Public Health 256 (2026) 106298

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

The impact of ageing and rurality on the use of medical services in Parkinson's disease: A data linkage study using the 45 and Up Study and Medicare Benefits Schedule

Peter S. Micalos [a,e,*], Marguerite Bramble [b,e], Shanna Fealy [c,e], Patricia Logan [a,e], Alfred Wong [d,e]

[a] School of Dentistry and Medical Sciences, Charles Sturt University, Australia
[b] School of Nursing, Paramedicine and Healthcare Services, Charles Sturt University, Australia
[c] School of Nursing Paramedicine and Healthcare Sciences, Ageing Well in Rural and Regional Australia Research Group, Charles Sturt University, Port Macquarie, New South Wales, Australia
[d] School of Business, Charles Sturt University, Australia
[e] Charles Sturt University Ageing Well Research Group, Australia

ARTICLE INFO

Keywords:
Movement disorders
Metropolitan
Medical costs
General practitioner services
Neurology services
Pathology services

ABSTRACT

Objectives: Parkinson's disease (PD) is a neurological disorder with increasing prevalence and use of medical services. Both ageing and geographic locality have been shown to be associated with the prevalence of PD. Therefore, the purpose of this research was to determine the influence of ageing and locality on medical service use in PD.
Study design: A retrospective data linkage analysis.
Methods: Data were acquired from the Sax Institute's 45 and Up Study baseline and linked with the Social, Economic and Environmental Factors (SEEF) and Medicare Benefits Schedule (MBS) databases. Statistical analyses were performed on participant age and locality and persons who self-reported with PD living in New South Wales, Australia.
Results: A total of 1676 persons self-reported with PD from the 45 and Up Study baseline and were linked to the SEEF and MBS databases. Linear regression analysis showed increased likelihood for use of medical specialist services (46.9% for Neurology and 25.9% for Pathology) in major cities, however, there was a 44.9% increased use of General Practitioner (GP) services in rural, regional, remote (RRR) locality ($p < 0.01$). Moreover, a reduced Neurology and Pathology service use beyond the statistical age threshold was shown in PD ($p < 0.05$).
Conclusions: Specialist medical and support services are influential in the early stages of diagnosis and in maintaining health-related quality of life in persons with PD. Disparities in the use of medical services were identified between geographic locality and ageing in persons with PD. The increased use of GP services may be associated with reduced accessibility to medical specialist services in RRR localities.

1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder after Alzheimer's disease, with the incidence rate rising rapidly with ageing, and peaking at around 80 years of age.[1] Globally the burden of neurological disorders such as PD continues to rise as populations age and with public health systems facing increased demand for treatment, rehabilitation, and long-term residential care.[2] More recent research has identified age as the strongest risk factor for development of PD, with the median age of onset at 60 years, and the incidence rate approaching 93.1 persons per 100,000 between 70 and 79 years of age.[3,4] In Australia, 1 in every 308 persons is living with a diagnosis of PD, with this population being five times more likely to live in residential aged care facilities than persons without PD.[5]

There is increasing evidence that immune dysfunction associated with ageing, alongside genetic and environmental factors such as pesticide exposure, contributes to the development and progression of PD.[6] While early detection in the pre-motor stages remains a clinical

* Corresponding author. School of Dentistry and Medical Sciences, Charles Sturt University, Australia.
E-mail address: pmicalos@csu.edu.au (P.S. Micalos).

https://doi.org/10.1016/j.puhe.2026.106298
Received 9 July 2025; Received in revised form 18 March 2026; Accepted 14 April 2026
Available online 11 May 2026

priority,[1,6,7] further research is required on individuals with an established diagnosis. For these patients, access to specialist services is critical not only for confirming diagnosis but also for implementing appropriate treatment strategies targeting both motor and non-motor symptoms.[8] Understanding patterns of service use according to geographic locality is essential to inform the design of responsive care models, promote equitable access, and address health disparities for persons living with PD.[9]

Access to specialist services is essential not only for confirming a timely clinical diagnosis but also for guiding the long-term management of Parkinson's disease through tailored treatment strategies.[8,10] Recent research puts forward that persons living with PD in rural, regional, and remote (RRR) localities have reduced access to medical specialist services, resulting in delayed PD diagnosis and treatment.[1,11] Therefore, this research aims to assess the pattern of medical service use among persons with PD in the context of ageing and locality.

