A meta-analysis to identify factors associated with CPAP machine purchasing in patients with obstructive sleep apnea

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Abstract. Obstructive sleep apnea (OSA) is a common disease and related to several cardiovascular diseases. Treatment with a continuous positive airway pressure (CPAP) machine is effective. However, not all patients with OSA purchase a CPAP machine for personal use. Previous studies showed different predictors of CPAP machine purchasing in patients with OSA. The present study aimed to summarize and identify predictors of CPAP purchasing using meta-analysis. The study was conducted using factors associated with CPAP purchasing in patients with OSA. The types of studies conducted in adult patients with OSA included: Randomized controlled trials, observational studies or descriptive studies comparing factors between those who purchased CPAP and those who did not. A total of five databases, including PubMed, Central database, Scopus, CINAHL Plus and Web of Science, were searched, and the final search was performed on February 8, 2021. Predictors for CPAP purchasing were determined. There were 598 articles from five databases, which met the inclusion criteria. After duplicated article removal, 390 articles were included in the screening process. There were 12 eligible articles for full text evaluation, and of those, eight studies met the study criteria with 1,605 patients from four countries. There were 11 variables that were available for a comparison between those who purchased the CPAP machine and those who did not, and six factors were different between the two groups: Age, years of education, income, smoking, Epworth Sleepiness Scale (ESS) score and apnea hypopnea index/respiratory disturbance index (AHI/RDI). The AHI/RDI was significantly different between the two groups, with the highest mean difference of 10.40 events/h (95% CI, 4.95-15.86). Patients who purchased CPAP were older (1.11 years), had more years of education (0.93 years), smoked more (1.15 pack/year), and had both higher ESS (0.61) and AHI/RDI (10.40) than those who did not purchase CPAP. Additionally, those who purchased CPAP had a 1.47 times higher income than those who did not. In conclusion, specific personal customer and clinical factors were related to the decision of CPAP purchase in patients with OSA.

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Introduction

Obstructive sleep apnea (OSA) is a common disease in humans. A review on population studies reported that OSA may be found in both men and women with the highest prevalence rate of 37 and 50%, respectively (1). It is also known that OSA is related to five major cardiovascular diseases, including hypertension, heart failure, atrial fibrillation, coronary artery disease and stroke (2-5). A sleep cohort study, conducted in the USA, found that untreated patients with severe sleep disordered breathing presented with coronary artery disease or heart failure 2.6 times more often compared with those without OSA (95% CI, 1.1-6.1) (6). The first line treatment for OSA is the usage of a continuous positive airway pressure (CPAP) machine, as it is cost effective with 15,915 USD per quality-adjusted life year gained (7,8).

Other than the improvement in the quality of life, CPAP therapy, for at least 4 h per night in patients with OSA, reduces the risks of acute coronary artery disease or heart attack by 83% (95% CI, 0.03-0.81) (9). Despite the benefits of CPAP therapy, not all patients with OSA purchase the machine for personal use. The CPAP purchasing rate in patients with OSA varies between 33 and 77% (10,11). There are several predictors for CPAP purchasing in patients with OSA, such as income, socioeconomic status and health insurance (9-11). A study from Mexico (12) found that patients with OSA and public health insurance had a 1.71 times higher chance of purchasing a CPAP machine compared with those without insurance (95% CI, 1.04-2.83), whereas other studies reported that predictors for CPAP purchasing were age and OSA severity (11,13). An increase in age, by one year, showed a 7% higher chance of CPAP purchasing (13). Additionally, a previous study found that marketing strategies may be valid predictors for CPAP purchasing (10). Those who purchased a

CPAP machine preferred to have the option of several CPAP models than those who did not purchase a CPAP machine (3.79 vs. 3.36/5 by Likert scale; P=0.092). As there are several and inconsistent predictors of CPAP purchasing, the present study aimed to summarize and identify predictors of CPAP purchasing using meta-analysis. Furthermore, there is a lack of meta-analyses and systematic reviews of predictors of CPAP purchasing in patients with OSA in the literature.

Materials and methods

Study design. The present meta-analysis included factors associated with the purchase of a CPAP machine in patients with OSA. The types of studies conducted in adult patients with OSA included: Randomized controlled trials, observational studies or descriptive studies comparing factors between those who purchased CPAP and those who did not. The diagnosis of OSA was made using polysomnography upon evidence of an apnea-hypopnea index (AHI) or a respiratory disturbance index (RDI) of five or more events/h. After being diagnosed with OSA, CPAP trial or CPAP titration was initiated either in a sleep laboratory or at home. CPAP titration is performed with the aim of identifying the appropriate CPAP pressure for each patient. A decision to purchase a CPAP machine is made after CPAP titration. Studies conducted in adult patients with OSA that had received CPAP titration either in a sleep laboratory or at home were included.

