

# BMJ Open Hospitalisations related to nervous-system diseases in Australia, 1998–2019: a secular trend analysis

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**To cite:** Abuhamdah SMA, Naser AY. Hospitalisations related to nervous-system diseases in Australia, 1998–2019: a secular trend analysis. *BMJ Open* 2023;**13**:e074553. doi:10.1136/bmjopen-2023-074553

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2023-074553>).

Received 12 April 2023  
Accepted 12 September 2023



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## ABSTRACT

**Objective** The burden of neurological disease-related disabilities and deaths is one of the most serious issues globally. We aimed to examine the hospitalisation profile related to nervous system diseases in Australia for the duration between 1998 and 2019.

**Design** A secular trend analysis using a population-based dataset.

**Setting** This analysis used a population-based study of hospitalised patients in Australia. Hospitalisation data were extracted from the National Hospital Morbidity Database, which collects sets of episode-level information for Australian patients admitted to all private and public hospitals.

**Participants** All patients who were hospitalised in all private and public hospitalisations.

**Primary outcome measure** Hospitalisation rates related to nervous system diseases.

**Results** Hospitalisation rates increased by 1.04 times (from 650.36 (95% CI 646.73 to 654.00) in 1998 to 1328.90 (95% CI 1324.44 to 1333.35) in 2019 per 100 000 persons,  $p < 0.01$ ). Overnight-stay episodes accounted for 57.0% of the total number of hospitalisations. Rates of the same-day hospitalisation for diseases of the nervous system increased by 2.10-fold (from 219.74 (95% CI 217.63 to 221.86) in 1998 to 680.23 (95% CI 677.03 to 683.43) in 2019 per 100 000 persons). Rates of overnight-stay hospital admission increased by 42.7% (from 430.62 (95% CI 427.66 to 433.58) in 1998 to 614.70 (95% CI 611.66 to 617.75) in 2019 per 100 000 persons). ‘Episodic and paroxysmal disorders’ were the most prevalent reason for hospitalisation, which accounted for 49.0% of the total number of episodes. Female hospitalisation rates increased by 1.13-fold (from 618.23 (95% CI 613.24 to 623.22) in 1998 to 1316.33 (95% CI 1310.07 to 1322.58) in 2019 per 100 000 persons). Male hospitalisation rates increased by 86.4% (from 682.95 (95% CI 677.67 to 688.23) in 1998 to 1273.18 (95% CI 1266.98 to 1279.37) in 2019 per 100 000 persons).

**Conclusion** Hospitalisation rates for neurological disorders in Australia are high, potentially owing to the ageing of the population. Males had greater rates of hospitalisation than females.

## INTRODUCTION

Nervous system diseases (also known as neurological diseases)<sup>1</sup> affect hundreds of millions of individuals globally.<sup>2</sup> They are a

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This research examined the hospitalisation profile for all nervous system diseases between 1998 and 2019.
- ⇒ By using population-level aggregated data, we were unable to follow up with patients or detect important confounding factors.
- ⇒ The ability to look into key patient demographic information, such as comorbidities and ethnicity, was constrained by the use of aggregated data.

broad category of conditions that influence the body’s central, peripheral and autonomic nervous systems.<sup>3</sup> Nervous system diseases involve cerebral palsy and other paralytic syndromes; inflammatory diseases of the central nervous system; degenerative diseases of the nervous system; polyneuropathies and other disorders of the peripheral nervous system; extrapyramidal and movement disorders; nerve, nerve root and plexus disorders; demyelinating diseases of the central nervous system; episodic and paroxysmal disorders; systemic atrophies primarily affecting the central nervous system; diseases of myoneural junction and muscle; and other disorders of the nervous system.<sup>4</sup>

The burden of neurological disease-related disabilities and deaths is one of the most serious issues to global public health, and as the population ages, this burden will grow in the next decades.<sup>3,5</sup> Even while communicable neurological diseases have decreased over the past 30 years, there was a 15% increase in disability-adjusted life-years (DALYs) (the sum of years of life lost and years lived with disability) and a 39% increase in the absolute number of their associated fatalities.<sup>5</sup> In 2019, neurological diseases accounted for 3.8% of the global disease burden and 6.6% of the total disease burden in Australia.<sup>6</sup> Besides, between 1968 and 2020, the mortality rates for all nervous system diseases increased by

