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DOI:
10.3399/BJGP.2023.0026

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Citation for published version (APA):
Soley Bori, M., Ashworth, M., McGreevy, A., Wang, Y., Durbaba, S., Dodhia, H., & Fox-Rushby, J. (2023). Identifying disease patterns in high-cost individuals with multimorbidity in primary care. *British Journal of General Practice*. Advance online publication. https://doi.org/10.3399/BJGP.2023.0026

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Accepted Manuscript

British Journal of General Practice

Identifying disease patterns in high-cost individuals with multimorbidity in primary care

Soley-Bori, Marina; Ashworth, Mark; McGreevy, Alice; Wang, Yanzhong; Durbaba, Stevo; Dodhia, Hiten; Fox-Rushby, Julia

DOI: https://doi.org/10.3399/BJGP.2023.0026

To access the most recent version of this article, please click the DOI URL in the line above.

Received 12 January 2023
Revised 24 August 2023
Accepted 30 August 2023

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When citing this article please include the DOI provided above.

Author Accepted Manuscript
This is an 'author accepted manuscript': a manuscript that has been accepted for publication in British Journal of General Practice, but which has not yet undergone subediting, typesetting, or correction. Errors discovered and corrected during this process may materially alter the content of this manuscript, and the latest published version (the Version of Record) should be used in preference to any preceding versions

Title

Identifying disease patterns in high-cost individuals with multimorbidity in primary care

Authors

- Marina Soley-Bori PhD, Lecturer in Health Economics[1] (ORCID iD 0000-0002-8348-3575)
- Mark Ashworth DM, Professor of Primary Care [1] (ORCID iD 0000-0001-6514-9904)
- Alice McGreevy MA, Research Assistant in Health Economics[1] (ORCID iD 0000-0003-4903-8301)
- Yanzhong Wang PhD, Reader in Medical Statistics[1] (ORCID iD 0000-0002-0768-1676)
- Stevo Durbaba MSc, Research Software Engineer (Healthcare Data)[1] (ORCID iD 0000-0002-4098-5399)
- Hiten Dodhia FFPH, Consultant in Public Health, London Borough of Lambeth[1] (ORCID iD 0000-0002-2739-6901)
- Julia Fox-Rushby PhD, Professor of Health Economics [1] (ORCID iD 0000-0003-0748-0871)

Affiliations

[1]King's College London, School of Life Course & Population Sciences

Author

Address of corresponding author

Dr Marina Soley-Bori

King's College London, Department of Population Health Sciences

Guy's Campus, Addison House, AH 3.04

London SE1 1UL

Marina.soley_bori@kcl.ac.uk

Word count of main text: 2,499

Number of tables: 3
Number of figures: 0
Number of appendixes: 9
Number of references: 49

Accepted Manuscript – BJGP – BJGP.2023.0026

Abstract

Background: High-cost individuals with multimorbidity account for a disproportionately large share of healthcare costs and are at most risk of poor quality of care and health outcomes.
Aim: This paper compares high-cost with lower-cost individuals with multimorbidity and assesses whether these populations can be clustered based on similar disease patterns.
Design and Setting: Cross-sectional study based on 2019/20 electronic medical records from adults registered to primary care practices (n=41) in a London borough.
Method: Multimorbidity is defined as having two or more long-term conditions (LTCs). Primary care costs reflected consultations, which were costed based on provider and consultation types. High-cost was defined as the top 20% individuals in the cost distribution. Descriptive analyses identified combinations of 32 LTCs and their contribution to costs. Latent class analysis explored clustering patterns.
Results: Of 386,238 individuals, 101,498 (26%) had multimorbidity. The high-cost group (n=20,304) incurred 53% of total costs and had 6,833 unique disease combinations, about three times the diversity of lower-cost (n=81,194). The trio of Anxiety, Chronic Pain and Depression represented the highest share of costs (5.12%). High-cost individuals were best grouped into five clusters, but no cluster was dominated by a single LTC combination. In 3/5 clusters, mental health conditions were the most prevalent.
Conclusion: High-cost individuals with multimorbidity have extensive heterogeneity in LTCs, with no single LTC combination dominating their primary care costs. The frequent presence of mental health conditions in this population supports the need to enhance coordination of mental and physical healthcare to improve outcomes and reduce costs.

