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Original Article

Comparison of commonly used screening tools for determining obstructive sleep apnea amongst aviation employees

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ABSTRACT

Introduction: Epidemiological evidence suggests the prevalence of Obstructive Sleep Apnea (OSA) ranges 9–38%. Multiple screening tools are used to aid diagnosis. In professions that require high levels of attentiveness, safety, and responsibility for other's lives, inaccuracies and biases are probable for self-reported data. We sought to assess the best screening tool for OSA amongst aircraft pilots and air traffic controllers (ATCs).
Methods: Data were collected as part of routine clinical care for patients presenting to Sleep Disorders Specialized Clinic. A total 1384 patients attended the clinic (2012–2018), of which 254 were either pilots or ATCs. Patients responded to three questionnaires, regularly used for OSA screening: 1) Epworth Sleepiness Scale (ESS); 2) Berlin Questionnaire (BQ); 3) STOP-BANG Questionnaire (SBQ). We used non-parametric ROC analysis, sensitivity, and specificity measures, along with positive and negative predictive values (PPV/NPV) to determine the most accurate diagnostic instrument.
Results: The ROC (95% CI) for the ESS, BQ, and SBQ was 0.49 (0.39–0.59), 0.58 (0.49–0.67), and 0.56 (0.47–0.65), respectively. When the SBQ was used in combination with the ESS, the sensitivity was high at 100% (78.2–100.0), as were the PPV and NPV, 83.3% (58.6–96.4) and 100.0 (2.5–100.0), respectively.
Conclusion: The SBQ, in combination with the ESS, was the most reliable diagnostic tool for OSA in pilots and ATCs. Physicians should prioritize use of these screening tools for predicting OSA when assessing those working in the aviation industry and similar occupational groups, such as drivers. Given the scarcity of literature in this population, we recommend future studies replicate ours to either confirm or refute the findings.

1. Introduction

Obstructive Sleep Apnea (OSA) is an increasingly common sleep-disordered breathing (SDB) condition. It can manifest in adverse clinical outcomes including, but not limited to, metabolic dysfunction, cardiovascular consequences, neurocognitive deficits and psychological disorders [1–3]. A recent systematic review of epidemiological studies across different geographic locations revealed that the prevalence of OSA ranged from 9% up to 38% and was consistently higher in men [4]. There was, however, no data available from any Middle Eastern country in this review, where OSA and its comorbidities are markedly high. A recent study conducted in Saudi Arabia, which included 3374 participants, conservatively estimated the prevalence of OSA to be at least 8.8% [5]. Of particular concern, is the increasing prevalence of OSA across just a five-year time frame (2008–2013) [6]. The observed upsurge is likely due to the strong relationship between OSA and obesity, which has also intensified in recent decades [7,8]. Despite the growing prevalence of this sleep disorder, a case-control study in Australia concluded that there was a high prevalence of undiagnosed OSA amongst the general population [9].

OSA is usually diagnosed following an overnight sleep study and severity of the condition is assessed using the Apnea–Hypopnea Index (AHI). In the clinical setting, there are also a number of sleep questionnaires used to screen for OSA, which assist the clinician with the diagnosis. For example, obstructive sleep apnea syndrome (OSAS) requires the individual to not only have at least mild OSA but to also have accompanying symptoms such as daytime

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sleepiness and/or impaired daytime functioning. Two (Berlin Questionnaire [BQ] and Epworth Sleepiness Scale [ESS]) of the three instruments used to support diagnosis ask questions pertaining to falling asleep whilst in control of a vehicle. These types of questions can potentially result in biased subjective responses, which will undoubtedly affect the diagnostic accuracy of the tool during the screening process. This is likely to be particularly problematic in those with occupations that require high levels of alertness to operate machinery or vehicles carrying passengers, such as those in the aviation industry (aircraft pilots and air traffic controllers). Confessions about falling asleep whilst in control of a vehicle carrying passengers may result in their license being revoked, which threatens the individual's livelihood; thus, admissions about such serious implications may be limited. The third tool, the STOP-BANG questionnaire (SBQ), is comprised of eight items with dichotomous (yes/no) response options [10]. Of the eight items, five are fixed, non-changeable responses at the time of screening without any questions relating to falling asleep whilst operating machinery or a vehicle. Thus, as the instrument depends on more objective and fixed measures, it may be more reliable amongst those being screened for OSA, including those in professions who operate machinery (ie factory workers) or vehicles with passengers (ie drivers and pilots).