2. Methods

2.1. Study design and data sources

The present research applied a retrospective data-linkage analysis, leveraging data from The Sax Institute's 45 and Up prospective longitudinal study.[12,13] Initiated in the state of New South Wales (NSW) between 2005 and 2009, prospective participants aged 45 years and older were drawn at random from the Services Australia Medicare enrolment database, with those aged 80 years and over and residents of rural and remote areas intentionally oversampled.[14] This longitudinal study consists of a sample of respondents who have agreed to provide health-related and sociodemographic information in three survey data points, or waves.[12,13]

A total of 267,357 participants joined the 45 and Up Study by completing the baseline questionnaire between 2005 and 2009 and giving consent for follow-up and linkage of their information to health and other databases.[13] The estimated survey response rate was 19% representing approximately 11% of the NSW population aged 45 years and over.[13] In the present study, a data subset was identified for those participants in baseline who answered yes to the question: *"Has a doctor ever told you that you have [Parkinson's disease]?"* This question was repeated in the 2010 Social, Economic and Environmental Factors (SEEF) survey collected in 2010 and enabled the data linkage to the baseline dataset in the present study.[12,13] Participant survey data were also linked by the Sax Institute via deterministic matching using a unique identifier to the Medicare Benefits Schedule (MBS) database (2004 – 2019) supplied by Services Australia for records of the utilisation of medical service payments related to a Medicare item identification code.

2.2. Sample size analysis

An a priori sample size calculation was performed using G*Power[15] to estimate the necessary sample size for this study. This revealed a minimum sample size of 138 was required (G*Power setting: F-tests for a linear multiple regression, Effect size = 0.15; α err prob = 0.05, number of predictors = 5).

2.3. Informed consent statement

The 45 and Up Study survey complies with the privacy requirements of several applicable Acts of Parliament of Australia, including the Privacy Act 1988 (Commonwealth), Health Records and Information Privacy Act 2002 (NSW) and the NSW Health Privacy Manual for Health Information.

2.4. Statistical procedures

A member of the research team (AW) performed the data analysis within the Secure Unified Research Environment (SURE). Descriptive statistics were performed to determine frequencies and percentages for the demographic data pertaining to locality, age, gender, country of birth, and time since PD diagnosis from the merged dataset. Descriptive analysis was performed to outline the use of the most common MBS services (Neurology, Pathology, General Practitioner) accessed by persons with PD across the age groups. The variables "age" and "time since diagnosis" are defined as the patient's age and the duration since diagnosis at the patient's entry to the study.

The Sax Institute unique identifier was used to retrieve MBS provider data. MBS data were categorised and compared using the Australian Bureau of Statistics (ABS) categories for remoteness: major cities, inner region, outer region, remote and very remote regions. Where numbers for a specific region were low the regions were combined into a 'non-metropolitan' category.

All services accessed by the PD participants were initially retrieved and then sorted by frequency of access and in the case of General Practitioner (GP) access, they were then grouped for the purposes of reporting. Only those with a significant difference determined based on location are reported. A list of representative MBS item codes are presented in Appendix A. Service use data were compared across locations and analysed by service type, including Neurology, Pathology, and General Practitioner. Pathology services encompass diagnostic tests such as blood, urine, or tissue analysis used to detect, confirm, or monitor health conditions. To be eligible for Medicare benefits, these services must fall under Category 6 of the MBS and be formally requested by a treating practitioner. General practitioners are medically qualified professionals who meet specific criteria such as holding Fellowship with the Royal Australian College of General Practitioners (RACGP) or Australian College of Rural and Remote Medicine (ACRRM), or undertaking accredited general practice training that authorise them to provide and claim Medicare-funded services. These services include a wide range of clinical activities, from diagnosis and treatment to preventive health assessments and chronic disease management, all eligible for Medicare reimbursement.

