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Original Article

Screening for obstructive sleep apnea syndrome in patients with type 2 diabetes mellitus: a prospective study on sensitivity of Berlin and STOP-Bang questionnaires

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ABSTRACT

Background: Obstructive sleep apnea (OSA) is highly prevalent in patients with Type 2 diabetes mellitus representing an additional risk factor for already increased cardiovascular mortality. As cardiovascular diseases are the main cause of death in this population, there is a need to identify patients with moderate to severe OSA indicated for treatment. We aimed to evaluate the performance of the Berlin, STOP, and STOP-Bang screening questionnaires in a population of patients with Type 2 diabetes mellitus.
Methods: 294 consecutive patients with Type 2 diabetes mellitus filled in the questionnaires and underwent overnight home sleep monitoring using a type IV sleep monitor.
Results: Severe, moderate, and mild OSA was found in 31 (10%), 61 (21%), and 121 (41%) patients, respectively. The questionnaires showed a similar sensitivity and specificity for AHI ≥ 15: 0.69 and 0.50 for Berlin, 0.65 and 0.49 for STOP, and 0.59 and 0.68 for STOP-Bang. However, the performance of the STOP-Bang questionnaire was different in men vs. women, sensitivity being 0.74 vs. 0.29 ($p < 0.05$) and specificity 0.56 vs. 0.82 ($p < 0.05$).
Conclusions: Even the best-performing Berlin questionnaire failed to identify 31% of patients with moderate to severe OSA as being at high risk of OSA, thus preventing them from receiving a correct diagnosis and treatment. Considering that patients with Type 2 diabetes mellitus are at high risk of cardiovascular mortality and also have a high prevalence of moderate to severe OSA, we find screening based on the questionnaires suboptimal and suggest that OSA screening should be performed using home sleep monitoring devices.

1. Introduction

Obstructive sleep apnea syndrome (OSA) is a treatable sleep disorder characterized by repetitive partial or complete occlusion of the upper airway during sleep despite effort to breathe, leading to oxygen desaturations and sleep fragmentation. The severity of OSA is described by the number of apnea and hypopnea events per hour during sleep, also known as apnea–hypopnea index (AHI). According to The American Academy of Sleep Medicine guidelines, mild OSA is defined by AHI 5–14, moderate OSA by AHI 15–29, and severe OSA by AHI 30 or more [1]. In the population of patients with Type 2 diabetes mellitus, the prevalence of OSA reaches 50–75%, while moderate or severe OSA, which is recommended for continuous positive airway pressure treatment (CPAP) regardless of the presence of sleep related symptoms [1], is found in 25–35% of patients [2–4].

Patients with Type 2 diabetes mellitus have a shorter life expectancy mainly due to cardiovascular and cerebrovascular diseases [5]. It is therefore important, along with maintaining optimal glucose levels, to promptly address the major cardiovascular risk factors such as hypertension, dyslipidemia, obesity, and smoking. The detection and subsequent treatment of OSA is often omitted, even though epidemiological studies demonstrate that severe OSA is associated with higher cardiovascular as well as all-cause mortality [6–8]. Treatment of OSA has been shown to significantly reduce cardiovascular mortality [9–11] and all-cause mortality in men [12]. Also, an increasing number of studies provide strong evidence of an association between OSA, insulin resistance, and impaired glucose tolerance independent of shared risk factors [13]. Recent studies demonstrated that OSA treatment may improve insulin sensitivity in subjects with diabetes and prediabetes [14,15].

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Acknowledging the widespread impact of OSA, the International Diabetes Federation recommends screening every patient with Type 2 diabetes mellitus for the presence of OSA [16], while American Diabetes Association guidelines emphasize the need for OSA treatment [17]. Despite its clinical significance, the systematic screening of OSA in patients with Type 2 diabetes mellitus is compromised by the lack of evidence supporting a particular screening method. The tools currently used for OSA screening are questionnaires evaluating subjective signs (tiredness and snoring) and objective risk factors (such as hypertension, obesity, or neck circumference). The predictive performance of the most widely used questionnaires (ie, Berlin, STOP, and STOP-Bang questionnaires) has been validated with divergent results in the general population, preoperative and sleep clinic patients [18–24]. However, screening performance in Type 2 diabetes mellitus patients has not yet been assessed. Defining the optimal OSA screening method in Type 2 diabetes mellitus patients has strong implications for daily Type 2 diabetes mellitus management and provides a basis for the reasonable use of healthcare resources.