128.2% in Australia; among males and females increased by 115.9% and 139.1%, respectively.<sup>7</sup>

In the USA, neurological diseases such as neuromuscular diseases, epilepsy and cerebral palsy account for 5%–10% of the hospital admissions of young people and children. In addition, they are a significant and growing cause of hospital admissions, accounting for 14% of bed days and 20% of expenses.<sup>8,9</sup> In the USA, neurological diseases were responsible for around three times the number of young people and children admitted to intensive care units (ICUs) than other conditions, as well as for approximately half of all fatalities.<sup>9</sup> Moreover, patients with nervous system diseases are increasingly being admitted to hospitals in the UK.<sup>10</sup> The hospitalisation of nervous system diseases and the factors that affect changes in hospitalisation must be evaluated regularly and accurately; these analyses would aid in the assessments of the effects of responsive treatments, resource allocation and cost-effective healthcare planning. Yet there are so far no studies that assess trends of nervous system disease hospitalisations in Australia. Therefore, our study aims to examine the hospitalisation profile related to nervous system diseases in Australia.

## METHODS

### Study design

This is a secular trend analysis study that examines the hospitalisation pattern for nervous system diseases in Australia between 1998 and 2019.

### Data sources

#### National Hospital Morbidity Database

The National Hospital Data Collection (NHDC) includes information from the National Hospital Morbidity Database (NHMD). The Australian Institute of Health and Welfare (AIHW) maintains numerous important national hospital databases that are part of the NHDC.<sup>11</sup> The NHMD collects sets of episode-level information from morbidity data collection systems for Australian patients admitted to private and public hospitals. The objective of the National Minimum Data Set (NMDS) for admitted patient care is to collect information on the care provided to hospitalised patients in Australia. The NMDS comprises episodes of care for patients admitted to hospitals from all alcohol-and-drug-treatment institutions, private mental and acute hospitals, and independent day hospitals. We detected hospitalisations associated with nervous system diseases using the International Statistical Classification of Diseases and Related Health Problems (ICD)-10 (G00–G99). ICD codes are based on the principal diagnosis. All data used in this study are publicly available aggregated data. The term ‘same-day hospitalisation’ refers to a specific period of time in which an individual who has been admitted to a hospital as an inpatient is confined to a bed and spends the night within the hospital premises. The term ‘overnight-stay admitted care’ refers to the provision of treatment for a patient who is admitted to

a hospital for a minimum duration of one night and is subsequently discharged on a different date.

### Australian Bureau of Statistics

Between 1998 and 2019, mid-year population data were collected by the Australian Bureau of Statistics.<sup>12</sup> From 1998 to 2016, population data were collected using the historical population data.<sup>13</sup> Between 2017 and 2019, national, state and territorial populations were used to compile the relevant data.<sup>14</sup>

### Study population

All private and public hospitalisations in Australia from 1998 to 2019 were included in this study.<sup>15</sup>

### Statistical analysis

For all analyses, SPSS V.27 (IBM Corp) was used. Hospitalisation rates (95% CIs) were calculated by dividing hospitalisation episodes by the population at midyear. Using the Pearson  $\chi^2$  test for independence, we analysed the variation in hospitalisation rates between 1998 and 2019. The CI was estimated using the following equation for the population proportion:  $p^{+/-Z} \times (p(1-p)/n)^{0.5}$ .

### Patient and public involvement

None.

