



## Original Article

# Comparison of Sleep Apnea Questionnaires and Reported Diagnosis in Neurological Disorders of Aging

Teresa Gomes<sup>1,2</sup> , Andrea Benedetti<sup>2,3</sup>, Ron Postuma<sup>4</sup>, Dorrie Rizzo<sup>5</sup>, Marc Baltzan<sup>6</sup>, Richard John Kimoff<sup>2,7</sup> and Marta Kaminska<sup>2,7</sup> 

<sup>1</sup>Department of Integrated Program in Neuroscience, McGill University, Montreal, QC, Canada, <sup>2</sup>Respiratory Epidemiology and Clinical Research Unit, Research Institute of the McGill University Health Centre, Montreal, QC, Canada, <sup>3</sup>Department of Medicine and Department of Epidemiology, Biostatistics & Occupational Health, McGill University Health Centre, Montreal, QC, Canada, <sup>4</sup>Department of Neurology and Neurosurgery, McGill University, Montreal General Hospital, Montreal, QC, Canada, <sup>5</sup>Lady Davis Institute for Medical Research, Jewish General Hospital, Montreal, QC, Canada, <sup>6</sup>Mount Sinai Hospital Center, Montreal, QC, Canada and <sup>7</sup>Respiratory Division and Sleep Laboratory, McGill University Health Centre, Montreal, QC, Canada

**ABSTRACT: Background:** Obstructive sleep apnea (OSA) is associated with worse outcomes in stroke, Alzheimer's disease (AD) and Parkinson's disease (PD), but diagnosis is challenging in these groups. We aimed to compare the prevalence of high risk of OSA based on commonly used questionnaires and self-reported OSA diagnosis: 1. within groups with stroke, AD, PD and the general population (GP); 2. Between neurological groups and GP. **Methods:** Individuals with stroke, PD and AD were identified in the Canadian Longitudinal Study of Aging (CLSA) by survey. STOP, STOP-BAG, STOP-B28 and GOAL screening tools and OSA self-report were compared by the Chi-squared test. Logistic regression was used to compare high risk/self-report of OSA, in neurological conditions vs. GP, adjusted for confounders. **Results:** We studied 30,097 participants with mean age of 62.3 years (SD 10.3) (stroke  $n = 1791$ ; PD  $n = 175$ ; AD  $n = 125$ ). In all groups, a positive GOAL was the most prevalent, while positive STOP was least prevalent among questionnaires. Significant variations in high-risk OSA were observed between different questionnaires across all groups. Under 1.5% of individuals self-reported OSA. While all questionnaires suggested a higher prevalence of OSA in stroke than the GP, for PD and AD, there was heterogeneity depending on questionnaire. **Conclusions:** The wide range of prevalences of high risk of OSA resulting from commonly used screening tools underscores the importance of validating them in older adults with neurological disorders. OSA was self-reported in disproportionately small numbers across groups, suggesting that OSA is underdiagnosed in older adults or underreported by patients, which is concerning given its increasingly recognized impact on brain health.

**RÉSUMÉ : Comparaison entre des questionnaires portant sur l'apnée du sommeil et les diagnostics rapportés dans le cas de troubles neurologiques du vieillissement** **Contexte :** L'apnée obstructive du sommeil (AOS) est associée à une évolution défavorable de l'état de santé d'individus victimes d'AVC, mais aussi atteints de la maladie d'Alzheimer (MA) et de la maladie de Parkinson (MP). Un diagnostic demeure toutefois difficile à établir dans leur cas. Nous avons ainsi cherché à comparer la prévalence du risque élevé d'AOS sur la base de questionnaires couramment utilisés et de diagnostics auto-déclarés d'AOS au sein : 1) de cohortes de patients victimes d'un AVC ou atteints de la MA, de la MP en comparaison avec la population générale (PG) ; de groupes neurologiques en comparaison avec la PG. **Méthodes :** C'est au moyen d'enquêtes que des individus victimes d'un AVC ou atteints de MP et de MA ont été identifiés dans le cadre de l'Étude longitudinale canadienne sur le vieillissement (ELCV). Les outils de dépistage STOP, STOP-BAG, STOP-B28 et GOAL, de même que l'auto-évaluation de l'AOS, ont été comparés à l'aide d'un test du khi carré. Un modèle de régression logistique a par ailleurs permis de comparer le risque élevé ou l'auto-déclaration de l'AOS selon l'état neurologique des patients par rapport à la PG, et ce, en procédant à un ajustement tenant compte de facteurs de confusion (*confounders*). **Résultats :** Au total, nous avons étudié 30 097 participants dont l'âge moyen était de 62,3 ans ( $\sigma$  10,3 ; AVC :  $n = 1791$ , MP :  $n = 175$ , MA :  $n = 125$ ). Dans tous les groupes, des résultats positifs à l'outil d'évaluation GOA se sont avérés les plus répandus, tandis que des résultats positifs à l'outil STOP étaient les moins répandus. Des variations significatives du risque élevé d'AOS ont été observées entre les différents questionnaires, et ce, dans tous les groupes. Mentionnons aussi que moins de 1,5 % des individus ont déclaré être atteints d'AOS. Alors que tous les questionnaires suggèrent une prévalence plus élevée d'AOS dans le cas des AVC qu'au sein de la PG, on a observé, dans le cas de la MP et de la MA, une hétérogénéité en fonction des questionnaires. **Conclusions :** Un large éventail de prévalences de risque élevé d'AOS résultant d'outils de dépistage couramment utilisés souligne en bref l'importance de bien les valider chez les individus âgés qui sont atteints de troubles neurologiques. L'AOS a été auto-déclarée dans une proportion disproportionnellement plus faible dans tous les groupes, ce qui suggère qu'elle demeure sous-diagnostiquée chez les personnes âgées ou sous-déclarée par les patients. Cela est préoccupant compte tenu de l'impact de plus en plus reconnu de ce trouble sur la santé cérébrale.

**Keywords:** comparison; elderly; neurological disorder; obstructive sleep apnea; questionnaire; screening

(Received 29 February 2024; date of acceptance 20 April 2024)

**Corresponding author:** M. Kaminska; Email: [marta.kaminska@mcgill.ca](mailto:marta.kaminska@mcgill.ca)

**Cite this article:** Gomes T, Benedetti A, Postuma R, Rizzo D, Baltzan M, Kimoff RJ, and Kaminska M. Comparison of Sleep Apnea Questionnaires and Reported Diagnosis in Neurological Disorders of Aging. *The Canadian Journal of Neurological Sciences*, <https://doi.org/10.1017/cjn.2024.266>

© The Author(s), 2024. Published by Cambridge University Press on behalf of Canadian Neurological Sciences Federation.

