Healthcare & Medical Analytics

Group Coursework

Group E

Psychological Distress, Physical Multimorbidity, and Area Deprivation in England: Evidence from the Health Survey for England 2022

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1. Introduction

Physical multimorbidity, commonly defined as the coexistence of two or more long-term health conditions, represents one of the most significant challenges facing the National Health Service (NHS) in England. Individuals living with multiple conditions experience poorer health outcomes, lower quality of life, and greater healthcare utilisation. The burden of multimorbidity is expected to increase substantially over coming decades, with the largest increases projected in the most socioeconomically deprived communities (Head et al., 2024). Reducing health inequalities has therefore become a central priority of the NHS, particularly following the establishment of Integrated Care Systems under the Health and Care Act 2022.

Psychological distress is also a growing public health concern. Using nationally representative data from England, Jackson et al. (2023) reported a 46% increase in severe psychological distress between 2020 and 2022, particularly among younger and more disadvantaged groups. Existing evidence suggests that psychological distress is associated with a greater risk of developing physical multimorbidity (Arias-de la Torre et al., 2021), while multimorbidity itself is substantially more prevalent among individuals living in deprived areas (Knies and Kumari, 2022; Head et al., 2024).

While previous research has demonstrated associations between psychological distress and physical multimorbidity, and separately established strong socioeconomic gradients in multimorbidity prevalence, relatively little evidence has examined whether area deprivation modifies the relationship between psychological distress and physical multimorbidity within a contemporary English population. Understanding this relationship may help identify groups at elevated risk of both mental and physical ill health and inform NHS commissioning and public health policy aimed at reducing health inequalities.

Using data from the Health Survey for England (HSE) 2022, this study examines the association between psychological distress, measured using the 12-item General Health Questionnaire (GHQ-12), and physical multimorbidity among adults in England and investigates whether this association varies across levels of area deprivation. The research question addressed is: ***How is psychological distress associated with physical multimorbidity among adults in England, and does this relationship vary across levels of area deprivation?***

2. Descriptive Statistics

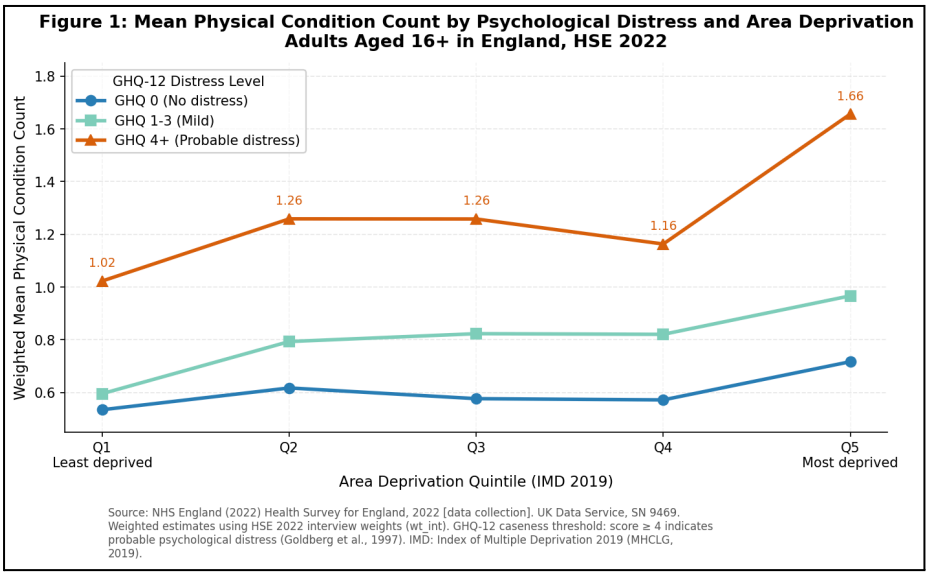
This analysis uses data from the Health Survey for England (HSE) 2022, a repeated cross-sectional survey of adults living in private households in England, commissioned by NHS England and made available through the UK Data Service (Study Number 9469). The rationale for dataset selection is provided in **Appendix A.0**. Following restriction to adults aged 16 and over and complete-case selection across all analytical variables, the final analytical sample comprises 4,735 respondents (**Appendix B.1**).

Descriptive statistics are estimated using the HSE 2022 interview weight (wt_int), which adjusts for unequal selection probabilities and differential non-response to improve representativeness of the English adult population. Weighting has little effect on estimates of psychological distress, with GHQ-12 caseness

changing only marginally from 17.2% unweighted to 17.4% weighted. In contrast, multimorbidity prevalence falls from 23.8% to 20.3% after weighting and mean condition count from 0.87 to 0.76, indicating that the analytical sample slightly over-represents individuals with higher physical condition burdens (Table C.2). Consequently, weighted estimates are reported throughout the descriptive analysis.

Psychological distress is measured using the GHQ-12 continuous score (0–12), while physical multimorbidity is measured using the number of grouped longstanding condition categories reported by respondents (0–6). Area deprivation is captured using the Index of Multiple Deprivation (IMD) 2019 quintile, where quintile 1 represents the least deprived areas and quintile 5 the most deprived. The weighted mean GHQ-12 score is 1.65, with 58.1% of respondents scoring zero and 17.4% meeting the caseness threshold of score ≥ 4, indicating probable psychological distress. Physical multimorbidity is also common, with 20.3% of respondents reporting two or more longstanding condition categories and a weighted mean condition count of 0.76. The weighted sample is broadly distributed across demographic and socioeconomic groups, with 51.4% female respondents, 46.4% employed in managerial or professional occupations, and 41.2% holding degree-level qualifications (Table C.1). To account for potential confounding, the analysis includes demographic, socioeconomic, lifestyle, and geographic control variables. Full variable definitions are provided in Table A.1. Detailed coding decisions are documented in Appendix A, while justification for control variable selection is provided in Appendix A.9.

Substantial differences in physical health burden are observed across levels of psychological distress. Respondents reporting no distress have a mean condition count of 0.59, rising to 0.78 among those with mild distress and 1.27 among those with probable distress. Similarly, multimorbidity prevalence increases from 15.3% to 21.0% and 36.1% respectively (Table C.5b). Among the conditions examined, the largest gradients are observed for arthritis and rheumatism, which increase from 6.2% among respondents with no distress to 12.5% among those with probable distress, and asthma, which rises from 3.8% to 7.2% (Table C.5a; Figure C.6.1).



A clear socioeconomic gradient is also evident. The prevalence of probable psychological distress increases from 15.0% in the least deprived quintile to 22.6% in the most deprived quintile (Figure C.6.2). Physical multimorbidity follows a similar pattern, with mean condition count rising from 0.62 to 0.99 and multimorbidity prevalence increasing from 15.6% to 27.6% across the deprivation distribution (Table C.5c).

Figure 1 (above) presents the central descriptive finding of the study. Across all deprivation quintiles, individuals experiencing probable psychological distress report substantially higher physical condition counts than those without distress. The highest burden is observed among adults with probable distress living in the most deprived areas, who report an average of 1.66 condition categories, compared with 0.54 among adults reporting no distress in the least deprived areas. The absolute gap between distress groups widens from 0.49 conditions in quintile 1 to 0.94 in quintile 5, largely reflecting the higher baseline burden of physical illness observed in more deprived communities. Together, these descriptive findings provide preliminary evidence of an association between psychological distress and physical multimorbidity, while suggesting that deprivation may further compound this burden.

3. Methods and Results

The outcome variable, physical condition count (condlcnt), is a non-negative integer ranging from 0 to 6. Descriptive analysis indicated substantial overdispersion in the outcome distribution, with a variance-to-mean ratio of 1.54 (mean = 0.759, variance = 1.333), violating the Poisson assumption of equality between the mean and variance. A formal likelihood ratio test confirmed that the negative binomial model provided a significantly better fit than the equivalent Poisson specification (LR = 122.68, $p < 0.001$), with the estimated dispersion parameter $\alpha = 0.304$ significantly greater than zero (**Appendix F.1**). Negative binomial regression was therefore used throughout. The primary explanatory variable is psychological distress, measured using the GHQ-12 score, while area deprivation is captured using IMD quintiles. Demographic, socioeconomic, lifestyle, and geographic controls were included to account for potential confounding, with full variable definitions provided in **Table A.1**.

Four nested models were estimated. Model 1 includes GHQ-12 score only. Model 2 adds demographic controls (sex, age group, and ethnicity). Model 3 incorporates the full set of demographic, socioeconomic, lifestyle, geographic, and deprivation-related controls and serves as the preferred specification. Model 4 extends Model 3 by introducing GHQ-12 × IMD interaction terms to assess whether the association between psychological distress and physical multimorbidity differs across levels of area deprivation. All models were estimated on the complete-case sample (N = 4,735) without survey weights, consistent with the objective of estimating associations rather than population prevalence. Coefficients are reported as incidence rate ratios (IRRs), where values greater than one indicate a higher expected physical condition count.

The association between psychological distress and physical multimorbidity is positive, statistically significant, and highly stable across all model specifications. In the fully adjusted model (Model 3), each one-point increase in GHQ-12 score is associated with a 9.7% increase in the expected physical condition count (IRR = 1.097, 95% CI [1.085, 1.108], $p < 0.001$). The estimated effect remains remarkably consistent across specifications, with the IRR equal to 1.097 in both the unadjusted model (Model 1) and the fully adjusted model (Model 3), and only modestly higher in Model 2 (IRR = 1.110). This suggests that the observed association is not substantially explained by the demographic, socioeconomic, lifestyle, or

geographic characteristics included in the analysis. ***Table 1*** presents the key coefficients from the preferred specification, while full regression results are reported in **Appendix D.1**.

