–122.

6 Roy T, Lloyd CE. Epidemiology of depression and diabetes: a systematic review. *J Affect Disord* 2012; **142**: S8–S21.

7 Osborn CY, Egede LE. The relationship between depressive symptoms and medication nonadherence in type 2 diabetes: the role of social support. *Gen Hosp Psychiat* 2012; **34**: 249–253.

8 Hopkins D, Lawrence I, Mansell P, Thompson G, Amiel S, Campbell M *et al*. Improved biomedical and psychological outcomes 1 year after structured education in flexible insulin therapy for people with type 1 diabetes: the U.K. DAFNE experience. *Diabetes Care* 2012; **35**: 1638–1642.

9 NHS England. *NHS Five Year Forward View*, 2014. Available at https://www.england.nhs.uk/five-year-forward-view/ Last accessed X XX 201X.

10 Katon WJ, Lin EHB, Von Korff M, Ciechanowski P, Ludman EJ, Young B *et al*. Collaborative care for patients with depression and chronic illnesses. *N Engl J Med* 2010; **363**: 2611–2620.

11 Petrak F, Baumeister H, Skinner TC, Brown A, Holt RIG. Depression and diabetes: treatment and health-care delivery. *Lancet Diabetes Endocrinol* 2015; **3**: 472–485.

12 Hippisley-Cox J, O'Hanlon S, Coupland C. Association of deprivation, ethnicity, and sex with quality indicators for diabetes: population based survey of 53,000 patients in primary care. *BMJ* 2004; **329**: 1267–1269.

13 Riste L, Khan F, Cruickshank K. High prevalence of type 2 diabetes in all ethnic groups, including Europeans, in a British inner city: relative poverty, history, inactivity, or 21st century Europe? *Diabetes Care* 2001; **24**: 1377–1383.

14 Gary TL, Batts-Turner M, Yeh H-C, Hill-Briggs F, Bone LR, Wang NY *et al*. The effects of a nurse case manager and a community health worker team on diabetic control, emergency department visits, and hospitalizations among urban African Americans with type 2 diabetes mellitus. *Arch Intern Med* 2009; **169**: 1788–1794.

15 Glazier RH, Bajcar J, Kennie NR, Willson K. A systematic review of interventions to improve diabetes care in socially disadvantaged populations. *Diabetes Care* 2006; **29**: 1675–1688.

16 Doherty AM, Gayle C, Morgan-Jones R, Archer N, Laura-Lee, Ismail K *et al*. Improving quality of diabetes care by integrating psychological and social care for poorly controlled diabetes. *Int J Psychiat Med* 2016; **51**: 3–15.

17 Concato J, Shah N, Horwitz RI. Randomized, controlled trials, observational studies, and the hierarchy of research designs. *N Engl J Med* 2000; **342**: 1887–1892.

18 Department for Communities and Local Government. *Indices of Deprivation*. Available at https://data.london.gov.uk/dataset/indices-of-deprivation-2015 Last accessed 19 November 2016.

19 Healthcare for London, NHS. *Diabetes Guide for London*. Available at http://www.londonprogrammes.nhs.uk/wp-content/uploads/2011/03/diabetes-guide.pdf Last accessed 11 November 2017.

20 World Health Organization. *International Statistical Classification of Diseases and Related Health Problems - 10th Revision*. Available at http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf Last accessed X XX 20XX.

21 Plotnikoff RC, Karunamuni N, Courneya KS, Sigal RJ, Johnson JA, Johnson ST. The Alberta Diabetes and Physical Activity Trial (ADAPT): a randomized trial evaluating theory-based interventions to increase physical activity in adults with type 2 diabetes. *Ann Behav Med* 2012; **45**: 45–56.

22 Spitzer RL, Kroenke K, Williams JB. Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. *JAMA* 1999; **282**: 1737–1744.

23 Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med* 2006; **166**: 1092–1097.

24 Fisher L, Glasgow RE, Mullan JT, Skaff MM, Polonsky WH. Development of a brief diabetes distress screening instrument. *Ann Fam Med* 2008; **6**: 246–252.

25 Killaspy H, White S, Taylor TL, King M. Psychometric properties of the Mental Health Recovery Star. *Br J Psychiat* 2012; **201**: 65–70.