## Introduction

Obstructive sleep apnea (OSA) is characterized by repetitive upper airway obstruction during sleep. OSA, defined by an apnea-hypopnea index  $\geq 15$  events per hour on polysomnography (PSG), is prevalent in 49.7% of men and 23.4% of women aged 40–85 years, and increases with age.<sup>1</sup> OSA remains largely underdiagnosed and undertreated in the general population (GP).<sup>2–4</sup> OSA contributes to poor outcomes like excessive daytime sleepiness, motor vehicle accidents, neurocognitive impairment and cardiometabolic diseases.<sup>5</sup>

Sleep disturbances are frequent in neurodegenerative diseases.<sup>6</sup> OSA is prevalent in 20–66% of individuals with Parkinson's disease (PD),<sup>7</sup> 38%–53% in Alzheimer's disease (AD)<sup>8</sup> and 30%–80% in stroke.<sup>9</sup> OSA appears to have a bidirectional association with several neurological disorders.<sup>10</sup> It is an independent risk factor for worse neurocognitive outcomes.<sup>11–13</sup> and treatment can improve neurocognitive,<sup>14–16</sup> and functional<sup>17–19</sup> outcomes. Hence OSA may be a modifiable risk factor in neurodegenerative conditions<sup>11</sup> but a large burden of untreated OSA remains.

PSG, the gold standard for diagnosis of OSA, is often difficult to obtain, costly and burdensome to individuals with neurodegenerative disease. Several screening instruments exist that might help identify patients at high risk for OSA (HROSA) for more targeted testing.<sup>20</sup> However, few tools have been validated specifically in neurological populations.

The primary aim for this study was to compare, in the Canadian Longitudinal Study on Aging (CLSA), the prevalence of HROSA using commonly used questionnaires and of self-reported OSA, in individuals with PD, AD, and stroke. Secondary aims were to compare the prevalence of HROSA and of self-reported OSA diagnosis between neurological conditions versus the general population (GP).

## Methods

We conducted a cross-sectional study using the CLSA, a population-based, prospective research cohort of older Canadians that recruited 51,338 participants, aged 45–85 years, with no major cognitive impairment.<sup>21</sup> The CLSA comprehensive cohort collected data through face-to-face and telephone interviews on demographic, social, medical, functional and other aspects relevant to aging at baseline with a plan for follow-up at three-year intervals. We used baseline (collected 2011–2015) and three-year follow-up data (collected 2015–2018). This study was approved by the Research Ethics Board of the McGill University Health Centre.

Stroke or TIA were ascertained with a positive answer to: “Has a doctor ever told you that you: have experienced a stroke or cerebrovascular accident (CVA); have experienced a mini-stroke or TIA; or suffer from the effects of a stroke, CVA, ministroke or TIA?”<sup>21</sup> PD (Parkinsonism) was identified based on an affirmative response to “Has a doctor ever told you that you had Parkinsonism or Parkinson's Disease?” combined with either taking PD medications or a score  $\geq 3$  on the Tanner Questionnaire.<sup>21,22</sup> AD was identified with a positive answer to: “Has a doctor ever told you that you have dementia or Alzheimer's disease?”. It should be noted that patients with major neurocognitive disorder are excluded from CLSA enrollment so AD patients would have mild impairment and not be representative of the whole AD population. Individuals were identified at baseline or at 3-year follow-up and were excluded from the general population.

Hypertension was defined as systolic blood pressure  $\geq 140$  mmHg or diastolic  $\geq 90$  mmHg (mean of 4 measures), history of

hypertension or taking antihypertensive medications. Diabetes, depression, thyroid dysfunction, chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD) and heart disease were identified from the questionnaire item: ‘Has a doctor ever told you that you have...’. Head trauma was ascertained with the question: Have you suffered a head injury from any of the following...? Participants who answered “yes” for being a current smoker or using any type of tobacco products were categorized as smokers. Participants were categorized as regular alcohol drinkers if they drank  $\geq 1$  time per week in the past 12 months.

The STOP questionnaire (snoring, tiredness, observed apneas, hypertension)<sup>23</sup> was included in the CLSA assessment. A score  $\geq 2$  is considered HROSA. The STOP-BAG<sup>24</sup> is based on the STOP-BANG<sup>25</sup> and consists of the STOP with body mass index (BMI)  $> 35$  kg/m<sup>2</sup>, age ( $> 50$  years) and gender (male). A score  $\geq 3$  indicates HROSA. The STOP-B28 is based on the STOP with BMI  $> 28$  kg/m<sup>2</sup>.<sup>26</sup> The GOAL questionnaire consists of gender (males), obesity ( $\geq 30$  kg/m<sup>2</sup>), age ( $\geq 50$  years), and loud snoring<sup>27</sup> items, with a score  $\geq 2$  indicating HROSA.<sup>27</sup> Because sex and age are risk factors for the neurological conditions, and because hypersomnolence can be a feature of the disease process, screening scores in these conditions can be driven upwards by factors unrelated to apnea. Therefore, we analyzed specific symptoms (questionnaire items) individually. Participants who self-reported OSA under “Do you have any other long-term physical or mental condition that has been diagnosed by a health professional?” were categorized as having self-reported OSA.

## Analyses

Patients with missing data were excluded. Descriptives statistics (mean, standard deviation, count, percentage) were used to report baseline characteristics of the study groups. We calculated the prevalence with 95% confidence intervals (CIs) of HROSA from each questionnaire and of individual OSA symptoms, for each of the groups (PD, AD, Stroke, GP). We compared the prevalence of HROSA and reported OSA within each group using Pearson chi-square test with False Discovery Rate corrections. Logistic regression was used to estimate odds ratios (ORs) for HROSA in neurological conditions versus the GP, unadjusted and adjusted for age, sex and BMI. We used analytic weights for better representation of the population in the regression analyses as provided by the CLSA.<sup>28</sup> Data were analyzed using SPSS 24.0 and R version 3.6.  $P < 0.05$  was considered statistically significant.

## Results

Baseline characteristics of participants included in our analyses are presented in Table 1. Among 30,097 participants included, 175 (0.58%) had PD, 125 (0.41%) had AD and 1791 (6.0%) had Stroke/TIA.

### Prevalence of symptoms and HROSA

The prevalence of snoring, sleepiness and observed apnea are shown in Table 2. Snoring was highly prevalent across all groups. Observed apnea was the second most prevalent variable in all groups. The combination of snoring and sleepiness presented a prevalence ranging from 3.5% to 6.5% across groups.