The purpose of this study was to validate questionnaires commonly used for OSA screening – the Berlin, STOP, and STOP-Bang Questionnaires – in a population of patients with Type 2 diabetes mellitus. We aimed to define questionnaire performance (sensitivity, specificity, positive and negative predictive values) at a cut-off point of AHI ≥ 15 indicative of moderate or severe OSA; this AHI level is recommended for treatment with CPAP as a standard patient-care strategy regardless of the presence of sleep-related symptoms [1].

2. Materials and methods

2.1. Participants

The study was conducted in secondary and tertiary diabetes care practices located in Prague, Czech Republic. We identified 494 consecutive patients during their regular follow-up visits between March 2014 and June 2015. Inclusion criteria were treatment for Type 2 diabetes mellitus and age < 80 years. Exclusion criteria were an unstable psychiatric disorder (five patients) and already treated OSA (six patients), four patients declined participation. Body weight was recorded and neck circumference was measured in the physician's office. Patients filled in the Berlin and STOP-Bang questionnaires during a physician-assisted interview [18,21]. The study was approved by the Ethical Committee of the Third Faculty of Medicine and all subjects provided their written informed consent.

2.2. Questionnaires

Berlin, STOP, and STOP-Bang questionnaires are designed to identify patients at high risk of OSA. They contain questions about snoring, observed apneas, tiredness, history or treatment for hypertension, as well as anthropometric data (BMI and neck circumference), sex, and age. The Berlin questionnaire contains 11 questions organized into three categories. In the first category, a point is attributed to each of the following: snoring, high volume snoring, high frequency, and for observed pauses in breathing. In the second category, a point is attributed to each of the following: tiredness after waking up, tiredness during the day, and drowsiness while driving. In the third category, a point is attributed to hypertension and for BMI > 30 kg/m^2. The category is labeled as "positive" if the total number of points in the category is two or more, and a high risk of OSA is determined by two or more categories scored as "positive" [18]. The STOP questionnaire includes four Yes/No questions for the presence of snoring, tiredness, observed pauses in breathing, and blood pressure. High risk is determined by answering at least two questions with "Yes." The STOP-Bang questionnaire incorporates another four Yes/No questions: BMI > 35 kg/m^2, Age > 50 years, Neck circumference > 40 cm, male gender. In the STOP-Bang questionnaire, a score ≥5 points was used to determine a high risk of OSA in this study, unless otherwise stated [21].

2.3. Home sleep study

Patients were subsequently invited for a home sleep study using a type IV device (ApneaLink, ResMed, San Diego, CA, USA) continually recording levels of hemoglobin oxygenation, heart rate, and nasal airflow during sleep. This device has been proven to detect respiratory events during sleep with a high sensitivity and specificity in comparison with conventional polysomnography [25–29]. Patients were trained to set up the device and instructed to follow regular sleep habits. All the patients had access to a non-stop phone help-line and returned the device to investigators the following morning. All sleep recordings were manually reviewed and scored by a trained physician. Apneas were identified if there was ≥90% reduction in airflow for at least 10 s, hypopneas were identified if there was ≥30% reduction in airflow for at least 10 s together with hemoglobin desaturation of ≥4%.

2.4. Statistical analysis

Statistical analysis was performed using Prizm 5 for Windows Software (GraphPad Software Inc., La Jolla, CA, USA). Differences in anthropometrical parameters between the patients who participated and those who declined the sleep study were analyzed using a T-test and a χ^2 test (testing differences in proportions) while ANOVA was used to compare differences in quantitative variables between OSA severity groups (no OSA, mild, moderate, severe OSA). Differences in proportions between OSA severity groups (no OSA, mild, moderate, and severe OSA) were evaluated using the χ^2 test. Sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were calculated including respective confidence intervals. Data are presented as mean ± SD or number (%). Statistical significance was set to $p < 0.05$.