Linear regression analysis was performed to ascertain the relationship between use of medical services (Neurology, Pathology, General Practitioner) as dependent variables. The dependent variables represent the average number of MBS services per person included in the sample. Log transformation was applied to these variables to address distributional irregularities commonly found in empirical data. Independent variables for locality, age, gender, and time since diagnosed with PD were included. Statistical significance threshold was set at $p < 0.05$. Since PD is generally considered an age-related disease,[16] we account for the non-linear effect of patient age on medical care[17] by adding an age-squared variable to the regression model. This approach allows us to determine the age threshold[18] which may vary according to the type of MBS services considered in this paper. In estimating the models, robust standard errors are employed to correct for heteroskedasticity, which can distort OLS standard errors, a frequent concern in applied empirical research. In addition, time fixed effects are incorporated into the model to account for period-specific factors that might otherwise bias the results.[19] In this study, the analysis of medical services spans multiple years. Time fixed effects are included to account for economic cycles and health-related regulatory changes that may influence healthcare access, service quality, and affordability in any given year.

While Poisson regression may be more appropriate for modelling count data, the primary objective of this study is to examine the average relationship between variables rather than to capture the underlying distribution of the counts. Therefore, a linear regression framework is better aligned with the study's overall objectives. Furthermore, the absolute values of the log-transformed dependent variables range from 0.3 to 0.7, indicating a distribution that more closely aligns with normality

than with the assumptions underlying Poisson or negative binomial models.

3. Results

3.1. Participant demographics

From the Sax Institute's baseline survey (2005 to 2009), a subset of 1676 respondents who self-reported as having PD were identified of whom 1624 had linkage to MBS service use data. The respondents who took part in the survey were linked to the MBS service data collected from 2004 to 2019. The median duration of MBS service utilisation over the period was 13.1 years, with an interquartile range of 2.9 years. Participant demographic characteristics across remoteness (locality), age, gender, country of birth, and time since diagnosis are shown in Table 1. The descriptive analysis using ABS geographic boundaries were merged due to low numbers of survey respondents from remote areas. The median age of those with PD in major cities was 72.9 years compared to 72.6 years in RRR localities. The minimum age across both regions was 46 years and maximum age was 98 in major cities and 97 years in RRR. A greater proportion of persons with PD lived in major cities (55.4%) compared to RRR localities. The highest proportion (44.4%) of persons with PD were in the 75+ years age group. There was a greater proportion of male participants with PD (56.7%). The mean number of years since PD diagnosis was 7.8 years (±9.1) with most PD participants being Australian born (74.5%), refer to Table 1. In Table 1, "age" and "time since diagnosis" represent the mean values calculated in 2005.

3.2. Number of medical services with age in Parkinson's disease

Results for the total number of medical services based on the Medicare Benefits Schedule among persons with PD shows a marked incline from 28,568 to a peak of 222,120 medical services across each age group (Fig. 1). However, results for the number of medical services per person with PD shows a peak within the 65-74 age group.

Table 1
Participant demographic characteristics.

Variables[a]	Mean	SD	N	%
Locality[b]			1676	
Major city			928	55.4
Rural			748	44.6
Age[c]	71.8	10.5	1676	
45-54			123	7.3
55-64			294	17.6
65-74			515	30.7
75 +			744	44.4
Gender			1676	
Male			951	56.7
Female			725	43.3
Country of birth				
Australian born			1676	
Yes			1249	74.5
No			427	25.5
PD condition				
[c]*Time since diagnosed (years) ((years(yrs.)*	7.8	9.1	1676	
Number of MBS services				
Neurology	13.7	22.6	1624	
Pathology	98.3	106.9	1624	
GP	58.3	66.3	1624	

SD, standard deviation.
N, number of participants.
GP, General practitioner.
[a] Baseline questionnaire data book https://www.saxinstitute.org.au/wp-content/uploads/December-2011-DATA-BOOK-_final_5531.pdf.
[b] Merged localities were formed due to low numbers of survey responses from remote areas. This included merging the responses from Outer regional, Remote, and Very Remote into a single locality titled Rural.
[c] Calcuated in 2005.

3.3. Medical service use (neurology, pathology, general practitioner) in persons with Parkinson's disease

Regression analysis between medical service use and location, age, gender, time since PD diagnosis is shown in Table 2. These results reveal that in major cities compared to RRR locality there was 46.9% (=exp (0.385)- 1), and 25.9% increased likelihood for the use of Neurology and Pathology services, respectively. However, there was a 30.9% (=exp (-0.371)-1) reduced use of General Practitioner (GP) services in major cities compared to RRR locality among persons with PD. In the context of RRR locality, this translates to a 44.9% increased use of GP services (=exp(0.371)-1) compared to major cities ($p < 0.01$).