We found a positive GOAL to have the highest prevalence in all groups (Table 3) and most notably in Stroke/TIA (81.1%) and PD (79.3%). Positive STOP-BAG and STOP-B28 occurred in similar

**Table 1.** Demographic characteristics of participants with and without neurological conditions in the Canadian longitudinal study on aging

Parameters	PD (n = 175)	AD (n = 125)	Stroke/TIA (n = 1791)	General population (n = 28 006)
Age (years), mean(sd)	70.6 (9.1)	74.1 (9.2)	70.9 (9.7)	62.4 (10.1)
Gender (Male), n (%)	109 (62.3)	67 (53.6)	961 (53.7)	13 640 (48.7)
BMI (kg/m <sup>2</sup> ), mean(sd)	27.15 (4.6)	26.79 (4.7)	28.8 (5.8)	28.0 (5.4)
Smoking, N (%)	10 (5.7)	14 (11.2)	198 (11.1)	2836 (10.1)
Alcohol consumption, N (%)	88 (50.3)	50 (40.0)	887 (49.5)	16 231 (58.0)
Hypertension, N (%)	92 (52.6)	67 (53.6)	1329 (74.2)	13 024 (46.5)
Diabetes, N (%)	44 (25.3)	35 (28.0)	540 (30.2)	4723 (16.9)
Thyroid dysfunction, N (%)	31 (17.7)	21 (16.8)	325 (18.1)	4033 (14.4)
Depression, N (%)	24 (13.7)	22 (17.6)	348 (19.4)	4540 (16.2)
COPD, N (%)	16 (9.1)	8 (6.4)	214 (11.9)	1498 (5.4)
CKD, N (%)	9 (5.1)	6 (4.8)	134 (7.5)	741 (2.7)
Heart disease, N (%)	44 (25.1)	37 (29.6)	616 (34.4)	3026 (10.8)
Head trauma, N (%)	33 (18.9)	17 (13.6)	340 (19.0)	3879(13.9)

PD = Parkinson's Disease; AD = Alzheimer's Disease; TIA = Transient Ischemic Attack; COPD = Chronic obstructive pulmonary disease; CKD = Chronic kidney disease; BMI = Body Mass Index.

**Table 2.** Prevalence of OSA symptoms in neurological conditions and general population in the Canadian longitudinal study on aging

Parameters N (%) (95% CI)	PD (n = 175)	AD (n = 125)	Stroke/TIA (n = 1791)	General population (n = 28 006)
Snoring	62 (36.3) (29.4,43.7)	38 (33.0) (25.1,42.1)	667 (39.6) (37.3,42.0)	9185 (34.2) (33.7,34.8)
Snoring and sleepiness	11 (6.4) (3.6,11.2)	5 (4.4) (1.9,9.8)	110 (6.5) (5.4,7.8)	971 (3.6) (3.4,3.9)
Sleepiness,	31 (17.7) (12.8,24.1)	17 (13.6) (8.7,20.7)	259 (14.5) (13.0,16.2)	2415 (8.6) (8.3,9.0)
Observed apnea	32 (18.7) (13.6,25.2)	28 (24.1) (17.3,32.7)	404 (23.9) (22.0,26.0)	4388 (16.4) (16.0,16.8)

PD = Parkinson's Disease; AD = Alzheimer's Disease; TIA = Transient Ischemic Attack; N = total number of individuals in the population; CI = Confidence Interval.

**Table 3.** The prevalence of high risk of OSA using different definitions in neurological conditions and general population

Outcomes N (%; 95% CI)	PD (n = 175)	AD (n = 125)	Stroke/TIA (n = 1791)	General population (n = 28 006)
STOP $\geq$ 2,	63 (36.8; 30.0, 44.3)	36 (31.3;23.6,40.3)	797 (47.3;45.0,50.0)	7769 (29.0;28.4,29.5)
STOP-B28 $\geq$ 2	86 (51.2;43.7,58.7)	53 (46.1;37.3,55.2)	1101 (67.2;64.9,69.5)	12 472 (47.2;46.7,47.9)
STOP-BAG $\geq$ 3	98 (59.8; 50.8,65.5)	58 (55.2;45.7,64.4)	1152 (69.9;67.6,72.1)	13 757 (52.1;51.5,52.7)
GOAL $\geq$ 2,	130 (79.3;72.4,84.8)	80 (76.2;67.2,83.3)	1332 (81.1;79.2,83.0)	16 147 (61.2;60.6,61.8)
OSA diagnosis	1 (0.6;0.1,3.2)	1 (0.8;0.1,4.4)	16 (0.9;0.6,1.4)	341 (1.2;1.1,1.4)

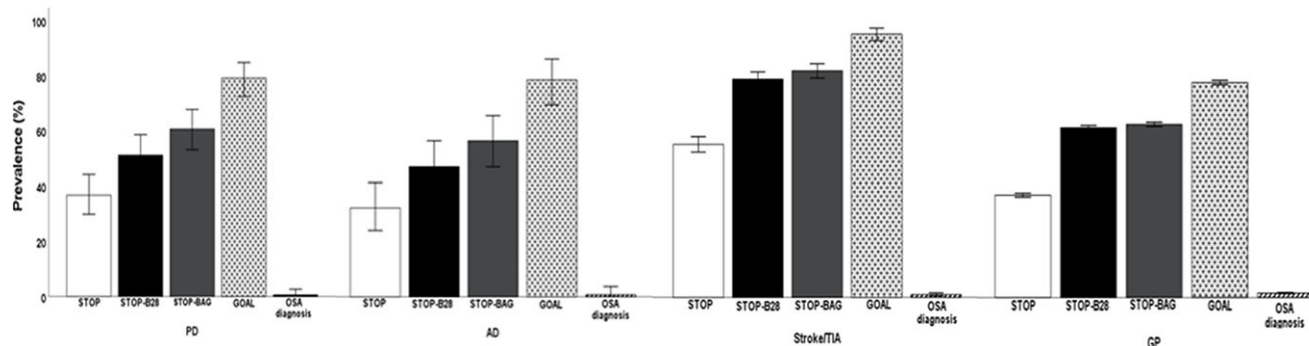
PD = Parkinson's Disease; AD = Alzheimer's Disease; TIA = Transient Ischemic Attack; BMI = Body Mass Index; N = total number of individuals in the population; CI = Confidence Interval.

proportions across all diagnostic groups. A positive STOP had the lowest prevalence of all questionnaires. OSA was self-reported in a much lower proportion than prevalence of HROSA by any questionnaire (Fig. 1).