Word count of abstract:250

Key words: Multimorbidity; primary care; high-cost; long-term conditions; primary care electronic health records

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How this fits in:

High-cost individuals with multimorbidity tend to have the highest risk of unmet health need, poorly coordinated and duplicated care, and worse health outcomes. Understanding the healthcare needs of these individuals is essential to inform quality improvement and cost containment efforts. To our knowledge, this is the first study to characterise high-cost individuals with multimorbidity based on their primary care costs and disease prevalence, and compare them with lower-cost individuals. We identify the most expensive combinations of diseases and assesses whether high-cost individuals can be clustered based on similar patterns of disease using a young, urban, multi-ethnic population-based sample.

Abbreviations: LTCs=Long-term conditions; SD=Standard Deviation; UK=United Kingdom; CKD=Chronic Kidney Disease; GP=General Practitioner; IMD=Index of Multiple Deprivation; PSSRU =Personal Social Services Resource Unit; QOF=Quality and Outcomes Framework.

Introduction

Multimorbidity–the presence of two or more long-term conditions (LTCs)—has become a major public health concern across healthcare systems(1–3). With an ageing population and higher prevalence of conditions such as obesity in younger cohorts, multimorbidity is now the norm across Europe(4). In the United Kingdom (UK), two-thirds of people over the age of 65 are expected to live with multimorbidity by 2035(5). Primary care is organised into general practices, which are the first point of contact for health needs and play a major role in preventing, diagnosing, and caring for individuals with multimorbidity(6–8). Funding and recruitment shortfalls have resulted in increasing workload, with more patients per general practitioner (GP) (9,10), challenging their ability to care properly for people with multimorbidity (11,12). This problem is magnified among "high-cost" multimorbid individuals (13) who have the highest risk of unmet health need, poorly coordinated and duplicated care, and worse health outcomes (14,15). Understanding the healthcare needs of these patients better can inform quality improvement and cost containment efforts(16).

Little is known about high-cost individuals with multimorbidity. Research into the prevalence and combinations of LTCs has considered either the overall multimorbid population or separate age groups

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(17–20). Clusters of LTCs are defined by prevalence to date and may not correspond to the patient groups with worse outcomes and/or more frequent health service use(21). In a nationally representative sample from the UK, Zhu et al identified the cluster with a high prevalence of depression, anxiety, and pain as having the greatest health service use(18). Soley-Bori et al found that the disease/condition-based clusters of alcohol and substance dependence, followed by anxiety and depression, had the highest primary care use as additional LTCs develop over time(22). However, understanding the distribution and concentration of costs is needed (13) and identifying clusters based on primary care costs rather than disease prevalence may yield different results. International literature reports highly concentrated hospital costs, where the top 10% of patients account for between 50%-80% of costs(23). Similar evidence in primary care, particularly within the multimorbid population in the UK, is lacking.

This paper aims to (1) characterise and compare high-cost with lower-cost individuals with multimorbidity in primary care, in terms of LTC combinations and their contribution to primary care costs and (2) assess whether these populations can be grouped into clusters of similar LTCs.

Methods

Study design, setting, participants and data

This retrospective cross-sectional study of 386,238 electronic primary care medical records included adults (≥18 years) registered between 1st April 2019 and 31st March 2020 at 41 general practices in the Lambeth DataNet (LDN). Individuals with multimorbidity (defined as the co-occurrence of two or more of 32 selected LTCs, **Supplementary Box 1**) totaled 101,498.