We therefore sought to examine the most effective screening tool for determining OSA in aircraft pilots and air traffic controllers (ATC) from three commonly used sleep questionnaires. We also set out to determine the optimal cut point of neck circumference, as well as the three instruments, for OSA. We hypothesized, based on the above rationale, that the SBQ would be the best diagnostic screening tool for OSA as compared to the ESS and BQ.

2. Materials and methods

A total of 1384 patients attended a Specialized Sleep Disorders Clinic in Al Ain, United Arab Emirates between 2012 and 2018. Ethical approval was obtained from the United Arab Emirates University Human Research Ethics Committee (EHR-2019-5962 19-10). All patients were screened for OSA in the sleep laboratory using polysomnography (PSG) and completed three sleep questionnaires which are commonly used as screening tools and to support OSA diagnosis. Before the sleep study, all subjects were requested to complete the ESS, BQ, and SBQ. All subjects underwent physical examinations by the corresponding author. First, the ESS is an eight-item questionnaire where patients respond to each scenario based on the likelihood of them dozing during each of the eight given situations [11]. Second, the BQ is divided into three categories and investigates common OSA symptomatology such as snoring, falling to sleep whilst driving along with two items on the third category pertaining to BMI and hypertension [12]. Third, the SBQ which contains eight items, three of which are subjective [13]. The remaining five items are based on factual evidence and/or objective measurements taken during the clinic at the time the patient presents (being treated or have hypertension, BMI >35, aged >50 years, neck circumference >40 cm, and male gender). All questionnaires were scored according to standardized scoring criteria. Scores of ≥3 on the SBQ, ≥10 on the ESS and ≥2 on the Berlin, were considered as high risk for OSA. OSA was defined using the AHI, where <5 indicated an absence of OSA and an AHI of ≥5 was characterized as OSA. Anthropometric data such as neck circumference (cm), blood pressure and body mass index (BMI; kg/m^2) were measured, documented during clinical examinations, and used as responses to the corresponding questions on the SBQ and BQ, as appropriate.

2.1. Polysomnography (PSG)

The nocturnal PSG consisted of continuous polysomnographic (Compumedics Grael and Somte PSG, Australia) recordings of a standard electroencephalographic montage comprised of six electroencephalograms (F3−M2, F4−M1, C3−M2, C4−M1, O1−M2, O2−M1), right and left electro-occulogram, submental and bilateral tibial electromyogram, and electrocardiogram, using surface electrodes. Respiration was monitored with oronasal thermocouples and with nasal pressure transducers. Thoracoabdominal movements were monitored using Respiratory Inductance Plethysmography (RIP). Continuous pulse oximetry was also observed. Sleep stage scoring was performed in 30-s epochs by a certified Registered Polysomnographic Technologists according to American Association of Sleep Medicine (AASM) criteria [14]. Apnea was defined as cessation of airflow for more than 10 s. Hypopneas were scored as at least 30% decrease in airflow with 3% oxygen desaturation and/or arousal. The Apnea−Hypopnea Index (AHI) was defined as the total number of apneas and hypopneas per hour of sleep time. An apneas/hypopnea index (AHI) of ≥5 was considered as diagnosis of OSA. Patients with sleep apnea were classified into three subgroups according to their AHI: mild (5 to <15 events per hour), moderate (15 to <30 events per hour), and severe (≥30 events per hour).