For the Age variable, there was an increased likelihood for Pathology service use, denoting that for each additional year of age, the use of Pathology services increased by 14.6% (=exp(0.137)-1) for persons with PD. Due to the non-linear effect of age on service type, the coefficient for age-squared ($Age^2/100$) was significant and negative for Neurology and Pathology. Specifically, for $Age^2/100$ there was a reduced likelihood of Neurology and Pathology service use above the age threshold among persons with PD. The respective age thresholds for Neurology and Pathology are estimated as 55.98 (=-exp(0.051)/(2*(-exp(-0.062)))*100) and 62.80 (=-exp(0.137)/2*(-exp(-0.091))*100). This indicates that for each year beyond the age threshold, there was a 1.88% and 1.83% reduced likelihood for the use of Neurology and Pathology services in PD, respectively.

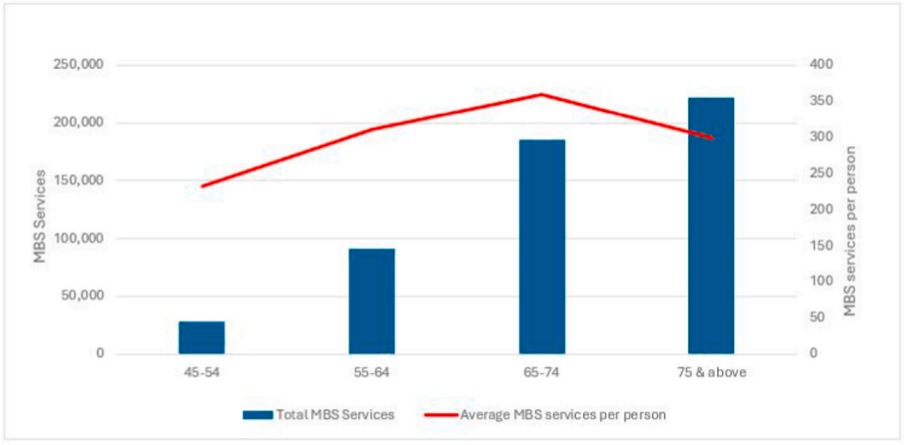
Although statistical significance was marginal ($p = 0.07$), there was a 14.3% reduced likelihood for GP service use in female participants with PD. For the variable Time since diagnosis of PD, there was an 1.6% increased likelihood use of Neurology services compared to initial diagnosis among persons with PD. This indicates that for each year since PD diagnosis, there is an increase in the likelihood for use of Neurology services by an additional 1.6%. Over a period of 10 years this reveals a 16% increase in the use of Neurology services among persons with PD.

4. Discussion

The purpose of this research was to determine the impact of medical service use among persons with PD in the context of ageing and rurality. Demographic findings in this research, as based on data from NSW, Australia, revealed that 44.6% of persons with PD lived in rural, regional, and remote localities. This differentiates from research based on data from Ontario, Canada, showing 10.7% of persons with PD living in rural localities.[20] Hence the present results show a substantive proportion of persons with PD living in RRR localities in NSW. Previous research has revealed inequalities in the provision of Parkinson's disease specific care within Australian RRR localities.[1] RRR localities are often under resourced with reduced capacity for medical specialist services which has a significant bearing on PD health provision and quality of life.

Ageing remains the biggest risk factor for developing idiopathic Parkinson's disease.[15] The present results reveal the highest proportion age group for persons with PD was 75 years and above. This is in accord with previous research showing the highest prevalence of PD within the 65-84 year age brackets.[20] With advancing age, the accumulation of several deficits such as mitochondrial DNA defects and oxidative damage, increases the vulnerability of substantia nigra neurons towards cell death in PD.[15] However, there remains a significant gap in the knowledge base into what specific age-related factors predispose some individuals to develop Parkinson's disease.

The present results revealed a linear increase in the overall medical services utilised by persons with PD across the age groups. However, the average number of medical services per person shows a peak within the 65-74 year age group. It is not exactly certain why this peak lies within



MBS, Medicare Benefits Schedule

Fig. 1. Total medical services by age group and per person with Parkinson's disease.

Table 2
Regression analysis of medical service use (Neurology, Pathology, GP) in persons with Parkinson's disease.

