Sleep Medicine Reviews 74 (2024) 101910

Contents lists available at ScienceDirect

Sleep Medicine Reviews

journal homepage: www.elsevier.com/locate/smrv

Personality traits and pre-treatment beliefs and cognitions predicting patient adherence to continuous positive airway pressure: A systematic review

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ARTICLE INFO

Handling Editor: M Vitello

Keywords:
Obstructive sleep apnoea
Continuous positive airway pressure
Adherence
Prediction
Personality
Health beliefs
Cognitions
Behaviour

ABSTRACT

Adherence to Continuous Positive Airway Pressure (CPAP) for obstructive sleep apnoea (OSA) can be improved by behavioural interventions which modify patients' beliefs and cognitions about OSA, CPAP, and themselves. We have conducted the first systematic review of the literature on beliefs and cognitions held before starting treatment, and personality (which influences the former) that predict the decision to purchase or start CPAP, or CPAP adherence one month or more after CPAP initiation. A systematic search and screen of articles identified 21 eligible publications from an initial 1317. Quality assessment performed using an adapted Newcastle-Ottawa Scale demonstrated that 13 (62%) studies were poor quality and only seven (33%) were high quality. Eighteen factors, such as self-efficacy (confidence) in using CPAP and value placed on health predicted CPAP adherence; however, for only six (33%), utility as an intervention target is known, from calculation of individual predictive power. Studies did not use new behavioural frameworks effective at explaining adherence behaviours, nor did they interview patients to collect in-depth data on barriers and facilitators of CPAP use. Future studies cannot have these limitations if high quality evidence is to be generated for intervention development, which is currently sparse as highlighted by this review.

1. Introduction

There is an epidemic of obstructive sleep apnoea (OSA), with its estimated prevalence at one billion, an eighth of the world's population [1], compared to its rarity when first described five decades ago [2]. The disease burden is considerable, and in part comes from patients who are not adherent to first-line therapy with Continuous Positive Airway Pressure (CPAP) who therefore continue to suffer OSA-related ill-health [3,4].

CPAP non-adherence rates are high, ranging from 17% up to 71% at 1–3 months following CPAP initiation in trials from various countries [5]. We, and others, have reported non-adherence rates of approximately 60% in UK patients within clinical services, 1–3 months after CPAP initiation [6,7], while this was similarly high at 46% in a German clinical cohort [8]. These are using the widely accepted criteria for adherence, which are a minimum usage of 4 hours use a night for at least 70% of nights over a given period [9]. In the UK, this means the majority of CPAP does not meet the National Health Service cost-effectiveness threshold [10]. In the US also, the cost implications of non-adherence to CPAP are considerable with non-adherent patients' healthcare costs exceeding those of adherent patients by 40% [3].

Poor CPAP adherence has also hindered advancement in knowledge about the benefits of CPAP. Several trials to determine whether CPAP prevents disease, such as the SAVE trial [11], completed with insufficient trial participants adherent to CPAP to meet the sample size for the power calculation. This has affected clinical care and potentially CPAP uptake and adherence, as this information is unavailable when patients decide to start or continue CPAP therapy.

CPAP adherence rates have also not improved over the last two decades [12]. The main changes to practice have been use of more comfortable masks and devices and greater use of telemonitoring

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https://doi.org/10.1016/j.smrv.2024.101910
Received 14 February 2023; Received in revised form 9 January 2024; Accepted 12 February 2024
Available online 21 February 2024

Abbreviations

BAS Behavioural activation system
BCT Behaviour change techniques
BIS Behavioural inhibition system
CBT Cognitive behavioural therapy
COM-B Capability, opportunity, motivation-behaviour
CPAP Continuous positive airway pressure
CSM Common-sense model of self-regulation
FOSQ Functional outcomes of sleep questionnaire
HBM Health belief model
IPQ-R Illness perception questionnaire-revised
NOS Newcastle-Ottawa scale
PRISMA Preferred reporting items for systematic reviews and meta-analyses
PROSPERO International prospective register for systematic reviews
OSA Obstructive sleep apnoea
SCT Social cognitive theory
SE Self-efficacy
SEMSA Self-efficacy measure in sleep apnea