Variable	IRR	95% CI	p
GHQ-12 score	1.097	[1.085, 1.108]	<0.001***
IMD Q2 (ref: Q1)	1.148	[1.031, 1.279]	0.012*
IMD Q3 (ref: Q1)	1.067	[0.951, 1.197]	0.268
IMD Q4 (ref: Q1)	1.144	[1.016, 1.287]	0.026*
IMD Q5 (ref: Q1)	1.253	[1.105, 1.419]	<0.001***
Model fit			
N	4,735		
Log-likelihood	-5,658.00		
AIC	11,404.10		
α (dispersion)	0.304		

Table 1: Main Regression Results from the Preferred Negative Binomial Model (Model 3)

Area deprivation is independently associated with higher levels of physical multimorbidity. Relative to respondents living in the least deprived areas, those living in the most deprived quintile report a 25.3% higher expected condition count after adjustment for all controls (IRR = 1.253, 95% CI [1.105, 1.419], $p < 0.001$). A general deprivation gradient is observed across the IMD distribution, with respondents in more deprived areas tending to experience higher expected condition counts than those in the least deprived areas. These findings indicate that both psychological distress and area deprivation contribute independently to physical multimorbidity.

Several control variables are also significantly associated with physical condition count. Age exhibits the strongest gradient, with respondents aged 75 years and over reporting almost three times the expected condition count of those aged 16–24 (IRR = 2.736, $p < 0.001$). Current smokers have a 24.3% higher expected condition count than never-smokers (IRR = 1.243, $p < 0.001$), while respondents in routine and manual occupations report a 14.6% higher expected condition count than those in managerial and professional occupations (IRR = 1.146, $p = 0.008$). Non-drinkers also report significantly higher condition counts than lower-risk drinkers (IRR = 1.193, $p < 0.001$), which may reflect the well-documented sick quitter effect whereby individuals reduce or cease alcohol consumption following deteriorating health.

To examine whether deprivation modifies the relationship between psychological distress and physical multimorbidity, GHQ-12 × IMD interaction terms were introduced in Model 4. None of the interaction coefficients were statistically significant (all $p > 0.60$). Consistent with this finding, both the likelihood ratio test (LR $\chi^2(4) = 1.21$, $p = 0.877$) and Wald test (Wald $\chi^2(4) = 1.21$, $p = 0.877$) failed to reject the null hypothesis that all interaction terms are jointly equal to zero (**Appendix D.2**). The interaction model also produced a higher AIC than the preferred specification (11,410.9 versus 11,404.1), indicating no improvement in model fit. Model 3 is therefore retained as the preferred specification. Together, these results

suggest that psychological distress and area deprivation operate largely as independent predictors of physical multimorbidity, with deprivation increasing the overall burden of physical illness without significantly altering the strength of the distress–multimorbidity association.

Average marginal predictions from Model 3 further illustrate this pattern (**Appendix E**). At a GHQ-12 score of zero, predicted condition counts range from 0.643 in the least deprived quintile to 0.805 in the most deprived quintile. At the maximum GHQ-12 score of 12, predicted condition counts increase to 1.941 and 2.432 respectively. This represents an increase of approximately 1.30 conditions in the least deprived areas and 1.63 conditions in the most deprived areas. The predictions therefore demonstrate that both psychological distress and area deprivation are associated with substantially higher expected multimorbidity burdens, with the highest burden observed among individuals experiencing both severe distress and high deprivation.

Three robustness checks support the stability of the main findings. First, ordinary least squares regression produced a positive and statistically significant association between GHQ-12 score and physical condition count ($\beta = 0.102$, $p < 0.001$). Second, logistic regression using a binary multimorbidity indicator yielded an odds ratio of 1.177 (95% CI [1.149, 1.205], $p < 0.001$). Third, inclusion of nurse-measured BMI in the subset of respondents with valid BMI data (N = 3,293) resulted in only a modest change in the GHQ-12 coefficient (IRR = 1.087 compared with 1.097 in the main model). Collectively, these findings suggest that the observed association between psychological distress and physical multimorbidity is robust to alternative model specifications, outcome definitions, and additional adjustment for BMI (**Appendix F**).

Given the cross-sectional nature of the HSE 2022 data, the results should be interpreted as associations rather than causal effects. Reverse causality remains plausible, as individuals with a greater burden of physical illness may also experience higher levels of psychological distress.

4. Limitations

Several limitations should be considered when interpreting the findings of this study. The most important is the cross-sectional design of the HSE 2022, which precludes causal inference. While the analysis identifies a robust association between psychological distress and physical multimorbidity, the direction of this relationship cannot be established. Reverse causality is plausible, as individuals living with multiple longstanding conditions may experience poorer mental health as a consequence of their physical illness burden. The true relationship is likely to be bidirectional, and longitudinal data would be required to establish temporal ordering and move closer to causal identification.

The analytical sample is also affected by systematic missingness. The two largest sources of sample loss were missing GHQ-12 responses (1,617 observations, 20.9% of the adult sample) and missing equivalised household income data (1,068 observations, 21.9%). As shown in **Appendix B.2**, respondents with missing GHQ-12 data were younger, more likely to live in deprived areas, and reported fewer physical conditions than those with valid responses. Consequently, complete-case analysis may underrepresent certain population groups and introduce selection bias. Although survey weights were used for descriptive

statistics, they do not fully address the systematic pattern of GHQ-12 non-completion, and the estimated association may therefore differ from that observed in the full target population.

Residual confounding also remains possible. Although the analysis adjusts for a wide range of demographic, socioeconomic, lifestyle, and geographic characteristics, other relevant determinants of both psychological distress and physical multimorbidity were not available within the dataset. These include factors such as social support, housing conditions, healthcare utilisation, and early-life health circumstances. Body mass index (BMI), an established predictor of multimorbidity, could not be included in the primary specification because valid nurse-measured BMI data were unavailable for a substantial proportion of respondents. However, sensitivity analysis suggested that inclusion of BMI did not materially alter the estimated GHQ-12 effect (**Appendix F.4**). Both key variables are also subject to self-report bias, as the GHQ-12 does not capture clinically diagnosed mental health conditions and physical condition count may be affected by differential reporting behaviour across demographic groups.

Finally, the HSE samples adults living in private households and therefore excludes institutionalised populations, including care-home residents and long-term hospital patients. These groups are likely to experience higher levels of both psychological distress and physical multimorbidity than the general population. As a result, the findings may not fully generalise to the most clinically vulnerable segments of the English population. Despite these limitations, the consistency of findings across multiple model specifications, interaction analyses, marginal prediction exercises, and robustness checks provides confidence that the observed association between psychological distress and physical multimorbidity is statistically robust and substantively meaningful.

5. Conclusion

This study finds that higher levels of psychological distress are consistently associated with greater physical multimorbidity among adults in England. Each one-point increase in GHQ-12 score is associated with a 9.7% higher expected physical condition count after full adjustment, with the finding stable across all model specifications and robustness checks. Area deprivation independently compounds this burden, with residents of the most deprived communities reporting 25.3% higher expected condition counts than those in the least deprived areas. Crucially, the strength of the distress–multimorbidity association does not vary significantly across deprivation levels, suggesting that adults experiencing psychological distress face elevated physical health risk across the full deprivation distribution, not only in the most disadvantaged areas. For NHS Integrated Care Boards, this finding supports the case for embedding psychological distress screening within physical health pathways for adults with longstanding conditions, regardless of area deprivation. While causal conclusions cannot be drawn from cross-sectional data, the findings suggest that psychological distress may serve as an important marker of broader physical health vulnerability and could help inform strategies to identify individuals at greater risk of multimorbidity and reduce the burden of long-term conditions.

6. References

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Generative artificial intelligence (AI) tools, including ChatGPT and Claude, were used during the preparation of this report to support brainstorming, code debugging, proofreading, and the refinement of written expression. All research design decisions, data preparation, statistical analyses, interpretation of results, and final content were developed, verified, and approved by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the work submitted.

7. Appendices

Note on code: All variable construction, analysis, and output code referenced in this appendix is provided in the accompanying R Notebook. The R Notebook sections are labelled to match the corresponding appendix sections, such as Appendix A.1 and Appendix B.2, for ease of navigation.