3. Results

3.1. Anthropometrical parameters

Out of 479 enrolled patients, 158 declined the home sleep study, 27 home sleep study recordings had insufficient technical quality preventing event scoring, resulting in a final set of 294 patients available for analysis as summarized in Fig. 1.

Sub-analysis revealed that subjects who declined the home sleep study were not different from those who underwent the home sleep study in gender, neck circumference, and BMI. However, they were older (66.1 ± 8.7 vs. 63.9 ± 9.2, $p < 0.05$) and more of them were identified as being at low risk of OSA by all used questionnaires, Table 1.

Table 1
Characteristics of patients who underwent or declined home sleep study.

	All	No sleep study	Sleep study done
Patients, n (%)	479 (100%)	185 (39%)	294 (61%)
Men, n (%)	268 (56%)	96 (52%)	172 (59%)
Age, years	64.7 ± 9.1	66.1 ± 8.7	63.9 ± 9.2*
Body mass index, kg/m^2	31.1 ± 6.4	31.2 ± 7.7	31.1 ± 5.6
Neck circumference, cm	41.3 ± 4.2	41.0 ± 4.4	41.1 ± 5.7
High risk of OSA			
Berlin, n (%)	243 (51%)	79 (43%)	164 (56%)*
STOP-Bang score ≥ 5, n (%)	169 (35%)	50 (27%)	119 (40%)*
STOP score ≥ 2, n (%)	242 (51%)	78 (42%)	164 (56%)*

Data represent mean ± SD or proportions (%).
* $p < 0.05$ for differences between "No Sleep Study" and "Sleep Study Done" groups (T-test, Chi-square).

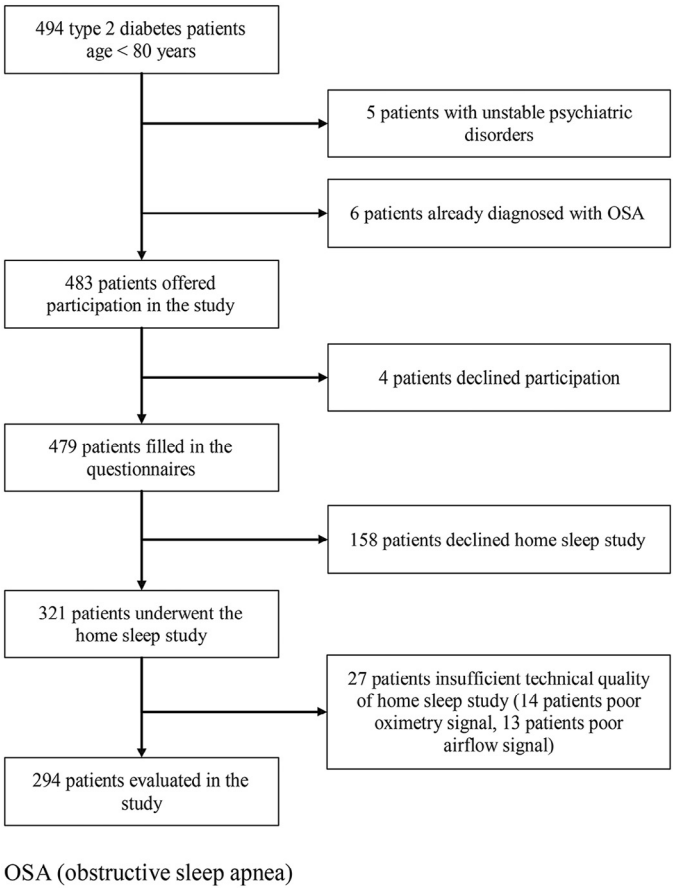

Fig. 1. Flow diagram of subjects in the study.