Literature search and data extraction. In the present meta-analysis, five databases were searched: PubMed (https://pubmed.ncbi.nlm.nih.gov), Central database (www.cochranelibrary.com/central), Scopus (www.scopus.com), CINAHL Plus (https://web.s.ebscohost.com/) and Web of Science (www.webofknowledge.com). The search terms used were 'obstructive sleep apnea', 'sleep apnea syndrome', 'predict*', 'independent', 'factor*', 'variable*', 'purchase*', 'buy', 'bought', 'pay', 'paid', 'expend*' and 'spend*', where '*' was used to search for all terms which began with the preceding letters. The full list of search terms is shown in Tables SI-V. The final search was performed on February 8, 2021. After the duplicates were removed, initial screening was performed for non-relevant articles. Studies were considered relevant if they had been conducted to evaluate different factors between patients who purchased a CPAP machine and those who did not. Data extraction and full text reports were reviewed by two independent authors (BS and KS). Of these, the articles that met the study criteria were included in the final analysis (14).

Studied variables and outcomes. The studied variables included both marketing and clinical factors. The definitions of the studied variables were as follows: Average to high income determined in each study, which may vary among countries; health insurance covering CPAP machine costs, which indicated cost reimbursement by the insurer; and Epworth Sleepiness Scale (ESS) score, which is a subjective sleepiness evaluation method with a value range of 0-24 (15). The primary outcome assessed were factors that varied between patients who purchased a CPAP machine and those who did not. At least two studies were required to calculate the differences of the studied variables between the two groups. The mean differences were calculated between the two groups with a 95% CI for numerical factors and the odds ratio with 95% CI for categorical outcomes. Heterogeneity was computed and reported as I squared (I^2). A forest plot of each comparison was created based on I^2. If I^2 was ≤75%, fixed effect was used. For factors displaying an I^2 value of >75%, the random effect was used.

Evaluation of the study quality. The Newcastle-Ottawa Scale, adapted for cross-sectional studies, was used to evaluate the study quality of observational studies (16). The scale comprised three categories: Selection process, comparability and outcome measurement, with a score of 5, 2 and 3 points, respectively. The total score was 10 points and classified as very good (9-10 points), good (7-8 points), satisfactory (5-6 points) and non-satisfactory (0-4 points). Study quality was evaluated independently by two authors (BS and CN). Disagreements between these two authors were discussed and a final decision was made by a third reviewer (KS). All analyses were performed using Review Manager 5.4 (Copenhagen, The Nordic Cochrane Centre, The Cochrane Collaboration, Denmark).

Results

Study inclusion. There were 598 articles from five databases, which met the search criteria (Fig. 1). After duplicate article removal, 390 articles were included in the screening process. There were 12 articles found to be eligible for full text evaluation. A total of four studies were excluded: Two studies were excluded as CPAP compliance was evaluated, not purchasing of CPAP machines; one study was excluded as the rate of CPAP purchasing did not include variable evaluation; and one study was excluded as only the abstract was available, which was from a conference. In total, there were eight eligible studies involving 1,605 patients from four countries (6-10,17): Five studies from Israel (11,16-20), one from Mexico (12), one from Poland (17) and one from Thailand (10). The most recent study was published in 2018 by Sawunyavisuth (10) from Thailand (Table I).

Details of the included studies. The most common study design was cross-sectional and was used in three of the studies (10,13,18). The diagnosis of OSA was made using polysomnography; however, the inclusion criteria for OSA were variable, with the highest AHI of 30 events/h (11). The duration of CPAP titration or trial, prior to CPAP purchase, was a maximum of 2 weeks (11,13,18). Not all patients with OSA, in three of the studies, underwent CPAP titration [Brin *et al* (18), 183/400 patients; Shahrabani *et al* (19), 150/194 patients; Simon-Tuval *et al* (13), 132/162 patients]. In these three studies, data for analysis were obtained from the total population in the study. Most studies used self-administered questionnaires or telephone interviews to record patient information. The numbers of participating patients varied between 50 (20) and 400 (18), with an average CPAP purchasing rate of 49.8%. Only one study evaluated marketing strategies on CPAP purchasing (10).

Study outcomes. There were 11 variables available for comparison between patients who purchased a CPAP

Table I. Eligible studies for meta-analysis of patients who purchased a CPAP machine and those who did not.