Appendix A: Variable Construction

Variable	HSE Variable	Definition / Coding	Type	Role
GHQ-12 score	ghq12scr	Continuous score 0–12; higher = greater distress	Continuous	Primary exposure
Condition count	condlcnt	Count of grouped longstanding condition categories (0–6)	Count	Primary outcome
IMD quintile	qimd19	Area deprivation quintile (1 = least, 5 = most deprived)	Ordinal categorical	Key moderator
Sex	Sex	Male (ref) / Female	Binary	Control
Age group	ag16g10	Seven bands: 16–24 (ref), 25–34, 35–44, 45–54, 55–64, 65–74, 75+	Categorical	Control
Ethnicity	origin2	White (ref), Black, Asian, Mixed, Any other	Categorical	Control
Income quintile	eqv5	Equivalised household income quintiles (Q1 ref)	Ordinal categorical	Control
NS-SEC	nssec3	Managerial/professional (ref), Intermediate, Routine/manual	Categorical	Control
Education	topqual3	Degree (ref) to no qualification; seven categories	Categorical	Control
Smoking status	cigst1_19	Never (ref), Ex-occasional, Ex-regular, Current smoker	Categorical	Control
Alcohol risk	totalwug2_22	Lower risk (ref), Non-drinker, Increased risk, Higher risk	Categorical	Control
Region	GOR1	Nine Government Office Regions; London as reference	Categorical	Control
GHQ caseness	ghq	Binary: 0 = score 0–3, 1 = score ≥ 4	Binary	Descriptive / robustness
GHQ distress group	ghqg2	Grouped: score 0, 1–3, 4+	Ordinal categorical	Descriptive only
Multimorbidity	multimorbid	Binary: 1 if condlcnt ≥ 2	Binary	Descriptive / robustness

Table A.1: Summary of Constructed Analysis Variables

Appendix A.0: Dataset Selection

The primary dataset used in this analysis is the Health Survey for England (HSE) 2022, a repeated cross-sectional survey of adults residing in private households in England, commissioned by NHS England and made available through the UK Data Service (Study Number 9469). The HSE was selected because it contains all variables required to address the research question within a single nationally representative dataset. In particular, it includes a validated measure of psychological distress (GHQ-12), detailed information on longstanding health conditions, and the Index of Multiple Deprivation (IMD) 2019 quintile. This combination allows direct examination of the relationship between psychological distress, physical multimorbidity, and area deprivation. The HSE also provides survey weights to support representative descriptive analysis and contains a sufficiently large sample to support multivariable regression modelling after applying exclusion criteria.

Several alternative datasets were considered, including Understanding Society. While Understanding Society contains a broad range of health and socioeconomic measures and has been used extensively in UK health inequalities research, the HSE was preferred because it provides more detailed information on longstanding physical health conditions and includes a pre-derived condition count measure (condlcnt) directly aligned with the study outcome. In addition, the HSE includes linked IMD information and established health measures within a single survey wave, allowing the research question to be addressed using a consistent cross-sectional analytical framework. Given the study's focus on contemporary

associations between psychological distress, multimorbidity, and deprivation in England, the HSE 2022 was considered the most appropriate dataset.

Appendix A.1: GHQ-12 Psychological Distress Score

Psychological distress was measured using the 12-item General Health Questionnaire (GHQ-12), a validated screening instrument included in the Health Survey for England (HSE) 2022 self-completion questionnaire. The HSE provides derived GHQ variables, which were retained without modification.

Three GHQ-based variables were used in the analysis. The primary exposure variable was the continuous GHQ-12 score (ghq12scr), ranging from 0 to 12, with higher scores indicating greater psychological distress. For descriptive analyses, a grouped GHQ variable (ghqg2) was used, categorising respondents into no distress (score = 0), mild distress (score = 1–3), and probable psychological distress (score ≥ 4). A binary caseness indicator (ghq) was also used, where scores of 4 or above were classified as probable psychological distress, consistent with the standard GHQ-12 threshold used in UK population health research.

Following data cleaning, 6,112 respondents had valid GHQ-12 scores and 1,617 observations (20.9%) contained missing values. Valid scores ranged from 0 to 12, with no observations outside the expected range.

Appendix A.2: Physical Condition Count

Physical health status was measured using condlcnt, a pre-derived HSE variable recording the number of grouped longstanding condition categories reported by each respondent. Conditions are grouped into broad ICD-based disease categories by HSE and the variable was used as the primary outcome measure throughout the analysis.

A binary multimorbidity indicator (multimorbid) was additionally derived and coded as 1 where condlcnt ≥ 2 and 0 otherwise. This variable was used only in robustness analyses.

Six individual condition indicators (compexp1, compexp3, compexp4, compexp6, compexp7, and compexp9) representing diabetes, IHD/stroke/angina, hypertension, COPD/bronchitis, asthma, and arthritis/rheumatism were retained for descriptive analyses only. These variables were not included in regression models because they represent component conditions underlying the aggregate condition count measure.

Appendix A.3: Area Deprivation — IMD Quintile

Area-level socioeconomic deprivation was measured using the Index of Multiple Deprivation 2019 (IMD 2019), provided in HSE as the derived variable qimd19. The IMD is England's official measure of relative area deprivation and combines information across multiple domains, including income, employment, education, health, crime, housing, and the living environment.

Respondents were assigned to deprivation quintiles based on their area of residence, with Quintile 1 representing the least deprived areas and Quintile 5 representing the most deprived areas. The variable was treated as a categorical measure throughout the analysis. As the IMD is derived from area-level characteristics, it should be interpreted as a measure of neighbourhood deprivation rather than individual socioeconomic circumstances.

Appendix A.4: Demographics

Three demographic control variables were included in the analysis: sex, age, and ethnicity.
Sex was measured using the HSE variable Sex and coded as male or female, with male used as the reference category in regression models.

Age was measured using the derived variable ag16g10, which groups respondents into seven age bands (16–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75+ years). The youngest age group (16–24 years) was used as the reference category. Exact individual ages were removed from the safeguarded dataset for disclosure control purposes.

Ethnicity was measured using the derived variable origin2, which classifies respondents into five broad ethnic groups: White, Black, Asian, Mixed/multiple ethnic background, and Any other ethnic group. White ethnicity was used as the reference category in regression models.

Appendix A.5: Socioeconomic Status

Three variables were included to capture different dimensions of socioeconomic position: household income, occupational social class, and educational attainment.

Household income was measured using the HSE-derived variable eqv5, which classifies respondents into quintiles of equivalised household income. Equivalisation adjusts household income for household size and composition to improve comparability across households. The lowest income quintile was used as the reference category in regression models. Observations coded as -90 (“age of household member refused”) were treated as missing.

Occupational social class was measured using the National Statistics Socio-economic Classification (NS-SEC) variable nssec3, which groups respondents into managerial and professional occupations, intermediate occupations, and routine/manual occupations. Managerial and professional occupations were used as the reference category. Observations coded as 99 (“Other”) were treated as missing.

Educational attainment was measured using the derived variable topqual3, representing the respondent’s highest qualification level. Categories ranged from degree-level qualifications to no formal qualifications. Degree-level qualifications were used as the reference category in regression models.

Appendix A.6: Lifestyle

Smoking status was measured using cigst1_19, a derived HSE variable recording cigarette smoking history across four categories: never smoked, used to smoke occasionally, used to smoke regularly, and current smoker.

Alcohol consumption was measured using totalwug2_22, a derived HSE variable classifying respondents into risk groups based on weekly alcohol consumption using the revised 2022 HSE alcohol guidelines: non-drinker or not drunk in the last 12 months, lower-risk drinker (up to 14 units per week), increased-risk drinker, and higher-risk drinker.

Appendix A.7: Geography

Geographic location was measured using GOR1, a pre-derived HSE variable identifying respondents' Government Office Region of residence within England. The variable comprises nine regions: North East, North West, Yorkshire and The Humber, East Midlands, West Midlands, East of England, London, South East, and South West. No missing values were recorded for this variable in the full adult sample (N = 7,729).

Appendix A.8: BMI Variable Consideration

Body mass index (BMI) was initially considered for inclusion as a control variable because of its documented association with both psychological distress and physical health outcomes. The HSE-derived variable bmisrg3 classifies respondents as underweight/normal weight, overweight, or obese.

However, BMI was excluded from the final analytical model due to substantial missingness. Of the 7,729 adult respondents, 5,260 (68.1%) had missing BMI information. Inclusion of BMI would have reduced the analytical sample from 4,735 to 1,075 observations, representing a loss of 77.3% of the regression sample. BMI was therefore excluded to preserve statistical power and sample representativeness.

Appendix A.9: Justification for Control Variable Selection

Control variables were selected to capture key demographic, socioeconomic, lifestyle, and geographic factors that may confound the relationship between psychological distress and physical multimorbidity.

Demographics. Sex, age group, and ethnicity are included because both psychological distress and physical multimorbidity vary substantially across demographic groups. Age is particularly important given its strong association with longstanding illness and multimorbidity, while sex and ethnicity are associated with differences in both mental and physical health outcomes.

Socioeconomic status. Equivalised household income quintile, NS-SEC occupational classification, and educational attainment capture complementary dimensions of socioeconomic position, including

material resources, occupational status, and human capital. All three are independently associated with mental and physical health and help distinguish the effects of individual socioeconomic circumstances from area-level deprivation.

Lifestyle factors. Smoking status and alcohol consumption risk group are included because health behaviours are associated with both physical illness burden and psychological distress, making them potential confounders of the relationship of interest.

Geography. Government Office Region captures geographic variation in population health, healthcare access, and service provision that is not fully captured by IMD quintile alone. Including regional controls helps account for broader contextual differences across England.

Together, these variables account for major individual and contextual factors identified in the literature as determinants of both psychological distress and physical multimorbidity, improving the validity of the estimated association between the two outcomes.

Appendix B: Sample Construction and Missingness

Appendix B.1: Sample Construction

The analytical sample was constructed using complete-case analysis, retaining respondents with valid values for all variables included in the main regression model. The full HSE 2022 dataset contained 9,122 observations. Restriction to adults aged 16 years and over yielded an initial sample of 7,729 respondents. Complete-case selection was then applied across all analytical variables, resulting in a final analytical sample of 4,735 respondents. Table B.1 summarises the sequential sample selection process.