The analyzed group consisted of 172 men (59%) (62.6 ± 9.8 years, BMI 30.9 ± 5.3, neck circumference 43.2 ± 5.6 cm) and 122 (41%) women (65.6 ± 8.1 years, BMI 31.3 ± 6.0, neck circumference 38.2 ± 4.6 cm). The home sleep study identified 31 (10%) subjects with AHI ≥ 30, 61 (21%) subjects with AHI 15–29, and 121 (41%) subjects with AHI 5–14, suggesting severe, moderate, and mild OSA. Subjects in the highest AHI group were of a similar age, gender distribution, and prevalence of tiredness compared to other groups, however, they were characterized by higher BMI and larger neck circumference. Increasing AHI was also associated with a higher prevalence of hypertension. The number of subjects identified as having high risk of OSA by Berlin, STOP, and STOP-Bang questionnaires increased proportionally with increasing AHI. Detailed anthropometrical characteristics and questionnaire responses are summarized in Table 2, while pharmacological treatment in all groups is summarized in Table 3.

Table 3
Pharmacotherapy overview in all OSA severity groups.

	OSA absent (AHI < 5)	Mild OSA (AHI < 5)	Moderate OSA (AHI < 5)	Severe OSA (AHI < 5)
Metformin (%)	88.8	82.9	81.4	81.1
DPP IV inhibitors (%)	26.5	33.3	27.1	29.7
Sulfonylurea (%)	19.4	21.6	18.6	8.1
Glitazones (%)	6.1	8.1	3.4	8.1
Gliflozines (%)	5.1	0.9	6.8	0.0
Diet only (%)	1.0	3.6	8.5	2.7
Insulin (%)	17.3	10.8	13.6	21.6
GLP-1 agonists (%)	2.0	2.7	1.7	0.0
Beta-blockers (%)	33.7	36	45.8	54.1
ACE-inhibitors (%)	21.4	43.2	39.0	45.9
Ca_{2+}-channel blockers (%)	50.0	76.6	64.4	59.5
Diuretics (%)	46.9	73.9	64.4	48.6
Statins/ezetimibe (%)	14.3	46.8	30.5	32.4
Antidepressives (%)	4.1	1.8	3.4	5.4

Abbreviations: DPP IV = dipeptidyl peptidase, GLP-1 = glucagon like peptide-1, ACE = angiotensin converting enzyme.
Data represent proportion of patients in each OSA severity group treated with the drug.

3.2. Questionnaire performance characteristics

The performance characteristics of all three questionnaires stratified by AHI are summarized in Table 4. As the main aim of questionnaire screening is to identify patients at risk of moderate or severe OSA, where treatment is recommended, we have particularly focused on the performance characteristics at AHI ≥ 15. At this cut-off, the Berlin, STOP, and STOP-Bang questionnaires reached a similar performance level (although the Berlin questionnaire showed the highest sensitivity, the difference was not statistically significant).

As various scoring values (ie, 3 or 5) for STOP-Bang were previously identified as being indicative of high risk of OSA [22], we

Table 2
Characteristics of screened patients.