First author/s, year	Country	Study design	Diagnosis of OSA	Duration of CPAP trial	Data	Total cases, n	Purchased, n (%)	Did not purchase,n (%)	(Refs.)
Torre Bouscoulet *et al*, 2007	Mexico	NA	AHI >5/h or desaturation index >15/h	NA	Telephone contact	304	169 (55.6)	135 (44.4)	(12)
Brin *et al*, 2005[a]	Israel	Cross-sectional	RDI >20/h or RDI <20/h with EDS and ESS >9	2 weeks	Self-administered questionnaire	400 183[b]	128 (32) 128 (70)[b]	272 (68) 55 (30)[b]	(18)
Byśkiniewicz, 2006	Poland	NA	NA	NA	NA	184	116 (63)	68 (37)	(17)
Sawunyavisuth, 2018	Thailand	Cross-sectional	Polysomnography	3 nights	Self-reported questionnaire	53	41 (77.36)	12 (22.64)	(10)
Shahrabani *et al*, 2014[a]	Israel	NA	NA	Varied	Phone interview	194	100 (52)	94 (48)	(19)
Simon-Tuval *et al*, 2009[a]	Israel	Cross-sectional	NA	2 weeks	Questionnaire	162	65 (40)	97 (60)	(13)
Tarasiuk *et al*, 2012[c,d]	Israel	Longitudinal interventional	AHI >30/h or >15/h with ESS >10 (moderate to severe)	2 weeks	Questionnaire, telephone survey	121 (control group) 137 (incentive group)	40 (33.1) 65 (47.4)	81 (66.9) 72 (52.6)	(11)
Tzischinsky *et al*, 2011	Israel	NA	NA	NA	Questionnaire, telephone interview	50	24 (48)	26 (52)	(20)

[a]Not all patients underwent CPAP titration [Brin *et al* (18), 183/400 patients; Shahrabani *et al* (19), 150/194 patients; Simon-Tuval *et al* (13), 132/162 patients]; [b]underwent CPAP titration; [c]comprised of two groups, control group and incentive group; [d]comprised of two groups. CPAP, continuous positive airway pressure; OSA, obstructive sleep apnea; RDI, respiratory disturbance index; EDS, excessive daytime sleepiness; ESS, Epworth Sleepiness Scale score; AHI, apnea-hypopnea index; NA, not available.