Step	N Remaining	N Lost
Full adult sample (16+)	7729	—
Drop missing: GHQ-12	6112	1617
Drop missing: Condition count	6109	3
Drop missing: IMD quintile	6109	0
Drop missing: Income	5041	1068
Drop missing: NS-SEC	4841	200
Drop missing: Education	4830	11
Drop missing: Smoking	4817	13
Drop missing: Alcohol	4739	78
Drop missing: Sex	4739	0
Drop missing: Age	4739	0
Drop missing: Ethnicity	4735	4
Drop missing: Region	4735	0
Final analytical sample	4735	

Table B.1: Sequential Sample Construction

Appendix B.2: Missing Data Analysis

Table B.2 reports missingness rates for all analytical variables in the adult sample (N = 7,729). GHQ-12 and equivalised household income had the highest rates of missing data, at 20.9% and 21.9% respectively. All other variables had missingness below 7%, with IMD quintile, sex, age, and region containing no missing values.

Tables B.3 and B.4 compare selected characteristics between respondents with and without valid GHQ-12 and income data. Respondents missing GHQ-12 data were slightly younger (mean age band 4.22 vs 4.50), more deprived (mean IMD 2.91 vs 2.84), more ethnically diverse (mean origin2 1.32 vs 1.23), and had fewer recorded physical conditions (mean 0.71 vs 0.88) than respondents with valid GHQ-12 responses. Respondents missing income data were slightly older (mean age band 4.61 vs 4.40) and more deprived (mean IMD 3.00 vs 2.81) than respondents with valid income data.

These comparisons indicate some observable differences between respondents with complete and incomplete data. The implications of these patterns for the analytical sample are considered in the limitations section.

Variable	N Valid	N Missing	% Missing
GHQ-12 (ghq12scr)	6,112	1,617	20.90%
Condition count (condlcnt)	7,722	7	0.10%
IMD quintile (qimd19)	7,729	0	0.00%
Income (eqv5)	6,036	1,693	21.90%
NS-SEC (nssec3)	7,207	522	6.80%
Education (topqual3)	7,655	74	1.00%
Smoking (cigst1_19)	7,628	101	1.30%
Alcohol (totalwug2_22)	7,457	272	3.50%
Sex	7,729	0	0.00%
Age (ag16g10)	7,729	0	0.00%
Ethnicity (origin2)	7,661	68	0.90%
Region (GOR1)	7,729	0	0.00%

Table B.2: Variable Missingness Rates (Adult Sample, N=7,729)

Variable	Has GHQ (n=6,112)	Missing GHQ (n=1,617)	Difference
Age band	4.502	4.224	0.278
Sex	1.552	1.535	0.017
IMD quintile	2.84	2.913	-0.072
Ethnicity	1.229	1.315	-0.087
Condition count	0.882	0.712	0.17

Table B.3: Characteristics by CHQ-12 Response Status

Variable	Has Income (n=6,036)	Missing Income	Difference
Age band	4.397	4.611	-0.214
Sex	1.545	1.561	-0.016
IMD quintile	2.814	3.002	-0.187
Ethnicity	1.225	1.323	-0.098
Condition count	0.842	0.863	-0.021

Table B.3: Characteristics by Income Response Status

Appendix C: Descriptive Statistics

Appendix C.1: Sample Characteristics

Table C.1 presents weighted descriptive statistics for the analytical sample (N = 4,735). Panel A reports weighted means and weighted standard deviations for the two continuous study variables. Panel B reports weighted percentages for all categorical variables. All estimates use the HSE 2022 interview weight (wt_int) to account for survey design and differential non-response.

Table C.1: Sample Characteristics

Variable	W.Mean	W.SD	Min	Max
GHQ-12 score (0-12)	1.653	2.839	0	12
Condition count	0.759	1.093	0	6

Panel A: Continuous Variables

Demographic Variables	Weighted %	Socioeconomic Variables	Weighted %	Health & Outcome Variables	Weighted %
Sex		**Income quintile**		**GHQ-12 caseness**	
Male	48.6%	Q1 Lowest ($\le$£19,180)	16.2%	Score 0-3 (no caseness)	82.6%
Female	51.4%	Q2 (£19,181-£27,705)	19.2%	Score 4+ (distress)	17.4%
Age group		Q3 (£27,706-£42,763)	19.1%	**Multimorbidity (2+ cond)**	

16-24	7.7%	Q4 (£42,764-£66,901)	22.1%	No (0-1 conditions)	79.7%
25-34	17.7%	Q5 Highest (>£66,901)	23.5%	Yes (2+ conditions)	20.3%
35-44	17.0%	**Education**		**Smoking status**	
45-54	16.4%	Degree or equivalent	41.2%	Never smoked	53.8%
55-64	17.6%	Higher ed below degree	12.8%	Ex-occasional smoker	8.5%
65-74	13.6%	A Level equivalent	17.2%	Ex-regular smoker	25.4%
75+	10.0%	O Level equivalent	15.4%	Current smoker	12.3%
Ethnicity		NVQ1/CSE	2.5%	**Alcohol risk**	
White	87.6%	Foreign/other	0.5%	Non-drinker	14.9%
Black	3.1%	No qualification	10.4%	Lower risk	58.9%
Asian	6.2%	**NS-SEC**		Increased risk	21.0%
Mixed/multiple	2.2%	Managerial/professional	46.4%	Higher risk	5.3%
Any other	0.9%	Intermediate	21.6%		
IMD quintile		Routine/manual	32.0%		
Q1 (Least deprived)	24.1%				
Q2	22.2%				
Q3	20.5%				
Q4	17.9%				
Q5 (Most deprived)	15.2%				

Panel B: Categorical Variables

Appendix C.2: Weighted vs Unweighted Comparison

Table C.2 compares weighted and unweighted estimates for key variables in the analytical sample. The largest difference is observed for multimorbidity prevalence, which falls from 23.8% unweighted to 20.3% weighted, a difference of 3.5 percentage points. Mean condition count shows a similar pattern, falling from 0.867 unweighted to 0.759 weighted. GHQ-12 caseness and the IMD quintile distribution are largely unaffected by weighting. Income quintile shows a modest upward shift in the highest quintile after weighting (+2.6 percentage points), suggesting slight underrepresentation of higher-income households in the analytical sample. Overall, the comparison indicates that weighting has a meaningful effect on estimates of physical health burden but relatively little effect on the distribution of psychological distress or deprivation.

Variable	Unweighted	Weighted	Difference
Continuous variables (mean)			
GHQ-12 score	1.654	1.653	0
Condition count	0.867	0.759	-0.108
GHQ caseness (% score 4+)			
GHQ 4+ (probable distress)	17.20%	17.40%	0.001
Multimorbidity (% 2+ conditions)			
2+ conditions	23.80%	20.30%	-3.50%
IMD quintile (%)			
Q1 (Least deprived)	24.70%	24.10%	-0.60%
Q2	22.20%	22.20%	0.001
Q3	19.40%	20.50%	0.011
Q4	17.70%	17.90%	0.002
Q5 (Most deprived)	16.00%	15.20%	-0.80%
Income quintile (%)			
Q1 Lowest	15.80%	16.20%	0.004
Q2	21.50%	19.20%	-2.30%
Q3	20.10%	19.10%	-1.00%
Q4	21.80%	22.10%	0.003
Q5 Highest	20.90%	23.50%	0.026

Table C.2: Weighted vs Unweighted Comparison

Appendix C.3: GHQ-12 Distribution

Table C.3 and Figure C.3 summarise the distribution of GHQ-12 psychological distress scores in the analytical sample. The distribution is heavily right-skewed (skewness = 2.04), with 58.1% of respondents scoring zero and a weighted mean of 1.65. The median score is 0. Probable psychological distress (score ≥ 4) was recorded in 17.4% of the weighted sample. Figure C.3 presents the weighted frequency distribution.

Weighted mean	1.653
Median	0
SD (unweighted)	2.867
Skewness	2.038
Proportion at score 0	58.1%
Proportion at score 12	1.4%
Weighted caseness (score ⩾ 4)	17.4%

Table C.3: GHQ-12 Summary Statistics (Analytical Sample, N = 4,735)