## RESULTS

### Trends in nervous system hospitalisation

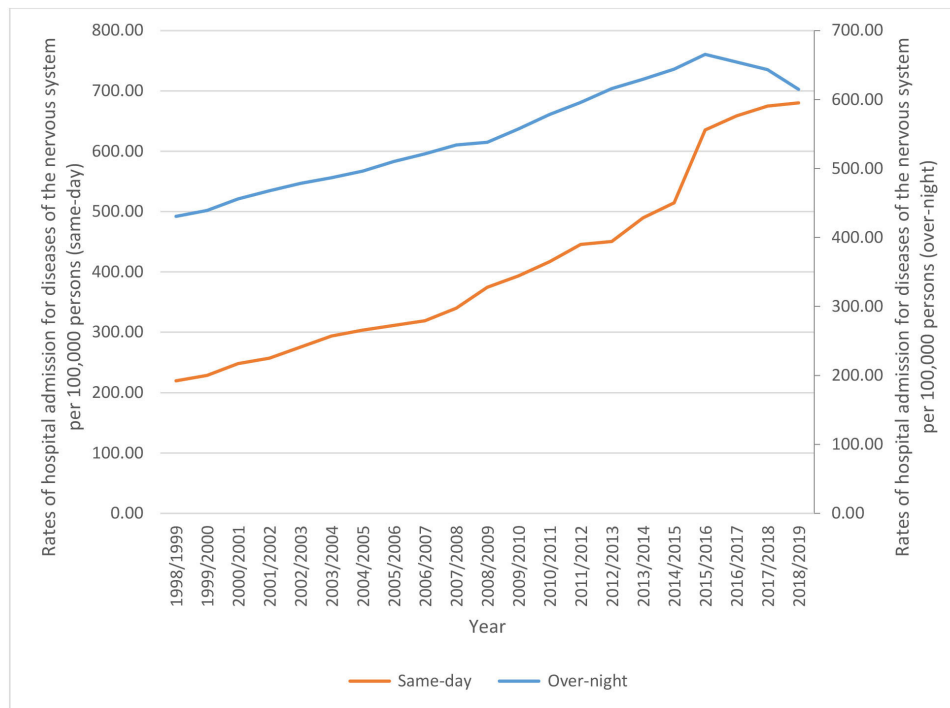
In Australia, hospitalisations of nervous system-related diseases accounted for 4500065 episodes between 1998 and 2019. The overall yearly number of episodes for diverse reasons increased by 1.75 times from 122348 in 1998 to 336745 in 2019, expressing an increase in hospitalisation rate of 1.04 times (from 650.36 (95% CI 646.73 to 654.00) in 1998 to 1328.90 (95% CI 1324.44 to 1333.35) in 2019 per 100000 persons,  $p < 0.01$ ).

Overnight-stay episodes accounted for 57.0% of the total number of hospitalisations, and 43.0% were for the same-day patients. Rates of the same-day hospitalisation for diseases of the nervous system increased by 2.10-fold (from 219.74 (95% CI 217.63 to 221.86) in 1998 to 680.23 (95% CI 677.03 to 683.43) in 2019 per 100000 persons). Rates of overnight-stay hospital admission increased by 42.7% (from 430.62 (95% CI 427.66 to 433.58) in 1998 to 614.70 (95% CI 611.66 to 617.75) in 2019 per 100000 persons) (figure 1).

‘Episodic and paroxysmal disorders’ were the most prevalent reason for hospitalisation, which accounted for 49.0% of the total number of episodes, followed by ‘nerve, nerve root and plexus disorders’ with 19.0%, ‘polyneuropathies and other disorders of the peripheral nervous system’ with 7.7%, and ‘demyelinating diseases of the central nervous system’ with 6.9% (table 1).

### Trends in hospitalisation stratified by indication

During the study time, the hospitalisation rate for nervous system diseases increased as follows: ‘myoneural



**Figure 1** Rates of the same-day and overnight-stay hospitalisation in Australia between 1998 and 2019.

junction and muscle’ increased by 8.76-fold; ‘demyelinating diseases’ increased by 5.63-fold; ‘polyneuropathies and other disorders of the peripheral nervous system’ increased by 5.26-fold; ‘extrapyramidal and movement disorders’ increased by 2.40-fold; ‘inflammatory diseases of the central nervous system’ increased by 1.53-fold; ‘cerebral palsy and other paralytic syndromes’ increased by 1.30-fold; ‘other disorders of the nervous system’ increased by 1.25-fold; ‘systemic atrophies primarily affecting the central nervous system’ increased by 1.19-fold; ‘other degenerative diseases of the nervous system’ increased by 1.03-fold; ‘episodic and paroxysmal disorders’ increased by 56.0%; ‘nerve, nerve root and plexus disorders’ increased by 30.9% (online supplemental table S1, figure 2).