2.2. Statistical analysis

All data were analyzed using Stata version 13 (Texas, US). Continuous variables were inspected for range and distribution. The diagnostic accuracy of the BQ, ESS, and SBQ, for identifying the presence of OSA, was assessed using the receiver operating characteristic (ROC) curve where the scores for the BQ, SBQ, and ESS were entered as continuous. We further calculated sensitivity and specificity for each of the three instruments. We repeated this for the BQ and SBQ paired with the ESS (score of ≥10) to assess if this improved the sensitivity and/or specificity for detecting OSA. We also obtained the positive and negative predictive values for each of the five variations (i. BQ, ii. SBQ, iii. ESS, iv. BQ with the ESS, and v. SBQ with the ESS). Finally, the empirical cut point estimation command (cutpt) was used to determine the optimal cut point for neck circumference and each of the three screening instruments. The Liu method was applied, which maximizes sensitivity and specificity [15].

3. Results

Of the 1384 patients who were screened for OSA, 72% (n = 1003) met the diagnostic criteria for OSA. Of the total sample, 254 (18%) reported working in the aviation industry (n = 217 pilots; n = 37 ATCs). Participant characteristics are highlighted in Table 1. In brief, the presence of OSA was detected in 74% of those in the aviation industry. All participants were males and the median age was 51 years. Interestingly, the majority of pilots/ATCs were low risk for OSA according to the BQ and ESS (62% and 91%), respectively. In contrast, just 17% were screened as low risk for OSA when the SBQ was utilized.

Table 2 highlights the number of true positives, true negatives, false positives and false negatives by screening instrument for the sample of pilots and ATCs combined. Complete diagnostic OSA information was available for 180 participants (BQ), 184 for the SBQ, and 181 for the ESS. There were a small number of false negatives for the BQ (n = 12), and a high number of false positives for the ESS (n = 121). Conversely, the number of true positives for the SBQ formed the majority (n = 121).

Table 1
Characteristics of pilots and air traffic controllers in the sample.

Characteristic	
OSA, n (%)	
Absent	53 (26)
Present	152 (74)
Neck circumference (cm)	42 (40–43)
BMI (kg/m^2)	32 ± 6
Gender, n (%)	
Male	252 (100)
Female	0 (0)
Age (years)	51 (42–55)
BQ, n (%)	
Low risk	137 (62)
High risk	85 (38)
SBQ, n (%)	
Low risk	40 (17)
High risk	189 (83)
ESS, n (%)	
Low risk	205 (91)
High risk	20 (9)

Data are presented as mean ± standard deviation or median (interquartile range), unless otherwise specified.
OSA = obstructive sleep apnea; BMI = body mass index; BQ = Berlin questionnaire; SBQ = STOP-BANG questionnaire; ESS = Epworth sleepiness scale.

Data pertaining to sensitivity and specificity for each of the instruments as well as the positive and negative predictive values are highlighted in Table 3. The SBQ showed high sensitivity for OSA for the combined sample of pilots and ATCs (88%). Specificity for the tool was low at 19%. Conversely, the BQ had high specificity (73%) but sensitivity was relatively low (44%). The highest specificity was observed for the ESS (91%) but the sensitivity of this tool was just 11% (see Table 3). The positive predictive values (PPV) were 83.1%, 78.9% and 76.1% for the BQ, ESS, and SBQ, respectively. The negative predictive value (NPV) was highest for the SBQ at 36% and lowest for the ESS at 25.3%.

The optimal cut point for predicting OSA for neck circumference in our sample of pilots and ATCs was 40.5 cm with 71% sensitivity and 48% specificity. The BQ remained the same as the current standard cut point of two with 44% and 73% sensitivity and specificity, respectively. Interestingly, the optimal cut point suggested for the SBQ was four, in comparison to the current accepted cut point of three.