Patient-level primary care costs reflect primary care use and workload, measured by consultations. Consultations were costed for type of provider delivering care (GP, nurse, other healthcare professional) and mode of delivery (face-to-face, telephone, home visits, electronic). Other healthcare professionals included pharmacists, healthcare assistants/support workers, and physician associates. National unit costs

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from 2019-20 were used for valuation, adjusted by average duration of consultation(26). For example, to cost a GP face-to-face consultation, the cost per hour for a GP (£255) was adjusted for the average duration of a GP face-to-face consultation (9.22mins), resulting in a unit cost of £39 (£255*(9.22/60)).

High-cost individuals were defined as those at the top 20% (≥80th percentile) of the primary care cost distribution. Lower-cost individuals were the remaining sample (<80%). While thresholds are often set at 10% or 5% quantiles (14,27), our more inclusive approach yields a larger sample size, still reflects higher cost individuals and allows assessment of the principle of cost disproportionality(28), where the relative medical expenditure of a population is larger than their relative size. Sensitivity analyses using the 70th and 90th percentile thresholds were conducted.

Statistical methods

The full distribution of primary care costs are described for high- and lower-cost groups. Demographic characteristics (age, gender, ethnicity and index of multiple deprivation (IMD 2019)), death rates, prevalence of LTCs, consultations and costs were summarised. Differences in these variables between high- and lower-cost individuals were tested using t-tests (Mann-Whitney-Utest for non-normal distributions) and Pearson chi-square tests (for categorical variables). Missing data were kept as missing (**Supplementary Box 2**).

With 32 LTCs, the possible number of disease combinations is extensive (496(=16*31) pairs, 4,960(=32!/(29!*3!)) triads, 35,960(=32!/(28!*4!)) tetrads, etc.). To characterise disease heterogeneity among high- and lower-cost individuals, LTC combinations were identified with average and total costs computed. This step identified combinations of LTCs with a major contribution to primary care costs.

Latent class analysis explored whether multimorbid individuals could be grouped into a more parsimonious and interpretable set of clusters based on their underlying LTC prevalence. Each patient cluster captures a different LTC prevalence and combination, with up to five classes tested. The final model was chosen by balancing goodness of fit measure, model stability and convergence(29). Entropy

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then measured model fit(30). The resulting clusters were described based on demographic characteristics, death rates, average consultations and costs, average number of LTCs and prevalence of individual LTCs and LTC combinations. Further details in **Supplementary Box 2**.

SAS (version 9.4) was used for analyses, including PROC LCA to implement the clustering technique. This study is reported using STROBE guidelines.

Results

Population

High-cost individuals with multimorbidity (n=20,304) were older, more often female, other than White, and more deprived than the lower-cost (n=81,194) group (all p-values<0.001) (**Table 1**). They had an average of 4.28 LTCs (SD=1.99), with chronic pain, anxiety, hypertension, depression, and osteoarthritis the most prevalent LTCs. A higher prevalence of chronic pain (77% versus 50%), hypertension (46% versus 31%), and osteoarthritis (30% versus 16%) was observed among high- versus lower-cost individuals (p-value<0.001). The high-cost group used primary care four times more than lower-cost (mean annual consultation 23 (SD=11.08) versus 6 (4.67), p-value<0.001).

Primary care costs and disease combinations

As consultation costs of high-cost individuals amounted to £13.1 million (**Supplementary Table 1**), this 20% of the sample incurred 53% of total consultation costs of the multimorbid population. Disproportionality starts at the 70th percentile, with costs for individuals in the 70-80th percentile accounting for 14.26% of total costs (**Supplementary Table 2**).

The mean annual cost of consultations by high-cost individuals was £643 (SD=269) compared with £145 (SD=115) for lower-cost. The cost distribution for high-cost was more right-skewed and had a longer tail (**Supplementary Table 1**).

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High-cost individuals had a total of 6,833 unique combinations of LTCs , nearly three times more heterogeneity than lower-cost (adjusting for size of group) (**Table 2**). The combination of LTCs with the largest contribution to costs was the trio of Anxiety&ChronicPain&Depression (5.12%), followed by the pairs Anxiety&Chronic Pain (2.52%) and Anxiety&Depression (2.37%). The top ten combinations of LTCs, by share of costs, involve six LTCs: anxiety, chronic pain, depression, asthma, hypertension and osteoarthritis (**Table 2**). Sensitivity analyses showed similar results (**Supplementary Tables 3&4**).