Variables	Neurology services	p-value	95% CI	Pathology services	p-value	95% CI	GP services	p-value	95% CI
	Coef.			Coef.			Coef.		
Major cities	0.385***	**0.0000**	[0.255,0.515]	0.231***	**0.0000**	[0.119,0.343]	−0.371***	**0.0000**	[-0.538,-0.205]
Age	0.051	0.2340	[-0.033,0.133]	0.137***	**0.0010**	[0.056,0.218]	0.032	0.5660	[-0.078,0.142]
Age^2/100	−0.062**	**0.0450**	[-0.122,-0.001]	−0.091***	**0.0020**	[-0.147,-0.034]	−0.013	0.7490	[-0.091,0.065]
Female	0.017	0.7960	[-0.109,0.142]	−0.005	0.9290	[-0.112,0.102]	−0.154*	**0.0700**	[-0.319,0.012]
Time since diagnosed	0.016***	**0.0000**	[0.008,0.024]	−0.004	0.2470	[-0.012,0.003]	−0.007	0.1510	[-0.016,0.002]
R-squared	0.369			0.315			0.224		
F-test	26.976***			19.926***			16.133***		
Number of observations	792			897			849		

Log Neurology, Pathology, General Practitioner (GP).
***p < 0.01, **p < 0.05, *p < 0.1. All regressions are performed with robust standard errors and controlled for year fixed effects. Note that the number of observations does not exactly match the cohort size of 1,676, as not all participant IDs could be successfully linked to the MBS service use data.

this age bracket when PD incidence rates have been shown to peak within the 70-79 age bracket.[21] In research by Willis et al., PD incidence rate in ages 65 and older ranged from 108 to 212 per 100,000 persons, however, the 45 years and older age group reveals a PD incidence rate ranging from 47 to 77 per 100,000 persons.[22] Hence, the average number of medical services per patient which peaked within the 65-74 year bracket in the present research is likely associated with the added medical costs attributed to disease diagnosis and establishing treatment protocols.

Findings in the present research also exposed differences in medical service use in PD between major cities and RRR. This revealed a significant 46.9% increased likelihood for the use of neurology and 25.9% increased pathology medical service use within major cities compared to RRR localities. In contrast, there was an 44.9% increased use of GP services in in RRR localities compared to major cities. It is likely this is due to a reduced accessibility of specialist medical services in RRR localities which could lean towards an increased reliance on GP service use.[23] For persons with PD living in Australian rural and remote localities, accessing specialist care remains a challenge,[11] particularly in early disease assessment and management. Diagnosis is a vital stage in accessing treatment and care, however, diagnostic error and delay is a significant problem in PD.[24,25] Our results also reveal an increased use of Neurology specialist services with age, suggesting a reliance on this medical service, particularly in the early stages of PD.[26] For those living in RRR localities with reduced accessibility to PD specialist care, delays in diagnosis and treatment can lead to worsening symptoms, heightened morbidity from falls, and increased hospital admissions which translates to suboptimal PD management, lower health-related quality of life, and greater healthcare costs.[1,27]

Access to health care can be defined as 'the opportunity to reach and obtain appropriate health care services in situations of perceived need for care'.[28] The inequity in PD specialist service use and the increased dependence on GP services in RRR localities in the present study aligns with previous studies. In research by Crighton et al.,[29] there was marked spatial variability in PD-related service utilisation in Ontario, Canada, with neurology visits being significantly higher in urban areas. Moreover, the rates of family physician visits were shown to be higher in more rural and remote areas. This pattern is consistent with spatial accessibility patterns. In neurology service use, the positive relationship between specialist accessibility and increased visitation to neurologists has been established.[29] However, this relationship can diverge as shown with North American Appalachian metropolitan areas indicating lower neurological service use, potentially due to factors such as cultural attitudes, reduced specialist care-seeking behaviour, and lower demand for specialist services.[30]

In the context of medical service use and ageing in PD, the present findings reveal that as a person with PD ages there is a reduced use of specialist medical services (Neurology and Pathology). This also aligns with previous research in Ontario, Canada, showing reduced Neurology service use with ageing in PD.[28] It is not certain why this pattern of medical service use arises with ageing in PD however this may be associated with increased dependence on multidisciplinary and non-pharmacological interventions in the post-diagnostic stage.[24] With disease progression, many features of PD do not respond to pharmacotherapy. Hence the reduced medical specialist service use with ageing in PD may be associated with a greater uptake of interventions such as

physiotherapy, exercise, and gait training. Support strategies such as PD nurse specialists have also been sporadically rolled out across NSW RRR localities,[4] however, this healthcare model does not overcome the diagnostic and pharmacologic requirements in early disease management.[23]