### Neurological conditions vs. general population

To compare prevalence of symptoms, HROSA and OSA diagnosis between neurological disorders versus the GP, we performed logistic regression. In adjusted analyses, all OSA symptoms were more likely in individuals with stroke than the GP, including

snoring with sleepiness. Participants with PD had higher odds of sleepiness than the GP. Those with AD had higher odds of observed apnea compared with the GP (Table 2). Table 4 shows ORs for HROSA in neurological disorders versus the GP. Individuals with stroke had higher adjusted odds of HROSA for each questionnaire. Individuals with PD showed higher odds for positive STOP-BAG and GOAL only. Those with AD had lower odds for positive STOP-B28 but higher for positive GOAL, compared with the GP. There were no significant differences between any neurological disorder and the GP with respect to self-reported OSA diagnosis.



**Figure 1.** Bar graph comparing the prevalence of high risk of OSA using different definitions in neurological conditions and the general population. The prevalence was statistically significantly different between all OSA measures (questionnaires or OSA diagnosis) within each study group, except for STOP-BAG vs. STOP-B28 in PD, AD and stroke. Differences within-group tested with Pearson chi-squared and post hoc false discovery rate correction.

**Table 4.** Logistic regression analysis comparing prevalence of high risk of OSA using different definitions in neurological conditions versus the general population

Outcomes OR (95% CI)	PD (n = 175)		AD (n = 125)		Stroke/TIA (n = 1791)	
	Unadjusted	Adjusted <sup>1</sup>	Unadjusted	Adjusted <sup>1</sup>	Unadjusted	Adjusted <sup>1</sup>
STOP ≥ 2	1.5* (1.1,2.0)	1.2 (0.8,1.6)	1.1 (0.8,1.7)	0.7 (0.4, 1.1)	2.2* (2.1,2.5)	1.8* (1.6,2.0)
STOP-BAG ≥ 3	1.7* (1.2,2.3)	1.5 * (1.1,2.1)	1.3 (0.9,1.9)	1.2 (0.8,1.8)	2.5* (2.2,2.8)	2.4* (2.1,2.6)
STOP-B28 ≥ 2	1.2 (0.9,1.6)	1.0 (0.7,1.5)	0.9 (0.6,1.4)	0.6* (0.4,1.0)	2.3* (2.1,2.5)	1.9* (1.7,2.1)
GOAL ≥ 2	2.6* (1.8,3.8)	1.7 * (1.0,2.7)	2.1* (1.4,3.4)	1.9* (1.1,3.4)	2.9* (2.5,3.3)	2.7* (2.3,3.1)
OSA diagnosis	0.5 (0.03,2.1)	0.07 (2.2 <sup>-6</sup> ,1.4)	0.65 (0.04,2.9)	0.1 (2.1 <sup>-6</sup> ,1.7)	0.7 (0.4,1.2)	0.7 (0.4, 1.1)

PD = Parkinson's Disease; AD = Alzheimer's Disease; TIA = Transient Ischemic Attack; OR = Odds ratio; OSA = Obstructive sleep apnea; CI = Confidence Interval.

<sup>1</sup>OR values adjusted for age, sex and BMI

\*Significant *p*-value at < 0.05.

## Discussion

In this study, we found that different screening questionnaires result in a wide range of estimated prevalence of HROSA in older adults with and without neurological disorders, while OSA may be heavily underreported. Our findings indicate prevalence of questionnaire-based HROSA of 47%–81% in stroke, 37%–79% in PD and 31%–76% for AD (Table 3). Questionnaires in the somewhat younger GP were positive in 21%–61% of participants. Individuals with stroke were consistently more likely to have positive questionnaires than the GP. This corresponds to the high previously documented prevalence of OSA in stroke patients.<sup>9,29</sup> Compared with the GP, individuals with PD were more likely to have a positive STOP-BAG and GOAL. Individuals with AD were more likely to have a positive GOAL, but less likely to have a positive STOP-B28.

The prevalence of OSA increases with age, estimated at more than 60% of people aged 65–99.<sup>30–32</sup> This is associated with age-related physiological changes such as decreased endurance and strength of head and neck muscles, hormonal, sleep, respiratory chemosensitivity alterations and comorbidities.<sup>32</sup> Several screening questionnaires have been developed to identify HROSA, which might be used to prioritize patients for sleep testing, or in epidemiological studies. Using the STOP with percentage of body fat, the estimated prevalence of OSA was 17.5% in the CLSA baseline cohort.<sup>33</sup> However, only few studies have validated OSA screening tools in older populations or in neurodegenerative disorders.<sup>26,34,35</sup> In the elderly, a lower BMI cutoff than used in

middle-aged individuals has been found to be predictive of OSA, yielding an adapted tool, the STOP-B28.<sup>26</sup> In stroke patients, the STOP has been shown to have good characteristics with sensitivity 91% and specificity 93%.<sup>36</sup> The STOP-BAG had a sensitivity of 91% but lower specificity of 48%.<sup>37</sup> This suggests that the prevalence of HROSA ascertained by STOP, in individuals with stroke in our CLSA population, closely reflects the true prevalence of OSA in that group. OSA is known to be highly prevalent in stroke and an independent risk factor for stroke.<sup>38</sup> It may predate stroke, worsen during acute stages, and persist subsequently.<sup>39</sup> OSA is associated with recurrent stroke, cognitive decline and increased physical disability.<sup>9</sup> Given the high prevalence of OSA and related adverse outcomes, it has been argued all stroke patients should be screened for OSA, irrespective of symptoms or other risk factors, and treated if OSA is found.<sup>11</sup> Conversely, prescreening with a questionnaire like STOP may help reduce testing burden and help efficient resources utilization.

In a previous study,<sup>35</sup> our group examined the diagnostic characteristics of OSA questionnaires in a PD clinical cohort. We found that GOAL ≥ 2 had the highest sensitivity (83%) but low specificity (35%), STOP-BAG ≥ 3 had sensitivity 74%, specificity 40%, STOP-B28 ≥ 2 sensitivity 76%, specificity 65% and STOP ≥ 2 sensitivity 65%, specificity 70%. These results are congruent with the current study, with the highest rate of HROSA identified by GOAL in each group, and the lowest with STOP. It is probable that GOAL and STOP-BAG are identifying more false positive cases given their lower specificity, especially given demographics of the



**Table 5.** Logistic regression analysis comparing OSA symptoms in neurological conditions versus the general population

Outcomes OR (95% CI)	PD (n = 175)		AD (n = 125)		Stroke/TIA (n = 1791)	
	Unadjusted	Adjusted <sup>1</sup>	Unadjusted	Adjusted <sup>1</sup>	Unadjusted	Adjusted <sup>1</sup>
Snoring	1.1 (0.8,1.5)	1.1 (0.8,1.5)	0.9 (0.6,1.4)	0.7 (0.5,1.1)	1.3* (1.1,1.4)	1.2* (1.1,1.3)
Snoring and sleepiness	1.9* (1.0,3.4)	1.2 (0.6,2.4)	1.3 (0.4,2.8)	0.6 (0.1,1.8)	1.9* (1.6,2.4)	1.7* (1.3,2.1)
Sleepiness	2.3* (1.5,3.3)	2.1* (1.3,3.0)	1.7 (1.0,2.7)	1.6 (0.9,2.6)	1.8* (1.6,2.1)	1.5* (1.3,1.8)
Observed apnea	1.2 (0.8,1.7)	1.2 (0.8,1.8)	1.6* (1.0,2.5)	1.9* (1.2,3.1)	1.6* (1.4,1.8)	1.5* (1.4,1.7)

PD = Parkinson's Disease; AD = Alzheimer's Disease; TIA = Transient Ischemic Attack; OR = odds ratio; OSA = Obstructive sleep apnea; CI = Confidence Interval.