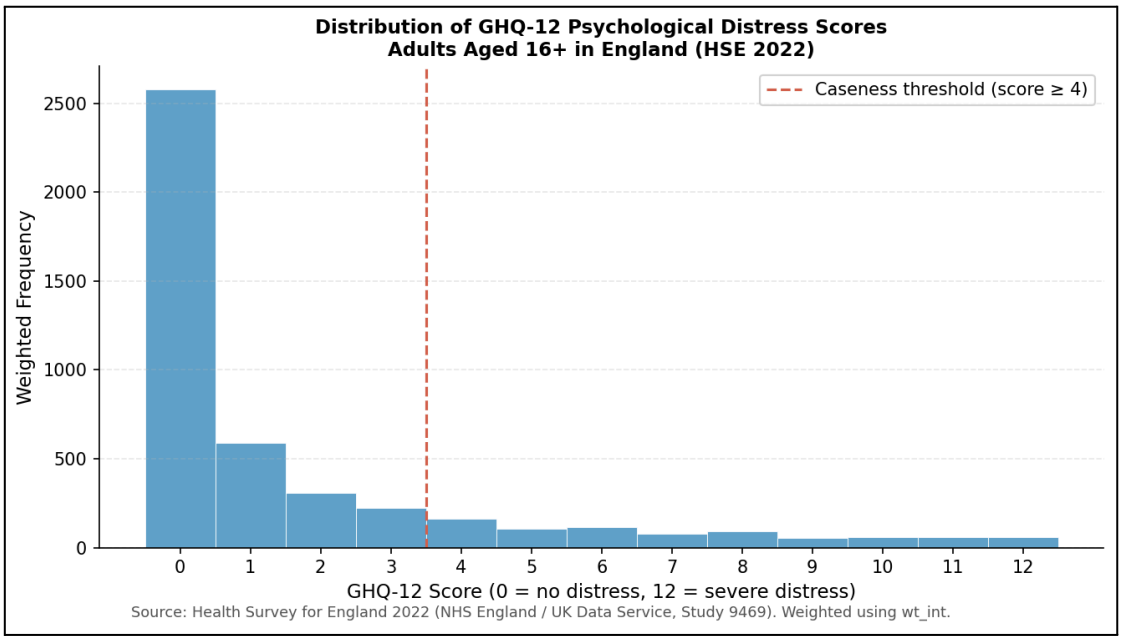

Figure C.3: Distribution of GHQ-12 Psychological Distress Scores

Appendix C.4: Condition Count Distribution

Table C.4 presents summary statistics for the physical condition count in the analytical sample. The distribution is right-skewed (skewness = 1.42), with 52.5% of respondents reporting zero conditions. The weighted mean condition count is 0.759 and the median is 0. The variance-to-mean ratio of 1.538 (mean = 0.867, variance = 1.333) indicates overdispersion, providing empirical justification for the use of negative binomial regression in preference to Poisson. Weighted multimorbidity prevalence (2+ conditions) was 20.3%. Figure C.4 presents the weighted frequency distribution.

Metric	Value
Weighted mean	1.653
Median	0
SD (unweighted)	2.867
Skewness	2.038
Proportion at score 0	58.10%
Proportion at score 12	1.40%
Weighted caseness (score ≥ 4)	17.40%

Table C.4: Physical Condition Count Summary Statistics (Analytical Sample, N = 4,735)

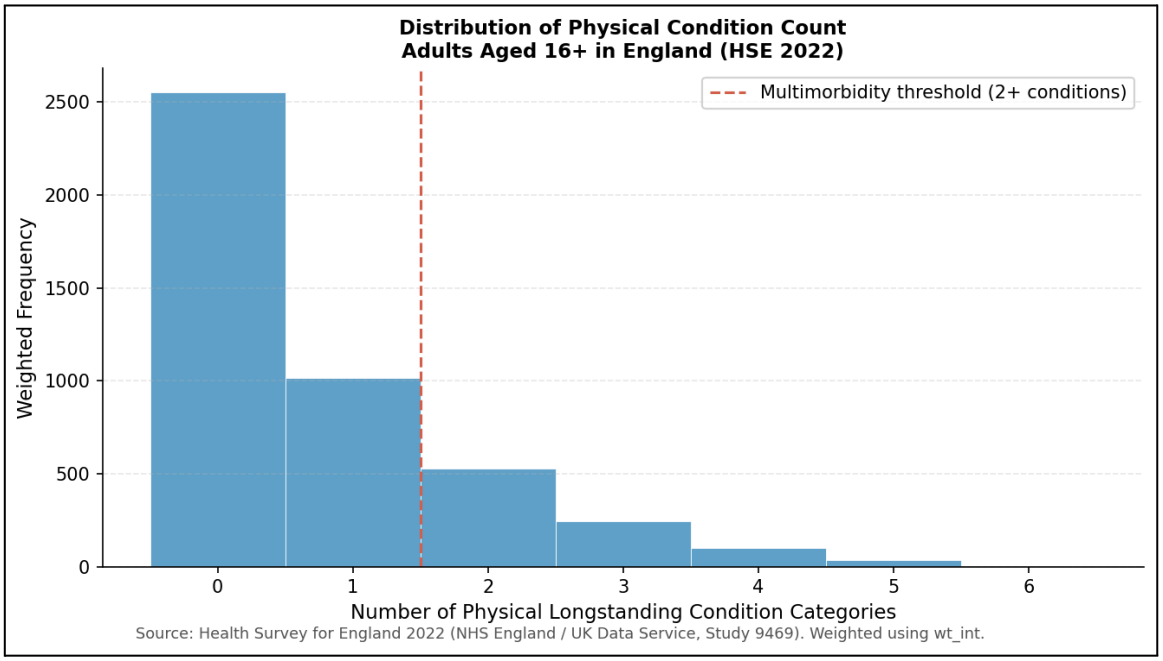

Figure C.4: Distribution of Physical Condition Count

Appendix C.5: Condition Prevalence by CHQ Group

Table C.5a presents weighted prevalence of six selected physical conditions by GHQ-12 distress group. Table C.5b presents weighted mean condition count and multimorbidity prevalence by GHQ-12 distress group. Table C.5c presents weighted mean condition count and multimorbidity prevalence by IMD deprivation quintile. Together these tables describe how physical condition burden varies across psychological distress categories and area deprivation levels prior to regression adjustment.

Condition	GHQ 0	GHQ 1-3	GHQ 4+	Total
Diabetes	4.30%	3.30%	5.70%	4.30%
IHD/stroke/angina	1.50%	1.10%	2.20%	1.50%
Hypertension	5.90%	3.80%	4.70%	5.20%
COPD/bronchitis	1.30%	1.80%	2.30%	1.60%
Asthma	3.80%	6.10%	7.20%	5.00%
Arthritis/rheumatism	6.20%	6.80%	12.50%	7.50%

Table C.5a: Weighted Prevalence of Selected Physical Conditions by GHQ-12 Group (%)

GHQ Group	N	W.Mean condlcnt	W.% Multimorbid
0 (No distress)	2,753	0.594	15.30%
1-3 (Mild)	1,166	0.783	21.00%
4+ (Probable distress)	816	1.27	36.10%

Table C.5b: Weighted Mean Condition Count and Multimorbidity Prevalence by GHQ-12 Group

IMD Quintile	N	W.Mean condlcnt	W.% Multimorbid
Q1 (Least deprived)	1,168	0.623	15.60%
Q2	1,051	0.759	21.10%
Q3	920	0.758	20.10%
Q4	837	0.744	19.80%
Q5 (Most deprived)	759	0.991	27.60%

Table C.5c: Mean Physical Condition Count and Multimorbidity Prevalence by Area Deprivation Quintile (Weighted, N = 4,735)

Appendix C.6: Figures

Figure C.6.1 presents a heatmap of weighted prevalence for six selected physical conditions by GHQ-12 distress group. Figure C.6.2 presents weighted prevalence of probable psychological distress (GHQ-12 score ≥ 4) by IMD deprivation quintile.

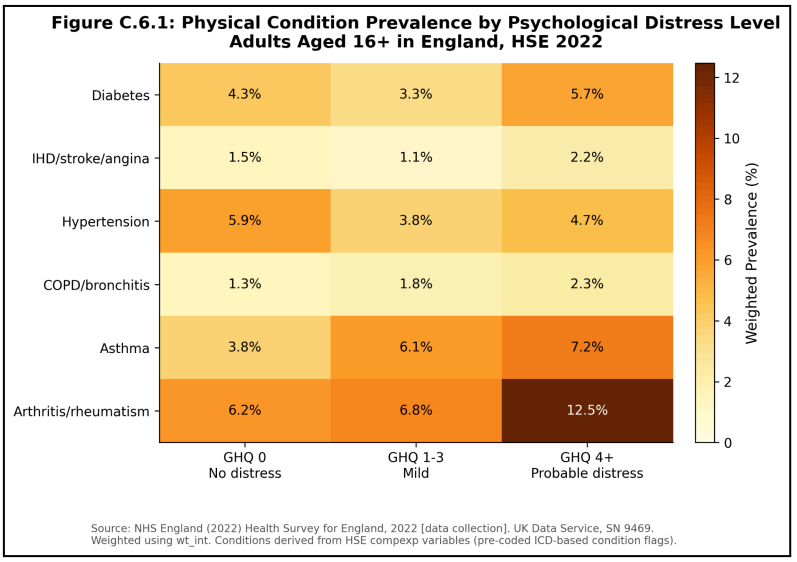

Figure C.6.1: Physical Condition Prevalence by Psychological Distress Level Adults Aged 16+ in England

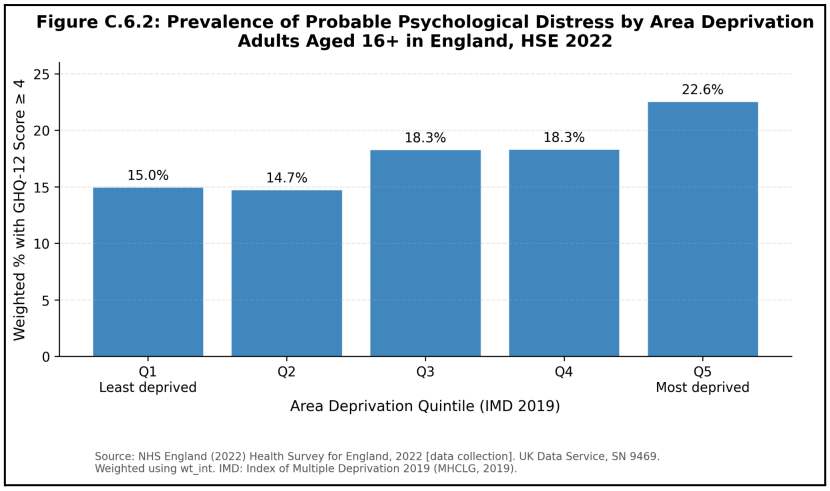

Figure C.6.2: Prevalence of Probable Psychological Distress by Area Deprivation

Appendix D: Regression Results

Appendix D.1: Full Regression Results

Table D.1a presents model fit statistics for the four negative binomial regression models estimated in the analysis. Model fit improves substantially as additional covariates are introduced, with the log-likelihood increasing from −5,976.9 in Model 1 to −5,658.0 in Model 3. The estimated dispersion parameter (α) declines from 0.60 to 0.30 across specifications, indicating that part of the observed overdispersion is explained by demographic, socioeconomic, lifestyle, geographic, and deprivation-related factors. Model 3 achieves the lowest AIC and BIC values and is therefore retained as the primary specification.