Among the lower-cost population, the combination of LTCs with the highest contributions to costs were also the pair Anxiety&Depression (6.92%), the trio Anxiety&ChronicPain&Depression (5.87%), and the pair Anxiety&ChronicPain (3.89%)(**Table 2**). Osteoarthritis did not appear in the top 10 combinations as it did with the high-cost individuals, whereas diabetes did.

Latent class analysis

Within high-cost individuals, five clusters proved the best grouping (**Supplementary Table 6**). No single combinations of LTCs accounted for a large proportion of the clusters, except for cluster 1 where 15% of individuals had the trio Anxiety&ChronicPain&Depression (**Table 3**). This cluster was younger (mean=47, SD=14), with a high percentage of females (75%). For the remaining clusters, all LTC combinations had a prevalence under 5%. In three of the five clusters, mental health conditions were prominent (30%, 63%, and 79% in clusters 1, 2 and 4 had depression, respectively), along with asthma (cluster 1), alcohol dependence (cluster 2), and chronic pain (cluster 4). In cluster 3, diabetes and osteoarthritis were the most prevalent LTCs (39% each). Individuals in cluster 5 showed a noticeable prevalence of cardiac diseases and CKD, accompanied by other LTCs (average of 7 LTCs, SD=1.94), and had the highest average costs (£725, SD=336). They also had the highest average age (79, SD=11) and lowest proportion from deprived areas (24%). In four of the five clusters, the average count of LTCs was higher than the average of each the lower-cost clusters. Clusters 2 and 4 had the highest rates of patients dying (3.6% and 3.2% respectively); higher than any of the lower-cost clusters.

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Three clusters best grouped lower-cost individuals (**Supplementary Table 7)**. All three were characterized by a relatively high prevalence of chronic pain (45%, 49%, and 46% across clusters 1, 2 and 3, respectively), along with diabetes (cluster 1), asthma (cluster 2) and depression (cluster 3) (**Table 3**). Unlike the high-cost group, each cluster had at least one combination of LTCs with over 5% prevalence (e.g., 6% in cluster 1 had Diabetes&Hypertension, 23% in cluster 3 had Anxiety&Depression). Cluster1 had the highest average cost at £173 (SD=112), the highest average age (65years, SD=14) and lowest percentage of white ethnicity (43%).

Discussion

Summary

High-cost individuals with multimorbidity accounted for 53% of the total costs of primary care consultations. They were grouped into five clusters with mental health (anxiety and depression) highly prevalent in three clusters. Chronic pain sufferers were concentrated in one cluster, with a prevalence in the whole high-cost sample of 77%. Individuals with cardiac conditions dominated another cluster and alcohol dependence (along with depression and anxiety), asthma, and osteoarthritis were also present across clusters.

High-cost individuals are a more heterogenous group of patients than those with lower costs. This is evidenced by; the higher mean number of LTCs (4.28 vs 3.03, $p<0.0001$), the larger number of clusters (5 vs 3), and the three times larger number of LTC combinations. High-cost individuals only showed combinations of LTCs above 5% prevalence in 1/5 clusters, meaning no single combination of LTCs made a sizeable contribution to primary care costs, the largest being Anxiety&ChronicPain&Depression. This contrasts with the lower-cost group where each cluster had between 1-5 LTC combinations above 5%, indicating a greater concentration in specific combinations of LTCs.

Comparison with existing literature

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Previous literature on clustering multimorbid individuals has not focused on the high-cost group, yet some similarities are apparent. Zhu et al identified the highest primary care use in clusters with depression, anxiety and pain(18). These LTCs were highly prevalent among the clusters we found. Soley-Bori et al pointed at the alcohol dependence and substance dependence cluster as the one with the highest expected primary care demand as further LTCs develop(22). In this study, alcohol dependence was common in one of the clusters with high-cost individuals.

