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Healthcare Expenditure and Catastrophic Healthcare Expenditure among Patients with Type 2 Diabetes Mellitus in Bangladesh: Socioeconomic and Centre-Level Variation in a Multicentre Longitudinal Study

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Abstract

Background: Type 2 diabetes mellitus (T2DM) imposes substantial and recurrent out-of-pocket costs on patients and households. In Bangladesh, evidence remains limited on longitudinal changes in healthcare expenditure and catastrophic healthcare expenditure (CHE), particularly how financial burden differs across socioeconomic groups and diabetes service-delivery settings.

Methods: This multicentre quasi-experimental longitudinal study enrolled 840 adults with established T2DM from eight Bangladesh Diabetic Association (BADAS) centres, one from each administrative division. Participants were followed for 12 months during an intervention programme comprising clinical monitoring, study-funded diagnostic tests, health education, self-management support, and SMS reminders; 772 (91.9%) completed endline assessment. Economic outcomes were total healthcare expenditure and CHE at 10% and 25% of household income. Mixed-effects regression models examined adjusted associations and whether longitudinal changes in financial outcomes varied by household income and centre.

Results: Mean total healthcare expenditure decreased from BDT 19,422.7 at baseline to BDT 17,180.7 at endline (p=0.0013); CHE10 declined from 57.8% to 53.2% (p=0.0154) and CHE25 from 20.2% to 16.2% (p=0.0051). At baseline, participants with household income >BDT 20,000 had 60.49% higher adjusted expenditure (95% CI 38.08-86.53) but substantially lower odds of CHE10 (AOR=0.14, 95% CI 0.08-0.24) and CHE25 (AOR=0.02, 95% CI 0.003-0.09) than lower-income participants (all p<0.001). Longitudinal changes in expenditure, CHE10, and CHE25 differed significantly by household income and across BADAS centres (all interaction tests p<0.001), indicating heterogeneity in financial trajectories. Total expenditure and CHE10 were higher among participants with baseline comorbidity, although these associations were not statistically significant; the CHE25 estimate was imprecise.

Conclusion: Healthcare expenditure and catastrophic healthcare expenditure were lower overall at 12-month follow-up, but substantial financial vulnerability persisted, particularly among lower-income households. Variation in financial trajectories across BADAS centres indicates that the affordability of long-term diabetes care may differ across local service-delivery contexts. Strengthening financial protection, improving the affordability and availability of essential medicines and services, and addressing local barriers to chronic diabetes care may help reduce financial hardship. Because the study lacked a concurrent comparison group, observed changes should be interpreted as temporal associations rather than causal intervention effects.

Keywords: Type 2 diabetes mellitus; social determinants of health; healthcare expenditure; catastrophic healthcare expenditure; financial burden; health policy; Bangladesh.

Introduction

Type 2 diabetes mellitus (T2DM) is a major and growing public health challenge, particularly in low- and middle-income countries (LMICs). The International Diabetes Federation estimates that hundreds of millions of adults are living with diabetes worldwide, with the burden expected to increase further over coming decades [1]. Diabetes requires sustained clinical management and periodic monitoring, and its microvascular and macrovascular complications—including cardiovascular disease, nephropathy, neuropathy, and retinopathy—substantially increase healthcare needs and costs [1, 2]. Recent estimates suggest that approximately 13.9 million adults in Bangladesh are living with diabetes, making the country one of the largest contributors to the diabetes burden in South Asia [3]. The burden of diabetes has risen alongside population ageing, urbanisation, dietary transition, physical inactivity, and obesity [1, 4]. Recent analyses of the Bangladesh diabetes care cascade also demonstrate major gaps in diagnosis, treatment, and glycaemic control and show that education and household wealth are important determinants of progression through the care continuum [5].

The financial consequences of diabetes are substantial for patients and households. Direct medical expenditure arises from consultations, medicines, laboratory investigations, hospitalisation, and treatment of complications [6-8]. In Bangladesh, where out-of-pocket (OOP) payments account for a large share of health spending, these costs may expose households to financial hardship [9]. A nationally representative analysis reported an average annual OOP expenditure of approximately BDT 25,473 per patient with diabetes, with medicines accounting for about three-quarters of OOP costs; 14.3% and 5.9% of affected households experienced catastrophic healthcare expenditure (CHE) at the 10% and 25% thresholds, respectively [6]. More recent evidence from rural Bangladesh similarly shows that diabetes care entails considerable direct and indirect costs, with medicines remaining a major cost component and comorbid conditions contributing to higher expenditure [10].

Social determinants of health (SDOH)—the social and economic conditions in which people are born, grow, live, work, and age—shape both diabetes outcomes and access to care which is recognized by The World Health Organization (WHO) [11]. Income, education, employment, gender, and geographic location may influence the affordability and use of consultations, medicines, laboratory monitoring, and follow-up care [11-13]. These mechanisms are particularly relevant in settings where OOP payments dominate healthcare financing. In Bangladesh, recent evidence indicates that socioeconomic position is associated with key stages of the diabetes care cascade, including diagnosis, treatment, and glycaemic control [5]. Consequently, socioeconomic disadvantage may contribute not only to poorer disease management but also to a greater risk of financial hardship from diabetes-related healthcare expenditure.

Comorbidity may further intensify this economic burden. Patients with T2DM frequently experience coexisting non-communicable diseases (NCDs), such as hypertension, cardiovascular disease, chronic kidney disease, chronic respiratory diseases, dyslipidaemia, and other chronic conditions, increasing the need for consultations, diagnostic investigations, multiple medicines, specialist care, and hospitalisation. Multimorbidity has consistently been associated with greater healthcare utilisation and higher costs across health systems [14, 15]. Bangladesh-specific studies have likewise shown that diabetes complications and comorbid conditions are important drivers of hospitalisation and healthcare expenditure [8]. Recent rural evidence also indicates that comorbidities are associated with higher direct costs of diabetes care [10]. Understanding SDOH and baseline comorbidity jointly is therefore important for identifying groups at heightened risk of adverse economic outcomes.

Regular monitoring is a cornerstone of T2DM management. Clinical guidelines recommend periodic assessment of glycaemic control and diabetes-related complications using tests such as fasting plasma glucose, glycated haemoglobin (HbA1c), serum creatinine, and lipid profiles [2]. However, the cost of repeated diagnostic investigations may create barriers for socioeconomically disadvantaged patients, particularly where services are financed predominantly through OOP payments. Interventions that combine patient education, adherence support, lifestyle counselling, mobile-health approaches, and financial support for essential services may improve access and self-management [16]. A systematic review of interventions in lower-middle-income countries found that patient education, financial assistance, facility-quality improvements, and early-detection strategies can reduce OOP expenditure, although effects are often modest and the evidence base remains heterogeneous [17].

Important evidence gaps nevertheless remain. In Bangladesh, much of the published evidence on diabetes-related expenditure has been based on cross-sectional, cost-of-illness, or secondary household-survey analyses [6, 8, 10]. At the South Asian level, a systematic review found that most economic studies of diabetes and cardiovascular disease were cost-of-illness studies and, notably, none of the included studies assessed longitudinal patient-level costs; the authors called for higher-quality longitudinal evidence [18]. A systematic review of economic evaluations of T2DM interventions in LMICs likewise identified a limited and heterogeneous evidence base, with more than half of included studies relying on decision-analytic modelling rather than prospective empirical follow-up [19]. Thus, there remains limited longitudinal evidence from Bangladesh and comparable South Asian settings on how SDOH and comorbidity relate to changes in healthcare expenditure and CHE over time, and whether such changes differ across socioeconomic and service-delivery contexts.

Therefore, this multicentre quasi-experimental longitudinal study was conducted among patients with T2DM attending selected BADAS centres to examine the financial burden of long-term diabetes care and its variation across socioeconomic groups and service-delivery settings over 12 months. Specifically, the study aimed to: (i) quantify total healthcare expenditure and CHE at the 10% and 25% household-income thresholds at baseline and 12-month endline; (ii) examine associations of household income and other social determinants of health with total healthcare expenditure and CHE; (iii) determine whether longitudinal changes in these economic outcomes differed by household income and BADAS centre; and (iv) assess the association of baseline comorbidity with healthcare expenditure and CHE. The analysis was intended to generate evidence relevant to the affordability, financial protection, and delivery of long-term diabetes services in Bangladesh.

Materials and Methods

Study design and setting

This was a multicentre quasi-experimental longitudinal study employing a single-group before-and-after design. A sampling frame was prepared by compiling the BADAS diabetes centres located in districts within each of the eight administrative divisions of Bangladesh. One BADAS centre was then randomly selected from each division for inclusion in the study. The eight selected centres were located in Dinajpur, Sherpur, Bogura, Sylhet, Dhaka (BIRDEM), Cox's Bazar, Barishal, and Khulna, thereby providing eight study sites across the eight administrative divisions of Bangladesh (Figure 1).

Participant recruitment was conducted from March to July 2024. Each enrolled participant was followed for 12 months; accordingly, endline assessments were completed between March and July 2025, with the final study follow-up completed in July 2025.

******** Insert Figure 1 here ********

Figure 1 title: Geographical location of the eight BADAS diabetes centres included in the study across Bangladesh

Study population and eligibility criteria

The study population comprised adults with established type 2 diabetes mellitus (T2DM) who were registered for care at the participating BADAS centres. The parent-study protocol prespecified an age threshold of 40 years and a minimum T2DM duration of five years; therefore, adults younger than 40 years were outside the protocol-defined study population.

Participants were eligible if they: (i) were aged 40 years or older; (ii) were registered with a participating BADAS centre; (iii) had been diagnosed with T2DM for at least five years; (iv) had access to a mobile phone and were able to read SMS messages independently or with assistance; (v) resided within the catchment area of the participating centre; and (vi) were willing to participate and provide written informed consent. For recruitment and the original sample-size framework, participants were also classified according to average monthly household income as <=20,000 BDT/month or >20,000 BDT/month [4].

Sample size calculation

The sample size was determined for the parent quasi-experimental study using glycaemic control as the primary clinical outcome. Healthcare expenditure and catastrophic healthcare expenditure (CHE), which are the focus of the present manuscript, were prespecified secondary economic outcomes. Participants were stratified for sample-size estimation into two household-income categories using the threshold applied in the cited Bangladesh study [4]: ≤20,000 BDT/month and >20,000 BDT/month. These categories are referred to in the present manuscript as the lower-income and higher-income groups, respectively.

The required sample size was estimated separately for the two income groups using methods for comparison of two proportions described by Fleiss et al. [20] and Lwanga and Lemeshow [21], assuming a two-sided significance level of 5%, 80% power, and an anticipated improvement in glycaemic control after 12 months. Based on prior evidence [4], glycaemic control in the lower-income group was assumed to increase from 14.6% to 40.6%, yielding a required sample of 45 participants per site; after allowing for 10% loss to follow-up, the target was 50 per site. In the higher-income group, glycaemic control was assumed to increase from 20.0% to 46.0%, yielding a required sample of 50 participants per site; after allowing for 10% loss to follow-up, the target was 55 per site. Thus, 105 participants were targeted at each of the eight study sites, giving a total planned sample size of 840 participants. Detailed calculations are provided in the Supplementary File.

No separate a priori sample-size calculation was undertaken specifically for the economic outcomes because these were secondary outcomes of the parent study. The present economic analysis therefore included all participants with data available for the relevant outcomes and covariates, and effect estimates are reported with 95% confidence intervals to convey the precision of the estimated associations and changes.

Participant enrolment and sampling

Eligible patients attending the participating BADAS centres during the recruitment period were enrolled consecutively until the prespecified sample requirement for each household-income

category was reached at each site. Recruitment started in March 2024 and ended in July 2024, when the target enrolment of 840 participants had been achieved.

Baseline data collection

Baseline data were collected through face-to-face interviews using a structured paper-based questionnaire administered by trained data collectors. Information relevant to the present manuscript included sociodemographic characteristics and social determinants of health (SDOH) indicators (household income, education, gender, age, and occupation), diagnosed comorbid chronic conditions, healthcare-seeking behaviour, and out-of-pocket (OOP) healthcare expenditure during the preceding six months. Anthropometric measurements and selected biomarker tests were also obtained as part of the parent study. Other patient-reported and clinical measures collected for the broader study but not analysed in the present economic-outcomes manuscript are not described further here.