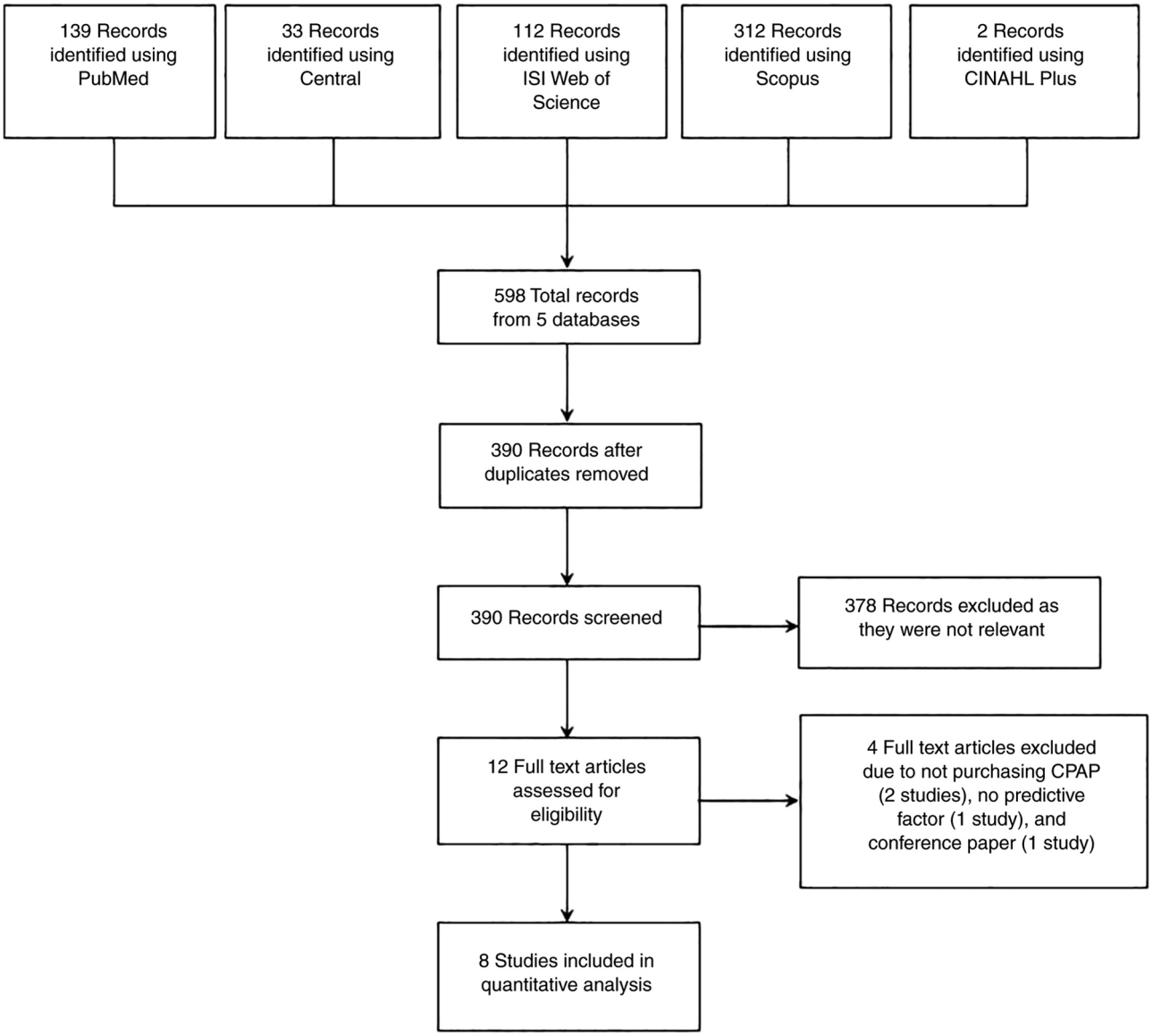

Figure 1. A flow chart showing the stages involved in searching of literature and meta-analysis on purchasing a CPAP machine in patients with obstructive sleep apnea. CPAP, continuous positive airway pressure.

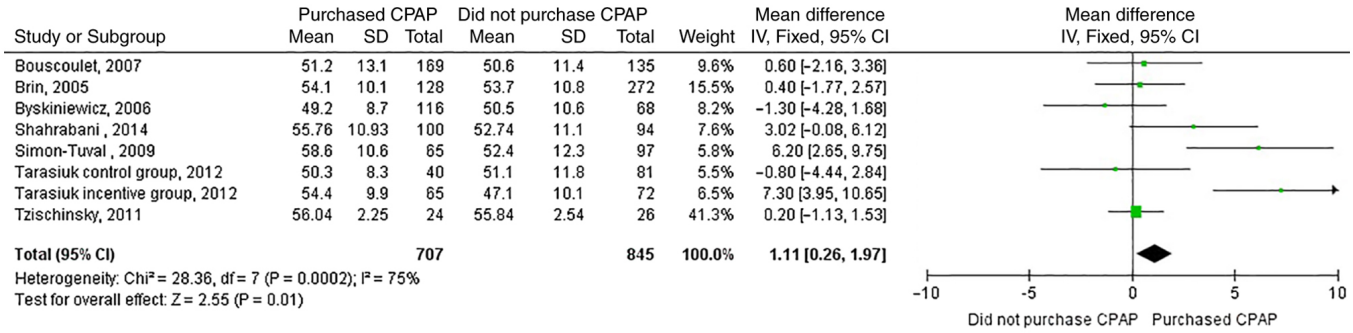

Figure 2. Comparison of age between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance.

machine and those who did not (Figs. 2-12). These factors were age (Fig. 2), sex (Fig. 3), years of education (Fig. 4), living with a partner (Fig. 5), income (Fig. 6), insurance (Fig. 7), smoking (Fig. 8), hypertension/cardiovascular disease (Fig. 9), ESS (Fig. 10), body mass index (Fig. 11) and AHI/RDI (Fig. 12). A total of six factors were found to be significantly different between both groups: Age (Fig. 2), years of education (Fig. 4), income (Fig. 6), smoking (Fig. 8),