Stokes et al concluded that no single combination of LTCs contributed significantly to total secondary care costs, with the pair Diabetes and Hypertension representing the highest share (3.2%)(21). The current study reached similar conclusions based on primary care data. A total of 13,388 LTC combinations existed in the overall multimorbid sample, 6,833 among the high-cost subgroup. No single combination made a major contribution to primary care costs, with Anxiety&ChronicPain&Depression accounting for just 5% of total primary care costs incurred by high-cost-multimorbid individuals.

Tran et al(24) found the combination of cancer and mental health conditions was the most expensive. This study did not find cancer to be a major contributor to primary care costs. However, Tran et al included hospitalizations and outpatient care, suggesting cancer incurs significant costs outside primary care compared to other LTCs.

Strengths and Limitations

This study advances existing literature on health service use and costs of individuals with multimorbidity by focusing on the most expensive cases. Descriptive analyses of combinations of LTCs and their contribution to costs are complemented by latent class analyses to understand clusters of individuals with similar patterns of LTCs. A large sample with urban, deprived, and ethnically diverse individuals is used, with sociodemographic, medical, and primary care use information. This fills an important research gap given the crucial role of primary care in managing an increasingly multimorbid population. The diverse population allows for meaningful analysis of ethnic minority groups, who are typically underrepresented

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in health research(25). Costs reflect workload of primary care providers. Identifying high-workload individuals is important given the current mismatch between workforce demand and supply.

Results may not be generalizable to rural, older, or less ethnically diverse populations. For example, having a smaller proportion of patients from ethnic minority groups may reduce prevalence of hypertension and diabetes(38,39) whereas older populations may have more multimorbidity given its correlation with age(40). Primary care costs reflect consultations only and the inclusion of medication costs may affect results since the cost of medication relative to total costs can vary by condition(41-43). Averages from the PSSRU were used for consultation duration. Actual duration may vary by LTC. LTCS were defined based on diagnostic read codes which may miss patients who do not have a formal diagnosis despite receiving treatment, the extent of which may vary by LTC(44-46). Similarly, the presence of a condition was defined as a diagnostic code prior or during to the study period and therefore, any changes to diagnoses were not considered. Limited by cross-sectional data, this study could not differentiate between one-year high-cost individuals and more persistent cases over time(27). Our work considers primary care only, and it is not clear whether conclusions would hold across secondary and social care settings, or the extent to which the degree of substitution and complementarity among care components should be accounted for(13). Finally, our paper describes costs only, and this debate should also be informed by outcomes.

Implications for research and practice

Enhancing care co-ordination across specialties caring for individuals with multimorbidity is considered necessary for high-quality and efficient care(35). This strategy is particularly important for high-cost patients, who use a disproportionate percentage of healthcare services. Understanding the most common clusters of LTCs may help to prioritise care coordination and integration efforts(2). Three of the five 'high-cost' clusters identified in this study had a high prevalence of anxiety and depression, suggesting mental health issues expand primary care use in this group. Prioritising mental health and enhancing its coordination with physical LTCs may improve outcomes and reduce costs among high-cost individuals.

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The Improving Access to Psychological Therapies for people with LTCs (called IAPT-LTC), currently underway, is an example of an initiative to facilitate access to mental health services and coordination between mental and physical health providers(36). Further research on the impact of mental health on healthcare needs, costs and outcomes of individuals with multimorbidity is needed.

Findings from this study underscore the wide heterogeneity of high-cost individuals with multimorbidity and further research should consider if this is associated with increased clinical complexity and a higher risk of unmet need and/or poorer health outcomes. Individualised care, tailored and centered around each patient, reflecting their preferences —rather than one-size-fits-all strategies—seems like the appropriate response. This conflicts with limited primary care resources and mostly single-disease-oriented payment incentives such as the Quality and Outcomes Framework. To ease this tension, research is needed on enhanced payment mechanisms that transcend disease boundaries and explores the design of cost-effective interventions that facilitate—through technology, data, or other mechanisms—healthcare delivery for individuals with multimorbidity.