#### Trends in hospitalisation stratified by gender

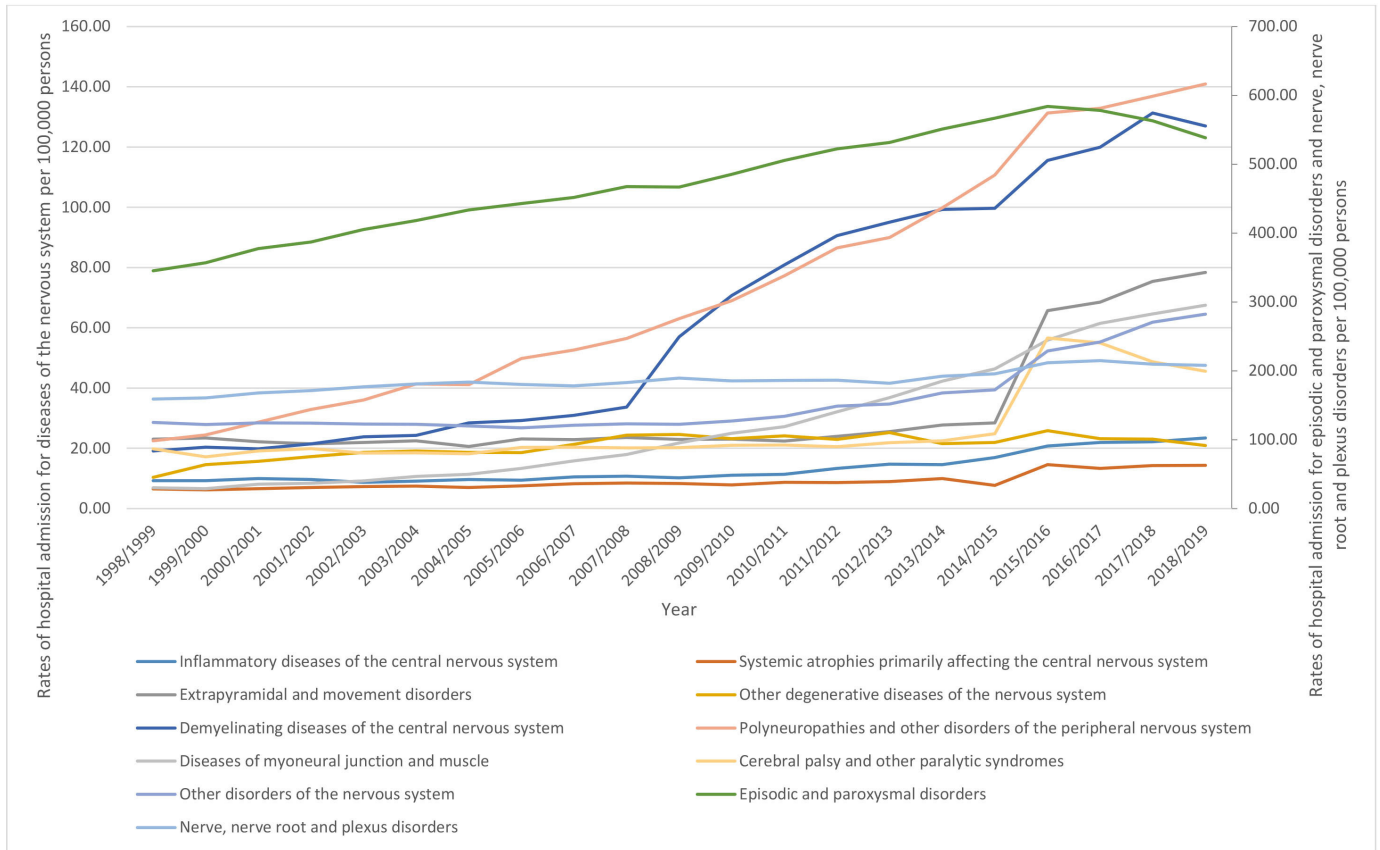
Males accounted for 50.7% of all episodes, with an average of 107 940 episodes per year. Males were responsible for 2 266 743 hospitalisation episodes. Female hospitalisation rates increased by 1.13-fold (from 618.23 (95% CI 613.24 to 623.22) in 1998 to 1316.33 (95% CI 1310.07 to 1322.58) in 2019 per 100 000 persons). Male hospitalisation rates increased by 86.4% (from 682.95 (95% CI 677.67 to 688.23) in 1998 to 1273.18 (95% CI 1266.98 to 1279.37) in 2019 per 100 000 persons) (figure 3).