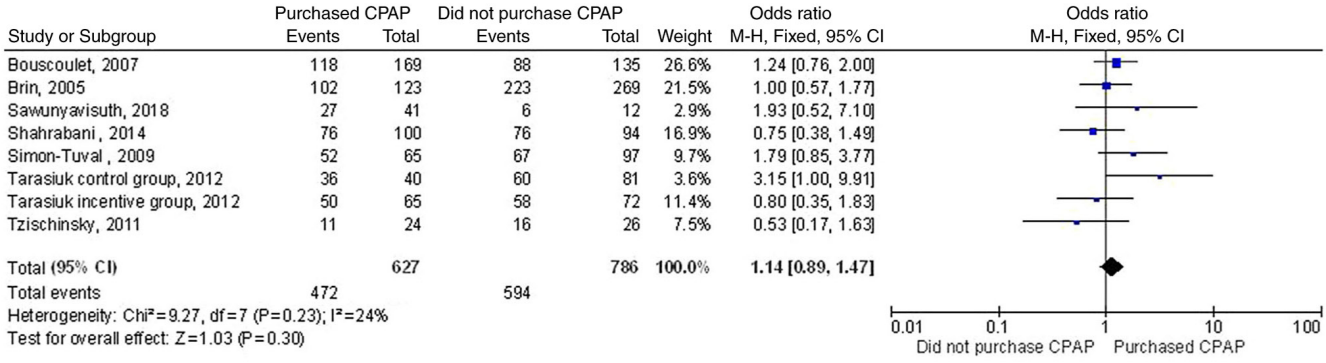

Figure 3. Comparison of male sex between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; M-H, Mantel-Haenszel.

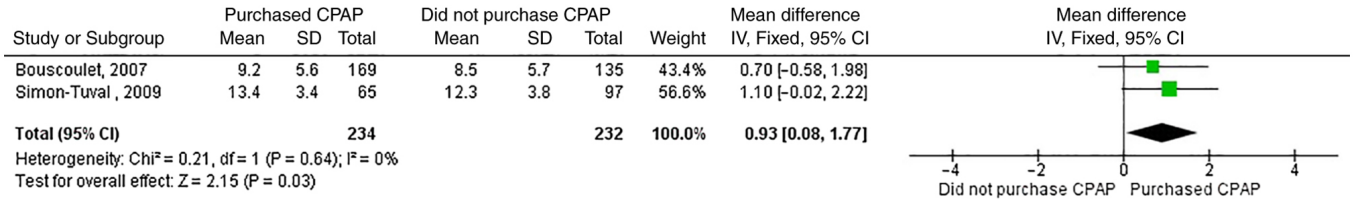

Figure 4. Comparison of years of education between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance

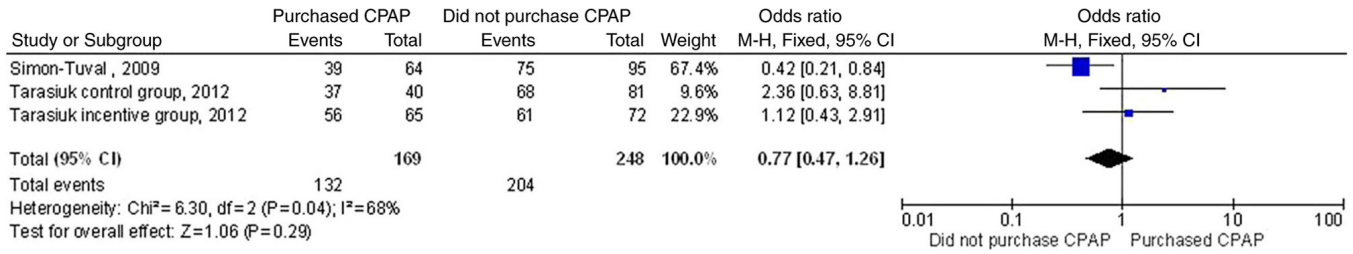

Figure 5. Comparison of living with partner between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; M-H, Mantel-Haenszel.

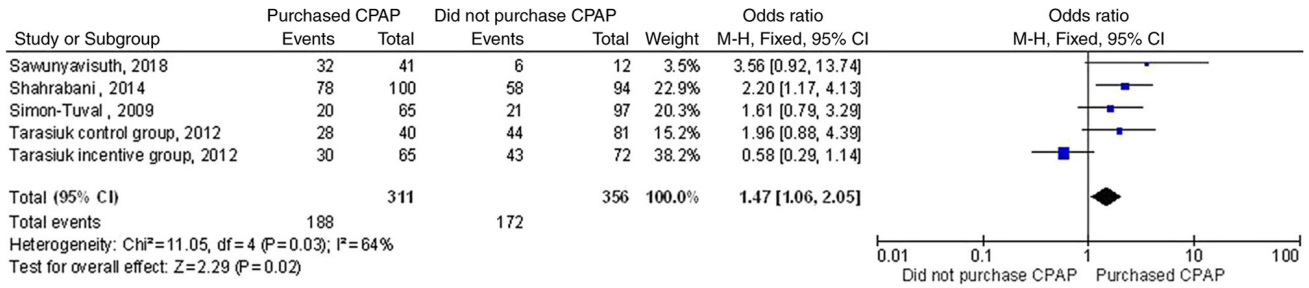

Figure 6. Comparison of average to high income between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; M-H, Mantel-Haenszel.