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Declarations

Conflict of interests: The authors declare that they have no competing interests

Funding: This research was funded by Impact on Urban Health, part of Guy's & St Thomas' Foundation, a charitable foundation (Charity No: 1160316) [grant number EIC180901]. The funder did not contribute to the design of the study, the collection, analysis, and interpretation of data or the writing of the manuscript. Mark Ashworth has been funded through UKRI: 'MELD-B', NIHR203988; 'Born in South London (eLIXIR)', MR/X009742.

Ethics approval and consent to participate: All data were extracted under the terms of a signed data sharing agreement with each practice and with project-specific approval following submission of a data privacy impact assessment, approved by Lambeth Clinical Commissioning Group in 2 November 2017. Information governance approval required 'low number suppression', ensuring that data could not be

displayed if the patient number was 10 or less in any given category; in these circumstances, data reporting would state: '≤10 patients'. Separate ethical committee approval was not required (Health Research Authority, 29 September 2017) since all data were fully anonymised for the purposes of research access, and all patient identifiable data had been removed.

Availability of data and materials: The datasets generated and/or analysed during the current study are not publicly available due the condition for pseudonymised data extraction by included general practices was that the data would not be shared beyond parties named in the Data Sharing Agreement, but are available from the corresponding author on reasonable request.

Authors' contributions: Marina Soley-Bori: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Mark Ashworth:** Conceptualization, Methodology, Resources, Writing - Review & Editing, Investigation, Supervision, Project administration, Funding acquisition. **Alice McGreevy**: Validation, Writing - Review & Editing. **Yanzhong Wang**: Writing - Review & Editing, Funding acquisition. **Stevo Durbaba**: Data curation, Software, Writing - Review & Editing. **Hiten Dodhia**: Conceptualization, Resources, Writing - Review & Editing, Investigation, Funding acquisition; **Julia Fox-Rushby**: Conceptualization, Methodology, Resources, Writing - Review & Editing, Investigation, Supervision, Funding acquisition.

Acknowledgements: The process for selecting LTCs and Risk Factors for this study was led by Outcomes Based Healthcare (OBH), London, United Kingdom (https://outcomesbasedhealthcare.com/). King's College London and OBH devised a process to select Read, EMIS and SNOMED codes for the presence of each of the included LTCs and Risk Factors; also, for the remission or relapse of LTCs and Risk Factors over the course of the study period .
This research was supported by a grant from Impact on Urban Health, United Kingdom (Charity No: 1160316) [grant number EIC180901].

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Tables included in the main body of the manuscript

Table 1. Description of study sample, individuals with multimorbidity in 2019/20

	All	High primary care costs		p-value
		Yes	No	
N	101,498	20,304	81,194	
Age	52.24 (17.98)	58.21 (18.19)	50.75 (17.61)	<.0001
Gender (% female)	55.87%	64.33%	53.75%	<.0001
Ethnicity				<.0001
White ethnicity	54.38%	50.10%	55.45%	
Black ethnicity	25.44%	30.04%	24.29%	
Asian ethnicity	6.69%	7.64%	6.46%	
Mixed ethnicity	4.70%	4.68%	4.71%	
Other ethnicity	2.41%	2.65%	2.35%	
Index of multiple deprivation				<.0001
IMD 1- most deprived	23.59%	26.70%	22.82%	
IMD 2	21.42%	21.53%	21.39%	
IMD 3	17.48%	16.84%	17.64%	
IMD 4	18.55%	17.56%	18.79%	
IMD5 -least deprived	17.94%	16.58%	18.28%	
Number of LTCs	3.28(1.6)	4.28(1.99)	3.03(1.38)	<.0001
Five most prevalent LTCs				<.0001
Chronic pain	55.46%	76.52%	50.19%	
Anxiety	49.96%	50.52%	49.83%	
Hypertension	33.98%	45.74%	31.04%	
Depression	43.09%	45.12%	42.59%	
Osteoarthritis	18.55%	30.30%	15.61%	
Primary care consultations	9.20(9.47)	23.03(11.08)	5.74(4.66)	<.0001

Notes: LTC=long-term condition. IMD=Index of multiple deprivation. It is a composite index aimed at measuring social deprivation based on 7 domains, including income, education, unemployment, crime, and housing, among others (37). Standard deviation is presented in brackets for continuous variables.