4. Discussion

For the first time, we assessed three commonly used screening questionnaires for predicting OSA in those employed within the aviation industry in jobs requiring high levels of alertness and responsibility for other human lives. Our findings revealed that the ESS had the poorest diagnostic accuracy for positively predicting OSA, which is perhaps not surprising given that this tool is used to assess daytime sleepiness rather than OSA *per se*. Whilst the BQ had high specificity but low sensitivity, out of the three tools assessed it had the highest PPV. However, due to the inconsistency between sensitivity and the PPV, we suggest this is not the optimal tool to use to screen pilots and ATCs for OSA. In contrast, the best tool, for detecting OSA was the SBQ, which demonstrated consistently high levels of sensitivity (88.3%) as well as PPV (76.1%) as well as the highest NPV (36.0%). We conclude that the optimal approach for detecting OSA amongst those in the aviation industry with jobs requiring high levels of alertness, responsibility for other human lives and decision-making under pressure, is administration of the SBQ, paired with the ESS where the PPV was 83.3% and the NPV, as well as sensitivity was 100%. Moreover, the optimal neck circumference cut point for predicting OSA was 40.5 cm in this sample, supported by relatively high specificity (48%) and sensitivity (71%). The BQ optimal cut point remained the same at two and the SBQ increased slightly to four (one more than the currently accepted cut point of three). However, increasing the cut point to four for the SBQ reduced the sensitivity to 43% (versus 88% with the standard accepted cut point of three). The specificity increased to 64%, compared to 19% with the currently accepted cut point.

A recent study conducted in 328 airline pilots across the Gulf Cooperation Council (GCC) region assessed the prevalence of fatigue, psychological health and sleepiness levels [16]. The participants completed the ESS as well as the BQ and excessive daytime sleepiness was present in 34.1% of the sample. Moreover, the BQ indicated that 29.3% were at high risk of OSA. Surprisingly, 45.1% testified to falling asleep on duty at least once without prediscussion with the co-pilot. Although the study did not assess the effectiveness of the ESS and BQ, the findings do suggest that the tools should be used in combination, which is in line with our study findings. However, we recommend the use of the SBQ paired with the ESS based on our results of sensitivity and specificity. Given that pilots and ATC's have a duty of responsibility for the safety of other lives, it is imperative that the screening tools used in clinical practice effectively capture those with OSA. Our findings showed that when the ESS and SBQ are used together, the tools are effective for predicting an 83.3% probability for those screening positive actually do have OSA. Moreover, 100% NPV demonstrates that all subjects who screen negative on the tools will not have the condition. High levels of sensitivity as well as predictive values (negative and positive) are fundamental for this specific population, given the responsibility they have for the safety of extensive numbers of passengers that travel by air every day.

In a case-control study which recruited 793 individuals from the general population in Australia, participants underwent overnight PSG in their own environment and completed the BQ [9]. Of the total sample, 9.1% met the diagnostic criteria for moderate to severe OSA. Specifically, sensitivity for the BQ was just 54% although the rate of true negatives detected was higher at 70%. The authors concluded that the BQ was a sub-optimal tool but that questions pertaining to the frequency of snoring and hypertension could be used to screen out moderate to severe OSA in the general population. These results are similar to our findings and, whilst the sensitivity in the remaining patients was high for this tool, specificity did not reach 40%. Furthermore, others have found that the BQ and SBQ are only useful for detecting OSA, if they are combined with those scoring eight or more on the ESS [17].

Conversely, another study recruited 1305 participants, of which 101 had overnight PSG and concluded that the Korean version of the BQ was a useful screening tool for those at high-risk of OSA amongst the general population [18]. Sensitivity of 69% and 83% specificity for the tool to detect OSA (defined as AHI $\geq$ 5) was reported by the authors. Other groups have also confirmed that the BQ is a useful screening tool in the general population with high

Table 2
Number of true–false positives-negatives according to the three screening instruments amongst pilots and air traffic controllers.

	OSA negative (PSG)	OSA positive (PSG)
BQ negative	33 (30)	76 (70)
BQ positive	12 (17)	59 (83)
SBQ negative	9 (36)	16 (64)
SBQ positive	38 (24)	121 (76)
ESS negative	41 (25)	121 (75)
ESS positive	4 (21)	15 (79)

Data are presented as n (%).
BQ = Berlin questionnaire; PSG = polysomnography; OSA = obstructive sleep apnea; ESS = Epworth sleepiness scale.