26 Riva M, Curtis SE. Long-term local area employment rates as predictors of individual mortality and morbidity: a prospective study in England, spanning more than two decades. *J Epidemiol*

Community Health 2012; **66**: 919–926.

27 Mihaylova B, Briggs A, O'Hagan A, Thompson SG. Review of statistical methods for analysing healthcare resources and costs. *Health Econ* 2011; **20**: 897–916.

28 Heinze G, Juni P. An overview of the objectives of and the approaches to propensity score analyses. *Eur Heart J* 2011; **32**: 1704–1708.

29 Thinkpublic, NHS London. *Findings from Interviews with Patients of the 3DFD Service: A Research Report Based on Interviews with Patients of the 3DFD Programme*, 2011. Available at https://www.kcl.ac.uk/ioppn/depts/pm/research/Diabetes-Psychiatry-Psychology/3DFD-report-(1).pdf Last accessed X XX 20XX.

30 Atlantis E, Fahey P, Foster J. Collaborative care for comorbid depression and diabetes: a systematic review and meta-analysis. *BMJ Open* 2014; **4**: e004706.

31 Coventry P, Lovell K, Dickens C, Bower P, Chew-Graham C, McElvenny D *et al*. Integrated primary care for patients with mental and physical multimorbidity: cluster randomised controlled trial of collaborative care for patients with depression comorbid with diabetes or cardiovascular disease. *BMJ* 2015; **350**: h638.

32 Mitchell C, Catalan J, McIntosh C, Feher MD. Joint liaison-psychiatry–diabetes clinic: a new specialist service. *Diabet Med* 2000; **17**: 481–483.

33 Zhuo X, Zhang P, Barker L, Albright A, Thompson TJ, Gregg E. The lifetime cost of diabetes and its implications for diabetes prevention. *Diabetes Care* 2014; **37**: 2557–2564.

34 Joint Formulary Committee. *British National Formulary 71*. London: Pharmaceutical Press, 2016.

35 Katon W, Russo J, Lin EH, Schmittdiel J, Ciechanowski P, Ludman E *et al*. Cost-effectiveness of a multicondition collaborative care intervention: a randomized controlled trial. *Arch Gen*

Psychiatry 2012; **69**: 506–514.

36 Tadros G, Salama RA, Kingston P, Mustafa N, Johnson E, Pannell R *et al*. Impact of an integrated rapid response psychiatric liaison team on quality improvement and cost savings: the Birmingham RAID model. *Psychiatrist* 2013; **37**: 4–10.

37 Salisbury C, Man M-S, Bower P, Guthrie B, Chaplin K, Gaunt DM *et al*. Management of multimorbidity using a patient-centred care model: a pragmatic cluster-randomised trial of the 3D approach. *Lancet* 2018; **392**: 41–50.

FIGURE 1 Study flow diagram.

<H1>Supporting Information

Additional Supporting Information may be found in the online version of this article.

Figure S1. Cost-effectiveness plane, plotting bootstrapped estimates of improvement in HbA_{1c} vs. intervention cost.

Table S1. Change in biomedical variables from baseline to 12-month follow-up in 3DFD vs. control group.

Table S2. Propensity score analysis of group status and change in HbA_{1c}, controlling for baseline HbA_{1c}.

Table S3. Comparison of psychological outcomes in the 3DFD group at baseline and 12-month follow-up.