In the past decade telehealth has emerged as a strategy to combat shortages of medical and health services. In a geographically vast yet urbanised country such as Australia, telehealth has offered the potential to deliver timely and cost effective health services.[31] This model could potentially extend into remote areas and deliver PD specialist care. However, despite high demand for health services and health disparities across rural and remote Australia, the uptake of telehealth has been slow and *ad hoc*.[32] There are several possible and complex reasons for this including the 'digital divide' and digital literacy between rural and metropolitan areas. Social-cognitive factors associated with ageing or living with disability also impact on the skills, motivation, and the confidence in using digital technologies.

4.1. Strengths and limitations

Limitations within the present study include that the data is based on survey responses requiring participants to self-report their PD status. In the present study, some geographic regions were merged due to low participant numbers in remote regions. Hence aggregate data may not accurately reflect outcomes in the remote areas. While this data is an early baseline dataset from the 45 and Up Study 2005-2009 recruitment phase, the linked MBS data is 2004 to 2019 and so provides a larger dataset to potentially reveal future trends in a longitudinal comparative analysis. Another potential limitation of our study is that participants diagnosed with PD were enrolled between 2005 and 2009, while the MBS data span from 2004 to 2019. As a result, some medical service use data may reflect the period prior to a participant's PD diagnosis. However, the average time since PD diagnosis was 7.8 years as of 2005, indicating that most participants were already diagnosed at the start of the study period. Therefore, we expect minimal, if any, impact on our main findings. It should be noted that the 45 and Up Study cohort reflects the oversampling of people aged over 80 and those resident in rural and remote areas; includes higher income groups, and the potential under-representation of First Nations people in NSW. Therefore, the generalisability of the results must be approached with some caution.[13,33] Unfortunately, patient follow-up data were not available to researchers at the time of the study. We acknowledge this limitation and intend to incorporate follow-up data in future research to strengthen the depth and robustness of our analyses.

4.2. Conclusion

Differences in the use of medical services were identified between geographic locality and ageing in persons with PD. Rural, regional, remote locality revealed lower rates of Neurology and Pathology specialist service use compared to major cities, suggesting inequities in medical specialist accessibility. However, a higher rate of GP service use implies a greater reliance in this medical service among rural, regional, remote localities. The increased reliance on general practitioner services in these settings underscores the need for targeted public health strategies to improve specialist accessibility and support equitable care delivery.

Ethical statement

The 45 and Up Study received approval from the Human Research Ethics Committee (HREC) at the University of New South Wales. Additionally, ethics approval for this research was also obtained from the Charles Sturt University Human Research Ethics Committee (Approval code: H19297). The Sax Institute project approval was provided with access date commencing April 26th, 2020. Data linkage analysis was conducted in the Secure Unified Research Environment (SURE), which is provided and managed by the Sax Institute where the survey data access, database linkages, and statistical analysis is undertaken.

Author contributions

PM: conceptualisation; methodology; investigation; original writing, review and editing. MB: conceptualisation; methodology; investigation; writing – review and editing. PL: conceptualisation; methodology; investigation; writing – review and editing; project administration and resources including funding applications. SF: writing – review and editing. AW: conceptualisation; methodology; investigation; formal analysis and data visualisation; data curation; writing – review and editing.

Declaration of generative AI and AI-assisted technologies in the writing process

Artificial generative technologies were not applied in the writing process. AI was used to develop the graphical abstract.

Funding

Financial support for this project was provided by Charles Sturt University, Faculty of Science Research Infrastructure Grant (FoS RISS, 2019) to support the single-year licence fee enabling access to the Secure Unified Research Environment (SURE) for data access and analysis. The SURE environment is managed by The Sax Institute. The project was further supported by the Faculty of Justice, Business, and Behavioural Science and the School of Dentistry and Medical Science.

Declaration of competing interest

The authors declare no conflicts of interest.