	All	OSA absent (AHI < 5)	Mild OSA (AHI 5–14)	Moderate OSA (AHI 15–29)	Severe OSA (AHI ≥ 30)
Patients, n (%)	294 (100%)	81 (28%)	121 (41%)	61 (21%)	31 (10%)
Men, n (%)	172 (59%)	37 (46%)	74 (61%)	38 (62%)	23 (74%)
Age, years	63.9 ± 9.2	62.1 ± 9.1	64.9 ± 8.8	65.2 ± 9.9	61.9 ± 8.9
Body mass index, kg/m^2	31.1 ± 5.6	28.9 ± 4.5	31.1 ± 4.9*	32.3 ± 5.1*	34.2 ± 9.0*†
Neck circumference, cm	41.5 ± 4.0	28.9 ± 5.6	40.9 ± 6.4*	42.4 ± 3.7*†	44.8 ± 3.7*†
AHI	13.6 ± 14.7	2.2 ± 1.2	8.7 ± 2.7*	20.6 ± 4.2*†	48.3 ± 15.9*†‡
Hypertension, n (%)	243 (83%)	59 (73%)	102 (84%)	52 (85%)	30 (97%)§
Dyslipidemia, n (%)	262 (89%)	73 (90%)	110 (91%)	53 (87%)	26 (84%)
Myocardial infarction/PCI, n (%)	38 (13%)	11 (14%)	14 (12%)	8 (13%)	5 (16%)
High risk of OSA					
Berlin, n (%)	164 (56%)	36 (44%)	65 (54%)	36 (59%)	27 (87%)§
STOP-Bang score ≥ 5, n (%)	119 (40%)	20 (25%)	45 (37%)	30 (49%)	24 (77%)§
STOP score ≥ 2, n (%)	164 (56%)	38 (47%)	66 (55%)	35 (57%)	25 (81%)§
Epworth Sleepiness Scale	5.9 ± 3.8	5.0 ± 3.3	6.0 ± 3.6	6.1 ± 4.2	7 · 5 ± 4 · 2*

Abbreviation: PCI = percutaneous coronary intervention.
Data represent mean ± SD or proportions (%).
* $p < 0.05$ for comparison with "OSA absent" (ANOVA with Tukey's correction for multiple testing).
† $p < 0.05$ for comparison with "Mild OSA" (ANOVA with Tukey's correction for multiple testing).
‡ $p < 0.05$ for comparison with "Moderate OSA" (ANOVA with Tukey's correction for multiple testing).
§ $p < 0.05$ Chi-square test for trend (increasing prevalence with increasing OSA severity).

Table 4
Predictive parameters for Berlin, STOP, and STOP-Bang questionnaires.

Sensitivity (95% CI)		Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)
AHI ≥ 5						
Berlin	60.1 (53.2–66.7)	55.6 (44.1–66.6)	78.1 (70. 9–84.1)	34.6 (26.5–43.5)	1.4 (1.0–1.8)	0.7 (0.6–0.9)
STOP score ≥ 2	59.2 (52.2–65.8)	53.1 (41.7–64.3)	76.8 (69.6–83.1)	33.1 (25.1–41.9)	1.3 (1.0–1.6)	0.8 (0.6–1.0)
STOP-Bang score ≥ 5	46.5 (39.6–53.4)	75.3 (64.5–84.2)	83.2 (75.2–89.4)	34.9 (27.8–42.4)	1.9 (1.3–2.8)	0.7 (0.6–0.9)
STOP-Bang score ≥ 3	88.3 (83.2–92.3)	32.1 (22.2–43.4)	77.4 (71.6–82.5)	51.0 (36.6–65.3)	1.3 (1.1–1.5)	0.4 (0.2–0.6)
AHI ≥ 15						
Berlin	68.5 (58.0–77.8)	50.0 (43.0–57.1)	38.4 (30.9–46.3)	77.7 (69.6–84.5)	1.4 (1.1–1.7)	0.6 (0.5–0.9)
STOP score ≥ 2	65.2 (54.6–74.9)	48.5 (41.4–55.6)	36.6 (29.2–44.5)	75.4 (67.1–82.5)	1.3 (1.0–1.6)	0.7 (0.5–1.0)
STOP-Bang score ≥ 5	58.7 (48.0–68.9)	67.8 (60.9–74.2)	45.4 (36.2–54.8)	78.3 (71.4–84.2)	1.8 (1.4–2.4)	0.6 (0.5–0.8)
STOP-Bang score ≥ 3	89.1 (80.9–94.7)	20.1 (15.0–26.5)	33.7 (27.8–40.1)	80.4 (66.9–90.2)	1.1 (1.0–1.2)	0.5 (0.3–1.0)
AHI ≥ 30						
Berlin	87.1 (70.2–96.4)	47.9 (41.7–54.1)	16.5 (11.1–23.0)	96.9 (92.3–99.2)	1.7 (1.4–2 .0)	0.3 (0 .1–0.7)
STOP score ≥ 2	80.7 (62.5–92.6)	47.2 (41.0–53.4)	15.2 (10.1–21.7)	95.4 (90.2–98.3)	1.5 (1.2–1.9)	0.4 (0.2–0.9)
STOP-Bang score ≥ 5	77.4 (58.9–90 · 4)	63.9 (57.8–69.7)	20.2 (13.4–28.5)	96.0 (91.9–98.4)	2.1 (1.7–2.8)	0.4 (0.2–0.7)
STOP-Bang score ≥ 3	96.8 (83.3–99.9)	19.0 (14.5–24.3)	12 .4 (8.5–17.2)	98.0 (89.6–100 .0)	1.2 (1.1–1.3)	0.2 (0.0–1.2)