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Table 3
Sensitivity, specificity, and predictive values for three OSA screening tools in the combined sample of pilots and air traffic controllers.

Tool	AUC (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
BQ	0.58 (0.49–0.67)	43.7 (35.2–52.5)	73.3 (58.1–85.4)	83.1 (72.3–91.0)	30.3 (21.8–39.8)
SBQ	0.56 (0.47–0.65)	88.3 (81.7–93.2)	19.1 (9.1–33.3)	76.1 (68.7–82.5)	36.0 (18.0–57.5)
ESS	0.49 (0.39–0.59)	11.0 (6.3–17.5)	91.1 (78.8–97.5)	78.9 (54.5–93.9)	25.3 (18.8–32.7)
BQ & ESS	0.60 (0.21–0.99)	86.7 (59.5–98.3)	50.0 (6.8–93.2)	86.7 (59.5–98.3)	50.0 (6.8–93.2)
SBQ & ESS	0.60 (0.20–1.00)	100.0 (78.2–100.0)	25.0 (0.6–80.6)	83.3 (58.6–96.4)	100.0 (2.5–100.0)

Data are expressed as percentages, except for AUC.
AUC = area under curve; SE = standard error; BQ = Berlin questionnaire; SBQ = STOP-BANG questionnaire; ESS = Epworth sleepiness scale.

levels of sensitivity and specificity [19] but data surrounding its use for detection of OSA amongst those with occupations similar to our sample is extremely limited, despite the great importance and far-reaching implications.

A recent systematic review and meta-analysis, which included 35 studies, showed that both specificity and sensitivity was high for detecting clinically relevant OSA within sleep clinic populations, whereas specificity was low in other groups. The authors concluded and recommended utilization of the BQ in more specific patient populations [20] but this did not include those with occupations where individuals require high levels of attention and alertness and are responsible for the safety of passenger lives. As a standalone tool, it can be concluded that the BQ is not paramount for OSA screening. A better approach is however, to compare across different tools, which is what one group did recently when they conducted another meta-analysis to compare the diagnostic accuracy of the BQ, SBQ, and ESS for detecting OSA severity. Partially in line with our findings, the authors concluded that the BQ had the poorest performance [21]. Consistent with our observations, the authors concluded that the optimal tool to utilize in clinical sleep settings is the SBQ given its accuracy for detecting each level of OSA severity [21]. Further support for the high performance of the SBQ for detecting OSA came from a meta-analysis of 17 studies, demonstrating 90% sensitivity and 46% specificity amongst clinical sleep populations [22]. Thus, whilst the BQ was one of the first tools developed for screening patients with possible OSA, the SBQ, which contains more objective OSA symptomatology, is arguably the best currently available instrument for predicting this sleep-related breathing disorder in those presenting to a sleep clinic.

To date, no studies have specifically examined the diagnostic accuracy of instruments for identifying OSA amongst those with occupations that require high levels of alertness and/or the responsibility of passenger lives such as aircraft pilots and/or air traffic controllers. A very recent study did, however, assess the association between OSA and the risk of workplace accidents in 965 employees that operated heavy machinery [23]. Of the 965 employees, the SBQ identified 142 (14.7%) workers to be at high risk for OSA. One hundred and ten employees agreed to an overnight PSG, of which 62.7% had an AHI >5 and 35.5% of them had either almost or actually been involved in an accident at work due to sleepiness. Thus, the SBQ appears to be a useful tool for predicting OSA and may also be effective for forecasting the rate of accidents within the workplace setting of these individuals. Whilst we cannot make a direct comparison of these results with our study findings, it could be assessed in future research studies. Another recently published study assessed 948 drivers (trucks, buses, cars, minibuses and vans) in Iran using the SBQ and ESS [24]. Whilst the focus of this study was not to determine the effectiveness of these tools for predicting OSA, it did reveal a correlation between the SBQ and metabolic syndrome, of which many components are comorbidities of OSA [24]. One further study which aimed to assess the psychometric properties of the SBQ amongst commercial drivers in Serbia showed that, of 100 male participants, the SBQ indicated 69% of the sample to be at risk of OSA. PSG measures confirmed this in 57% of the drivers who met the diagnostic criteria for OSA [25]. Other previous research has shown that daytime sleepiness, a common consequence of OSA, is particularly concerning amongst commercial truck drivers, where the crash risk increases by 50% in those who remain untreated for the condition [26]. In line with these findings, a study conducted in 283 drivers of dangerous goods vehicles demonstrated that 49.1% were suspected of having OSA based on the ESS and the Sleep Disorder Score questionnaire, with 35.7% receiving a subsequent diagnosis after PSG assessment [27]. The study also demonstrated that when those with OSA were treated with continuous positive airway pressure (CPAP), the number of near miss accidents were similar to those without OSA [27]. It is important to note that as the ESS and BQ have an item that specifically asks about falling to sleep whilst driving, this is likely to have reduced the sensitivity in detecting OSA amongst our sample of pilots and ATCs.