Table D.1b shows the estimated association between psychological distress and physical multimorbidity across progressively adjusted models. The GHQ-12 coefficient remains positive, statistically significant, and highly stable across all specifications. In the fully adjusted model (Model 3), each one-point increase in GHQ-12 score is associated with a 9.7% increase in the expected physical condition count (IRR = 1.097, $p < 0.001$), controlling for demographic, socioeconomic, lifestyle, geographic, and deprivation-related factors. The persistence of the coefficient across models suggests that the association between psychological distress and physical multimorbidity is not solely explained by observed confounding factors.

Model 4 introduces interaction terms between GHQ-12 score and IMD quintile to assess whether the association between psychological distress and physical multimorbidity varies across levels of area deprivation. None of the interaction terms are statistically significant ($p > 0.60$ in all cases), providing no evidence that the relationship differs systematically across deprivation quintiles. This finding suggests that psychological distress is associated with higher physical multimorbidity throughout the deprivation distribution, while deprivation independently contributes to higher overall condition counts.

Full coefficient tables for all four models are presented in Tables D.1c–D.1f, with reference categories stated for all dummy variables.

Model	N	Log-lik	AIC	BIC	Alpha
Model 1: GHQ only	4735	-5976.887	11959.773	11979.161	0.6017
Model 2: + Demographics	4735	-5748.746	11525.492	11615.971	0.3884
Model 3: + Full controls	4735	-5658.049	11404.098	11688.459	0.3041
Model 4: + GHQ x IMD interaction	4735	-5657.445	11410.889	11721.101	0.3035

Table D.1a Model Fit Statistics

Model	Coef	IRR	SE	95% CI	p	Significance
Model 1: GHQ only	0.0923	1.0967	0.0059	[1.084, 1.109]	0.0000	***
Model 2: + Demographics	0.1043	1.11	0.0056	[1.098, 1.122]	0.0000	***
Model 3: + Full controls	0.0921	1.0965	0.0055	[1.085, 1.108]	0.0000	***
Model 4: + GHQ x IMD (ref: Q1)	0.0936	1.0981	0.0132	[1.070, 1.127]	0.0000	***

Table D.1b: GHQ-12 Coefficient Across Progressive Model Specifications

Variable	Coef	IRR	SE	95% CI	p	Significance
GHQ-12 score	0.0923	1.0967	0.0059	[1.084, 1.109]	0	***

N=4,735 Log-lik=-5976.887 AIC=11959.773 BIC=11979.161 Alpha=0.6017

Table D.1c: Full Regression Coefficients — Model 1 (GHQ-12 Only)

Variable	Coef	IRR	SE	95% CI	p	Significance
GHQ-12 score	0.1043	1.11	0.0056	[1.098, 1.122]	0.0000	***
Female (ref: Male)	0.0442	1.0451	0.0374	[0.971, 1.125]	0.2380	
Age 25-34 (ref: 16-24)	-0.0111	0.989	0.1394	[0.753, 1.300]	0.9368	
Age 35-44 (ref: 16-24)	0.0502	1.0515	0.1355	[0.806, 1.371]	0.7110	
Age 45-54 (ref: 16-24)	0.4893	1.6311	0.1313	[1.261, 2.110]	0.0002	***
Age 55-64 (ref: 16-24)	0.7224	2.0593	0.1286	[1.601, 2.649]	0.0000	***
Age 65-74 (ref: 16-24)	0.9628	2.619	0.1276	[2.040, 3.363]	0.0000	***
Age 75+ (ref: 16-24)	1.0964	2.9933	0.1297	[2.322, 3.859]	0.0000	***
Ethnicity: Black (ref: White)	-0.2378	0.7883	0.1479	[0.590, 1.053]	0.1078	
Ethnicity: Asian (ref: White)	-0.3023	0.7391	0.1024	[0.605, 0.903]	0.0032	**
Ethnicity: Mixed (ref: White)	-0.1601	0.852	0.1641	[0.618, 1.175]	0.3293	
Ethnicity: Other (ref: White)	-0.421	0.6564	0.2917	[0.371, 1.163]	0.1490	

N=4,735 Log-lik=-5748.746 AIC=11525.492 BIC=11615.971 Alpha=0.3884

Table D.1d: Full Regression Coefficients — Model 2 (GHQ-12 + Demographics)

Variable	Coef	IRR	SE	95% CI	p	Significance
GHQ-12 score	0.0921	1.0965	0.0055	[1.085, 1.108]	0	***
Female (ref: Male)	0.0154	1.0155	0.0377	[0.943, 1.093]	0.6824	
Age 25-34 (ref: 16-24)	-0.0368	0.9638	0.1387	[0.734, 1.265]	0.7906	
Age 35-44 (ref: 16-24)	0.0507	1.052	0.1351	[0.807, 1.371]	0.7077	
Age 45-54 (ref: 16-24)	0.4547	1.5756	0.1309	[1.219, 2.037]	0.0005	***
Age 55-64 (ref: 16-24)	0.686	1.9857	0.1281	[1.545, 2.552]	0	***
Age 65-74 (ref: 16-24)	0.8958	2.4492	0.1284	[1.904, 3.150]	0	***
Age 75+ (ref: 16-24)	1.0066	2.7362	0.1326	[2.110, 3.548]	0	***
Ethnicity: Black (ref: White)	-0.2758	0.759	0.1479	[0.568, 1.014]	0.0622	
Ethnicity: Asian (ref: White)	-0.3069	0.7357	0.1049	[0.599, 0.904]	0.0034	**
Ethnicity: Mixed (ref: White)	-0.1664	0.8467	0.1615	[0.617, 1.162]	0.3027	
Ethnicity: Other (ref: White)	-0.4417	0.6429	0.2993	[0.365, 1.134]	0.1268	
Income Q2 (ref: Q1 lowest)	0.1112	1.1176	0.0557	[1.002, 1.246]	0.0458	*
Income Q3 (ref: Q1 lowest)	-0.0119	0.9882	0.0608	[0.877, 1.113]	0.8455	
Income Q4 (ref: Q1 lowest)	-0.1217	0.8854	0.0647	[0.780, 1.005]	0.0598	
Income Q5 (ref: Q1 lowest)	-0.1595	0.8526	0.0713	[0.741, 0.980]	0.0252	*
NS-SEC: Intermediate (ref: Managerial)	0.0988	1.1039	0.051	[0.999, 1.220]	0.0527	
NS-SEC: Routine/manual (ref: Managerial)	0.1361	1.1458	0.0513	[1.036, 1.267]	0.0081	**
Education: HE below degree (ref: Degree)	-0.0233	0.977	0.0608	[0.867, 1.101]	0.702	
Education: A Level (ref: Degree)	-0.1145	0.8918	0.0617	[0.790, 1.007]	0.0636	
Education: O Level (ref: Degree)	-0.0683	0.9339	0.0584	[0.833, 1.047]	0.2417	
Education: NVQ1/CSE (ref: Degree)	0.0013	1.0013	0.1148	[0.800, 1.254]	0.9906	
Education: Foreign/other (ref: Degree)	-0.1818	0.8338	0.188	[0.577, 1.205]	0.3334	
Education: No qual (ref: Degree)	-0.1256	0.882	0.0668	[0.774, 1.005]	0.0601	
Smoking: Ex-occasional (ref: Never)	0.0764	1.0794	0.07	[0.941, 1.238]	0.2749	
Smoking: Ex-regular (ref: Never)	0.1967	1.2173	0.0427	[1.120, 1.324]	0	***
Smoking: Current (ref: Never)	0.2175	1.243	0.06	[1.105, 1.398]	0.0003	***
Alcohol: Non-drinker (ref: Lower risk)	0.1763	1.1928	0.051	[1.079, 1.318]	0.0005	***
Alcohol: Increased risk (ref: Lower risk)	-0.182	0.8336	0.0498	[0.756, 0.919]	0.0003	***
Alcohol: Higher risk (ref: Lower risk)	0.0854	1.0892	0.078	[0.935, 1.269]	0.2734	
Region: North East (ref: London)	0.0168	1.017	0.0873	[0.857, 1.207]	0.8473	
Region: North West (ref: London)	0.1474	1.1588	0.0852	[0.980, 1.370]	0.0838	
Region: Yorkshire (ref: London)	-0.0342	0.9664	0.0879	[0.813, 1.148]	0.6973	
Region: East Midlands (ref: London)	0.1169	1.124	0.0908	[0.941, 1.343]	0.1982	
Region: West Midlands (ref: London)	-0.1211	0.886	0.0939	[0.737, 1.065]	0.1973	
Region: East of England (ref: London)	0.2382	1.269	0.0842	[1.076, 1.497]	0.0046	**
Region: South East (ref: London)	-0.0053	0.9948	0.0814	[0.848, 1.167]	0.9485	
Region: South West (ref: London)	0.0141	1.0142	0.0855	[0.858, 1.199]	0.869	
IMD Q2 (ref: Q1 least deprived)	0.1384	1.1484	0.055	[1.031, 1.279]	0.0119	*
IMD Q3 (ref: Q1 least deprived)	0.065	1.0671	0.0587	[0.951, 1.197]	0.2684	
IMD Q4 (ref: Q1 least deprived)	0.1342	1.1436	0.0603	[1.016, 1.287]	0.0261	*
IMD Q5 (ref: Q1 least deprived)	0.2253	1.2526	0.0638	[1.105, 1.419]	0.0004	***