#### Trends in hospitalisation stratified by age group

Regarding differences in the age group in terms of hospitalisation, the age group 40–59 years accounted for 31.6% of the total number of episodes, followed by the age group

**Table 1** Percentage of diseases from total number of episodes per ICD code

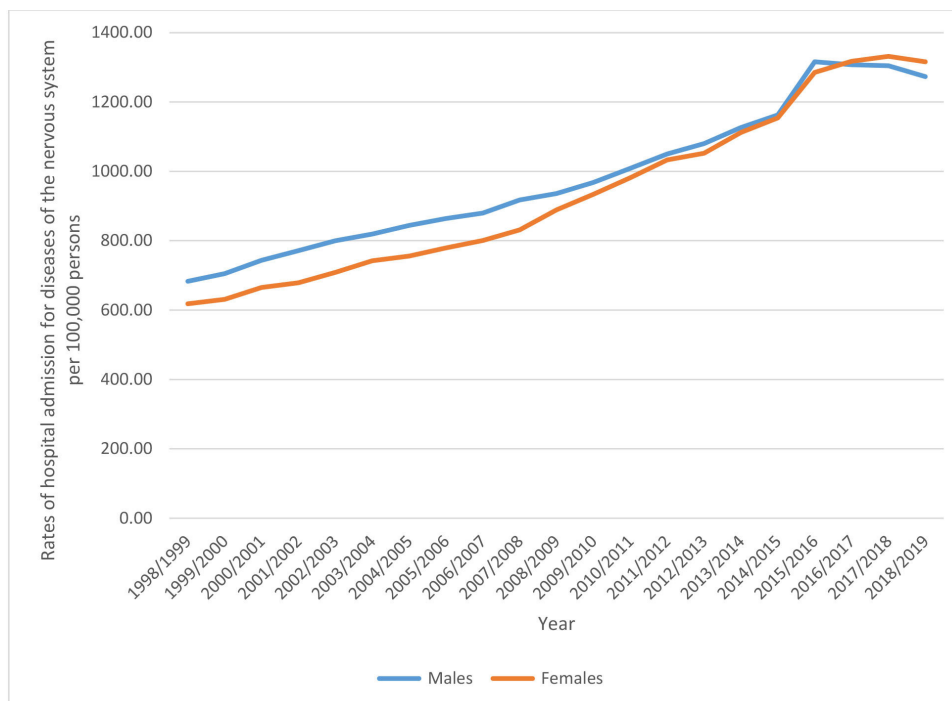
ICD code	Description	Percentage
G00–G09	‘Inflammatory diseases of the central nervous system’	1.4
G10–G14	‘Systemic atrophies primarily affecting the central nervous system’	0.9
G20–G26	‘Extrapyramidal and movement disorders’	3.5
G30–G32	‘Other degenerative diseases of the nervous system’	2.1
G35–G37	‘Demyelinating diseases of the central nervous system’	6.9
G40–G47	‘Episodic and paroxysmal disorders’	49.0
G50–G59	‘Nerve, nerve root and plexus disorders’	19.0
G60–G64	‘Polyneuropathies and other disorders of the peripheral nervous system’	7.7
G70–G73	‘Diseases of myoneural junction and muscle’	3.0
G80–G83	‘Cerebral palsy and other paralytic syndromes’	2.8
G90–G99	‘Other disorders of the nervous system’	3.7



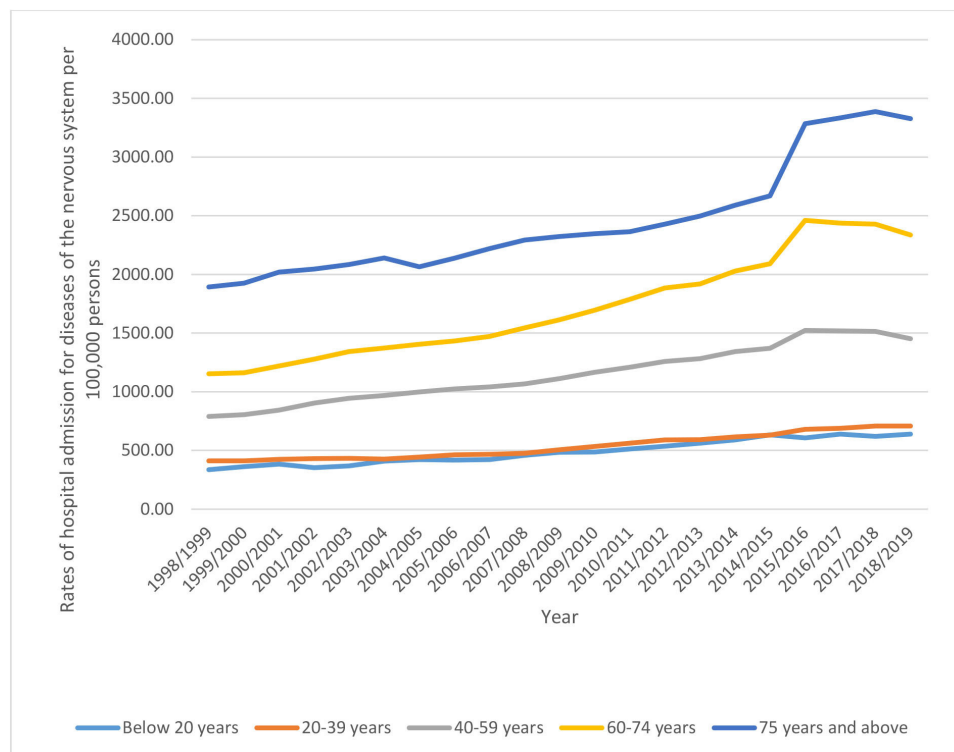
**Figure 2** Rates of hospitalisation stratified by type.