<sup>1</sup>OR values adjusted for age, sex and BMI

\*Significant *p*-value at < 0.05.

population in question. Studies in PD have yielded inconsistent results with some studies finding that OSA is more common in PD and associated with its severity<sup>40</sup> and others finding no association,<sup>41</sup> possibly due to different OSA definitions, study populations or confounders such as medications. A recent meta-analysis found OSA to be present in close to 50% of PD patients,<sup>42</sup> and PD and non-PD risk factors were identified. The mechanisms contributing to the association between OSA and PD are not fully understood but there appears to be a causal bidirectional link.<sup>43</sup> Treatment of OSA in PD has been found to be beneficial.<sup>16,44</sup> More research is needed to confirm OSA relationships and benefits of treatment but data to date suggest benefit to identify and treat OSA in PD when possible.

OSA is found with increased prevalence in patients with AD.<sup>45</sup> Preexisting OSA is associated with increased risk of AD.<sup>46</sup> OSA treatment may improve outcomes.<sup>47,14</sup> OSA is also a risk factor for hypertension, diabetes, depression and heart failure, all of which are common risk factors for AD.<sup>48</sup> The STOP-BANG has been evaluated in AD<sup>49</sup> and found to have sensitivity 77% for at least moderate OSA but specificity of only 35%; modification of cutoffs for certain questions, e.g. age, BMI improved the characteristics of the questionnaire. This latter study and the one by Martins *et al.*<sup>26</sup> demonstrate that questionnaires developed for OSA screening of middle-aged individuals may not be well-suited for older individuals with or without neurodegenerative disorders. Moreover, cognitive decline may affect reliability of self-reported questionnaires. Currently, none of the commonly used questionnaires have been shown to have adequate diagnostic characteristics in AD, particularly in more advanced stages.

Participants with neurodegenerative conditions are more likely to be male and > 50 years old, which are both risk factors for OSA. Therefore, the GOAL and STOP-BAG, which include these two components, may not adequately distinguish those with OSA among individuals with neurodegenerative conditions (e.g. > 50% of PD patients would have a positive score based solely on sex and age). Snoring and BMI are best discriminatory factors for OSA in the GP.<sup>50,51</sup> However, the threshold of 30 kg/m<sup>2</sup> in GOAL and 35 kg/m<sup>2</sup> in STOP-BAG may not be suitable for older individuals or those with neurological conditions.<sup>26</sup> We found all OSA symptoms to be more common in individuals with stroke compared with the GP (Table 5). Sleepiness was more common in individuals with PD. This is consistent with known high prevalence of sleepiness in PD, with OSA being one of multiple contributing causes.<sup>52</sup> Individuals with AD were more likely to have observed apneas compared with the GP. Though the confidence intervals are wide, the potential differences in

symptoms further support the need for development and validation of specific tools for distinct patient populations.

Given the significant impact of OSA on health and quality of life in aging individuals with neurological diseases, screening, diagnosis and treatment can have a meaningful impact on these patients, caregivers and the healthcare system. Previous studies estimated that over 80% of individuals of all ages with moderate-to-severe OSA remain undiagnosed and untreated.<sup>4</sup> Only 3% of Canadians aged 18 years or older received a formal OSA diagnosis despite high rates of symptoms.<sup>53</sup> Our findings show that only a small proportion of older individuals in the CLSA cohort self-reported an OSA diagnosis despite having OSA symptoms (Fig. 1). Low diagnosis may have several causes such as poor symptom reporting to physicians, lack of access to medical care including specialist evaluation<sup>54</sup> and testing, lack of recognition of OSA as a possible diagnosis by physicians or perception that it is not worth pursuing in this population. Alternatively, a diagnosis may have been made but not reported by patients due to poor recall or understanding. While not statistically significant, reported diagnosis of OSA in those with neurological disorders was lower than in the GP. We suspect that Canadians with neurological diagnoses might not be as frequently assessed for OSA while they might benefit most from treatment, this warrants further investigation.

### Strengths and limitations

To date, our study is the first comparing different screening instruments for HROSA in neurological diseases, using a large population cohort that included the STOP assessment. Several limitations are noted. First, neurological conditions were self-reported. Second, there were no objective measures of OSA. Reporting OSA symptoms and diagnosis depends on participant recall and could be underreported due to low perceived importance. However, this emphasizes the point that older individuals do not perceive OSA as a significant medical condition, despite the associated adverse outcomes. There is also no information on the use of Continuous Positive Airway Pressure or other OSA therapy. Moreover, self-selection bias may have resulted in a study population not be fully representative of the Canadian population. Patients with moderate-severe dementia were excluded from the CLSA baseline evaluation, hence we cannot extrapolate results to advanced stages of the diseases. Participants in the CLSA were more educated, had higher household incomes, and were mostly White and Canadian-born, which may negatively influence the generalizability and external validity of results.<sup>55</sup>

## Conclusion

In conclusion, we report, in a population-based cohort, that prevalence of HROSA in individuals with stroke, PD, AD and the GP, varies widely depending on screening tool. While all questionnaires suggest a higher prevalence of OSA in stroke/TIA than the GP, for PD and AD, there was wide variation of estimated prevalence depending on questionnaire. A self-reported diagnosis of OSA was found in a much smaller proportion of patients, suggesting that OSA is underdiagnosed or underreported in older adults. Strategies should be implemented to improve awareness of OSA in older Canadians and their healthcare providers with shared decision-making on testing and treatment.