Table 1 Baseline characteristics of 3DFD and control participants

Baseline characteristics		3DFD (n = 277)*	Control (n = 292)†	P-value
Age, years (SD)		46.8 (15.0)	57.2 (14.2)	**< 0.001**
Gender, female		168 (60.7)	137 (47.7)	**0.003**
Ethnicity	White	114 (41.2)	150 (51.4)	
	African/Caribbean	127 (45.)	93 (31.9)	**0.003**
	Asian/Mixed/Other	36 (13.0%)	49 (16.8)	
IMD 2010 quintile‡ (%)	1, least deprived	2 (0.7)	0	
	2	6 (2.2)	0	
	3	22 (8.0)	48 (16.4)	**< 0.001**
	4	147 (53.3)	108 (37.0)	
	5, most deprived	99 (35.9)	136 (46.6)	
Type of diabetes	Type 1	90 (32.5)	23 (8.0)	**< 0.001**
	Type 2	187 (67.5)	264 (92.0)	
Duration of diabetes, years (SD)		11.4 (8.8)	9.4 (7.3)	**0.015**§
Current insulin therapy		183 (66.3)	119 (40.8)	**< 0.001**
HbA_{1c}, mmol/mol (SD)		97 (21)	93 (17)	**0.013**
HbA_{1c}, % (SD)		11.0 (1.9)	10.7 (1.6)	
Serum cholesterol, mmol/l (SD)		4.77 (1.33)	4.69 (1.23)	0.53
eGFR, ml min^{-1} 1.73m^{-2} (SD)		80.2 (25.6)	74.6 (15.5)	**0.007**
ACR, mg/mmol (SD)		8.4 (17.5)	10.8 (37.9)	0.30§
BMI, kg/m^2 (SD)		30.0 (7.7)	31.5 (6.4)	**0.032**
BP systolic, mmHg (SD)		130.3 (18.7)	132.4 (15.8)	0.21
BP diastolic, mmHg (SD)		77.4 (10.1)	78.9 (9.7)	0.12
Macrovascular complications	None	87 (43.3)	112 (41.0)	0.69
	At least one	114 (56.7)	161 (59.0)	
Microvascular complications	None	66 (32.2)	80 (30.4)	0.76
	At least one	139 (67.8)	183 (69.6)	

Data are mean (SD) or n (%), as appropriate. Percentages were calculated after the missing data for the respective variable were excluded.
Values in bold are statistically significant.
*Number of missing cases for the 3DFD group is: gender, 5; IMD quintile, 1; type of diabetes, 5; macrovascular complications, 76; microvascular complications, 72.
†Number of missing cases for the control group is: gender, 5; type of diabetes, 5; macrovascular complications, 19; microvascular complications, 29.
‡IMD quintiles were derived from the national deciles (i.e. deciles 1 and 2 were collapsed to form quintile 1).
§Diabetes duration and albumin-to-creatinine ratio values were skewed and non-parametric tests were used.
IMD, Index of Multiple Deprivation; ACR, albumin-to-creatinine ratio.

Table 2 Results of the regression analyses predicting change in HbA_{1c} and other biomedical outcomes and total follow-up healthcare costs

	HbA_{1c} (mmol/mol)	Serum cholesterol (mmol/L)	eGFR (ml min^{-1} 1.73m^{-2})	ACR (mg/mmol)	BMI (kg/m^2)	BP systolic (mmHg)	BP diastolic (mmHg)	Total follow-up costs (£)
Model coefficients	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)*
Treatment group (control vs. 3DFD)	**−10.5 (−15.2 to −5.8)**	−0.11 (−0.54 to 0.32)	0.66 (−2.67 to 3.99)	**−12.08 (−22.24 to −1.93)**	−0.04 (−0.63 to 0.56)	0.29 (−3.88 to 4.47)	0.53 (−1.91 to 2.96)	**1336.65 (242 to 2351)**
Age (years)	**−0.4 (−0.6 to −0.2)**	0 (−0.01 to 0.02)	−0.11 (−0.24 to 0.02)	−0.14 (−0.51 to 0.24)	0.01 (−0.01 to 0.03)	0.04 (−0.12 to 0.19)	−0.03 (−0.12 to 0.06)	−5.62 (−43.82 to 32.16)
Gender (male vs. female)	−0.4 (−4.7 to 4.0)	**−0.39 (−0.78 to −0.01)**	−1.99 (−4.96 to 0.98)	3.72 (−4.74 to 12.17)	−0.07 (−0.61 to 0.47)	−2.39 (−6.17 to 1.39)	1.03 (−1.18 to 3.23)	−521.48 (−1382.2 to 525.3)
Ethnicity (white vs. black)	1.5 (−3.3 to 6.4)	−0.05 (−0.48 to 0.37)	−0.16 (−3.47 to 3.15)	−0.84 (−10.21 to 8.53)	0.09 (−0.51 to 0.69)	−0.13 (−4.34 to 4.09)	−0.8 (−3.26 to 1.66)	**−1532.02 (−2664 to −492)**
Ethnicity (white vs. other)	**7.2 (1.2 to 13.3)**	0.1 (−0.46 to 0.67)	−0.19 (−4.51 to 4.14)	2.34 (−9.51 to 14.18)	0.42 (−0.33 to 1.18)	0.62 (−4.65 to 5.89)	−0.42 (−3.51 to 2.67)	−1153.53 (−2252 to −163)
Type of diabetes (Type 1 vs. Type 2)	6.1 (−1.2 to 13.4)	−0.33 (−1 to 0.33)	1.21 (−4.12 to 6.54)	**−17.69 (−33.29 to −2.09)**	−0.47 (−1.42 to 0.48)	−0.21 (−6.74 to 6.32)	1.71 (−2.11 to 5.53)	−1451.17 (−2963 to 657)
IMD 2010 score	0.1 (−0.3 to 0.4)	0.01 (−0.02 to 0.04)	0.01 (−0.22 to 0.23)	0.08 (−0.57 to 0.73)	0 (−0.04 to 0.04)	0.01 (−0.27 to 0.3)	−0.02 (−0.19 to 0.14)	−6.07 (−60.34 to 46.47)
Diabetes duration (years)	**0.5 (0.2 to 0.8)**	0.01 (−0.02 to 0.03)	0.01 (−0.2 to 0.21)	0.19 (−0.42 to 0.79)	0.01 (−0.03 to 0.05)	**−0.31 (−0.57 to −0.06)**	−0.1 (−0.25 to 0.05)	27.03 (−38.75 to 83.31)
Change in HbA_{1c} (mmol/mol)								−11.47 (−31.78 to 8.53)
Total baseline costs (£)								**0.39 (0.27 to 0.94)**
Model statistics								
Adjusted R^2	0.06	0.00	−0.01	0.02	−0.01	0.00	−0.01	0.33