60–74 years with 23.3%, the age group 75 years and above with 16.1%, the age group 20–39 years with 16.0%, and the age group below 20 years with 13.1%.

The highest increase in the rate of hospitalisations was observed in patients aged 60–74 years, which was 1.03-fold. This was followed by an increase of 89.7% for the age



**Figure 3** Hospitalisation rates stratified by gender.



**Figure 4** Hospitalisation rates stratified by age group.

group below 20 years. Rates of hospitalisation for patients aged 40–59 years, 75 years and over, and those aged 20–39 years increased by 83.7%, 75.7% and 72.1%, respectively (online supplemental table S2). **Figure 4** presents the rates of admissions stratified by age group.

#### Trends in hospitalisation stratified by indication and gender

The majority of hospitalisation rates were higher among males compared with females (online supplemental figure S1). However, hospitalisation rates for ‘demyelinating diseases’, ‘nerve, nerve root and plexus disorders’ and ‘diseases of myoneural junction and muscle’ were higher among females compared with males (online supplemental figure S2).

#### Trends of hospitalisation rate stratified by indication and age group

The majority of hospitalisations were more prevalent among the age group of 75 years and above. However, the hospitalisation rates for ‘inflammatory diseases’ and ‘polyneuropathies and other disorders of the peripheral nervous system’ were more prevalent among the age group 60–74 years. Further, the hospitalisation rates for ‘demyelinating diseases’ were more prevalent in the age group 40–59 years (online supplemental figure S2).

## DISCUSSION

The nervous system plays a critical role in managing and harmonising all the body’s activities, and any disruption or damage to it can result in significant ramifications.<sup>16</sup> Nervous system disorders encompass a wide range of

conditions,<sup>17</sup> including mild conditions such as migraines and neuropathy as well as more severe illnesses such as multiple sclerosis, Parkinson’s disease and Alzheimer’s disease.<sup>4</sup> These diseases are considered one of the top 10 main causes of death worldwide in 2020.<sup>18,19</sup> The key findings of our study are: (1) hospitalisation rates for nervous system diseases increased significantly during the past two decades; (2) overnight-stay episodes accounted for more than half of the total number of hospitalisations; (3) rates of the same-day hospitalisation for diseases of the nervous system doubled during the study period and rates of overnight-stay hospital admissions increased to a lower extent; (4) ‘episodic and paroxysmal disorders’ were the most prevalent reason for hospitalisation; (5) males accounted for almost half of all episodes; (6) female hospitalisation rates increased significantly and to a higher extent than those of males; and (7) the age group 40–59 years accounted for almost one-third of the total number of episodes, followed by the age group 60–74 years, which accounted for one-quarter of the number of episodes.