ESS (Fig. 10) and AHI/RDI (Fig. 12). AHI/RDI was significantly different between the two groups with the highest mean difference of 10.40 events/h (95% CI, 4.95-15.86) as shown in Fig. 12. Patients who purchased a CPAP machine were older (by 1.11 years), had more years of education (0.93 years more), were smoking more (by 1.15 pack/year), and had higher ESS (by 0.61) and AHI/RDI (by 10.40) scores than those who did not purchase a CPAP machine, as shown in Figs. 2, 4, 8, 10 and 12, respectively. Additionally, those who purchased a CPAP machine had a 1.47 times higher income than those who did not (Fig. 6). The quality of most of the studies was evaluated as satisfactory, except for the longitudinal study by Tarasiuk *et al* (11), which was considered as good, with a score of 7/10 (Table II). Furthermore,

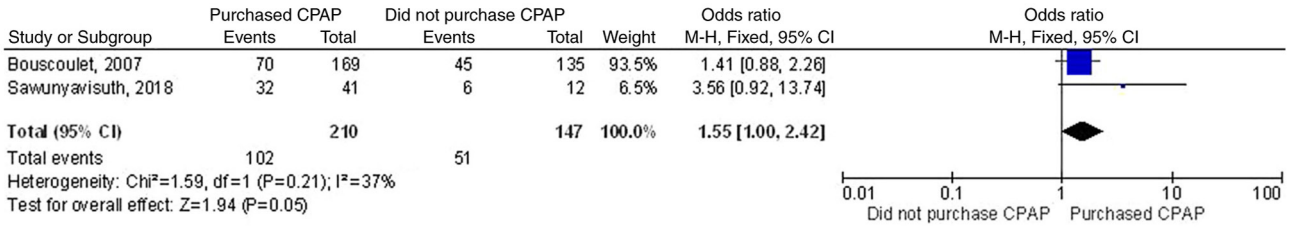

Figure 7. Comparison of having health insurance cover between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; M-H, Mantel-Haenszel.

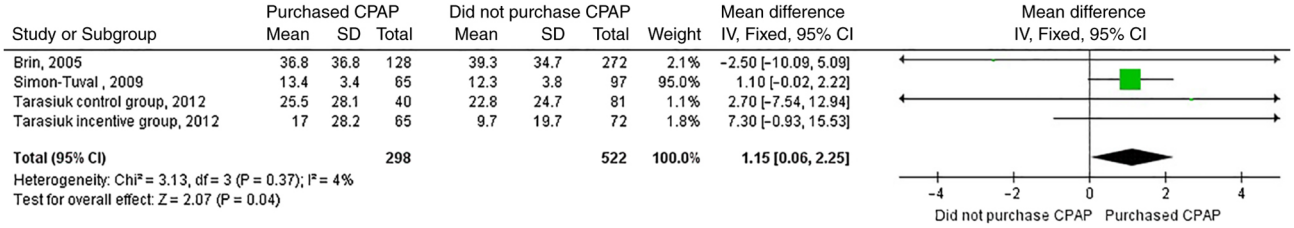

Figure 8. Comparison of smoking (pack/year) between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance.

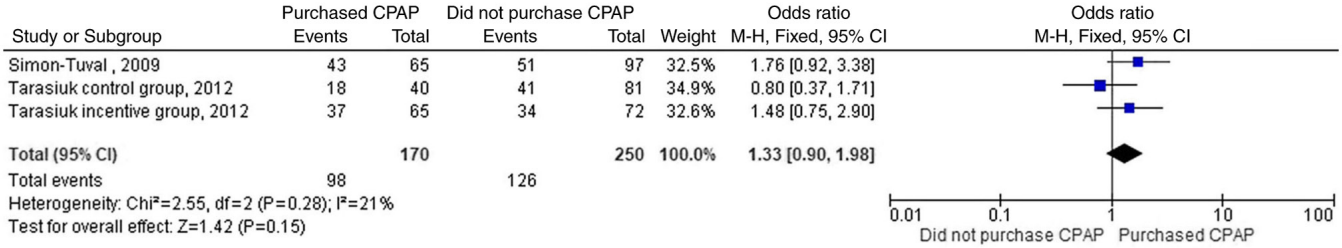

Figure 9. Comparison of having hypertension/cardiovascular disease between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; M-H, Mantel-Haenszel.