**Acknowledgements.** We thank Dr Nadia Gosselin for her help with the CLSA dataset.

**Author contributions.** TG: design of the study, data preparation and analyses, interpretation of the data, manuscript writing, provided final approval for publication, and accepted accountability for all aspects of the work, AB: design of the study, help with data analyses, interpretation of the data, critical review, approval for publication and accepted accountability for all aspects of the work, RP: critical review, approval for publication and accepted accountability for all aspects of the work, DR: help with data, critical review, approval for publication and accepted accountability for all aspects of the work, MB: interpretation of the data, critical review, approval for publication and accepted accountability for all aspects of the work, RJK: interpretation of the data, critical review, approval for publication and accepted accountability for all aspects of the work, MK: study conceptualization, design and interpretation of the data, manuscript writing, critical review, approval for publication and accepted accountability for all aspects of the work.

**Funding statement.** CIHR Catalyst Grant: Analysis of Canadian Longitudinal Study in Aging (CLSA) Data (ACD-187256).

**Competing interests.** The author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication. Declaration for each author: TG: None, AB: None, RP: grants and personal fees from Fonds de la Recherche en Sante, grants from Canadian Institute of Health Research, grants from Michael J. Fox Foundation, grants from Webster Foundation, personal fees from Biogen, personal fees from Curasen, personal fees from Novartis, personal fees from Eisai, other from Parkinson Canada, grants from National Institute of Health, personal fees from International Parkinson and Movement Disorders Society, personal fees from Merck, personal fees from Vaxxinity, personal fees from Bristol Myers Squibb, personal fees from Clinilabs, personal fees from Ventus, personal fees from Korro, personal fees from Calico, outside the submitted work. DR: None, MB: research grants from Lady Davis Institute for Medical Research, Ministère des transports du Québec and the Réseau de recherche en sécurité routière, various speakers fees Eisai, Idorsia, GSK, Astra-Zeneca, Jazz Pharmaceuticals, Canadian Academy of Clinical Sleep Disorders Disciplines, FMOQ, FMSQ, CIUSSS Centre-Ouest de l'île de Montréal, fiduciary role in Canadian Academy of Clinical Sleep Disorders Disciplines, RJK: research grants from the Canadian Institutes of Health Research, The Multiple Sclerosis Society of Canada, Fonds de Recherche du Québec – Santé, Research operating funds from Philips-Respironics Inc., Equipment support from ResMed Inc., and VitalAire Inc., Advisory board: Powell-Mansfield Inc., Eisai Inc., MK: Temple, Quebec Sleep Network, and various speaker fees, Research grants and in-kind support from Philips, the American Thoracic Society Foundation, Canadian Institutes for Health Research; Advisory Committee for Biron Soins du Sommeil; Advisory Board for Jazz Pharmaceuticals.

## References

- Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. *Lancet Respir Med.* 2015;3:310–8. DOI: [10.1016/s2213-2600\(15\)00043-0](https://doi.org/10.1016/s2213-2600(15)00043-0).

- Kapur V, Strohl KP, Redline S, Iber C, O'Connor G, Nieto J. Underdiagnosis of sleep apnea syndrome in U.S. communities. *Sleep Breath.* 2002;6:49–54. DOI: [10.1007/s11325-002-0049-5](https://doi.org/10.1007/s11325-002-0049-5).
- Fuhrman C, Fleury B, Nguyễn XL, Delmas MC. Symptoms of sleep apnea syndrome: high prevalence and underdiagnosis in the French population. *Sleep Med.* 2012;13:852–8. DOI: [10.1016/j.sleep.2012.04.005](https://doi.org/10.1016/j.sleep.2012.04.005).
- Flemons WW, Douglas NJ, Kuna ST, Rodenstein DO, Wheatley J. Access to diagnosis and treatment of patients with suspected sleep apnea. *Am J Respir Crit Care Med.* 2004;169:668–72. DOI: [10.1164/rccm.200308-1124PP](https://doi.org/10.1164/rccm.200308-1124PP).
- Knauer M, Naik S, Gillespie MB, Kryger M. Clinical consequences and economic costs of untreated obstructive sleep apnea syndrome. *World J Otorhinolaryngol Head Neck Surg.* 2015;1:17–27. DOI: [10.1016/j.wjorl.2015.08.001](https://doi.org/10.1016/j.wjorl.2015.08.001).
- Miner B, Kryger MH. Sleep in the aging population. *Sleep Med Clin.* 2017;12:31–8. DOI: [10.1016/j.jsmc.2016.10.008](https://doi.org/10.1016/j.jsmc.2016.10.008).
- Neto MS, Pereira M, Sobreira E, França Fernandes R, Tumas V, Eckeli A. Obstructive sleep apnea syndrome in Parkinson's disease: preliminary results. *Sleep Med.* 2013;14:e112. DOI: [10.1016/j.sleep.2013.11.246](https://doi.org/10.1016/j.sleep.2013.11.246).
- Gaeta AM, Benítez ID, Jorge C, et al. Prevalence of obstructive sleep apnea in Alzheimer's disease patients. *J Neurol.* 2020;267:1012–22. DOI: [10.1007/s00415-019-09668-4](https://doi.org/10.1007/s00415-019-09668-4).
- Liu X, Lam DC, Chan KPF, Chan HY, Ip MS, Lau KK. Prevalence and determinants of sleep apnea in patients with stroke: a meta-analysis. *J Stroke Cerebrovasc Dis.* 2021;30:106129. DOI: [10.1016/j.jstrokecerebrovasdis.2021.106129](https://doi.org/10.1016/j.jstrokecerebrovasdis.2021.106129).
- Rosenzweig I, Glasser M, Polsek D, Leschziner GD, Williams SC, Morrell MJTLRM. Sleep apnoea and the brain: a complex relationship. *Lancet Respir Med.* 2015;3:404–14.
- Boulos MI. The case for improving the detection and treatment of obstructive sleep apnea following stroke. *Can Med Assoc J.* 2023;195:E374–E5. DOI: [10.1503/cmaj.230240](https://doi.org/10.1503/cmaj.230240).
- Bubu OM, Andrade AG, Umasabor-Bubu OQ, et al. Obstructive sleep apnea, cognition and Alzheimer's disease: a systematic review integrating three decades of multidisciplinary research. *Sleep Med Rev.* 2020;50:101250. DOI: [10.1016/j.smrv.2019.101250](https://doi.org/10.1016/j.smrv.2019.101250).
- Gosselin N, Baril AA, Osorio RS, Kaminska M, Carrier J. Obstructive sleep apnea and the risk of cognitive decline in older adults. *Am J Respir Crit Care Med.* 2019;199:142–8. DOI: [10.1164/rccm.201801-0204PP](https://doi.org/10.1164/rccm.201801-0204PP).
- Costa YS, Lim ASP, Thorpe KE, et al. Investigating changes in cognition associated with the use of CPAP in cognitive impairment and dementia: a retrospective study. *Sleep Med.* 2023;101:437–44. DOI: [10.1016/j.sleep.2022.11.037](https://doi.org/10.1016/j.sleep.2022.11.037).
- Shieu MM, Zaheed A, Shannon C, et al. Positive airway pressure and cognitive disorders in adults with obstructive sleep apnea: a systematic review of the literature. *Neurology.* 2022;9:e334–46. DOI: [10.1212/wnl.000000000200383](https://doi.org/10.1212/wnl.000000000200383).
- Kaminska M, Mery VP, Lafontaine AL, et al. Change in cognition and other non-motor symptoms with obstructive sleep apnea treatment in Parkinson disease. *J Clin Sleep Med.* 2018;14:819–28. DOI: [10.5664/jcsm.7114](https://doi.org/10.5664/jcsm.7114).
- Ryan CM, Bayley M, Green R, Murray BJ, Bradley TD. Influence of continuous positive airway pressure on outcomes of rehabilitation in stroke patients with obstructive sleep apnea. *Stroke.* 2011;42:1062–7. DOI: [10.1161/strokeaha.110.597468](https://doi.org/10.1161/strokeaha.110.597468).
- Parra O, Sánchez-Armengol A, Bonnin M, et al. Early treatment of obstructive apnoea and stroke outcome: a randomised controlled trial. *Eur Respir J.* 2011;37:1128–36. DOI: [10.1183/09031936.00034410](https://doi.org/10.1183/09031936.00034410).
- Aaronson JA, Hofman WF, van Bennekom CA, et al. Effects of continuous positive airway pressure on cognitive and functional outcome of stroke patients with obstructive sleep apnea: a randomized controlled trial. *J Clin Sleep Med.* 2016;12:533–41. DOI: [10.5664/jcsm.5684](https://doi.org/10.5664/jcsm.5684).
- Ramachandran SK, Josephs LA. A meta-analysis of clinical screening tests for obstructive sleep apnea. *Anesthesiology.* 2009;110:928–39. DOI: [10.1097/ALN.0b013e31819c47b6](https://doi.org/10.1097/ALN.0b013e31819c47b6).
- Raina PS, Wolfson C, Kirkland SA, et al. Ascertainment of chronic diseases in the Canadian longitudinal study on aging (CLSA), systematic review. *Can J Aging.* 2009;28:275–85. DOI: [10.1017/s071498080999002x](https://doi.org/10.1017/s071498080999002x).