Baseline comorbidity was defined as the presence of at least one diagnosed chronic non-communicable disease other than T2DM. For expenditure assessment, participants were asked to report the total amount incurred during the preceding six months for consultations, medicines, diagnostic investigations, and inpatient services related to T2DM and related complications. Expenditure was recorded separately for these four domains and used to derive total healthcare expenditure.

The structured questionnaire and study data-collection forms were developed specifically for the parent study by the research team. The study instruments were administered in Bangla, with selected established measures incorporated where relevant to the broader parent study. Health related quality of life measurement questions were adopted from EuroQol Research Foundation. An English-language version of the study data-collection instruments is provided as Supplementary File 2.

Health intervention package

Following baseline assessment, all enrolled participants received a standardized 12-month intervention package implemented across the eight BADAS centres. The package comprised: (i) scheduled clinical review and clinical examination; (ii) anthropometric assessment, including height, weight, and body mass index; (iii) laboratory monitoring, with fasting plasma glucose, two-hour after-breakfast/postprandial glucose, and HbA1c measured at months 1, 4, 8, and 12, and lipid profile and serum creatinine measured at months 1 and 12; (iv) reimbursement by the study of the costs of the prespecified diagnostic tests performed at scheduled study visits; (v) structured health-education support covering personalized diet and physical activity, timely treatment initiation or intensification, medication adherence, and self-management, including

home blood-glucose and blood-pressure monitoring where applicable; and (vi) mobile-phone-based support consisting of SMS messages on healthy lifestyle practices, medication adherence, and reminders for scheduled follow-up visits. The intervention was implemented according to a common study protocol across all participating centres.

Follow-up and endline data collection

Participants were followed for 12 months after baseline, during which the study intervention package described above was implemented. Of the 840 participants enrolled, 772 (91.9%) completed the 12-month endline assessment and 68 (8.1%) were lost to follow-up. The documented reasons for loss to follow-up were migration (n=55), illness (n=8), and death (n=5) (Figure 2). Endline data were collected through face-to-face interviews using the same structured approach as at baseline. For the present manuscript, the endline assessment included the same economic outcomes and relevant sociodemographic and clinical variables required for longitudinal analysis, including comorbidity status, healthcare-seeking behaviour, and participant-paid healthcare expenditure during the preceding six months. Selected biomarker and anthropometric assessments were also repeated as specified in the parent protocol.

Study flow diagram

Participant recruitment, eligibility, baseline assessment, implementation of the 12-month intervention package, follow-up status, reasons for loss to follow-up, and endline assessment are summarized in Figure 2.

******** Insert Figure 2 here ********

Figure 2: Participant recruitment, intervention implementation and follow up process of the quasi-experimental study

Data management and quality assurance

Baseline and endline questionnaire data were collected in face-to-face interviews using structured paper-based forms administered by trained data collectors. Completed questionnaires were reviewed in the field to identify missing, incomplete, or inconsistent responses. Field supervisors conducted random checks of completed questionnaires to assess data quality and adherence to study procedures. After submission to the central study office, questionnaires underwent further review for completeness, consistency, and accuracy. Responses recorded under "other" categories were reviewed and coded using a standardized codebook.

Data were entered into pre-designed SPSS data-entry templates and independently verified through double-data verification procedures. Data consistency checks, editing, validation, and

cleaning were subsequently performed to identify and resolve potential entry errors, inconsistencies, and missing values before analysis.

Data analysis

Measurement of healthcare expenditure and catastrophic healthcare expenditure

For the economic analyses, OOP healthcare expenditure represented payments made directly by participants or their households. Costs of the prespecified diagnostic investigations paid or reimbursed by the study at scheduled intervention visits were not counted as participant OOP expenditure. Participants could, however, incur additional non-subsidized expenditure for consultations, medicines, diagnostic tests obtained outside the study-supported package, and inpatient care between scheduled visits; these participant-paid expenditures were captured in the expenditure assessment.

At both baseline and endline, expenditure on consultation, medicines, diagnostic investigations, and inpatient services related to T2DM and related complications was collected for the preceding six months. Each six-month expenditure amount was divided by six to obtain an average monthly expenditure for that domain, and the four average monthly domain-specific expenditures were summed to derive average monthly total healthcare expenditure. Average monthly household income was based on household income reported for the preceding 12 months. CHE was defined as average monthly total T2DM-related healthcare expenditure exceeding 10% or 25% of average monthly household income, generating CHE indicators at the 10% (CHE10) and 25% (CHE25) thresholds, respectively.

Descriptive and bivariate analyses

The distribution of participants across BADAS study centres and baseline sociodemographic and clinical characteristics were summarized using frequencies and percentages for categorical variables and means with standard deviations (SDs) and/or medians with interquartile ranges (IQRs) for continuous variables, as appropriate. Baseline characteristics of participants retained at the 12-month assessment were compared with those lost to follow-up to assess potential differential attrition. Age was categorised as 40 years, 41–60 years, and >60 years, based on categories used in an earlier study [4].

Economic outcomes included expenditure on consultation, medicines, diagnostic investigations, and inpatient care, as well as total healthcare expenditure. CHE was analysed at the 10% and 25% thresholds. Missing data were none or minimal (<5% for variables included in the analyses); therefore, an available-case approach was used, whereby participants with complete information for the variables required for a given analysis were included in that analysis.

The distributions of healthcare expenditure variables were examined using means, SDs, medians, IQRs, histograms, boxplots, and skewness statistics. Because expenditure variables exhibited substantial positive skewness, medians and IQRs were emphasized in descriptive reporting and non-parametric tests were used for unadjusted comparisons. Baseline-to-endline changes among participants with paired observations were assessed using the Wilcoxon signed-rank test [22], both overall and within prespecified categories of SDOH and baseline comorbidity. Differences in expenditure distributions across SDOH categories, baseline comorbidity status, and study centres were examined separately at baseline and endline using the Wilcoxon rank-sum test [23] for two-category variables and the Kruskal-Wallis test [24] for variables with three or more categories.

For CHE at the 10% and 25% thresholds, frequencies and percentages were reported at baseline and endline. Within-participant changes in CHE status between baseline and endline were assessed using McNemar's test [25], overall and within prespecified SDOH and baseline-comorbidity categories. Cross-sectional associations of SDOH, baseline comorbidity, and study centre with CHE prevalence were examined separately at baseline and endline using Pearson's chi-square test or Fisher's exact test [26] when expected cell frequencies were small. All bivariate analyses were considered unadjusted; adjusted longitudinal associations and differences in temporal change between participant subgroups were subsequently evaluated using multivariable mixed-effects regression models.

Multivariable longitudinal analyses

Mixed-effects linear regression analysis of total healthcare expenditure

Total healthcare expenditure was positively skewed and was therefore transformed using the natural logarithm [log(total healthcare expenditure + 1)] before multivariable modelling. To examine the associations of SDOH and baseline comorbidity with total healthcare expenditure over time, a mixed-effects linear regression model [27, 28] was fitted using repeated observations from baseline and endline. Survey round, household income category, educational attainment, gender, age group, occupation, baseline comorbidity, and BADAS study centre were entered as fixed effects. BADAS study centre was modelled as a categorical fixed effect to adjust explicitly for between-centre heterogeneity, with Sylhet specified as the reference centre. Baseline comorbidity was treated as a baseline clinical covariate because the analysis aimed to assess the association of baseline clinical status with subsequent economic outcomes.

To assess whether changes in total healthcare expenditure differed by household-income group, a survey round x household income interaction was included. To assess whether baseline-to-

endline changes varied across BADAS centres, a survey round x BADAS study centre interaction was also included. A participant-level random intercept accounted for within-participant correlation arising from repeated measurements. The overall survey round x centre interaction was assessed jointly, and centre-specific adjusted baseline-to-endline contrasts were estimated to aid interpretation of temporal heterogeneity. Regression coefficients were exponentiated and expressed as adjusted percentage changes using [exp(beta) - 1] x 100. Adjusted percentage changes, 95% confidence intervals (CIs), and two-sided p-values were reported, with statistical significance defined as $p<0.05$.

Mixed-effects logistic regression analysis of catastrophic healthcare expenditure

Mixed-effects logistic regression models [29] were fitted separately for CHE at the 10% threshold (CHE10) and 25% threshold (CHE25) using maximum likelihood estimation with a logit link. A participant-level random intercept accounted for repeated CHE measurements within individuals. The dependent variables were binary indicators of CHE, coded 1 for participants experiencing CHE and 0 otherwise. Fixed effects included survey round, household income category, educational attainment, gender, age group, occupation, baseline comorbidity, and BADAS study centre. Baseline, household income <=20,000 BDT, and Sylhet BADAS centre were used as reference categories for survey round, household income, and study centre, respectively.

Two interaction terms were included in each CHE model: survey round x household income, to assess whether temporal changes differed between income groups, and survey round x BADAS study centre, to assess whether temporal changes varied across the eight centres. The contribution of the survey round x centre interaction was evaluated by comparing the full model with a reduced model containing the same covariates and the survey round x household income interaction but excluding the round x centre interaction, using a likelihood-ratio chi-square test. Centre-specific adjusted endline-versus-baseline contrasts were then estimated from the full model. Fixed-effect estimates were exponentiated and reported as adjusted odds ratios (AORs) with 95% CIs and p-values. Because interactions were included, the main effects of survey round, household income, and BADAS centre were interpreted conditionally at their reference categories. Model convergence and singularity were checked. Statistical significance was assessed at the 5% level (two-sided $p<0.05$).

Statistical software

Statistical analyses were conducted using IBM SPSS Statistics version 31 (IBM Corp., Armonk, NY, USA), R version 4.6.0 (R Foundation for Statistical Computing, Vienna, Austria), and RStudio.

Results

Descriptive and bivariate analyses

Recruitment and follow-up of study participants

A total of 840 patients with T2DM were recruited at baseline from eight BADAS centres. At the 12-month follow-up, 772 participants were reassessed, corresponding to a retention rate of 91.9%; 68 participants (8.1%) were lost to follow-up. The distribution of participants across study centres and household income categories at baseline and endline is presented in Table 1.

******* Insert table 1 here **********

Sociodemographic and clinical characteristics at baseline

Among the 840 participants, 52.4% (n=440) had an average monthly household income >20,000 BDT and 47.6% (n=400) had an income ≤20,000 BDT. Mean monthly household income was 25,940.8 BDT (SD 19,146.0), with a median of 22,000 BDT (IQR 15,000–30,000). Nearly half had secondary or higher education (48.5%), 63.0% were female, and the mean age was 54.7 years (SD 9.6). Most participants were engaged in sedentary occupations (92.7%), and 95.7% had at least one chronic non-communicable disease in addition to T2DM (Supplementary Table ST1). Overall, the study population represented a broad range of socioeconomic, demographic, and clinical characteristics, including comorbidity status, providing a suitable basis for examining their associations with healthcare expenditure and catastrophic healthcare expenditure.

Assessment of potential differential attrition

Baseline characteristics were compared between participants retained at 12-month follow-up (n=772) and those lost to follow-up (n=68). No statistically significant differences were observed in household income category (p=0.393), monthly household income (p=0.427), educational attainment (p=0.141), gender (p=0.391), occupation (p=0.220), or baseline comorbidity (p=0.352). Participants lost to follow-up were significantly older than those retained (mean age 57.6 vs 54.4 years; p=0.008). Thus, the groups were comparable across most measured baseline characteristics, although the age difference indicates some potential for differential attrition by age (Table 2). Age was therefore included as a covariate in the multivariable analyses.

******* Insert table 2 here **********

Distribution of healthcare expenditure variables

Healthcare expenditure variables were positively skewed at both baseline and endline (Supplementary Table ST2). Skewness was particularly pronounced for consultation expenditure (7.49 at baseline; 8.20 at endline), diagnostic expenditure (12.61; 8.50), inpatient expenditure (8.01; 14.01), and total healthcare expenditure (2.43; 1.26), whereas medicine expenditure was less skewed (1.63; 0.77). Histograms of total healthcare expenditure showed concentration of

observations at lower expenditure levels with long right tails, and boxplots demonstrated substantial variability and numerous upper outliers (Supplementary Figures SF1 and SF2).