Acknowledgments

The authors wish to thank the SEEF Project investigators for access to data for this research and to acknowledge the support of the Charles Sturt University Faculty of Justice, Business, and Behavioural Science, and the Faculty of Science and Health. This research was completed using data collected through the 45 and Up Study (www.saxinstitute.org.au). The 45 and Up Study is managed by the Sax Institute in collaboration with major partner Cancer Council NSW, and partners the Heart Foundation, and the NSW Ministry of Health. We thank the many thousands of people participating in the 45 and Up Study. We are grateful to Services Australia for granting access to the Medicare claims.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2026.106298.

References

1. Fealy S, Logan PA, Micalos PS, et al. Exploring Parkinson's disease prevalence in regional, rural and remote Australia: a systematic scoping review. *Aust J Rural Health*. 2023;31(6):1156–1167. https://doi.org/10.1111/ajr.13054.
2. Feigin VL, Nichols E, Alam T, et al. Global, regional, and national burden of neurological disorders: a systematic analysis for the global burden of disease study 2016. *Lancet Neurol*. 2019;18(5):459–480. https://doi.org/10.1016/S1474-4422(18)30499-X.
3. Kouli A, Torsney KM, Kuan WL. Parkinson's disease: etiology, neuropathology, and pathogenesis. In: Stoker TB, Greenland JC, eds. *Parkinson's disease: Pathogenesis and Clinical Aspects*. Codon Publications; 2018.
4. Bramble M, Wong A, Carroll V, Schwebel D, Rossiter R. Using an economic evaluation approach to support specialist nursing services for people with Parkinson's in a regional community. *J Adv Nurs*. 2021/12/01 2021;77(12):4722–4732. https://doi.org/10.1111/jan.14920.