Our study found that the hospitalisation rates for nervous system diseases increased by 1.04 times during the study period. The increase in the hospitalisation rates for nervous system diseases is alarming as it is higher than the increase in all-cause hospitalisation rates in Australia in the same period. Between 1998 and 2021, all-cause hospitalisation rates in Australia increased by 51.5%. Same-day hospital-admitted patients accounted for 57.5% of all admissions, while 42.5% were overnight-stay admissions.<sup>11</sup> This rise can be attributed to risk factors including

population ageing, gender differences and population growth. From the beginning of the 21st century, the absolute number of persons who have died or remained incapacitated due to neurological illnesses has increased internationally. These figures are comparable to those provided in the 2016 Global Burden of Disease study.<sup>18</sup> In England, along the same lines, nervous-system patients admitted to the hospitals represent a high proportion of the hospitalised and inpatients population.<sup>20</sup> A previous study in the UK reported that the rate of hospital admissions due to nervous system diseases in England and Wales increased by 73.0% for the period between 1999 and 2019.<sup>10</sup>

Episodic paroxysmal movement disorders (PxMDs) are the most common conditions that can cause nervous system complications. PxMDs are heterogeneous disorders characterised by episodic involuntary movements.<sup>21</sup> In addition, nerve and nerve root problems caused by abrupt or prolonged pressure on the spinal nerve root are often the consequence of a herniated disc or osteoarthritis of the spine. The third condition was polyneuropathies, a disorder that affects skin, muscles and organs in which peripheral nerves are destroyed.<sup>22</sup> However, the most common cause of nerve damage is diabetes.<sup>23</sup> Nevertheless, episodic paroxysmal disorders were the most prevalent reason for hospitalisation, which accounted for 49.0% of the total number of episodes. However, episodic paroxysmal disorders accounted for 37.4% of hospitalisations and admissions in England and Wales.<sup>10</sup> Indeed, patients suffering from paroxysmal movement disorders require special care while the patients may suffer from a partial disability and reduced quality of life during the episodes,<sup>24</sup> which leads to an increase in the admission and hospitalisation rates for this patient group. Based on a meta-analysis published in 2019, there was a significant 39% increase in the number of deaths attributed to neurological disorders between the years 1990 and 2016. Additionally, the burden of disease, as measured by DALYs, also experienced a notable 15% increase during the same time period.<sup>18</sup> Among the various types of neurological disorders, episodic and paroxysmal disorders emerged as a leading cause of both DALYs and mortality. Notably, stroke, a subtype within this category, ranked as the second highest cause of death globally.<sup>18,19</sup> It is important to note that this category primarily encompasses conditions such as epilepsy, migraine, headache, stroke, transient cerebral ischaemic attacks, related syndromes and sleep disorders.<sup>4</sup>

Staying overnight at a hospital as an inpatient accounted for 57% of the total hospitalisations. For the exact purpose of most neurological disorders, these illnesses require close monitoring because deterioration can be rapid and fatal,<sup>25</sup> and that leads to an increase in the admission rate by the emergency department depending on the need for acute intervention or close monitoring.<sup>26</sup> Further, the overnight stay relies on multiple factors including the patient's case on arrival at the hospital, where it can determine the length of the

hospitalisation and the need for a clinical or non-clinical intervention.

Our finding identified gender differences in hospitalisation rates, reported to be higher in males than females. The reason for these results might be that the prevalence of neurological disorders may vary along with the gender difference,<sup>27,28</sup> and indeed admission rates among males were higher than those among females. Moreover, men were more likely to receive advanced therapy than females, since male hospitalisation rates increased by 86.4%. These differences in therapy response might be related to the gender differences in response to medications, especially pain treatments,<sup>28,29</sup> regarding which patients with nervous disease and psychiatric disorder have different treatment tolerability when it comes to sex differences. Multiple factors are included: genotype, psychosocial group, hormones and cultural influences are a few of the many factors that can affect differences in patients' outcomes.<sup>28</sup> In the context of Australia, it has been observed that the sex ratio at birth stands at roughly 106 males for every 100 females.<sup>30</sup> The phenomenon of higher mortality rates among males at early ages leads to a convergence of the male-to-female mortality ratio towards 100 by the time individuals reach the age of 30.<sup>30</sup> The phenomenon of international migration has the potential to exert an impact on the distribution of sexes within a population, particularly during the working ages, as historical trends have shown a higher proportion of male migrants.<sup>30</sup>