Changes in healthcare expenditure between baseline and endline

Among participants with paired observations, consultation expenditure decreased by 489.4 BDT ($p<0.001$), diagnostic expenditure by 1,114.5 BDT ($p<0.001$), and inpatient expenditure by 717.6 BDT ($p=0.0002$). Medicine expenditure showed no statistically significant change (mean difference 78.9 BDT; $p=0.111$). Total healthcare expenditure decreased from a mean of 19,422.7 BDT at baseline to 17,180.7 BDT at endline, corresponding to a mean reduction of 2,242.0 BDT (95% CI −3,351.9 to −1,170.1; $p=0.0013$) (Supplementary Table ST2).

Baseline-to-endline changes in total healthcare expenditure across SDOH, baseline comorbidity, and BADAS centres

Changes in total healthcare expenditure varied across socioeconomic, demographic, clinical, and geographic subgroups. Significant reductions were observed among participants with household income >20,000 BDT (mean difference −3,894.8 BDT; $p<0.001$), those with primary education (−2,085.8 BDT; $p=0.0488$) or secondary/higher education (−1,852.9 BDT; $p=0.019$), females (−2,403.7 BDT; $p=0.0016$), participants aged 41–60 years (−1,930.6 BDT; $p=0.014$) and >60 years (−3,899.0 BDT; $p=0.0311$), sedentary workers (−2,404.3 BDT; $p=0.0007$), and participants with baseline comorbidity (−2,175.8 BDT; $p=0.0024$). No statistically significant change was observed among participants with lower household income, no formal education, males, those aged ≤40 years, non-sedentary workers, or those without baseline comorbidity. By centre, expenditure decreased significantly in Sylhet, Dinajpur, and Bogura, whereas it increased significantly in Sherpur and Barishal (Table 3.1). These subgroup-specific comparisons describe within-group changes and do not, by themselves, establish statistically significant differences in change between subgroups.

******** Insert Table 3.1 here **********

Component-specific expenditure patterns

Component-specific analyses showed that consultation and diagnostic expenditure generally declined across most participant subgroups, whereas changes in medicine expenditure were smaller and less consistent. Inpatient expenditure also decreased in several subgroups, although the pattern was less uniform (Supplementary Table ST3).

Healthcare expenditure across SDOH and baseline comorbidity at baseline and endline

At baseline, total healthcare expenditure differed significantly by household income ($p<0.001$) and BADAS centre ($p<0.001$), but not by education, gender, age group, occupation, or baseline

comorbidity. The same pattern was observed at endline, with significant differences by household income (p=0.0003) and BADAS centre (p<0.001), while no statistically significant differences were observed for the other characteristics. Total healthcare expenditure was numerically higher among participants with baseline comorbidity than among those without at both rounds, but the differences were not statistically significant (baseline p=0.4945; endline p=0.0809) (Table 3.2). These unadjusted cross-sectional comparisons indicate persistent differences in expenditure by household income and study centre at both time points.

******** Insert Table 3.2 here **********

Other healthcare expenditure components across SDOH and baseline comorbidity

For the individual expenditure components, medicine expenditure showed a consistent income-related difference, with higher expenditure among participants from higher-income households at both survey rounds. Significant geographic variation across BADAS centres was also evident for several expenditure components. Baseline comorbidity was associated with diagnostic expenditure at baseline, but no consistent association with other component expenditures was observed across both rounds (Supplementary Table ST4).

Catastrophic healthcare expenditure: baseline-to-endline changes

At the 10% threshold, overall CHE declined from 57.8% at baseline to 53.2% at endline, a reduction of 4.53 percentage points (95% CI −8.08 to −0.98; p=0.0154). Significant reductions were observed among participants with household income >20,000 BDT (−10.72 percentage points; p<0.001), secondary/higher education (−8.92 percentage points; p=0.0009), males (−7.59 percentage points; p=0.0133), sedentary workers (−5.33 percentage points; p=0.0055), and those with baseline comorbidity (−4.21 percentage points; p=0.0282). CHE decreased significantly in Sylhet and Bogura but increased significantly in Sherpur (Table 4.1). At the 25% threshold, overall CHE declined from 20.2% to 16.2% (−4.02 percentage points; 95% CI −6.72 to −1.31; p=0.0051). Significant reductions were observed among higher-income participants (−6.48 percentage points; p<0.001), those with secondary/higher education (−3.94 percentage points; p=0.0369), females (−4.56 percentage points; p=0.0087), sedentary workers, and participants with baseline comorbidity (Supplementary Table ST6).

********** Insert Table 4.1 here **********

Catastrophic healthcare expenditure across SDOH and baseline comorbidity at baseline and endline

Cross-sectional comparisons showed substantial socioeconomic and geographic differences in CHE. At the 10% threshold, CHE differed significantly by household income and education at both baseline and endline, and by BADAS centre at both rounds; gender and occupation were

additionally associated with CHE at endline. Baseline comorbidity was not significantly associated with CHE10 at either baseline (p=0.9219) or endline (p=0.6943) (Table 4.2). At the 25% threshold, CHE similarly varied significantly by household income, education, and BADAS centre at both survey rounds, whereas baseline comorbidity was not significantly associated with CHE25 in the unadjusted cross-sectional comparisons (Supplementary Table ST7). These findings demonstrate that the magnitude and distribution of catastrophic expenditure differed across socioeconomic and geographic groups at each survey round; adjusted longitudinal models were subsequently used to assess whether temporal changes differed between groups.

********** Insert Table 4.2 here **********

Multivariable longitudinal analyses

Association of social determinants of health and baseline comorbidity with total healthcare expenditure

In the mixed-effects linear regression model, household income and occupation were significantly associated with total healthcare expenditure after adjustment for survey round, education, gender, age group, baseline comorbidity, BADAS centre, and the specified interaction terms. At baseline, participants from households with a monthly income >20,000 BDT had 60.49% higher total healthcare expenditure than those from households with an income ≤20,000 BDT (95% CI: 38.08% to 86.53%; p<0.001). Participants in sedentary occupations had 28.23% higher expenditure than those in non-sedentary occupations (95% CI: 2.12% to 61.02%; p=0.032). Education, gender, age group, and baseline comorbidity were not significantly associated with total healthcare expenditure.

Because the model included a survey round × BADAS centre interaction, the main BADAS-centre coefficients represent between-centre differences at baseline. Compared with Sylhet, baseline total healthcare expenditure was significantly lower in Dhaka (−41.70%; 95% CI: −56.37% to −22.08%; p<0.001), Sherpur (−43.53%; 95% CI: −57.83% to −24.38%; p<0.001), and Barishal (−55.23%; 95% CI: −66.65% to −39.91%; p<0.001). Differences for Dinajpur, Bogura, Cox's Bazar, and Khulna were not statistically significant (Figure 3).

**********Insert Figure 3 here **********

Figure 3 title: Mixed effects regression analysis of social determinants of health, baseline comorbidity and centre-level variation in total healthcare expenditure among patients with T2DM

The survey round × household income interaction was statistically significant (−29.22%; 95% CI: −41.07% to −14.97%; p<0.001), indicating that the baseline-to-endline change in total healthcare expenditure differed between household income groups. The main survey-round coefficient (12.60%; 95% CI: −14.38% to 48.07%; p=0.395) represents the endline-versus-baseline change for the reference income group (≤20,000 BDT) at the reference centre (Sylhet) and was not statistically significant.

There was strong evidence that temporal changes in total healthcare expenditure differed across BADAS centres (overall survey round × centre interaction: F=7.86, df=7, p<0.001). Centre-specific adjusted marginal contrasts showed significant increases in expenditure from baseline to endline in Dinajpur (30.14%; 95% CI: 0.21% to 69.01%; p=0.048), Sherpur (57.02%; 95% CI: 21.07% to 103.64%; p<0.001), and Barishal (74.55%; 95% CI: 34.42% to 126.66%; p<0.001), while expenditure decreased significantly in Bogura (−47.57%; 95% CI: −59.63% to −31.92%; p<0.001). No statistically significant baseline-to-endline changes were observed in Sylhet, Dhaka, Cox's Bazar, or Khulna. The model including the round × centre interaction provided a significantly better fit than the corresponding model without this interaction (likelihood-ratio χ^2=53.12, df=7, p<0.001), supporting the presence of centre-level heterogeneity in temporal expenditure patterns (Supplementary table ST5).

Overall, the revised analysis demonstrates that total healthcare expenditure was associated with household income and occupation and that changes over time were not uniform across income groups or BADAS centres. These findings should be interpreted as adjusted longitudinal associations within this single-group before-and-after study rather than as centre-specific causal effects of the intervention.

Adjusted associations with catastrophic healthcare expenditure at the 10% threshold

In the mixed-effects logistic regression model, household income remained strongly associated with catastrophic healthcare expenditure (CHE) at the 10% threshold. At baseline and in the reference BADAS centre (Sylhet), participants from households with a monthly income >20,000 BDT had substantially lower odds of CHE than those from households with an income ≤20,000 BDT (AOR=0.14, 95% CI: 0.08–0.24; p<0.001). The survey-round main effect was also statistically significant in the reference categories (Endline vs Baseline: AOR=0.31, 95% CI: 0.12–0.77; p=0.012). Educational attainment, gender, age group, occupation and baseline comorbidity were not independently associated with CHE10 after adjustment (all p>0.05), although the estimates for female gender and age 41–60 years were close to the conventional significance threshold.

Marked between-centre differences were evident at baseline. Relative to Sylhet, the adjusted odds of CHE10 were significantly lower in Dhaka (AOR=0.03, 95% CI: 0.01–0.09; p<0.001), Dinajpur (AOR=0.33, 95% CI: 0.11–0.96; p=0.042), Sherpur (AOR=0.03, 95% CI: 0.01–0.08; p<0.001), Bogura (AOR=0.10, 95% CI: 0.04–0.29; p<0.001), Barishal (AOR=0.03, 95% CI: 0.01–0.08; p<0.001), and Khulna (AOR=0.23, 95% CI: 0.08–0.69; p=0.008). The difference for Cox's Bazar was not statistically significant (Figure 4).

***** Insert Figure 4 here **********

Figure 4: Adjusted associations of social determinants of health, baseline comorbidity and centre-level variation with catastrophic healthcare expenditure at the 10% threshold

The interaction between survey round and household income remained statistically significant (AOR=0.35, 95% CI: 0.20–0.64; p<0.001), indicating that the temporal change in CHE10 differed between the two income groups. In addition, the set of survey round × BADAS centre interactions significantly improved model fit (likelihood-ratio χ^2=44.82, df=7; p<0.001), providing strong evidence that changes in CHE10 over time varied across study centres.

Centre-specific adjusted endline-versus-baseline contrasts showed significantly lower odds of CHE10 at endline in Sylhet (OR=0.18, 95% CI: 0.08–0.43; p<0.001) and Bogura (OR=0.11, 95% CI: 0.05–0.26; p<0.001), whereas Sherpur showed significantly higher odds at endline (OR=2.81, 95% CI: 1.34–5.87; p=0.006). Changes in Dhaka, Dinajpur, Cox's Bazar, Barishal and Khulna were not statistically significant. These findings demonstrate substantial centre-level heterogeneity in the temporal pattern of CHE10 after adjustment for SDOH, baseline comorbidity and repeated observations within participants (Supplementary Table ST8).

Adjusted associations with catastrophic healthcare expenditure at the 25% threshold

At the 25% threshold, household income remained the strongest socioeconomic correlate of CHE. At baseline and in Sylhet, participants from households earning >20,000 BDT had markedly lower odds of CHE25 than those from households earning ≤20,000 BDT (AOR=0.02, 95% CI: 0.003–0.09; p<0.001). Primary education was also associated with lower odds of CHE25 compared with no formal education (AOR=0.20, 95% CI: 0.04–0.92; p=0.039). Survey round, secondary-or-higher education, gender, age group and occupation were not statistically significant main effects after adjustment.