5. Parkinson's Australia. Statistics on parkinson's. Online. Available www.parkinsons.org.au/statistics; 2020.
6. Tansey MG, Wallings RL, Houser MC, Herrick MK, Keating CE, Joers V. Inflammation and immune dysfunction in Parkinson disease. *Nat Rev Immunol*. 2022/11/01 2022;22(11):657–673. https://doi.org/10.1038/s41577-022-00684-6.
7. Tolosa E, Garrido A, Scholz SW, Poewe W. Challenges in the diagnosis of Parkinson's disease. *Lancet Neurol*. 2021;20(5):385–397. https://doi.org/10.1016/S1474-4422(21)00030-2.
8. Micalos PS, Logan PA, Bramble M, Wong A. Prevalence and factors associated with mental health status in Parkinson's disease: data from the 45 and up study. 2024; 00: 1–10. *Aust J Rural Health*. 2024;32(4):693–702. https://doi.org/10.1111/ajr.13125.
9. *Parkinson Disease: A Public Health Approach: Technical Brief*. 2022.
10. Waller S, Williams L, Morales-Briceno H, Fung V. The initial diagnosis and management of Parkinson's disease. *Journal Article Aust J Gen Pract*. 2021;50(11): 793–890. https://doi.org/10.31128/AJGP-07-21-6087.
11. Coady V, Warren N, Bilkhu N, Ayton D. Preferences for rural specialist health care in the treatment of Parkinson's disease: exploring the role of community-based nursing specialists. *Aust J Prim Health*. 2019;25:49–53.
12. 45 and Up Study Collaborators, Banks E, Redman S. Cohort profile: the 45 and Up study. *Int J Epidemiol*. 2008;37:941–947. https://doi.org/10.1093/ije/dym184.
13. Bleicher K, Summerhayes R, Baynes S, et al. Cohort profile update: the 45 and Up study. *Int J Epidemiol*. 2022;52(1):e92–e101. https://doi.org/10.1093/ije/dyac104.
14. Byles J. The 45 and Up study: an investment in healthy ageing. *Public Health Res Pract*. 2022;32(4), e3242231. https://doi.org/10.17061/phrp3242231.
15. Reeve A, Simcox E, Turnbull D. Ageing and Parkinson's disease: why is advancing age the biggest risk factor? *Ageing Res Rev*. Mar 2014;14(100):19–30. https://doi.org/10.1016/j.arr.2014.01.004.
16. Raket LL, Oudin Åström D, Norlin JM, Kellerborg K, Martinez-Martin P, Odin P. Impact of age at onset on symptom profiles, treatment characteristics and health-related quality of life in Parkinson's disease. *Sci Rep*. 2022/01/11 2022;12(1):526. https://doi.org/10.1038/s41598-021-04356-8.
17. Moret L, Nguyen J-M, Volteau C, Falissard B, Lombrail P, Gasquet I. Evidence of a non-linear influence of patient age on satisfaction with hospital care. *Int J Qual Health Care*. 2007;19(6):382–389. https://doi.org/10.1093/intqhc/mzm041.
18. Mallik G, Basu PK, Hicks J, Sappey R. Do the determinants of employability and earnings returns produce similar outcomes in metropolitan and regional labour markets? The case of New South Wales, Australia. *Reg Stud*. 2014/10/03 2014;48 (10):1706–1718. https://doi.org/10.1080/00343404.2013.812780.
19. Allison PD. *Linear fixed effects models. Linear Fixed Effects Models*. SAGE Publications, Inc.; 2009.
20. Maclagan LC, Marras C, Sewell IJ, et al. Trends in health service use among persons with Parkinson's disease by rurality: a population-based repeated cross-sectional study. *PLoS One*. 2023;18(5), e0285585. https://doi.org/10.1371/journal.pone.0285585.
21. Hirsch L, Jette N, Frolkis A, Steeves T, Pringsheim T. The incidence of Parkinson's disease: a systematic review and meta-analysis. *Neuroepidemiology*. 2016;46(4): 292–300. https://doi.org/10.1159/000445751.
22. Willis AW, Roberts E, Beck JC, et al. Incidence of Parkinson disease in North America. *npj Parkinson's Dis*. 2022/12/15 2022;8(1):170. https://doi.org/10.1038/s41531-022-00410-y.
23. Logan PA, Micalos PS, Fealy S, Bramble M, Wong A. Comparing Parkinson's disease medications categorised by location in New South Wales, Australia: linking the 45 and up study and the pharmaceutical benefits scheme (PBS) data. *Aust J Rural Health*. Oct 2025;33(5), e70094. https://doi.org/10.1111/ajr.70094.
24. Bloem BR, Okun MS, Klein C. Parkinson's disease. *Lancet*. 2021/06/12/2021;397 (10291):2284–2303. https://doi.org/10.1016/S0140-6736(21)00218-X.
25. Kalia LV, Lang AE. Parkinson's disease. *Lancet*. 2015;386(9996):896–912. https://doi.org/10.1016/S0140-6736(14)61393-3.
26. Pirtošek Z, Bajenaru O, Kovács N, Milanov I, Relja M, Skorvanek M. Update on the management of parkinson's disease for general neurologists. *Parkinsons Dis*. 2020/01/01 2020;2020(1), 9131474. https://doi.org/10.1155/2020/9131474.
27. Willis AW, Schootman M, Tran R, et al. Neurologist-associated reduction in PD-related hospitalizations and health care expenditures. *Neurology*. Oct 23 2012;79 (17):1774–1780. https://doi.org/10.1212/WNL.0b013e3182703f92.
28. Levesque JF, Harris MF, Russell G. Patient-centred access to health care: conceptualising access at the interface of health systems and populations. *Int J Equity Health*. Mar 11 2013;12:18. https://doi.org/10.1186/1475-9276-12-18.
29. Crighton EJ, Ouédraogo AM, Sawada M, Mestre TA. Patterns and determinants of health care utilization among people with Parkinson's disease: a population-based analysis in Ontario, Canada. *PLoS One*. 2024;19(6), e0305062. https://doi.org/10.1371/journal.pone.0305062.
30. Buchalter RB, Gentry EG, Willis MA, McGinley MP. Disparities in spatial access to neurological care in Appalachia: a cross-sectional health services analysis. *Lancet Reg Health, Am*. 2023/02/01/2023;18, 100415. https://doi.org/10.1016/j.lana.2022.100415.
31. Hashiguchi TCO. *Bringing health care to the patient. OECD Health Working Papers*. OECD Publishing; 2020.
32. Warr D, Luscombe G, Couch D. Hype, evidence gaps and digital divides: telehealth blind spots in rural Australia. *Health*. 2021;27(4):588–606. https://doi.org/10.1177/13634593211060763.
33. Johar M, Jones G, Savage E. Healthcare expenditure profile of older Australians: evidence from linked survey and health administrative data. *Econ Pap*. 2012;31(4): 451–463. https://doi.org/10.1111/1759-3441.12009.