N=4,735 Log-lik=-5658.049 AIC=11404.098 BIC=11688.459 Alpha=0.3041

Table D.1e: Full Regression Coefficients — Model 3 (Full Controls, Preferred Specification)

Variable	Coef	IRR	SE	95% CI	p	Significance
GHQ-12 score	0.0936	1.0981	0.0132	[1.070, 1.127]	0.000	***
Female (ref: Male)	0.0159	1.016	0.0377	[0.944, 1.094]	0.673	
Age 25-34 (ref: 16-24)	-0.0314	0.9691	0.1389	[0.738, 1.272]	0.821	
Age 35-44 (ref: 16-24)	0.0554	1.057	0.1352	[0.811, 1.378]	0.682	
Age 45-54 (ref: 16-24)	0.4607	1.5851	0.1311	[1.226, 2.049]	0.000	***
Age 55-64 (ref: 16-24)	0.6927	1.9991	0.1284	[1.554, 2.571]	0.000	***
Age 65-74 (ref: 16-24)	0.9005	2.4609	0.1286	[1.913, 3.166]	0.000	***
Age 75+ (ref: 16-24)	1.0097	2.7448	0.1327	[2.116, 3.560]	0.000	***
Ethnicity: Black (ref: White)	-0.2743	0.7601	0.1478	[0.569, 1.016]	0.064	
Ethnicity: Asian (ref: White)	-0.3103	0.7333	0.105	[0.597, 0.901]	0.003	**
Ethnicity: Mixed (ref: White)	-0.1694	0.8441	0.1615	[0.615, 1.158]	0.294	
Ethnicity: Other (ref: White)	-0.4399	0.6441	0.2892	[0.365, 1.135]	0.128	
Income Q2 (ref: Q1 lowest)	0.107	1.1129	0.0558	[0.998, 1.242]	0.055	
Income Q3 (ref: Q1 lowest)	-0.0148	0.9853	0.0609	[0.874, 1.110]	0.808	
Income Q4 (ref: Q1 lowest)	-0.1246	0.8828	0.0647	[0.778, 1.002]	0.054	
Income Q5 (ref: Q1 lowest)	-0.1629	0.8497	0.0713	[0.739, 0.977]	0.022	*
NS-SEC: Intermediate (ref: Managerial)	0.0986	1.1036	0.0511	[0.998, 1.220]	0.054	
NS-SEC: Routine/manual (ref: Managerial)	0.1351	1.1447	0.0514	[1.035, 1.266]	0.009	**
Education: HE below degree (ref: Degree)	-0.0239	0.9763	0.0609	[0.867, 1.100]	0.694	
Education: A Level (ref: Degree)	-0.115	0.8913	0.0618	[0.790, 1.006]	0.063	
Education: O Level (ref: Degree)	-0.0686	0.9337	0.0584	[0.833, 1.047]	0.240	
Education: NVQ1/CSE (ref: Degree)	0.0024	1.0024	0.1147	[0.801, 1.255]	0.983	
Education: Foreign/other (ref: Degree)	-0.1765	0.8382	0.188	[0.580, 1.212]	0.348	
Education: No qual (ref: Degree)	-0.1256	0.882	0.0669	[0.774, 1.006]	0.060	
Smoking: Ex-occasional (ref: Never)	0.0783	1.0814	0.0701	[0.943, 1.241]	0.264	
Smoking: Ex-regular (ref: Never)	0.1982	1.2192	0.0427	[1.121, 1.326]	0.000	***
Smoking: Current (ref: Never)	0.2179	1.2434	0.0601	[1.105, 1.399]	0.000	***
Alcohol: Non-drinker (ref: Lower risk)	0.1781	1.195	0.0511	[1.081, 1.321]	0.001	***
Alcohol: Increased risk (ref: Lower risk)	-0.1817	0.8338	0.0498	[0.756, 0.919]	0.000	***
Alcohol: Higher risk (ref: Lower risk)	0.0875	1.0914	0.078	[0.937, 1.272]	0.262	
Region: North East (ref: London)	0.0187	1.0189	0.0873	[0.859, 1.209]	0.830	
Region: North West (ref: London)	0.1485	1.16	0.0853	[0.981, 1.371]	0.082	
Region: Yorkshire (ref: London)	-0.0346	0.966	0.0879	[0.813, 1.148]	0.694	
Region: East Midlands (ref: London)	0.115	1.1219	0.0909	[0.939, 1.341]	0.206	
Region: West Midlands (ref: London)	-0.1199	0.887	0.0939	[0.738, 1.066]	0.202	
Region: East of England (ref: London)	0.2401	1.2714	0.0842	[1.078, 1.500]	0.004	**
Region: South East (ref: London)	-0.0049	0.9951	0.0814	[0.848, 1.167]	0.952	
Region: South West (ref: London)	0.0146	1.0147	0.0856	[0.858, 1.200]	0.864	
IMD Q2 (ref: Q1 least deprived)	0.1444	1.1553	0.0646	[1.018, 1.311]	0.026	*
IMD Q3 (ref: Q1 least deprived)	0.0443	1.0453	0.0691	[0.913, 1.197]	0.522	
IMD Q4 (ref: Q1 least deprived)	0.1387	1.1488	0.071	[1.000, 1.320]	0.051	
IMD Q5 (ref: Q1 least deprived)	0.25	1.284	0.0749	[1.109, 1.487]	0.001	***
GHQ x IMD Q2 (ref: Q1)	-0.0032	0.9968	0.0177	[0.963, 1.032]	0.855	
GHQ x IMD Q3 (ref: Q1)	0.0086	1.0086	0.0178	[0.974, 1.044]	0.630	
GHQ x IMD Q4 (ref: Q1)	-0.0024	0.9976	0.0179	[0.963, 1.033]	0.894	
GHQ x IMD Q5 (ref: Q1)	-0.009	0.991	0.0172	[0.958, 1.025]	0.601	

N=4,735 Log-lik=-5657.445 AIC=11410.889 BIC=11721.101 Alpha=0.3035

Table D.1f: Full Regression Coefficients — Model 4 (Full Controls + GHQ-12 × IMD Interaction)

Appendix D.2: Interaction Terms and Tests of Effect Modification

Table D.2a presents the interaction model examining whether the association between psychological distress and physical multimorbidity varies across levels of area deprivation. In Model 4, the GHQ-12 coefficient represents the estimated association within the least deprived quintile (IMD Q1), while the interaction terms capture any additional effect in the remaining deprivation quintiles.

The estimated association between psychological distress and physical multimorbidity remains positive and statistically significant in the reference group (IRR = 1.098, $p < 0.001$). However, none of the

interaction terms are statistically significant, with all confidence intervals including unity. The estimated interaction effects are also substantively small, ranging from −0.9% to +0.9% relative to the reference quintile. These findings provide no evidence that the relationship between psychological distress and physical multimorbidity differs across levels of area deprivation.

Table D.2b formally evaluates effect modification using likelihood ratio and Wald tests. Both tests fail to reject the null hypothesis that all interaction terms are jointly equal to zero (LR $\chi^2(4) = 1.21$, $p = 0.877$; Wald $\chi^2(4) = 1.21$, $p = 0.877$). Model comparison statistics further support this conclusion, as the interaction model produces a higher AIC than the main-effects model (11,410.9 versus 11,404.1). Collectively, these results indicate that adding interaction terms does not improve model fit and that the association between psychological distress and physical multimorbidity is broadly consistent across deprivation quintiles.

The interaction analysis therefore suggests that psychological distress and area deprivation operate largely as independent predictors of physical multimorbidity. While residents of more deprived areas experience higher overall condition counts, the strength of the association between psychological distress and physical multimorbidity does not appear to vary systematically across the deprivation distribution.

Variable	Coef	IRR	SE	95% CI	p	Significance
GHQ-12 score (ref: IMD Q1)	0.0936	1.0981	0.0132	[1.070, 1.127]	0.0000	***
GHQ x IMD Q2 (vs Q1)	-0.0032	0.9968	0.0177	[0.963, 1.032]	0.8552	
GHQ x IMD Q3 (vs Q1)	0.0086	1.0086	0.0178	[0.974, 1.044]	0.6301	
GHQ x IMD Q4 (vs Q1)	-0.0024	0.9976	0.0179	[0.963, 1.033]	0.8941	
GHQ x IMD Q5 (vs Q1)	-0.009	0.991	0.0172	[0.958, 1.025]	0.6009	

Table D.2a: GHQ-12 × IMD Quintile Interaction Coefficients — Model 4

Test	Statistic	df	p-value
Likelihood Ratio Test	1.209	4	0.877
Wald Test	1.209	4	0.877
Model Comparison			
Model 3 AIC	11,404.10		
Model 4 AIC	11,410.90		
ΔAIC (M4 – M3)	6.8		

H_0: All GHQ-12 × IMD interaction terms jointly equal zero. Failure to reject H_0 indicates no evidence of effect modification by area deprivation.