Baseline comorbidity was associated with a higher estimated odds of CHE25 (AOR=27.44), but the confidence interval was extremely wide (95% CI: 0.67–1126.85) and the association was not statistically significant (p=0.081). Accordingly, the model does not support describing baseline

comorbidity as an independent predictor of CHE25. The imprecision of this estimate should also be recognized when interpreting the magnitude of the association.

At baseline, compared with Sylhet, significantly lower adjusted odds of CHE25 were observed in Dhaka (AOR=0.02, 95% CI: 0.001–0.35; p=0.007), Sherpur (AOR=0.008, 95% CI: <0.001–0.13; p<0.001), and Barishal (AOR=0.004, 95% CI: <0.001–0.08; p<0.001). The remaining centre main effects were not statistically significant at the 5% level (Figure 5).

***** Insert Figure 5 here **********

Figure 5: Adjusted associations of social determinants of health, baseline comorbidity and centre-level variation with catastrophic healthcare expenditure at the 25% threshold

The survey round × household income interaction was highly significant (AOR=0.02, 95% CI: 0.002–0.13; p<0.001), indicating that changes in CHE25 over time differed substantially by income group. The round × BADAS centre terms also significantly improved model fit (likelihood-ratio χ^2=33.34, df=7; p<0.001), demonstrating significant centre-level heterogeneity in temporal change.

Centre-specific adjusted contrasts showed significant reductions in the odds of CHE25 between baseline and endline in Sylhet (OR=0.06, 95% CI: 0.01–0.26; p<0.001), Dhaka (OR=0.06, 95% CI: 0.01–0.62; p=0.018), Dinajpur (OR=0.11, 95% CI: 0.03–0.46; p=0.002), and Bogura (OR=0.002, 95% CI: <0.001–0.02; p<0.001). Changes in Sherpur, Cox's Bazar, Barishal and Khulna were not statistically significant. Several centre-specific estimates and interaction confidence intervals were wide, indicating limited precision for some centre-by-round comparisons, particularly at the more stringent 25% CHE threshold (Supplementary Table ST9).

Overall the mixed-effects logistic regression analyses confirm a strong socioeconomic gradient in catastrophic healthcare expenditure at both thresholds, with higher household income associated with substantially lower odds of CHE. The significant survey round × household income interactions indicate that the temporal pattern of CHE differed by income group. Importantly, formal likelihood-ratio tests also showed significant survey round × BADAS centre interactions for both CHE10 and CHE25, demonstrating that changes over time were not uniform across the eight study centres. The models therefore provide a more complete assessment of centre-level variation than the models that adjusted for centre main effects alone. Because some CHE25 estimates were imprecise with very wide confidence intervals, centre-specific findings at the 25% threshold should be interpreted cautiously and emphasis should be placed on the overall interaction test and adjusted centre-specific contrasts rather than on isolated interaction coefficients.

Discussion

This multicentre quasi-experimental longitudinal study provides evidence on the financial burden of long-term T2DM care across eight BADAS centres in Bangladesh and on how that burden varies across household and service-delivery contexts. Three findings are particularly relevant to health services and financial protection. First, healthcare expenditure and CHE were lower overall at endline than at baseline, although medicine expenditure changed little and catastrophic spending remained common. Second, household income was strongly related to the distribution of financial burden: participants in the higher-income group had greater absolute healthcare expenditure at baseline but markedly lower odds of CHE than those in the lower-income group. Third, longitudinal changes in total healthcare expenditure and CHE differed significantly by household income and across BADAS centres, indicating that financial trajectories were not uniform across socioeconomic groups or service-delivery settings. Total healthcare expenditure and CHE10 were higher among participants with baseline comorbidity, but these adjusted associations were not statistically significant, while the CHE25 estimate was too imprecise for a firm conclusion. Together, these findings show that assessment of diabetes-related financial burden should consider not only how much patients spend, but also the affordability of that spending and the service context in which care is delivered.

At the population level, unadjusted analyses showed reductions between baseline and endline in consultation, diagnostic, inpatient, and total healthcare expenditure, while medicine expenditure changed little. CHE also declined overall, from 57.8% to 53.2% at the 10% threshold and from 20.2% to 16.2% at the 25% threshold. However, these average changes should be interpreted alongside the significant household-income and centre interactions, which show that financial trajectories were not shared uniformly across participants or service-delivery settings. The temporal patterns occurred during a 12-month intervention programme that included scheduled clinical review, study-funded diagnostic investigations, structured health education, lifestyle and medication-adherence support, and SMS-based follow-up. Because the study used a single-group before-and-after design without concurrent comparison, the changes cannot be attributed directly or causally to the intervention. They may reflect the intervention package, but secular changes in healthcare use or prices, changes in disease status, regression to the mean, unmeasured time-varying factors, or other contextual influences may also have contributed. The results are therefore interpreted as longitudinal temporal associations observed during the intervention period rather than estimates of intervention effectiveness.

Household income, healthcare expenditure and catastrophic financial burden

Household income was the clearest socioeconomic correlate of the economic outcomes. At baseline, after adjustment, participants with monthly household income >20,000 BDT had approximately 60% higher total healthcare expenditure than those with income <=20,000 BDT. In contrast, the higher-income group had substantially lower adjusted odds of CHE at both the

10% and 25% thresholds. This inverse relationship between absolute spending and catastrophic burden is important for health services: households with greater resources may be able to use more consultations, medicines, diagnostic tests, and other services while devoting a smaller share of household resources to those payments. Lower-income households may spend less in absolute terms yet experience greater financial hardship and may also have less capacity to obtain needed care when services require OOP payment.

This pattern is consistent with evidence from Bangladesh and the wider South Asian and LMIC literature. A nationally representative Bangladesh analysis reported substantial OOP expenditure among people with diabetes and found CHE at both 10% and 25% thresholds, with medicines accounting for the largest share of diabetes-related OOP costs [6]. Earlier national evidence also showed that CHE in Bangladesh was disproportionately concentrated among socioeconomically disadvantaged households and that OOP payments contributed to impoverishment [30]. Studies from India and Pakistan similarly document substantial direct costs of diabetes care and socioeconomic gradients in healthcare use and financial burden [31, 32]. More broadly, reviews of NCD-related financial burden in LMICs show that reliance on OOP financing exposes poorer households to disproportionate risk of catastrophic spending [33, 34]. The present longitudinal findings extend this evidence by showing that income-related differences remained evident across repeated observations even after adjustment for demographic, clinical, and centre-level factors.

The significant survey round x household-income interactions further show that financial trajectories differed between income groups over the 12-month period. For total healthcare expenditure, CHE10, and CHE25, the pattern of change was significantly different between the two income categories. These interactions should not be interpreted as evidence that one group benefited more from the programme, because the single-group design cannot separate programme effects from other time-varying influences. From a health-services perspective, however, the results indicate that average changes in expenditure can obscure important differences in affordability and financial risk between household groups. This is consistent with wider evidence that household resources and other social determinants influence healthcare utilisation, diabetes outcomes, and households' capacity to absorb health-related costs [11-13] [35, 36].

Healthcare expenditure components and the intervention period

The component-specific findings provide useful context for the overall reduction in expenditure. Consultation, diagnostic, and inpatient expenditure decreased between baseline and endline, whereas medicine expenditure did not change significantly. The decline in participant-paid diagnostic expenditure is particularly plausible in light of the study design because the costs of prespecified diagnostic tests at scheduled visits were paid or reimbursed by the study and were

therefore excluded from participant OOP expenditure. Accordingly, part of the observed decline in diagnostic spending is structurally consistent with this cost-sharing component. Reductions in consultation or inpatient expenditure may also reflect improved continuity of care and self-management support during the intervention period; however, these potential explanations could not be directly evaluated in the present study.

The persistence of medicine expenditure is important because medicines are a major component of diabetes-related OOP spending in Bangladesh. The nationally representative study by Hossain et al. found that medicines accounted for approximately three-quarters of diabetes-related OOP expenditure [6], while Bangladesh cost-of-illness evidence has also identified medicines, complications, and hospital care as important cost components [8] [10]. For chronic diseases requiring continuous pharmacotherapy, reducing the cost of selected diagnostic services may therefore be insufficient to eliminate financial hardship if households continue to bear substantial medicine costs. From a service-delivery perspective, reliable access to affordable essential medicines should be considered alongside clinical monitoring, diagnostic services, education, and follow-up support when designing long-term diabetes care programmes.

At the LMIC level, a systematic review found that patient education, financial assistance, facility-quality improvements, and early-detection strategies can reduce OOP expenditure, but effects were generally modest and heterogeneous [17]. Thus, a programme that subsidises selected diagnostic services and supports self-management may reduce some categories of spending without substantially changing the recurrent cost of medicines. This has direct policy relevance in settings where long-term pharmacological treatment remains largely financed by households.

Evidence from mHealth and structured diabetes self-management interventions suggests that text messaging and telemedicine can support medication adherence and aspects of diabetes management [16, 37-39]. Nevertheless, evidence that such approaches alone produce sustained reductions in household financial burden is less established. The present economic findings therefore should not be presented as proof of the effectiveness of the mobile-health component. Instead, they suggest that the economic trajectory observed during a multicomponent programme warrants further evaluation using controlled designs capable of isolating programme effects and identifying which components influence OOP expenditure.

Baseline comorbidity and economic outcomes

Comorbidity is clinically relevant to the economic burden of T2DM because coexisting chronic conditions can increase the need for consultations, diagnostic investigations, medicines, specialist care, and hospitalisation. International evidence consistently links multimorbidity with greater healthcare utilisation and higher costs [14, 15], and studies from Bangladesh have reported higher diabetes-related costs in the presence of complications or comorbid conditions

[8, 10]. A South Asian systematic review similarly found that costs of diabetes and cardiovascular disease rise substantially when complications occur [18].

In the present adjusted analyses, total healthcare expenditure and the odds of CHE10 were higher among participants with baseline comorbidity than among those without baseline comorbidity; however, these associations were not statistically significant. For CHE25, the estimated association with baseline comorbidity was considerably larger, but the 95% confidence interval was extremely wide and included the null value; therefore, the estimate was too imprecise to support a firm conclusion. This imprecision is consistent with limited information in the comparison group, as most participants had at least one additional chronic NCD at baseline. The result should consequently be interpreted as uncertain rather than as evidence that baseline comorbidity independently predicts severe catastrophic expenditure.

Differences from previous studies may reflect variation in study populations, definitions and severity of multimorbidity, included cost components, healthcare settings, and analytical approaches, all of which can influence estimated associations between multimorbidity and healthcare expenditure [14, 15, 18, 40]. Future studies with greater variation in comorbidity burden and measures of the number and severity of coexisting conditions would be better positioned to quantify its independent economic contribution.

Centre-level variation and implications for service delivery

Substantial variation across BADAS study centres was evident. Total healthcare expenditure differed by centre at baseline, and the overall survey round x centre interaction was highly significant. Adjusted centre-specific contrasts showed increases in total expenditure in Dinajpur, Sherpur, and Barishal and a reduction in Bogura, with no statistically significant change in the remaining centres. Similarly, longitudinal changes in CHE10 and CHE25 differed significantly across centres. For CHE10, adjusted odds decreased in Sylhet and Bogura but increased in Sherpur; for CHE25, significant reductions were observed in Sylhet, Dhaka, Dinajpur, and Bogura. Some CHE25 centre-specific estimates were very imprecise and should therefore be interpreted cautiously.

These findings suggest that a common programme protocol was accompanied by markedly different financial trajectories across service-delivery settings. Because one BADAS centre was included from each administrative division, the observed pattern points to geographic and health-service contextual variation; however, the study was not designed to estimate division-wide regional effects, and centre differences should not be interpreted as representative of entire divisions. Potential explanations include local prices, availability of medicines and diagnostic services, referral pathways, healthcare-seeking patterns, transport and other access

costs, local socioeconomic conditions, and centre-specific service use. Such heterogeneity is relevant to health-services planning because standardised chronic-care programmes may operate differently across local contexts [41]. The present analysis cannot identify which centre characteristics generated the differences; future health-services and implementation research should therefore collect facility- and locality-level data on service availability, prices, referral practices, programme delivery, continuity of care, and access barriers.