For HbA_{1c} and other biomedical outcomes, negative coefficient estimates indicate decreases in that variable from baseline to 12-month follow-up.
Values in bold are statistically significant.
Intercept terms were included in each model but are not reported here. IMD 2010 scores were entered as a continuous variable.
*Bootstrapped percentile 95% confidence intervals (CI) are presented.

Table 3 Healthcare use and costs per participant in the preceding 12 months from baseline and from 12-month follow-up in the 3DFD vs. control group

	3DFD			Control			Mean difference in costs (95% CI)†	*P*-value‡
	No. of participants (%)	No. of visits/length of stay	Cost (£)	No. of participants (%)	No. of visits/length of stay	Cost (£)		
Baseline								
Inpatient admissions	100 (36.1)	2.33 (2.14)	2324 (11 875)	39 (13.4)	5.79 (26.53)	652 (3645)	−1672 (−3137 to −207)	**< 0.001**
ED attendance	118 (42.6)	2.89 (3.40)	150 (316)	65 (22.3)	1.60 (1.73)	43 (122)	−107 (−147 to −68)	**< 0.001**
Outpatient clinic attendance	223 (80.5)	9.92 (10.66)	1012 (1555)	228 (78.1)	4.18 (3.92)	370 (466)	−642 (−833 to −450)	**< 0.001**
Total			3486 (12 253)			1065 (3870)	−2421 (−3936 to −905)	**< 0.001**
	Follow-up							
Inpatient admissions	103 (37.2)	3.06 (2.66)	2,365 (7549)	61 (20.9)	4.16 (21.34)	1025 (5446)	−1339 (−2428 to −250)	**< 0.001**
ED attendance	125 (45.1)	2.52 (2.78)	140 (285)	82 (28.1)	1.71 (1.02)	59 (116)	−81 (−117 to −45)	**< 0.001**
Outpatient clinic attendance	238 (85.9)	11.46 (11.84)	1,203 (1418)	221 (75.7)	5.44 (5.52)	487 (657)	−716 (−900 to −532)	**< 0.001**
3DFD intervention *			757.35					
Total			4465 (8214)			1571 (5760)	−2893 (−4068 to −1719)	**< 0.001**

Data are mean (SD) or *n* (%). *P*-values in bold are statistically significant.

No missing data. Length of stay is given in days.
*Cost of 3DFD intervention per participant is based on total delivery cost of £209 785.50 for 277 participants.
†3DFD costs are subtracted from control costs.
‡All variables were heavily skewed and Mann–Whitney *U*-tests were used to compare groups.
Ci, confidence intervals; ED, emergency department.