Abbreviations: AHI = apnea–hypopnea index, PPV = positive predictive value, NPV = negative predictive value, PLR = positive likelihood ratio, NLR = negative likelihood ratio.

addressed the question of how using a score of 3 vs. 5 affects the questionnaire's predictive performance. This study found that using the lower scoring value of 3 improved the sensitivity (59% vs. 89%, $p < 0.05$) but profoundly worsened the specificity (68% vs. 20%, $p < 0.05$) of the STOP-Bang questionnaire. The positive and negative predictive values (PPV and NPV) were not statistically different among the three analyzed questionnaires and ranged from 33 to 45% for PPV and from 75 to 80% for NPV.

3.3. Gender differences in predictive performance

The predictive performance of the Berlin and STOP questionnaires was not affected by gender for all AHI cut-off values. By contrast, the sensitivity and specificity of the STOP-Bang questionnaire (the only questionnaire including sex evaluation) were influenced by gender in all AHI groups. As depicted in Table 5, the sensitivity of the STOP-Bang questionnaire to identify men with AHI ≥ 15 was 74% with a specificity of 56%, while for women, the sensitivity reached only 29% with a specificity of 82% (all $p < 0.05$ for comparison between genders).

4. Discussion

This study has assessed the utility of the Berlin, STOP, and STOP-Bang questionnaires in identifying subjects with OSA in a population of Type 2 diabetes mellitus patients. It showed that all the questionnaires had a similar, but rather low, sensitivity (59%–69%) and specificity (49%–68%). It also demonstrated profound gender differences in the performance of the STOP-Bang questionnaire, where sensitivity for women was almost three times lower than for men.

The systematic screening for a disease represents an effort to identify subjects at risk of a disease or its complications using a suitable and simple test or question(s). The decision to perform a systematic screening for OSA in patients with Type 2 diabetes mellitus is motivated by the high prevalence of OSA in the Type 2 diabetes mellitus population and its association with excessive cardiovascular mortality, which is largely preventable by using available treatment [9–11]. Current International Diabetes Federation guidelines recommend screening all Type 2 diabetes mellitus patients for OSA [16], suggesting a questionnaire survey as the first line followed by sleep monitoring in high risk subjects based on the questionnaire score. However, such a recommendation is not supported by rigorous research and the success of such screening remains unknown. So far, no studies have evaluated the performance characteristics of the available questionnaires in the Type 2 diabetes mellitus population and even the number of studies performed in unselected non-diabetic populations is limited [18–22]. Furthermore, the results of these studies vary significantly.

The Berlin questionnaire was initially validated in primary care patients [18] with a sensitivity and specificity of 97% and 47%. However, these results were not repeated in subsequent studies [19,20], possibly due to the relatively low number of patients in the

Table 5
Gender differences in predictive parameters for the questionnaires.