Catastrophic healthcare expenditure and financial protection

The high prevalence of CHE at both survey rounds indicates substantial financial vulnerability among people receiving long-term diabetes care, particularly those with fewer household resources. At endline, 53.2% of participants exceeded the 10% threshold and 16.2% exceeded the 25% threshold, despite significant declines from baseline. These findings are broadly consistent with recent patient-level evidence from Bangladesh. A hospital-based study among 400 patients with diabetes attending a tertiary diabetes hospital in Rajshahi [42] reported that 50.7% experienced diabetes-related catastrophic expenditure, using diabetes-related healthcare costs of at least 10% of household income as the threshold. The same study found a strong association between lower household income and catastrophic expenditure, as well as greater economic burden with longer duration of diabetes. This closely parallels our finding that lower-income participants experienced substantially greater financial vulnerability despite incurring lower absolute healthcare expenditure than higher-income participants. Earlier nationally representative evidence from Bangladesh likewise showed that CHE was disproportionately concentrated among socioeconomically disadvantaged households, with poorer households experiencing greater financial burden than richer households [6, 30]. Taken together, these findings indicate that affordability remains a central challenge in long-term diabetes service use. Financial protection is therefore relevant not only as a financing objective but also as a condition for equitable access to continuing care. Policies that reduce OOP costs for essential medicines, diagnostics, consultations, and other necessary services may help lower the risk that economically disadvantaged patients face financial hardship or barriers to maintaining recommended care.

Implications for health services and policy

The findings have practical implications for the organisation and financing of diabetes services in Bangladesh and comparable LMIC settings. Study-funded diagnostic testing may have reduced one component of participant-paid expenditure, but persistent medicine expenditure, the strong income gradient in CHE, and variation across centres indicate that subsidising selected tests alone is unlikely to address the broader financial burden of long-term diabetes care. Service strategies warranting evaluation include improving the affordability and reliable availability of essential diabetes and NCD medicines, integrating diabetes and comorbidity management within

accessible chronic-care services, strengthening referral and continuity-of-care pathways, and targeting financial support towards households at greatest risk of catastrophic spending. Local differences in service availability, prices, referral pathways, and access barriers should also be considered when implementing standardised programmes. These approaches are consistent with universal health coverage objectives and with evidence that combinations of financial and non-financial interventions may be more useful than isolated measures for containing OOP expenditure in lower-middle-income settings [17, 30, 33, 34].

Strengths and limitations

This study has several strengths. It used a prospective longitudinal design with repeated patient-level economic measurements over 12 months, addressing an important evidence gap in South Asia, where previous reviews have noted a scarcity of longitudinal patient-level cost studies [18]. Participants were recruited from eight BADAS centres, with one centre selected from each administrative division, allowing assessment of geographic heterogeneity across a broad range of service contexts. The analysis considered both absolute healthcare expenditure and CHE at two thresholds, examined SDOH and baseline comorbidity jointly, and used mixed-effects models to account for repeated observations within participants. The models also included formal survey round x household-income and survey round x centre interactions, enabling direct assessment of heterogeneity in temporal change rather than relying on separate subgroup significance tests.

This study has some limitations. Approximately 8.1% of participants recruited at baseline were lost to follow-up because of migration, illness, or death. Nevertheless, the observed attrition was lower than the 10% loss to follow-up anticipated during the study design, and more than 90% of enrolled participants completed the 12-month assessment. Participants lost to follow-up were significantly older than those retained in the study. Age was included as a covariate in the mixed-effects regression models to account for potential confounding. Baseline data collection was also delayed by a period of substantial political unrest and governmental transition in Bangladesh, which created implementation and logistical challenges. Despite these circumstances, data collection and planned study activities were successfully completed across the participating centres through close coordination with and support of relevant stakeholders.

Conclusion

In this multicentre longitudinal study of patients with established T2DM in Bangladesh, healthcare expenditure and CHE were lower overall at 12-month endline, but substantial financial burden remained. Household income was strongly associated with the distribution of that burden: higher-income participants had greater absolute healthcare expenditure at baseline but substantially lower odds of CHE, whereas lower-income households remained more exposed to catastrophic spending. Longitudinal changes in total healthcare expenditure, CHE10, and

CHE25 also differed significantly by household income and across BADAS centres, demonstrating heterogeneity in financial trajectories across household and service-delivery contexts. Adjusted total healthcare expenditure and the odds of CHE10 were higher among participants with baseline comorbidity, but these associations were not statistically significant, and the CHE25 estimate was too imprecise to support a firm conclusion.

These findings support a health-services response that combines long-term clinical and self-management support with stronger financial protection. Improving the affordability and reliable availability of essential medicines and services, strengthening continuity of chronic care, and addressing local service-delivery barriers may be particularly important for lower-income households. Because the study had no concurrent comparison group, baseline-to-endline changes should be interpreted as temporal associations rather than direct causal effects of the programme. Further controlled and implementation-focused studies incorporating household, facility, and locality-level information are needed to identify which service and financing strategies can most effectively reduce OOP expenditure and financial hardship while supporting sustainable diabetes care in Bangladesh.

Declarations

Consent to Participate declaration

Written informed consent to participate was obtained from all participants prior to enrolment in the study.

Sources of funding

The study was funded by the Ministry of Health and Family Welfare, Bangladesh (Number: 59.00.0000.140.14.006.22.150).

Clinical trial number

Not applicable. This quasi-experimental study was not registered in a clinical trial registry.

Clinical trial registration details

Not applicable. This quasi-experimental study was not registered in a clinical trial registry.

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Ethical Review Committee of the Diabetic Association of Bangladesh (BADAS-ERC/EC/23/481, December 28, 2023). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent to participate was obtained from all participants prior to enrolment.

Consent for publication

Not applicable. This manuscript does not contain any identifiable individual participant data, images, or videos.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to participant privacy and confidentiality considerations but are available from the corresponding author on reasonable request.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Authors' contributions

EH, KI, RH and BB conceived and designed the study. RH, KI, BB and AHC developed the study protocol and data collection tools. KI, EK and AHC coordinated study implementation and supervised data collection. AHC developed the statistical analysis plan, performed the statistical analyses, interpreted the data, and prepared the figures and tables. AHC, RH drafted the manuscript. RH, BB, EH, KI and AHC critically revised the manuscript for important intellectual content and contributed to the interpretation of the results. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figure 1 title: Geographical location of the eight BADAS diabetes centres included in the study across Bangladesh

Figure 1. Geographical locations of the eight BADAS diabetes centers included in the study across Bangladesh

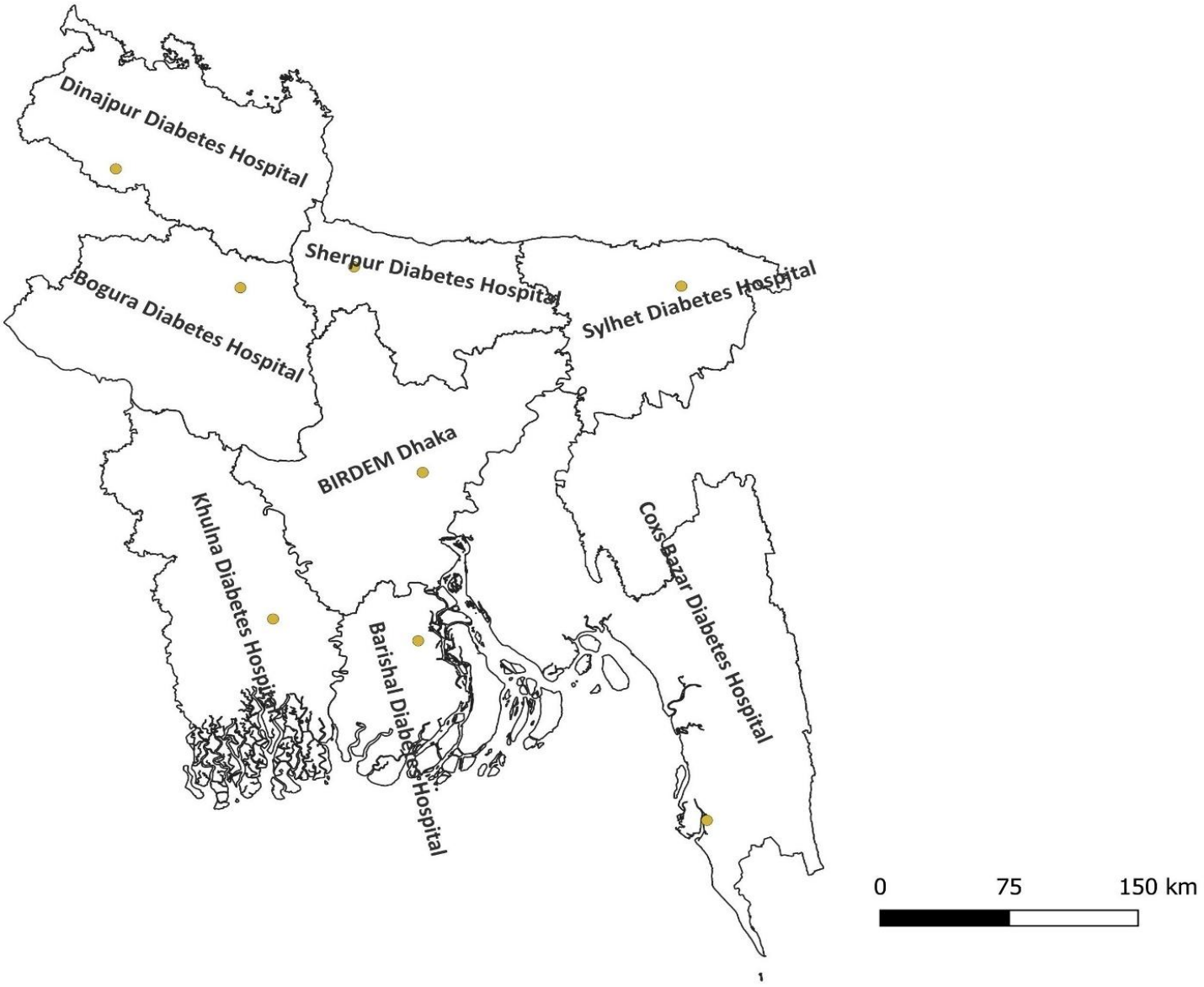
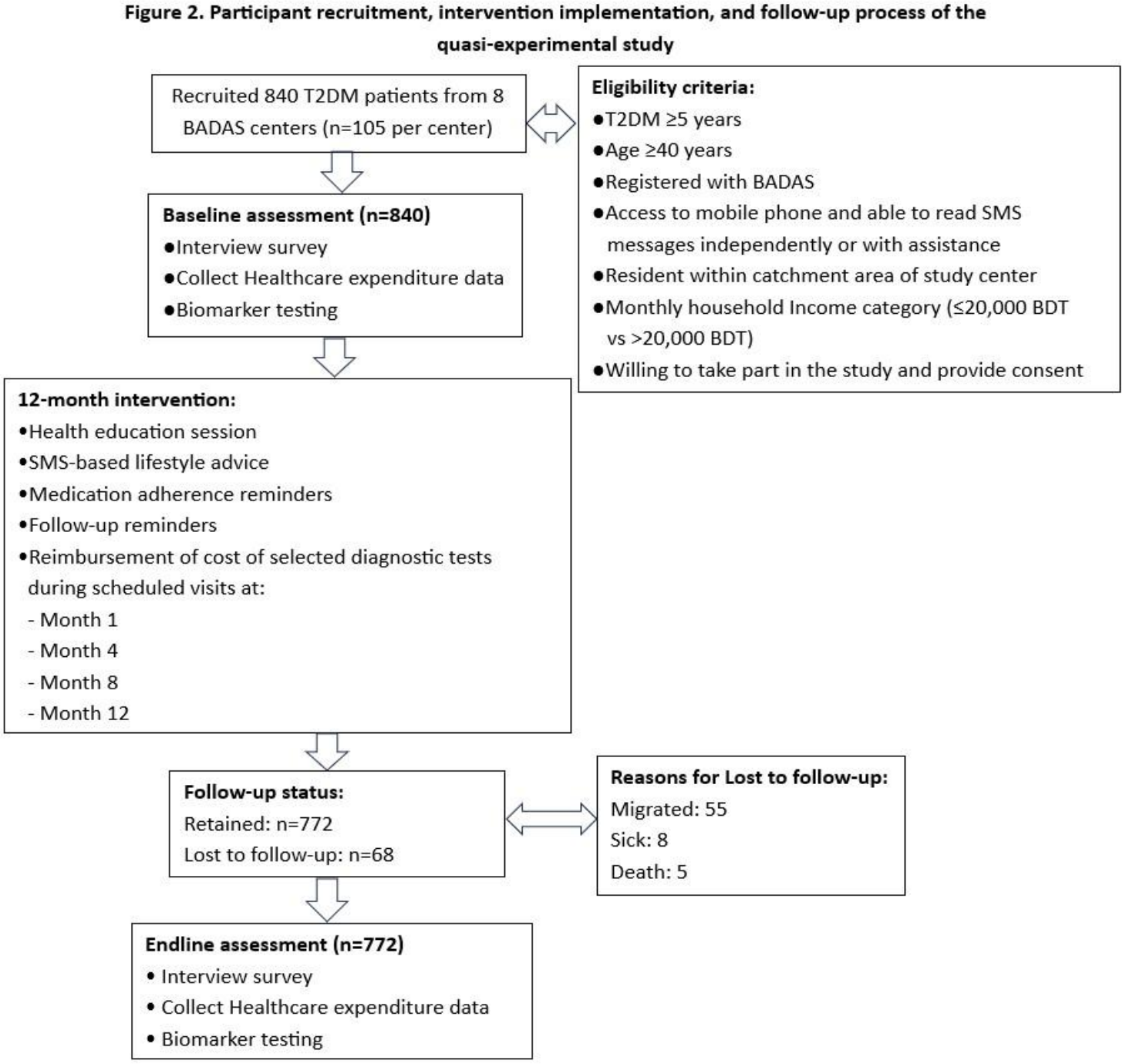