This study examined prespecified age group variables in relation to the primary outcome. Age plays a vital role in the prevalence of neurological disorders, where cerebrovascular diseases and neurodegenerative diseases have a more common prevalence in the elderly population,<sup>31</sup> since the Australian population is considered to be a rapidly ageing population.<sup>32</sup> The hospitalisation rates for demyelinating diseases were more prevalent among the age group 40–59 years, which accounted for most episodes, 31.6%, followed by the age group 60–74 years, which accounted for 23.3%. Moreover, the elderly patient population tends to be the highest age group hospitalised in our study, while in England the increase is in the hospitalisation and the admission rate of children and young people.<sup>20</sup> As a matter of fact, children with neurological disorders have a higher ICU admission rate and a high risk for death.<sup>33</sup> According to the AIHW, the population of Australia is experiencing the phenomenon of population ageing, which can be attributed to two main factors: the rise in life expectancy and the decline in birth rates.<sup>34</sup> The population of individuals in older age groups is experiencing growth, accompanied by a rising proportion of older individuals in relation to the overall population. During the period spanning from 1998 to 2019, there was a notable rise of 29.5% in the proportion of individuals aged 65 and above within the Australian population.<sup>34</sup> During the past two decades, there has been a decline in the percentage of children within the overall population, with the proportion decreasing from 20.7% to 18.6%.<sup>30</sup>

In addition, the demographic segment comprising individuals aged 15–64 years experienced a growth rate of 31.4%, which was somewhat slower than the growth rate observed in the rest of the population, amounting to 42.2%.<sup>30</sup>

Other factors that may impact the number of hospitalisations include the capacity of the healthcare system, changes in healthcare practices and policies, and the introduction of new technologies.<sup>35–37</sup> An optimally operating healthcare system, characterised by sufficient hospital bed capacity, a sufficient number of healthcare practitioners, and adequate resources, has the potential to effectively address and mitigate avoidable hospital admissions.<sup>35</sup> Besides, the rate of hospitalisations can be directly influenced by alterations in medical practices and healthcare regulations. The implementation of strategies focused on promoting health practices based on research evidence, preventative care, outpatient services and community-based care has the potential to mitigate the necessity of hospital admissions.<sup>37</sup> Moreover, the development of medical technologies has the potential to enhance the efficacy of diagnosing, treating and managing many medical problems. Health information technology plays a key role in enhancing the quality and safety of healthcare.<sup>38</sup> New technologies, such as minimally invasive procedures, telemedicine, remote monitoring devices and individualised treatments, have the potential to significantly influence the frequency of hospitalisations.<sup>39–41</sup> These technologies have the potential to facilitate the delivery of suitable healthcare to patients, which obviates the requirement for hospitalisation. Additionally, they can facilitate timely interventions that mitigate the progression of conditions, thereby averting the need for the hospital admission.

This study has limitations. The utilisation of population-level aggregated data hindered our ability to conduct patient follow-ups and identify significant confounding variables. This might have underestimate or overestimate our hospitalisation rate. The utilisation of aggregated data limited the capacity to access important patient demographic information, including comorbidities and ethnicity. The data that are accessible pertain to the population as a whole, with information aggregated as absolute numbers of hospitalisations categorised by age and gender. Unfortunately, this lack of patient-level data has hindered our ability to calculate age-standardised and sex-standardised hospitalisation rates. It is imperative to acknowledge that without access to data at the individual level, it becomes impractical to ascertain the extent of variation. Therefore, it is possible that the CIs obtained using the above formula may exhibit a lack of precision. In addition, the publically available data do not provide information on the prevalence of each neurological disease during the study period. Therefore, our findings should be interpreted carefully. Future research should investigate admissions for nervous system diseases by using individual-level data in order to identify potential risk factors and provide appropriate interventions.

## Conclusion

The nervous system is essential for regulating and coordinating bodily functions, and disorders affecting it can have severe consequences. Neurological disorders can range from mild conditions such as migraines and neuropathy to severe illnesses such as multiple sclerosis, Alzheimer's disease and Parkinson's disease, which are among the top 10 causes of death worldwide. This study examines hospitalisation rates related to neurological disorders in Australia and finds that hospitalisation rates are high, which may be due to population ageing. Additionally, the study has found that hospitalisation rates are highest among the elderly population, with demyelinating diseases being more prevalent among the age group of 40–59 years.

**Contributors** S.M.A.A. and A.Y.N. are responsible for conceptualisation, data acquisition, analysis, interpretation, writing original draft, review and editing. A.Y.N. act as guarantor for the work and the conduct of the study, had access to the data, and controlled the decision to publish.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available in a public, open access repository. The data used in this research are publicly available at the following URL: <https://meteor.aihw.gov.au/content/394352>.

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