	Sensitivity (%) M:W	Specificity (%) M:W	PPV (%) M:W	NPV (%) M:W	Positive LR M:W	Negative LR M:W
AHI ≥ 5						
Berlin	57.8:64.1	48.7:61.4	80.4:74.6	24.0:49.1*	1.1:1.7	0.9:0.6
STOP	56.3:64.1	56.8:50.0	82.6:69.4	26.2:44.0	1.3:1.3	0.8:0.7
STOP-Bang score ≥ 5	58.5:25.6*	59.5:88.6*	84.0:80.0	28.2:40.2	1.4:2.3	0.7:0.8
STOP-Bang score ≥ 3	97.0:73.1*	10.8:50.0*	79.9:72.2	50.0:51.2	1.1:1.5	0.3:0.5
AHI ≥ 15						
Berlin	68.9:67.7	50.5:49.5	43.3:31.3	74.7:81.8	1.4:1.3	0.7:0.7
STOP	68.9:58.1	55.0:40.7	45.7:25.0	76.3:74.0	1.5:1.0	0.6:1.0
STOP-Bang score ≥ 5	73.8:29.0*	55.9:82.4*	47.9:36.0	79.5:77.3	1.7:1.7	0.5:0.9
STOP-Bang score ≥ 3	98.4:70.1*	6.3:37.4*	36.6:27.9	87.5:79.1	1.1:1.1	0.3:0.8
AHI ≥ 30						
Berlin	91.3:75.0	49.0:46.5	21.7:9.0	97.3:96.4	1.8:1.4	0.2:0.5
STOP	87.0:62.5	51.7:41.2	21.8:7.0	96.2:94.0	1.8:1.1	0.3:0.9
STOP-Bang score ≥ 5	91.3:37.5	51.0:80.7*	22.3:12.0	97.4:94.9	1.9:1.9	0.2:0.8
STOP-Bang score ≥ 3	100:87.5	5.4:36.8*	14.0:8.9	100:97.7	1.1:1.4	0.0:0.3

Abbreviations: AHI = apnea–hypopnea index, PPV = positive predictive value, NPV = negative predictive value, LR = likelihood ratio, M = men, W = women.
* $p < 0.05$ for differences between men and women.

original study (100 subjects) and the disproportion of low risk patients in the sleep study in comparison to the number of low risk patients in the studied general population (31% vs. 62%). Other widely used screening questionnaires, STOP, and its upgraded version STOP-Bang, have been developed and validated in a setting of a preoperative care and also came up with rather low sensitivity and specificity (23% and 56%, respectively) [22] weakening previously published promising results [21].

Here, we provide unique and novel information on the performance of all three questionnaires in a specific population of Type 2 diabetes mellitus patients. Although the study demonstrated that questionnaire performance in Type 2 diabetes mellitus patients is comparable to performance in the general population [19,30], it must be emphasized that interpretation of the observed sensitivity and specificity should be critically evaluated. Using an example of the best-performing Berlin questionnaire with observed sensitivity of 69% and specificity of 50%, we can predict that 31% of the patients who are in need of OSA treatment were not recognized as such by the questionnaires and were incorrectly marked as having a low risk of OSA. It should also be noted that positive and negative predicting values of each questionnaire are proportionally dependent on the prevalence of the condition (OSA) within the investigated population. Identical questionnaires applied to a population with high disease prevalence will show higher positive predicting value and lower negative predicting value than in a population with lower disease prevalence [31]. As OSA is highly prevalent in Type 2 diabetes patients, the presented values need to be understood in this context and alternative parameters independent of disease prevalence; these parameters may include reported positive and negative likelihood ratios.

Findings presented in this study have extremely important clinical and ethical implications, as the Type 2 diabetes patient population already possesses elevated cardiovascular risk. Missing the opportunity to diagnose OSA in these subjects causes increased risk of death, brought about by moderate or severe OSA [6–8]. This conclusion is based on published mortality data in general and in elderly populations, as OSA-associated mortality data in the Type 2 diabetes mellitus population are not available. Criteria used for hypopnea scoring notably influence the performance characteristics of the questionnaires. It can be expected that employing 3% desaturation threshold instead of 4% would further decrease questionnaire sensitivity. On the other hand, 50% of the questionnaire screened patients who did not suffer from moderate or severe OSA were marked as having a high risk of OSA and would therefore undergo subsequent investigation and utilize healthcare resources unnecessarily. We also noted an unexpected and previously unreported observation of significant gender differences in the performance of the STOP-Bang questionnaire, which ascribes an extra point for male gender. In contrast, when gender variables are ignored (as in other tested questionnaires) no difference between men and women is observed in performance characteristics; this suggests that the risk of OSA brought by male sex (or protective effect of female sex) is not proportionally reflected in the STOP-Bang questionnaire. Rather poor performance characteristics of assessed questionnaires may be partially due to the fact that required information on snoring (frequency, loudness, perception of loudness) is not reflecting the true nature of the situation. Besides missing bed partners and marital status, it should also be noted that snoring represents a social stigma, which might not be fully accepted and reported by all patients.