Figure 2: Participant recruitment, intervention implementation and follow up process of the quasi-experimental study



1136

Table 1: Number of patients with type 2 diabetes mellitus (T2DM) recruited at baseline and retained at endline according to study site and household monthly income category						
BADAS centres	**Baseline**		**Total**	**Endline**		**Total**
	<=20000	**>20000**		**<=20000**	**>20000**	
Sylhet	50	55	105	49	48	97
Dinajpur	50	55	105	45	51	96
Bogura	50	55	105	46	50	96
Cox's bazar	50	55	105	47	50	97
Dhaka	50	55	105	46	51	97
Sherpur	50	55	105	45	52	97
Barishal	50	55	105	47	49	96
Khulna	50	55	105	46	50	96
Total	**400**	**440**	**840**	**371**	**401**	**772**

1137

Table 2. Comparison of baseline characteristics between participants retained at 12-month follow-up and those lost to follow-up			
Variable	**Retained (n=772) n (%) or Mean ± SD / Median (IQR)**	**Lost (n=68) n (%) or Mean ± SD / Median (IQR)**	**p-value**
Monthly household income (categorical)			0.393[a]
<=20,000 BDT	371 (48.1)	29 (42.6)	
>20,000 BDT	401 (51.9)	39 (57.4)	
Monthly household income (continuous), BDT	25763.3 ± 19112.8 22000 (15000 – 30000)	27955.9 ± 19548.4 25000 (15000 – 31250)	0.427[c]
Level of education			0.141[a]
No formal education	188 (24.4)	23 (33.8)	
Primary completed/ equivalent	203 (26.3)	19 (27.9)	
Secondary or Higher/ equivalent	381 (49.4)	26 (38.2)	
Gender			0.391[a]
Male	290 (37.6)	22 (32.4)	
Female	482 (62.4)	46 (67.6)	
Age, years	54.4 ± 9.5 55 (46-60)	57.6 ± 10.3 55 (50.3-65.8)	0.008[d]
Occupation			0.220[b]
Non-sedentary	59 (7.6)	2 (2.9)	
Sedentary	713 (92.4)	66 (97.1)	
Baseline Comorbidity (≥1 chronic NCD other than T2DM)			0.352[b]
No	35 (4.5%)	1 (1.5)	
Yes	737 (95.5%)	67 (98.5)	
Note: a: Chi square test ; b: Fisher's exact test ; c: Wilcoxon rank sum test ; d: Independent sample t test			

1138

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Table 3.1 Baseline–Endline comparison of total healthcare expenditure of T2DM patients across categories of social determinants of health and baseline comorbidity							
Category	**Paired n**	**Baseline (Mean ± SD)**	**Baseline Median (iqr)**	**Endline (Mean ± SD)**	**Endline Median (iqr)**	**Mean difference (95% CI)**	**p-value[A]**
Household monthly income							
≤20000 Tk	371	16474.8 ± 13421.21	12700 (6500, 22235)	16019.3 ± 9751.49	15000 (6200, 22100)	-455.5 (-1914.95, 873.64)	0.8498
>20000 Tk	401	22150.04 ± 18129.17	18500 (9500, 30000)	18255.24 ± 9964	18000 (12000, 24000)	-3894.8 (-5644.1, -2329.16)	<0.001
Education							
No formal education	188	20158.04 ± 18953.18	16210 (8150, 24695)	16958.83 ± 8931.39	18000 (10000, 24000)	-3199.21 (-5877.44, -645.74)	0.2834
Primary	203	18335.79 ± 14404.29	15600 (7700, 24110)	16250 ± 9891.09	16000 (9000, 24000)	-2085.79 (-4312.96, -33.92)	0.0488
Secondary or higher	381	19638.95 ± 15801.03	16400 (8000, 26500)	17786.09 ± 10368.95	18000 (12000, 24000)	-1852.86 (-3324.27, -475.51)	0.019
Gender							
Male	290	19885.48 ± 17330.35	16050 (7200, 26015)	17912.31 ± 10993.79	18000 (9000, 24000)	-1973.17 (-3909.05, 85.69)	0.2092
Female	482	19144.24 ± 15624.43	15895 (8800, 24675)	16740.54 ± 9196.59	18000 (9000, 24000)	-2403.71 (-3720.76, -1089.34)	0.0016
Age group							
40 years	49	15805.92 ± 10255.37	13200 (7500, 21000)	16160.2 ± 9099.44	16350 (10000, 18000)	354.29 (-2273.37, 3407.85)	0.5783
41–60 years	544	18909.12 ± 15087.17	16000 (7800, 24645)	16978.51 ± 9578.39	18000 (9000, 24000)	-1930.61 (-3153.14, -708.2)	0.014
>60 years	179	21973.55 ± 20351.49	16700 (9090, 30000)	18074.58 ± 11079.72	18000 (11000, 24000)	-3898.97 (-6997.63, -1391.74)	0.0311
Occupation							

Table 3.1 Baseline–Endline comparison of total healthcare expenditure of T2DM patients across categories of social determinants of health and baseline comorbidity							
Category	**Paired n**	**Baseline (Mean ± SD)**	**Baseline Median (iqr)**	**Endline (Mean ± SD)**	**Endline Median (iqr)**	**Mean difference (95% CI)**	**p-value[A]**
Non-sedentary	59	16261.53 ± 14140.46	13500 (6000, 23440)	15981.36 ± 9168.9	16000 (9000, 18000)	-280.17 (-3844.51, 3181.64)	0.9451
Sedentary	713	19684.27 ± 16425.07	16100 (8310, 26000)	17279.96 ± 9978.34	18000 (9000, 24000)	-2404.31 (-3541.21, -1305.71)	0.0007
Baseline comorbidity							
Yes	737	19484.7 ± 16323.76	15890 (8000, 25360)	17308.9 ± 9981.03	18000 (9000, 24000)	-2175.8 (-3299.25, -1129.47)	0.0024
No	35	18116.86 ± 15473.15	16100 (8100, 20520)	14481.43 ± 8174.1	12000 (12000, 18000)	-3635.43 (-7889.74, -69.7)	0.2022
BADAS centre							
Sylhet	97	27698.45 ± 20140.43	25500 (15000, 34560)	18257.11 ± 8775.16	16350 (12000, 24000)	-9441.34 (-13528.57, -5918.43)	<0.001
Dhaka	97	14179.07 ± 10474.1	12000 (6200, 18900)	13438.14 ± 7262.62	12000 (6000, 18000)	-740.93 (-2095.74, 474.61)	0.301
Dinajpur	96	27629.9 ± 22914.55	23900 (12000, 31762.5)	20864.27 ± 12033.49	18000 (12000, 24450)	-6765.62 (-11888.4, -1961.49)	0.0096
Sherpur	97	13201.34 ± 14345.02	9000 (6000, 18000)	16731.96 ± 7510.43	18000 (12000, 24000)	3530.62 (827.81, 5986.32)	<0.001
Bogura	96	17853.91 ± 12649.62	14530 (8810, 24020)	9280.21 ± 7625.79	9000 (6000, 9000)	-8573.7 (-11004.45, -6129.4)	<0.001
Cox's Bazar	97	22671.76 ± 13709.37	19320 (13020, 30000)	20883.51 ± 9813.35	18000 (15000, 30000)	-1788.26 (-4398.05, 1099.42)	0.0732
Barishal	96	11756.04 ± 8934.76	12000 (6000, 14200)	15635.42 ± 8269.31	12000 (9000, 24000)	3879.38 (2084.61, 5982.6)	0.0001
Khulna	96	20390.42 ± 13710.95	18500 (9500, 30500)	22348.96 ± 10289.49	21000 (18000, 30000)	1958.54 (-266.19, 4254.11)	0.107

Table 3.1 Baseline–Endline comparison of total healthcare expenditure of T2DM patients across categories of social determinants of health and baseline comorbidity							
Category	**Paired n**	**Baseline (Mean ± SD)**	**Baseline Median (iqr)**	**Endline (Mean ± SD)**	**Endline Median (iqr)**	**Mean difference (95% CI)**	**p-value[A]**
Note: Mean differences and 95% confidence intervals were calculated using paired observations; p-values were obtained using Wilcoxon signed-rank tests because expenditure variables were non-normally distributed. A = Wilcoxon signed-rank test							

1141

Table 3.2: Distribution of total healthcare expenditure of T2DM patients across social determinants of health and baseline comorbidity at baseline and endline									
Category	**Baseline n**	**Baseline mean ± sd**	**Baseline median (iqr)**	**Baseline p-value**	**Endline n**	**Endline mean ± sd**	**Endline median (iqr)**	**Endline p-value**	**Test statistic**
Household monthly income									
≤20000 Tk	371	16474.8 ± 13421.21	12700 (6500, 22235)	<0.001	371	16019.3 ± 9751.49	15000 (6200, 22100)	0.0003	Wilcoxon rank-sum test
>20000 Tk	401	22150.04 ± 18129.17	18500 (9500, 30000)		401	18255.24 ± 9964	18000 (12000, 24000)		
Education									
No formal education	188	20158.04 ± 18953.18	16210 (8150, 24695)	0.6071	188	16958.83 ± 8931.39	18000 (10000, 24000)	0.1275	Kruskal-Wallis test
Primary	203	18335.79 ± 14404.29	15600 (7700, 24110)		203	16250 ± 9891.09	16000 (9000, 24000)		
Secondary or higher	381	19638.95 ± 15801.03	16400 (8000, 26500)		381	17786.09 ± 10368.95	18000 (12000, 24000)		
Gender									
Male	290	19885.48 ± 17330.35	16050 (7200, 26015)	0.9135	290	17912.31 ± 10993.79	18000 (9000, 24000)	0.3794	Wilcoxon rank-sum test
Female	482	19144.24 ± 15624.43	15895 (8800, 24675)		482	16740.54 ± 9196.59	18000 (9000, 24000)		
Age group									