Data obtained from the Sleep Heart Health Study demonstrated that neck circumference was the most powerful predictor of the respiratory disturbance index (RDI) scores [28]. This suggests that this measure, which is usually obtained as part of the clinical screening process, is fundamental, and is perhaps the reason it was incorporated into the SBQ. However, just like BMI where different ethnic groups have different cut points, this may also be the case for neck circumference. For example, a cross-sectional study of 836 males in Romania revealed the optimal cut point for neck circumference to be 41 cm, showing 81% sensitivity and 52% specificity for OSA detection [29]. On the other hand, a study of 383 individuals presenting for OSA screening in Korea, revealed that neck circumference was the strongest linear predictor of AHI and that the optimal cut point for this population was just 34.5 cm for women and 38.75 cm for men [30]. The results of our study show that the optimal cut point of neck circumference is 40.5 cm. Sensitivity for this cut point was 71% and specificity was 48%. These results warrant a clear need for larger studies, which incorporate different ethnic groups, to establish a robust cut point for neck circumference to be used in clinical settings, given the variation of findings across the three studies outlined.

Whilst our study is the first to examine the diagnostic accuracy of three commonly used tools for OSA detection in pilots versus patients presenting to a sleep clinic, we acknowledge some study limitations. First, our sample was relatively small, although representative of the UAE population. Larger studies of different occupational groups are urgently needed, particularly in those where high levels of alertness and rapid decision-making are required, accompanied by safety as a major priority which, if compromised, can have catastrophic consequences. Second, all of our sample was comprised of men, and whilst women are under-represented in this occupational group, and indeed for OSA, this made it impossible to draw any potential gender differences as well as make suitable recommendations for optimal neck circumference.

In conclusion, our study findings suggest that the SBQ, in combination with the ESS, is the most promising tool for OSA detection

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amongst aviation employees presenting to a sleep clinic in the UAE. Given that the SBQ in combination with the ESS demonstrated 100% sensitivity, a high PPV of 83.3% and an NPV of 100%, we recommend these screening tools be used for aviation employees who present to sleep clinics for suspected OSA in future. We also recommend retaining the current accepted cut point of three and ten for the SBQ and ESS, respectively. The optimal cut point for neck circumference, which is one of the strongest predictors of OSA, was 40.5 cm, which is similar to the current guidelines on the SBQ. Given that the majority of the SBQ items are based on objective clinical measures or items which are fixed, it is perhaps not surprising that this tool had the greatest diagnostic accuracy for OSA. We therefore recommend that the SBQ, paired with the ESS, is a fundamental tool to support the diagnostic process amongst patients presenting to a sleep clinic for OSA screening. Further studies are needed to reach an agreement on an optimal cut point for neck circumference, as well as determine if this is different across cultures, like it is with gender.

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CRediT authorship contribution statement

Teresa Arora: Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Mohammed Al-Houqani:** Conceptualization, Methodology, Investigation, Resources, Data curation, Writing - review & editing, Visualization, Supervision, Project administration.

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Conflict of interest

None.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2020.07.008.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2020.07.008.

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