22. Oremus M, Postuma R, Griffith L, et al. Validating chronic disease ascertainment algorithms for use in the Canadian longitudinal study on aging. *Can J Aging*. 2013;32:232–9. DOI: [10.1017/s0714980813000275](https://doi.org/10.1017/s0714980813000275).
23. Chung F, Yegneswaran B, Liao P, et al. STOP questionnaire: a tool to screen patients for obstructive sleep apnea. *Anesthesiology*. 2008;108:812–21. DOI: [10.1097/ALN.0b013e31816d83e4](https://doi.org/10.1097/ALN.0b013e31816d83e4).
24. Waseem R, Salama Y, Baltzan M, Chung F. Comparison of STOP-Bang and STOP-Bag questionnaires in stratifying risk of obstructive sleep apnea. *Can J Respir Crit Care Sleep Med*. 2022;6:1–8. DOI: [10.1080/24745332.2022.2057883](https://doi.org/10.1080/24745332.2022.2057883).
25. Nagappa M, Liao P, Wong J, et al. Validation of the STOP-bang questionnaire as a screening tool for obstructive sleep apnea among different populations: a systematic review and meta-analysis. *PLoS One*. 2015;10:e0143697. DOI: [10.1371/journal.pone.0143697](https://doi.org/10.1371/journal.pone.0143697).
26. Martins EF, Martinez D, Cortes AL, Nascimento N, Brendler J. Exploring the STOP-BANG questionnaire for obstructive sleep apnea screening in seniors. *J Clin Sleep Med*. 2020;16:199–206. DOI: [10.5664/jcsm.8166](https://doi.org/10.5664/jcsm.8166).
27. Duarte RL, Magalhães-da-Silveira FJ, Oliveira ESTS, Silva JA, Mello FC, Gozal D. Obstructive sleep apnea screening with a 4-item instrument, named GOAL questionnaire: development, validation and comparative study with No-Apnea, STOP-bang, and NoSAS. *Nat Sci Sleep*. 2020;12:57–67. DOI: [10.2147/nss.S238255](https://doi.org/10.2147/nss.S238255).
28. CLSA TECHNICAL DOCUMENT. Sampling and computation of response rates and sample weights for the tracking (Telephone interview) participants and comprehensive participants. *Can Longitud Study Aging*. 2017. <https://www.clsa-elcv.ca/doc/1041>. Accessed 19 March 2024.
29. Hasan F, Gordon C, Wu D, et al. Dynamic prevalence of sleep disorders following stroke or transient ischemic attack: systematic review and meta-analysis. *Stroke*. 2021;52:655–63. DOI: [10.1161/strokeaha.120.029847](https://doi.org/10.1161/strokeaha.120.029847).
30. Laratta CR, Ayas NT, Povitz M, Pendharkar SR. Diagnosis and treatment of obstructive sleep apnea in adults. *CMAJ*. 2017;189:E1481–E1488. DOI: [10.1503/cmaj.170296](https://doi.org/10.1503/cmaj.170296).
31. Braley TJ, Dunitz GL, Chervin RD, Lisabeth LD, Skolarus LE, Burke JF. Recognition and diagnosis of obstructive sleep apnea in older Americans. *J Am Geriatr Soc*. 2018;66:1296–302. DOI: [10.1111/jgs.15372](https://doi.org/10.1111/jgs.15372).
32. Ralls F, Cutchen L. A contemporary review of obstructive sleep apnea. *Curr Opin Pulm Med*. 2019;25:578–93. DOI: [10.1097/mcp.0000000000000623](https://doi.org/10.1097/mcp.0000000000000623).
33. Thompson C, Legault J, Moullec G, et al. A portrait of obstructive sleep apnea risk factors in 27,210 middle-aged and older adults in the Canadian longitudinal study on aging. *Sci Rep*. 2022;12:5127. DOI: [10.1038/s41598-022-08164-6](https://doi.org/10.1038/s41598-022-08164-6).
34. Godoy PH, Nucera A, Colcher AP, de-Andrade JE, Alves D. Screening for obstructive sleep apnea in elderly: performance of the Berlin and STOP-bang questionnaires and the Epworth sleepiness scale using polysomnography as gold standard. *Sleep Sci*. 2022;15:203–8. DOI: [10.5935/1984-0063.20220020](https://doi.org/10.5935/1984-0063.20220020).
35. Gomes T, Benedetti A, Lafontaine A-L, Kimoff RJ, Robinson A, Kaminska M. Validation STOP-B28, and GOAL screening tools for identification of obstructive sleep apnea in patients with Parkinson disease. *J Clin Sleep Med*. 2023;19:45–54. DOI: [10.5664/jcsm.10262](https://doi.org/10.5664/jcsm.10262).
36. Swartz RH, Cayley ML, Lancôt KL, et al. The “DOC” screen: feasible and valid screening for depression, obstructive sleep apnea (OSA) and cognitive impairment in stroke prevention clinics. *PLoS One*. 2017;12:e0174451. DOI: [10.1371/journal.pone.0174451](https://doi.org/10.1371/journal.pone.0174451).
37. Katzan IL, Thompson NR, Uchino K, Foldvary-Schaefer N. A screening tool for obstructive sleep apnea in cerebrovascular patients. *Sleep Med*. 2016;21:70–6. DOI: [10.1016/j.sleep.2016.02.001](https://doi.org/10.1016/j.sleep.2016.02.001).