Table 3.2: Distribution of total healthcare expenditure of T2DM patients across social determinants of health and baseline comorbidity at baseline and endline									
Category	**Baseline n**	**Baseline mean ± sd**	**Baseline median (iqr)**	**Baseline p-value**	**Endline n**	**Endline mean ± sd**	**Endline median (iqr)**	**Endline p-value**	**Test statistic**
40 years	49	15805.92 ± 10255.37	13200 (7500, 21000)	0.204	49	16160.2 ± 9099.44	16350 (10000, 18000)	0.4844	Kruskal-Wallis test
41–60 years	544	18909.12 ± 15087.17	16000 (7800, 24645)		544	16978.51 ± 9578.39	18000 (9000, 24000)		
>60 years	179	21973.55 ± 20351.49	16700 (9090, 30000)		179	18074.58 ± 11079.72	18000 (11000, 24000)		
Occupation									
Non-sedentary	59	16261.53 ± 14140.46	13500 (6000, 23440)	0.0619	59	15981.36 ± 9168.9	16000 (9000, 18000)	0.2838	Wilcoxon rank-sum test
Sedentary	713	19684.27 ± 16425.07	16100 (8310, 26000)		713	17279.96 ± 9978.34	18000 (9000, 24000)		
Baseline comorbidity									
Yes	737	19484.7 ± 16323.76	15890 (8000, 25360)	0.4945	737	17308.9 ± 9981.03	18000 (9000, 24000)	0.0809	Wilcoxon rank-sum test
No	35	18116.86 ± 15473.15	16100 (8100, 20520)		35	14481.43 ± 8174.1	12000 (12000, 18000)		
BADAS centre									
Sylhet	97	27698.45 ± 20140.43	25500 (15000, 34560)	<0.001	97	18257.11 ± 8775.16	16350 (12000, 24000)	<0.001	Kruskal-Wallis test
Dhaka	97	14179.07 ± 10474.1	12000 (6200, 18900)		97	13438.14 ± 7262.62	12000 (6000, 18000)		
Dinajpur	96	27629.9 ± 22914.55	23900 (12000, 31762.5)		96	20864.27 ± 12033.49	18000 (12000, 24450)		
Sherpur	97	13201.34 ± 14345.02	9000 (6000, 18000)		97	16731.96 ± 7510.43	18000 (12000, 24000)		

Table 3.2: Distribution of total healthcare expenditure of T2DM patients across social determinants of health and baseline comorbidity at baseline and endline									
Category	**Baseline n**	**Baseline mean ± sd**	**Baseline median (iqr)**	**Baseline p-value**	**Endline n**	**Endline mean ± sd**	**Endline median (iqr)**	**Endline p-value**	**Test statistic**
Bogura	96	17853.91 ± 12649.62	14530 (8810, 24020)		96	9280.21 ± 7625.79	9000 (6000, 9000)		
Cox's Bazar	97	22671.76 ± 13709.37	19320 (13020, 30000)		97	20883.51 ± 9813.35	18000 (15000, 30000)		
Barishal	96	11756.04 ± 8934.76	12000 (6000, 14200)		96	15635.42 ± 8269.31	12000 (9000, 24000)		
Khulna	96	20390.42 ± 13710.95	18500 (9500, 30500)		96	22348.96 ± 10289.49	21000 (18000, 30000)		

1142

Table 4.1: Baseline–Endline comparison of catastrophic healthcare expenditure at 10% threshold across categories of social determinants of health and baseline comorbidity among patients with T2DM					
Category	**n_paired**	**Baseline**	**Endline**	**Percentage point difference (95% CI)**	**p-value[A]**
Overall					
Overall	772	446 (57.8%)	411 (53.2%)	-4.53 (-8.08, -0.98)	0.0154
Household monthly income					
≤20000 Tk	371	263 (70.9%)	271 (73%)	2.16 (-2.85, 7.16)	0.4606
>20000 Tk	401	183 (45.6%)	140 (34.9%)	-10.72 (-15.67, -5.78)	<0.001
Education					
No formal education	188	127 (67.6%)	129 (68.6%)	1.06 (-6.01, 8.13)	0.8828
Primary	203	118 (58.1%)	115 (56.7%)	-1.48 (-8.5, 5.55)	0.7835
Secondary or higher	381	201 (52.8%)	167 (43.8%)	-8.92 (-13.94, -3.91)	0.0009
Gender					
Male	290	157 (54.1%)	135 (46.6%)	-7.59 (-13.25, -1.92)	0.0133

Table 4.1: Baseline–Endline comparison of catastrophic healthcare expenditure at 10% threshold across categories of social determinants of health and baseline comorbidity among patients with T2DM					
Category	**n_paired**	**Baseline**	**Endline**	**Percentage point difference (95% CI)**	**p-value[A]**
Female	482	289 (60%)	276 (57.3%)	-2.7 (-7.24, 1.84)	0.2831
Age group					
40 years	49	25 (51%)	23 (46.9%)	-4.08 (-20.04, 11.88)	0.8026
41–60 years	544	321 (59%)	299 (55%)	-4.04 (-8.32, 0.24)	0.078
>60 years	179	100 (55.9%)	89 (49.7%)	-6.15 (-12.92, 0.63)	0.1093
Occupation					
Non-sedentary	59	36 (61%)	39 (66.1%)	5.08 (-9.34, 19.51)	0.6464
Sedentary	713	410 (57.5%)	372 (52.2%)	-5.33 (-8.98, -1.68)	0.0055
Baseline comorbidity					
No	35	21 (60%)	17 (48.6%)	-11.43 (-28.73, 5.87)	0.3428
Yes	737	425 (57.7%)	394 (53.5%)	-4.21 (-7.83, -0.58)	0.0282
BADAS centre					
Sylhet	97	80 (82.5%)	60 (61.9%)	-20.62 (-32.38, -8.86)	0.0021
Dhaka	97	39 (40.2%)	39 (40.2%)	0 (-7.56, 7.56)	1
Dinajpur	96	66 (68.8%)	67 (69.8%)	1.04 (-8.31, 10.4)	1
Sherpur	97	37 (38.1%)	50 (51.5%)	13.4 (2.47, 24.33)	0.0311
Bogura	96	53 (55.2%)	28 (29.2%)	-26.04 (-35.72, -16.36)	<0.001
Cox’s Bazar	97	74 (76.3%)	68 (70.1%)	-6.19 (-16.01, 3.64)	0.3074
Barishal	96	35 (36.5%)	40 (41.7%)	5.21 (-3.63, 14.05)	0.3588
Khulna	96	62 (64.6%)	59 (61.5%)	-3.12 (-12.46, 6.21)	0.6625
Note: A = McNemar test					

1143

Table 4.2. Distribution of catastrophic healthcare expenditure at 10% threshold of patients with T2DM across categories of social determinants of health and baseline comorbidity at baseline and endline								
category	**Baseline n**	**Baseline_ yes**	**Baseline_ no**	**Baseline p-value[A]**	**Endline n**	**Endline_ yes**	**Endline_ no**	**Endline p-value[A]**
Household monthly income								
≤20000 Tk	371	263 (70.9%)	108 (29.1%)	<0.001	371	271 (73%)	100 (27%)	<0.001
>20000 Tk	401	183 (45.6%)	218 (54.4%)		401	140 (34.9%)	261 (65.1%)	
Education								
No formal education	188	127 (67.6%)	61 (32.4%)	0.0035	188	129 (68.6%)	59 (31.4%)	<0.001
Primary	203	118 (58.1%)	85 (41.9%)		203	115 (56.7%)	88 (43.3%)	
Secondary or higher	381	201 (52.8%)	180 (47.2%)		381	167 (43.8%)	214 (56.2%)	
Gender								
Female	482	289 (60%)	193 (40%)	0.1128	482	276 (57.3%)	206 (42.7%)	0.0039
Male	290	157 (54.1%)	133 (45.9%)		290	135 (46.6%)	155 (53.4%)	
Age group								
40 years	49	25 (51%)	24 (49%)	0.4671	49	23 (46.9%)	26 (53.1%)	0.3133
41–60 years	544	321 (59%)	223 (41%)		544	299 (55%)	245 (45%)	
>60 years	179	100 (55.9%)	79 (44.1%)		179	89 (49.7%)	90 (50.3%)	
Occupation								
Non-sedentary	59	36 (61%)	23 (39%)	0.5995	59	39 (66.1%)	20 (33.9%)	0.0393
Sedentary	713	410 (57.5%)	303 (42.5%)		713	372 (52.2%)	341 (47.8%)	
Baseline comorbidity								
No	35	21 (60%)	14 (40%)	0.9219	35	17 (48.6%)	18 (51.4%)	0.6943
Yes	737	425 (57.7%)	312 (42.3%)		737	394 (53.5%)	343 (46.5%)	

Table 4.2. Distribution of catastrophic healthcare expenditure at 10% threshold of patients with T2DM across categories of social determinants of health and baseline comorbidity at baseline and endline								
category	**Baseline n**	**Baseline_ yes**	**Baseline_ no**	**Baseline p-value[A]**	**Endline n**	**Endline_ yes**	**Endline_ no**	**Endline p-value[A]**
BADAS centre								
Barishal	96	35 (36.5%)	61 (63.5%)	<0.001	96	40 (41.7%)	56 (58.3%)	<0.001
Bogura	96	53 (55.2%)	43 (44.8%)		96	28 (29.2%)	68 (70.8%)	
Cox's Bazar	97	74 (76.3%)	23 (23.7%)		97	68 (70.1%)	29 (29.9%)	
Dhaka	97	39 (40.2%)	58 (59.8%)		97	39 (40.2%)	58 (59.8%)	
Dinajpur	96	66 (68.8%)	30 (31.2%)		96	67 (69.8%)	29 (30.2%)	
Khulna	96	62 (64.6%)	34 (35.4%)		96	59 (61.5%)	37 (38.5%)	
Sherpur	97	37 (38.1%)	60 (61.9%)		97	50 (51.5%)	47 (48.5%)	
Sylhet	97	80 (82.5%)	17 (17.5%)		97	60 (61.9%)	37 (38.1%)	
Note: A = Chi square test								

Figure 3 title: Mixed effects regression analysis of social determinants of health, baseline comorbidity and centre-level variation in total healthcare expenditure among patients with T2DM

Figure 3. Mixed-effects regression analysis of social determinants of health, baseline comorbidity, and centre-level variation in total healthcare expenditure among patients with T2DM

Variable	Percent change (%)	95% CI	P value
Survey round: Endline vs Baseline	12.6%	-14.38 to 48.07	0.395
Income: >20000 Tk vs ≤20000 Tk	60.49%	38.08 to 86.53	<0.001
Education: Primary vs No formal education	-4.92%	-19.15 to 11.81	0.541
Education: Secondary or higher vs No formal education	-0.36%	-15.27 to 17.18	0.966
Gender: Female vs Male	6.35%	-6.8 to 21.35	0.360
Age: 41–60 years vs ≤40 years	11.01%	-12.33 to 40.56	0.385
Age: >60 years vs ≤40 years	19.15%	-8.09 to 54.47	0.185
Occupation: Sedentary vs Non-sedentary	28.23%	2.12 to 61.02	0.032
Baseline comorbidity: Yes vs No	15.49%	-12.36 to 52.2	0.306
Center: Dhaka vs Sylhet	-41.7%	-56.37 to -22.08	<0.001
Center: Dinajpur vs Sylhet	-19.4%	-39.77 to 7.86	0.147
Center: Sherpur vs Sylhet	-43.53%	-57.83 to -24.38	<0.001
Center: Bogura vs Sylhet	-24.12%	-43.37 to 1.67	0.064
Center: Cox's Bazar vs Sylhet	7.1%	-19.93 to 43.27	0.644
Center: Barishal vs Sylhet	-55.23%	-66.65 to -39.91	<0.001
Center: Khulna vs Sylhet	-7.79%	-31.47 to 24.07	0.592
Interaction: Endline × Income >20000 Tk	-29.22%	-41.07 to -14.97	<0.001
Interaction: Endline × Dhaka	22.26%	-15.16 to 76.2	0.281
Interaction: Endline × Dinajpur	37.38%	-4.77 to 98.18	0.089
Interaction: Endline × Sherpur	65.76%	15.01 to 138.89	0.007
Interaction: Endline × Bogura	-44.66%	-61.64 to -20.17	0.002
Interaction: Endline × Cox's Bazar	4.89%	-27.22 to 51.16	0.798
Interaction: Endline × Barishal	84.26%	27.73 to 165.79	0.001
Interaction: Endline × Khulna	29.07%	-10.53 to 86.18	0.172