Outcomes of the present study raise the question of whether OSA screening in Type 2 diabetes mellitus patients using any of the above-mentioned questionnaires is ethically justified, cost-effective, and therefore appropriate. Considering the growing availability of home sleep monitoring devices (similar to routinely performed 24-hour ECG or blood pressure monitoring devices) on one hand, and limited performance of screening questionnaires in diabetic population on the other hand, we strongly suggest performing OSA screening in Type 2 diabetes mellitus patients directly with home sleep monitoring devices. The use of screening questionnaires should be reserved for the general population, where the risks of omitting OSA treatment would probably have less serious consequences.

To our knowledge, this is the only study that focuses on OSA screening questionnaires in an unselected population of Type 2 diabetes mellitus patients. However, the study does have limitations. First, although our study was performed on a considerably large sample of 294 patients, the questionnaire performance for severe OSA (AHI ≥ 30) was limited by a modest number of patients in this group (31 subjects). Nevertheless, the main aim of this study, supported by clinical relevance, was to validate questionnaire performance at a cut-off of AHI ≥ 15, where the sample size was significant (92 subjects). Second, type IV devices (monitoring nasal flow and saturation) cannot distinguish between obstructive and central sleep apneas, so scoring includes events of both origins. It is important to emphasize that a gold standard for OSA diagnosis is represented by attended polysomnography, while type IV devices have been proven to detect respiratory events with sensitivity and specificity reaching or exceeding 90% (for moderate or severe OSA) in comparison with polysomnography [25–29]. As type IV devices are likely to underestimate AHI in comparison with polysomnography [1], interpretation of the results of the present study should consider this limitation. If the true AHI was higher than values measured by type IV device, performance characteristics of investigated questionnaires would be even worse than reported in this study. Third, the patients enrolled in the study were mostly from large cities with little need of long distance driving, which might introduce a bias in the Berlin questionnaire investigating drowsiness and probability of falling asleep during car driving. In fact, only 9% of patients in the present study ever experienced drowsiness and nobody admitted falling asleep three or more times a week, which is in contrast to previous reports, where as many as 19% of respondents reported drowsy driving and/or falling asleep [18]. Finally, as the questionnaires were used in the Czech language, the translation was tested on a small group of bilingual people outside our group to verify that no differences in meaning were introduced by using Czech language.

5. Conclusions

In conclusion, we provide a strong rationale for OSA screening using home sleep-monitoring devices instead of questionnaires in the population of Type 2 diabetes mellitus patients characterized by high risk of cardiovascular morbidity and mortality and high prevalence of moderate and severe OSA. Questionnaire screening might help to identify OSA patients in populations with a low cardiovascular risk, where the consequences of missing an OSA diagnosis are less severe. Using home sleep monitoring devices as the first line of screening was shown to be feasible for health care providers, acceptable to patients, and the overall effort was comparable to that of other routinely used monitoring devices.

Authors' contributions

K.W. recruited subjects, collected and analyzed data, and wrote the manuscript. A.P. collected data, and contributed to discussion and manuscript writing. M.P. provided sleep expertise, and discussed and edited manuscript. Z.L. provided sleep expertise and manually scored sleep recordings, and edited the manuscript. J.P. designed the study, collected and analyzed data, and reviewed the manuscript.

Conflict of interest

The authors declare that they have no competing interests.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2016.07.009.

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