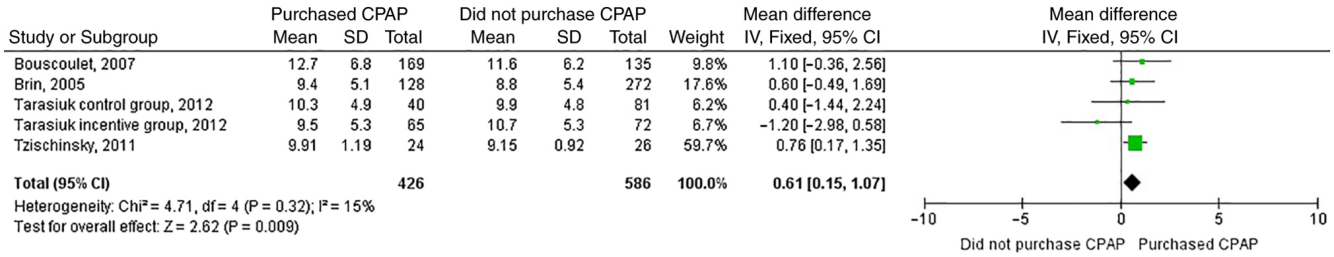

Figure 10. Comparison of Epworth Sleepiness Scale score between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance.

the study by Byśkiniewicz (17) was not scored as it was published in Polish.

Discussion

The six significant factors that were compared between patients with OSA who did or did not purchase a CPAP machine can be categorized into two groups: Customer-related and clinical factors. The personal customer factors included age, years of education and income, while the clinical factors were age, smoking, ESS and AHI/RDI. In addition, age was included in both groups as it can be classified as both a personal customer factor and clinical factor.

There are several customer behavior models, such as the Nicosia model, Howard Sheth model, or Engel, Blackwell and Minard model (21,22). The significant factors in the present study are personal customer factors, which is one factor of several customer behaviors in the black box consumer behavior model (23). Additionally, a previous study from China found that these personal factors are related to higher chances of purchasing healthcare devices; however, the purchase of a

Table II. Study quality evaluation using the Newcastle-Ottawa Scale adapted for cross-sectional studies of the included studies.

First author/s, year	Study design	Selection process (5)	Comparability (2)	Outcome measures (3)	Total (10)	Interpretation	(Refs.)
Torre Bouscoulet *et al*, 2007	NA	3	1	1	5	Satisfactory	(12)
Brin *et al*, 2005	Cross-sectional	3	1	1	5	Satisfactory	(18)
Byśkiniewicz, 2006	NA	NA	NA	NA	NA	NA due to non-English article	(17)
Sawunyavisuth, 2018	Cross-sectional	3	1	2	6	Satisfactory	(10)
Shahrabani *et al*, 2014	NA	3	1	2	6	Satisfactory	(19)
Simon-Tuval *et al*, 2009	Cross-sectional	3	1	2	6	Satisfactory	(13)
Tarasiuk *et al*, 2012	Longitudinal	4	1	2	7	Good	(11)
Tzischinsky *et al*, 2011	NA	3	1	2	6	Satisfactory	(20)

NA, not applicable.

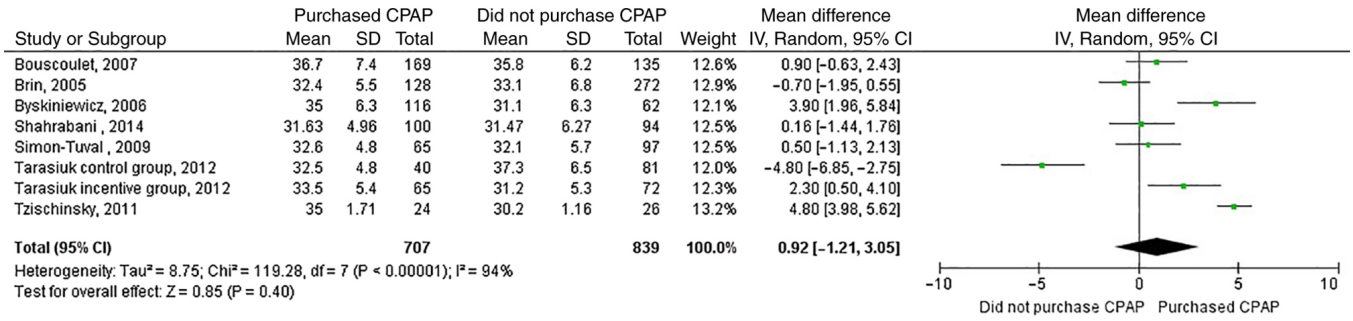

Figure 11. Comparison of body mass index (kg/m^2) between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance.