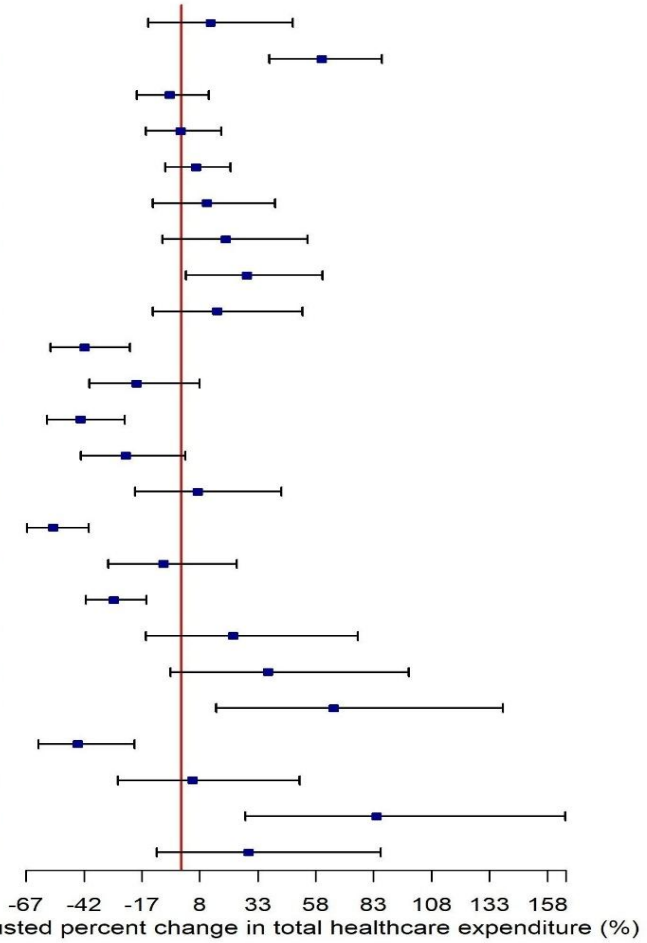


Figure 4: Adjusted associations of social determinants of health, baseline comorbidity and centre-level variation with catastrophic healthcare expenditure at the 10% threshold

Figure 4. Adjusted associations of social determinants of health, baseline comorbidity, and centre-level variation with catastrophic healthcare expenditure at the 10% threshold

Variable	AOR (95% CI)	P value
Survey round: Endline vs Baseline	0.309 (0.123, 0.774)	0.012
Income: >20,000 Tk vs ≤20,000 Tk	0.143 (0.085, 0.242)	<0.001
Education: Primary vs No formal education	0.647 (0.353, 1.184)	0.157
Education: Secondary or higher vs No formal education	0.804 (0.442, 1.463)	0.475
Gender: Female vs Male	1.531 (0.948, 2.472)	0.082
Age: 41–60 years vs ≤40 years	2.087 (0.899, 4.844)	0.087
Age: >60 years vs ≤40 years	1.855 (0.731, 4.704)	0.193
Occupation: Sedentary vs Non-sedentary	0.833 (0.364, 1.909)	0.666
Baseline comorbidity: Yes vs No	2.057 (0.777, 5.448)	0.147
BADAS centre: Dhaka vs Sylhet	0.030 (0.011, 0.088)	<0.001
BADAS centre: Dinajpur vs Sylhet	0.327 (0.111, 0.961)	0.042
BADAS centre: Sherpur vs Sylhet	0.028 (0.010, 0.081)	<0.001
BADAS centre: Bogura vs Sylhet	0.102 (0.036, 0.294)	<0.001
BADAS centre: Cox's Bazar vs Sylhet	0.527 (0.173, 1.603)	0.259
BADAS centre: Barishal vs Sylhet	0.027 (0.009, 0.079)	<0.001
BADAS centre: Khulna vs Sylhet	0.232 (0.079, 0.688)	0.008
Interaction: Endline × Income >20,000 Tk	0.354 (0.197, 0.636)	<0.001
Interaction: Endline × Dhaka	5.345 (1.699, 16.815)	0.004
Interaction: Endline × Dinajpur	6.971 (2.168, 22.417)	0.001
Interaction: Endline × Sherpur	15.246 (4.948, 46.976)	<0.001
Interaction: Endline × Bogura	0.612 (0.184, 2.038)	0.424
Interaction: Endline × Cox's Bazar	3.644 (1.105, 12.018)	0.034
Interaction: Endline × Barishal	7.878 (2.524, 24.586)	<0.001
Interaction: Endline × Khulna	4.669 (1.482, 14.715)	0.009

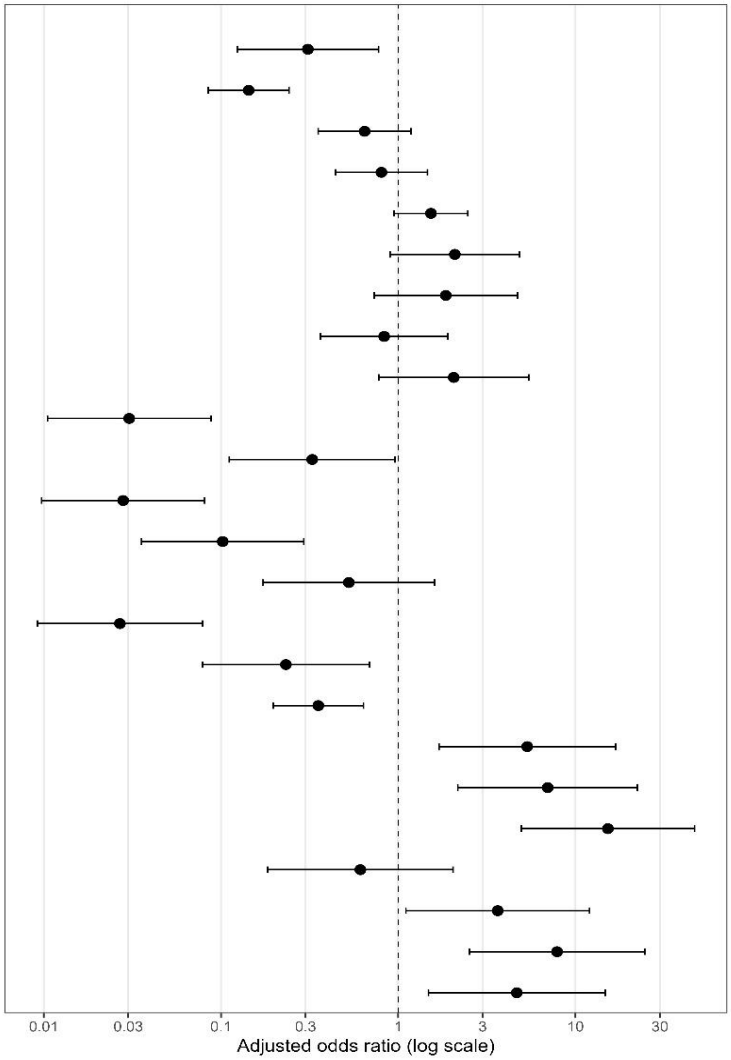
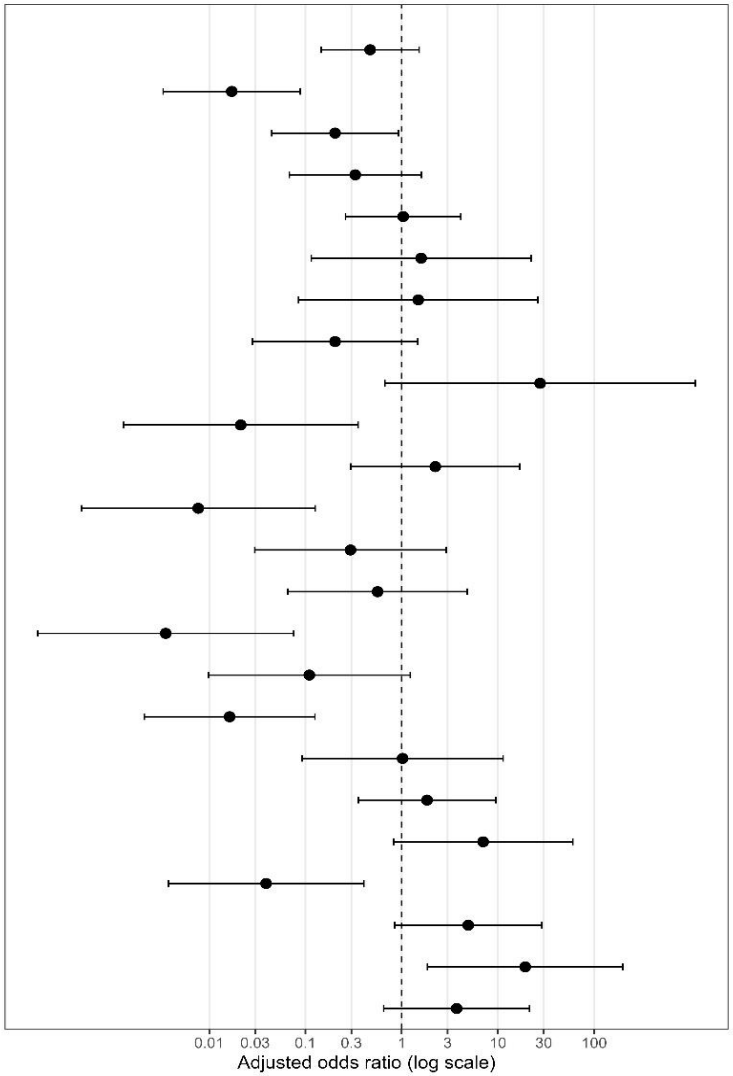


Figure 5: Adjusted associations of social determinants of health, baseline comorbidity and centre-level variation with catastrophic healthcare expenditure at the 25% threshold

Figure 5. Adjusted associations of social determinants of health, baseline comorbidity, and centre-level variation with catastrophic healthcare expenditure at the 25% threshold

Variable	AOR (95% CI)	P value
Survey round: Endline vs Baseline	0.470 (0.146, 1.516)	0.206
Income: >20,000 Tk vs ≤20,000 Tk	0.017 (0.003, 0.088)	<0.001
Education: Primary vs No formal education	0.203 (0.045, 0.922)	0.039
Education: Secondary or higher vs No formal education	0.329 (0.068, 1.595)	0.168
Gender: Female vs Male	1.037 (0.261, 4.116)	0.959
Age: 41–60 years vs ≤40 years	1.592 (0.115, 22.056)	0.729
Age: >60 years vs ≤40 years	1.485 (0.085, 25.987)	0.786
Occupation: Sedentary vs Non-sedentary	0.203 (0.028, 1.472)	0.115
Baseline comorbidity: Yes vs No	27.436 (0.668, 1126.853)	0.081
BADAS centre: Dhaka vs Sylhet	0.021 (0.001, 0.352)	0.007
BADAS centre: Dinajpur vs Sylhet	2.236 (0.295, 16.926)	0.436
BADAS centre: Sherpur vs Sylhet	0.008 (<0.001, 0.126)	<0.001
BADAS centre: Bogura vs Sylhet	0.294 (0.030, 2.903)	0.295
BADAS centre: Cox's Bazar vs Sylhet	0.562 (0.066, 4.815)	0.599
BADAS centre: Barishal vs Sylhet	0.004 (<0.001, 0.076)	<0.001
BADAS centre: Khulna vs Sylhet	0.110 (0.010, 1.230)	0.073
Interaction: Endline × Income >20,000 Tk	0.016 (0.002, 0.126)	<0.001
Interaction: Endline × Dhaka	1.022 (0.092, 11.301)	0.986
Interaction: Endline × Dinajpur	1.835 (0.355, 9.493)	0.469
Interaction: Endline × Sherpur	7.017 (0.822, 59.902)	0.075
Interaction: Endline × Bogura	0.039 (0.004, 0.404)	0.007
Interaction: Endline × Cox's Bazar	4.916 (0.844, 28.641)	0.077
Interaction: Endline × Barishal	19.181 (1.855, 198.362)	0.013
Interaction: Endline × Khulna	3.724 (0.650, 21.323)	0.140



Supplementary Files

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- SupplementaryFile2EnglishDataCollectionInstruments.docx