Table D.2b: Tests of Joint Significance of GHQ-12 × IMD Interaction Terms

Appendix E: Marginal Effects

Appendix E.1: Predicted Condition Count Table

Table E.1 presents average marginal predicted condition counts from the preferred negative binomial specification (Model 3). Predictions are generated by setting GHQ-12 score and IMD quintile to specified values for all respondents, while retaining each respondent's observed values for all other covariates. This approach provides adjusted predicted condition counts that reflect the empirical covariate distribution of the analytical sample, rather than holding all controls at their mean values.

Predicted physical condition counts increase steadily with higher GHQ-12 scores across all deprivation levels. In the least deprived quintile (IMD Q1), the predicted condition count rises from 0.64 at GHQ-12 score 0 to 1.94 at GHQ-12 score 12. In the most deprived quintile (IMD Q5), the corresponding increase is from 0.81 to 2.43. The absolute increase associated with moving from GHQ-12 score 0 to 12 is therefore larger in more deprived areas, rising from 1.30 conditions in Q1 to 1.63 conditions in Q5.

The predicted values also show that area deprivation is associated with a higher baseline burden of physical conditions at every level of psychological distress. For example, at the GHQ-12 caseness threshold of 4, the predicted condition count is 0.93 in IMD Q1, 0.99 in IMD Q3, and 1.16 in IMD Q5. At GHQ-12 score 12, the equivalent predictions are 1.94, 2.07, and 2.43 respectively. These results are consistent with the main regression findings: psychological distress is associated with higher expected condition counts across the full deprivation distribution, while deprivation shifts the overall level of physical health burden upward.

Tables E.1a and E.1b provide the full and condensed prediction matrices used to illustrate these adjusted relationships.

GHQ Score	IMD Q1	IMD Q3	IMD Q5
0	0.643	0.686	0.805
2	0.773	0.824	0.968
4	0.929	0.991	1.164
6	1.117	1.192	1.399
8	1.343	1.433	1.682
10	1.615	1.723	2.023
12	1.941	2.072	2.432
Absolute gap (GHQ=12 vs GHQ=0)	1.299	1.386	1.627

Predictions from Model 3 (negative binomial regression, unweighted, N=4,735). All other covariates retained at observed individual values. IMD Q1 = least deprived, IMD Q5 = most deprived. GHQ-12 caseness threshold = score ≥ 4.You said: e.

Table E.1a: Average Marginal Predicted Physical Condition Count by GHQ-12 Score and IMD Quintile

GHQ Score	IMD Q1	IMD Q3	IMD Q5
0	0.643	0.686	0.805
4	0.929	0.991	1.164
8	1.343	1.433	1.682
12	1.941	2.072	2.432

Predictions from Model 3 (negative binomial regression, unweighted, N=4,735). All other covariates retained at observed individual values. GHQ-12 score of 4 corresponds to the standard caseness threshold for probable psychological distress (Goldberg et al., 1997).

Table E.1b: Average Marginal Predicted Physical Condition Count — Condensed

Appendix E.2: Marginal Effects Figure

Figure E.2 visualises the average marginal predicted condition counts reported in Table E.1. The figure is based on the preferred negative binomial specification (Model 3), with predictions generated across the full GHQ-12 score range for respondents living in the least deprived, middle, and most deprived IMD quintiles. All other covariates are retained at their observed individual values.

The figure shows a clear upward relationship between psychological distress and predicted physical condition count. Across all three deprivation groups shown, predicted condition counts increase steadily as GHQ-12 score rises. The vertical line at GHQ-12 score 4 marks the caseness threshold for probable psychological distress. At this threshold, predicted condition counts are already higher in more deprived areas, with the most deprived quintile consistently positioned above the least deprived quintile across the full distress distribution.

The curves are broadly parallel because Model 3 does not include GHQ-12 × IMD interaction terms. This reflects the main regression finding that psychological distress is associated with higher expected physical condition counts across deprivation groups, while area deprivation shifts the overall level of condition burden upward. Figure E.2 therefore supports the interpretation that distress and deprivation are both associated with greater physical multimorbidity, but that there is limited evidence of effect modification by deprivation.

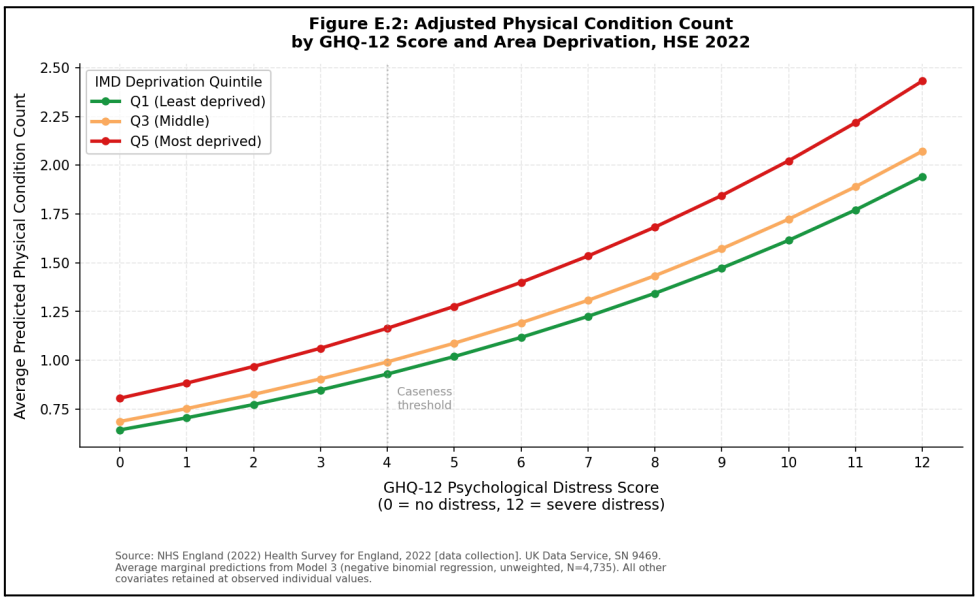

Figure E.2: Adjusted Physical Condition Count by GHQ-12 Score and Area Deprivation

Appendix F: Robustness Checks

Appendix F.1: Poisson versus Negative Binomial — Likelihood Ratio Test

To formally justify the use of negative binomial regression over Poisson, a likelihood ratio test was conducted comparing the two specifications using the same covariates as Model 3. The negative binomial model produced a substantially higher log-likelihood (−5,658.0 versus −5,719.4 for Poisson) and a lower AIC (11,404.1 versus 11,524.8). The likelihood ratio statistic of 122.68 (df = 1, $p < 0.001$) decisively rejects the Poisson specification in favour of the negative binomial. The estimated dispersion parameter $\alpha = 0.304$ is significantly greater than zero, confirming the presence of overdispersion. The GHQ-12 IRR under Poisson (1.092) is consistent with the negative binomial estimate (1.097), indicating that the main finding is not sensitive to the choice between these two count models. Full output is provided in the code submission.

Appendix F.2: OLS Robustness Check

Ordinary least squares regression was estimated using the same dependent variable and covariates as Model 3. The GHQ-12 coefficient is 0.102 (95% CI [0.092, 0.113], $p < 0.001$), indicating that each one-point increase in GHQ-12 score is associated with approximately 0.10 additional longstanding condition categories. This is directionally consistent with and of comparable magnitude to the negative binomial IRR of 1.097. The OLS R-squared is 0.184, indicating that the model explains approximately 18% of the variance in physical condition count. The consistency of findings across OLS and negative binomial specifications supports the robustness of the main association. Full output is provided in the code submission.

Appendix F.3: Logistic Regression — Binary Multimorbidity Outcome

To assess sensitivity to the choice of outcome variable, logistic regression was estimated using a binary multimorbidity indicator (1 if condlcnt ≥ 2, 0 otherwise) in place of the continuous condition count. The GHQ-12 odds ratio is 1.177 (95% CI [1.149, 1.205], $p < 0.001$), indicating that each one-point increase in GHQ-12 score is associated with a 17.7% increase in the odds of multimorbidity after full adjustment. This finding is consistent in direction and statistical significance with the negative binomial result, confirming that the association between psychological distress and physical multimorbidity holds regardless of whether multimorbidity is operationalised as a count or a binary indicator. Full output is provided in the code submission.

Appendix F.4: BMI Sensitivity Analysis

Body mass index (BMI) was excluded from the primary specification due to 68.1% missingness in the self-reported BMI variable. To assess whether omission of BMI materially confounds the main association, Model 3 was re-estimated on the subsample of respondents with valid nurse-measured BMI data (N = 3,293, representing a 30.5% reduction from the main analytical sample). On this subsample, the GHQ-12 IRR without BMI is 1.093, compared with 1.097 in the main model, indicating that the subsample produces a consistent estimate. When nurse-measured BMI is added as an additional control, the GHQ-12 IRR falls modestly to 1.087, while BMI itself is positively and significantly associated with condition count (IRR = 1.034, $p < 0.001$). The negligible change in the GHQ-12 coefficient following BMI adjustment suggests that the main association is not materially confounded by BMI. Full output is provided in the code submission.