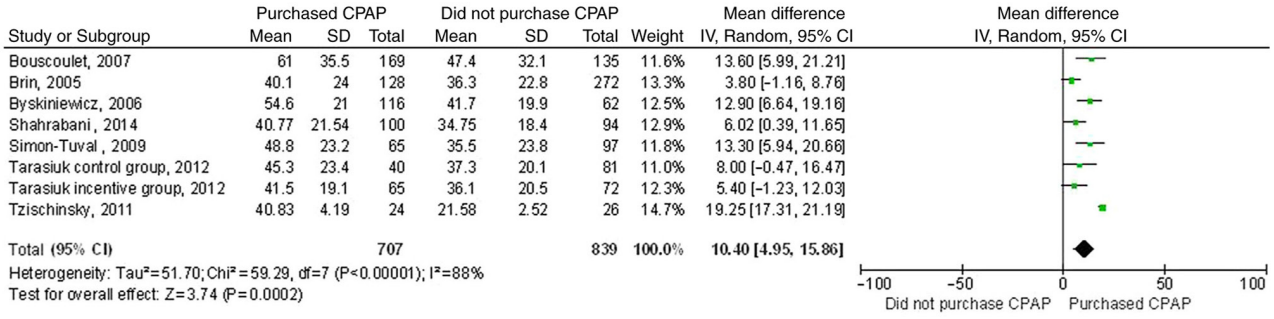

Figure 12. Comparison of apnea-hypopnea index or respiratory disturbance index between patients who purchased a CPAP machine and those who did not. CPAP, continuous positive airway pressure; df, degrees of freedom; I^2, percentage of variation across studies; IV, inverse variance.

CPAP machine was not included in the study (24). Patients with OSA who purchased a CPAP machine were 1.11 years older, had 0.93 years longer education and, on average, a 1.47 times higher income than those who did not purchase a CPAP machine. The previous Chinese study found that older age, higher education (Junior college degree) and higher income had odds ratios of 6.65, 4.02 and 7.88, respectively (24). Both studies identified similar trends for these predictors, but different magnitudes as this study was more specific to the use of CPAP machines by summation of several studies. Furthermore, differences in defining what constitutes high income among countries and currency differences require a cautious interpretation of CPAP purchase. Of note, the present meta-analysis indicated that patients with OSA and health insurance coverage had a 1.55 times higher chance of purchasing a CPAP machine than those without such coverage (95% CI, 1.00-2.42), as shown in

Fig. 7. It should be noted that insurance almost reached statistical significance in the present study. The aforementioned coverage reduces the machine's cost, making it more affordable.

The four clinical factors, which were found to change significantly between the two groups, were related to severity of OSA. Older age, smoking and daytime sleepiness are indicators of severe OSA (25-27). Older age has been reported to be related to increased severity of OSA, with a correlation coefficient of 0.331 (P<0.01) (25), whereas smoking was associated with moderate/severe OSA by 4.4 times (95% CI, 1.5-13) (26). A high ESS score of >10 was found more often in severe OSA, as compared with mild or moderate OSA (40.2 vs. 26.7 and 29.6%, respectively; P<0.001) (27). As a result, more patients with more severe OSA tended to purchase a CPAP machine more often than those with less severe OSA. In the present study, patients with OSA who purchased a CPAP machine had a higher AHI by 10.40 events/h than those who did not purchase a CPAP machine (Fig. 12). Of note, this AHI/RDI mean difference displayed the highest value among the studied variables. As previously reported, patients with severe OSA had higher chances of sudden death or developing cardiovascular diseases, including coronary artery heart disease, heart failure, left ventricular hypertrophy, hypertension or atrial fibrillation (28-30). Those patients with OSA with an AHI score of >20 events/h are likely to have sudden cardiac death (29). Therefore, patients with severe OSA may have several cardiovascular diseases, as well as being more symptomatic, leading to higher chances of purchasing a CPAP machine.

There are some limitations in the present study. First, most studies conducted in Israel may have different cultures or purchasing habits from other countries. Second, some patients did not undergo a CPAP trial prior to CPAP purchase (8-10). In addition, the duration of a CPAP titration prior to a decision of purchasing a CPAP machine varied (Table I). Third, some studied variables, such as body mass index and AHI, bore high heterogeneity. Fourth, CPAP compliance or other related conditions of OSA such as CPAP intervention, exercise intervention, cognitive function, or asthma were not studied (31-38). Finally, marketing strategies which may be related to CPAP purchase were investigated in only one study (10). Therefore, further studies regarding the roles of marketing strategies in CPAP purchase may be required.

In conclusion, personal customer factors and clinical factors were related to the decision of patients with OSA to purchase a CPAP device.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

BS designed the study, extracted the data, evaluated study quality, performed the statistical analysis, interpreted data, and wrote the manuscript. CN performed the searches, evaluated study quality, performed the statistical analysis, interpreted the data, and reviewed the manuscript. KS evaluated study quality, performed the statistical analysis, interpreted the data, and reviewed the manuscript. BS and KS confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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