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Table 2. Top 10 LTC combinations based on their contribution to total primary care costs, for high-cost and lower-cost individuals with multimorbidity, 2019/20

Panel 1: ***High-cost individuals with multimorbidity (N=20,304, total number of LTC combinations=6,833)***

LTC combination	Count	%	Average Primary care costs	Median Primary care costs	Interquartile Range Primary care costs	SD Primary care cost	Sum Primary care costs	Sum (% Total Primary care costs)
AX&CP&DP	1,077	5.30%	£ 620.71	£547.25	£243	£ 244.74	£ 668,504.50	5.12%
AX&CP	551	2.71%	£ 596.79	£525.25	£221.5	£ 211.76	£ 328,829.75	2.52%
AX&DP	562	2.77%	£ 550.48	£496.25	£151.25	£ 157.76	£ 309,368.50	2.37%
AX&AT&CP&DP	343	1.69%	£ 659.79	£565.5	£293	£ 267.55	£ 226,309.00	1.73%
CP&DP	305	1.50%	£ 583.95	£513.25	£203	£ 200.54	£ 178,103.25	1.36%
AX&AT	246	1.21%	£ 552.82	£508.75	£162	£ 146.41	£ 135,992.75	1.04%
CP&HY	214	1.05%	£ 575.17	£536.5	£209	£ 173.07	£ 123,086.75	0.94%
AX&AT&CP	175	0.86%	£ 611.81	£552.5	£280.75	£ 220.09	£ 107,066.25	0.82%
CP&HY&OA	180	0.89%	£ 586.79	£512.5	£210.5	£ 217.70	£ 105,621.75	0.81%
AX&CP&DP&OA	164	0.81%	£ 637.72	£580.13	£283.75	£ 241.15	£ 104,586.00	0.80%

Notes: AX=anxiety, CP=chronic pain, DP=depression, AT=asthma, HY=hypertension, OA=osteoarthritis. SD=standard deviation.

Panel 2: ***Lower-cost individuals with multimorbidity*** (N=81,194; number of LTC combinations=9,354)

LTC combination	Count	%	Average Primary care costs	Median Primary care costs	Interquartile Range Primary care costs	SD Primary care cost	Sum Primary care costs	Sum (% Total Primary care costs)
AX&DP	8,050	9.91%	£ 101.52	£78	£167	£ 104.24	£ 817,227.25	6.92%
AX&CP&DP	4,688	5.77%	£ 147.83	£134	£189	£ 115.46	£ 693,038.75	5.87%
AX&CP	3,232	3.98%	£ 142.31	£123.25	£187.25	£ 113.95	£ 459,949.00	3.89%
AX&AT	3,191	3.93%	£ 103.55	£78	£165	£ 103.51	£ 330,439.50	2.80%
CP&DP	2,249	2.77%	£ 123.53	£101	£184	£ 112.24	£ 277,814.75	2.35%
DM&HY	1,633	2.01%	£ 143.31	£128	£145.25	£ 99.68	£ 234,033.25	1.98%
CP&HY	1,122	1.38%	£ 160.57	£153.25	£170.5	£ 110.63	£ 180,162.75	1.52%
AX&AT&CP&DP	1,116	1.37%	£ 158.23	£147	£186.87	£ 116.36	£ 176,587.50	1.49%
AX&AT&DP	1,336	1.65%	£ 123.46	£102.13	£187.87	£ 111.80	£ 164,939.75	1.40%
AT&CP	1,250	1.54%	£ 126.27	£101	£168	£ 110.60	£ 157,835.00	1.34%

Notes: AX=anxiety, CP=chronic pain, DP=depression, AT=asthma, HY=hypertension, DM=diabetes mellitus

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Table 3. Results of LCA – Clusters among high-cost and lower-cost individuals with multimorbidity, 2019/20