38. Xie C, Zhu R, Tian Y, Wang K. Association of obstructive sleep apnoea with the risk of vascular outcomes and all-cause mortality: a meta-analysis. *BMJ Open*. 2017;7:e013983. DOI: [10.1136/bmjopen-2016-013983](https://doi.org/10.1136/bmjopen-2016-013983).
39. Young T, Palta M, Dempsey J, Peppard PE, Nieto FJ, Hla KM. Burden of sleep apnea: rationale, design, and major findings of the Wisconsin sleep cohort study. *WMJ*. 2009;108:246–9.
40. Crosta F, Desideri G, Marini C. Obstructive sleep apnea syndrome in Parkinson’s disease and other parkinsonisms. *Funct Neurol*. 2017;32:137–41. DOI: [10.11138/fneur/2017.32.3.137](https://doi.org/10.11138/fneur/2017.32.3.137).
41. De Cock VC, Abouda M, Leu S, et al. Is obstructive sleep apnea a problem in Parkinson’s disease? *Sleep Med*. 2010;11:247–52.
42. Maggi G, Giacobbe C, Iannotta F, Santangelo G, Vitale C. Prevalence and clinical aspects of obstructive sleep apnea in Parkinson disease: a meta-analysis. *Eur J Neurol*. 2024;31:e16109. DOI: [10.1111/ene.16109](https://doi.org/10.1111/ene.16109).
43. Jeon SH, Hwang YS, Oh SY, et al. Bidirectional association between Parkinson’s disease and obstructive sleep apnea: a cohort study. *J Clin Sleep Med*. 2023;19:1615–23. DOI: [10.5664/jcsm.10596](https://doi.org/10.5664/jcsm.10596).
44. Neikrug AB, Liu L, Avanzino JA, et al. Continuous positive airway pressure improves sleep and daytime sleepiness in patients with Parkinson disease and sleep apnea. *Sleep*. 2014;37:177–85. DOI: [10.5665/sleep.3332](https://doi.org/10.5665/sleep.3332).
45. Emamian F, Khazaie H, Tahmasian M, et al. The association between obstructive sleep apnea and alzheimer’s disease: a meta-analysis perspective. *Front Aging Neurosci*. 2016;8:78. DOI: [10.3389/fnagi.2016.00078](https://doi.org/10.3389/fnagi.2016.00078).
46. Osorio RS, Gumb T, Pirraglia E, et al. Sleep-disordered breathing advances cognitive decline in the elderly. *Neurology*. 2015;84:1964–71. DOI: [10.1212/wnl.0000000000001566](https://doi.org/10.1212/wnl.0000000000001566).
47. Cooke JR, Ayalon L, Palmer BW, et al. Sustained use of CPAP slows deterioration of cognition, sleep, and mood in patients with Alzheimer’s disease and obstructive sleep apnea: a preliminary study. *J Clin Sleep Med*. 2009;5:305–9.
48. Gaines J, Vgontzas AN, Fernandez-Mendoza J, Bixler EO. Obstructive sleep apnea and the metabolic syndrome: the road to clinically-meaningful phenotyping, improved prognosis, and personalized treatment. *Sleep Med Rev*. 2018;42:211–9. DOI: [10.1016/j.smrv.2018.08.009](https://doi.org/10.1016/j.smrv.2018.08.009).
49. Jorge C, Benitez I, Torres G, et al. The STOP-bang and Berlin questionnaires to identify obstructive sleep apnoea in Alzheimer’s disease patients. *Sleep Med*. 2019;57:15–20. DOI: [10.1016/j.sleep.2019.01.033](https://doi.org/10.1016/j.sleep.2019.01.033).
50. Kolotkin RL, LaMonte MJ, Walker JM, Cloward TV, Davidson LE, Crosby RD. Predicting sleep apnea in bariatric surgery patients. *Surg Obes Relat Dis*. 2011;7:605–10. DOI: [10.1016/j.soard.2011.04.226](https://doi.org/10.1016/j.soard.2011.04.226).
51. Duarte RL, Magalhães-da-Silveira FJ. Factors predictive of obstructive sleep apnea in patients undergoing pre-operative evaluation for bariatric surgery and referred to a sleep laboratory for polysomnography. *J Bras Pneumol*. 2015;41:440–8. DOI: [10.1590/s1806-37132015000000027](https://doi.org/10.1590/s1806-37132015000000027).
52. Sobreira-Neto MA, Pena-Pereira MA, Sobreira EST, et al. High frequency of sleep disorders in parkinson’s disease and its relationship with quality of life. *Eur Neurol*. 2017;78:330–7. DOI: [10.1159/000481939](https://doi.org/10.1159/000481939).
53. PHAC. What is the impact of sleep apnea on Canadians? Fast facts from the 2009 Canadian Community Health Survey — sleep apnea rapid response. Ottawa: Public Health Agency of Canada;2010. Available: [www.phac-aspc.gc.ca/cd-mc/sleepapnea-apneesommeil/pdf/sleep-apnea.pdf](http://www.phac-aspc.gc.ca/cd-mc/sleepapnea-apneesommeil/pdf/sleep-apnea.pdf). Accessed September 10, 2022.
54. Karunanayake CP, Rennie DC, Hagel L, et al. Access to specialist care in rural saskatchewan: the Saskatchewan rural health study. *Healthcare (Basel)*. 2015;3:84–99. DOI: [10.3390/healthcare3010084](https://doi.org/10.3390/healthcare3010084).
55. Raina P, Wolfson C, Kirkland S, et al. Cohort profile: the Canadian longitudinal study on aging (CLSA). *Int J Epidemiol*. 2019;48:1752–3j. DOI: [10.1093/ije/dyz173](https://doi.org/10.1093/ije/dyz173).