Panel 1*: *High-cost individuals with multimorbidity

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
N	7,283	1,566	7,107	2,198	2,150
N (%)	35.87%	7.71%	35%	10.83%	10.59%
Contribution to primary care costs	34.56%	8.29%	33.26%	11.96%	11.94%
Primary care consultations - mean (SD)	21.46(9.97)	24.93 (12.46)	22.04 (9.73)	26.09 (12.67)	27.11 (13.85)
Primary care costs - mean (SD)	£620.06 (253.69)	£691.67 (300.99)	£611.44 (227.53)	£711.02 (306.83)	£725.46 (335.65)
Primary care costs - median	£542.50	£596.50	£541.00	£619.75	£627.75
Primary care costs – interquartile range	£233.75	£314.00	£225.25	£336.00	£337.75
Unique LTC combinations (total number)	661	1002	2097	1257	1816
LTCs (mean, SD)	3.16 (1.05)	5.12 (1.86)	3.68 (1.34)	6.74 (1.49)	6.97 (1.94)
Mostly prevalent individual LTCs	Depression (30%), Asthma (29%)	Depression(63%), Anxiety(48%), Alcohol dep (47%)	Diabetes (39%), Osteoarthritis(39%)	Chronic pain(100%), Depression (79%)	Coronary Heart Disease (50%), CKD (49%), Diabetes (48%), Heart Failure(46%)
Most prevalent LTC combinations	AX&CP&DP(15%), AX&DP(8%), AX&CP(8%), AX&AT&CP&DP(5%)	All combinations <5% prevalence	All combinations <5% prevalence	All combinations <5% prevalence	All combinations <5% prevalence
% Dead (during study year)	2.87%	3.58%	2.69%	3.23%	2.70%
Age (mean, SD)	43.97 (13.93)	53.22 (12.03)	65.21 (14.85)	66.32 (12.18)	78.64 (11.37)
Gender (% female)	75.00%	39.85%	60.17%	72.00%	51.30%
IMD (% decile 1-most deprived)	26.27%	29.25%	26.73%	28.43%	24.47%
Ethnicity (% White)	54.74%	66.60%	39.81%	52.96%	53.49%

Notes: Sample size= N=20,304. AX=anxiety, CP=chronic pain, DP=depression, AT=asthma. IMD=Index of Multiple Deprivation (locally derived). SD=standard deviation.

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***Panel 2**: Lower-cost individuals with multimorbidity*

	Cluster 1	Cluster 2	Cluster 3
N	29,415	16,126	35,653
Contribution to primary care costs	43.09%	18.06%	38.85%
Primary care consultations - mean (SD)	7.21(4.74)	5.25(4.69)	4.76(4.26)
Primary care costs - mean (SD)	£173.09(112.19)	£132.31(114.54)	£128.77(113.61)
Primary care costs - median	165.75	113.50	108.00
Primary care costs – interquartile range	183.75	187.75	186.00
Unique LTC combinations (total number)	6027	2827	500
LTCs (mean, SD)	3.57(1.70)	2.90(1.31)	2.64(0.87)
Mostly prevalent individual LTCs	Chronic Pain (45%), Diabetes (39%)	Chronic Pain (49%), Asthma(40%)	Chronic Pain (46%), Depression (31%)
Most prevalent LTC combinations	DM&HY(6%)	AT&CP(8%)	AX&DP(23%), AX&CP&DP(13%), AX&CP(9%), AX&AT(9%), CP&DP(6%)
% Dead	2.90%	2.86%	2.89%
Age (mean, SD)	65.43(13.87)	46.64(14.35)	40.49(12.79)
Gender (% female)	50.63%	43.80%	60.83%
IMD (% decile 1-most deprived)	24.73%	24.47%	20.49%
Ethnicity (% White)	43.04%	55.69%	65.59%

Notes: N=81,194. DM = diabetes mellitus, HY=Hypertension, AT=Asthma, CP= Chronic Pain, AX=anxiety, DP=depression,

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