Glossary of terms

Adherence The extent to which a patient's action matches the agreed recommendations (which are recommendations agreed between prescriber and patient)
Affect An individual's experience of feeling, emotion or mood
Behavioural Activation System Motivational system regulating inherent drive towards positive rewards/goals
Behavioural Inhibition Motivational system regulating inherent aversion away from unpleasant stimuli
Belief Mental acceptance or conviction in the truth or actuality of some ideas
Cognition Mental representation formed by external and/or internal input being transformed, reduced, elaborated, stored, recovered, and used
COM-B Model Also known as the Behaviour change wheel; a validated framework conceptualising that without providing individuals with capability, opportunity and motivation for behaviour change, behaviour change will not occur
CPAP uptake Agreeing to start CPAP
Cronbach alpha A measure of reliability for a set of scale or test items, assessing the internal consistency (how closely related) a set of items are as a group
Framework Describes/represents a set of phenomenon and their interactions
Model Describes/represents a phenomenon or set of phenomenon
Necessity Concerns Framework A framework that postulates that adherence is determined by the balance between individual judgements about personal need for treatment (necessity beliefs) and the possibility of adverse effects of treatment (concerns)
Neuroticism Tendency to experience negative emotions and emotional instability
Newcastle Ottawa Scale Quality assessment tool for systematic reviews or meta-analyses of non-randomised studies
Outcome expectancy of using CPAP That individual's belief of the consequences of using CPAP
Perceived risk of OSA That individual's belief of the risk imposed by OSA
Perceived severity of OSA An individual's belief in the seriousness of consequences from a disease
Personality The dynamic organisation within the individual of those psychophysical systems that determine his characteristics, behaviour and thought
Planful problem solving A method of active coping, involving deliberate problem-focused efforts to alter a situation coupled with an analytic approach to solving the problem
Self-efficacy in using CPAP An individual's belief in his or her capacity to use CPAP
Social Cognitive models A genre of behavioural models where the premise is that individuals learn directly by observing others within the context of social interactions, experiences, and outside media influences. Started with Bandura with his Social Learning Theory (1977)
Theory Describes and explains a phenomenon or set of phenomenon
Type D personality A personality type which is vulnerable to general psychological distress, having a tendency towards a negative affect and social inhibition

(monitoring patient data from the device remotely). Since treatment side effects are not consistently related to CPAP adherence [5,6,13–16], the unchanged adherence rates are unsurprising.

In contrast, the importance of illness beliefs and cognitions to patient adherence to CPAP is evident from the numerous studies demonstrating their association [5,13,14,16–24] and also by the efficacy of behavioural interventions in improving CPAP adherence [25]. Beliefs are the mental acceptance or convictions in the truth or actuality of ideas [26], and cognitions are mental representations formed by external and/or internal input being transformed, reduced, elaborated, stored, recovered, and used [27]. Personality, as the dynamic organisation of an individual's psychophysical systems which determines their characteristics, behaviour and thought [28] would therefore also be expected to influence the likelihood of an individual adhering to CPAP, and there are, indeed, significant relationships between certain personality traits and high likelihood of non-adherence or good adherence. Behavioural interventions target patients' beliefs about OSA, CPAP and themselves. When implemented at or before CPAP initiation, they have been effective at increasing CPAP use, usually measured at either one month or three months after starting CPAP, as these correlate with longer-term CPAP use [25,29]. However, to date, interventions effective in trials have not been suitable for implementation by healthcare systems to make real-world impact [30].

There have been 13 reviews on predictors of CPAP adherence between 1997 and 2023 including [5,13,14,16–24] but there has not been a systematic review of the behavioural studies, until now. Our aim was to conduct this review to produce knowledge leading to development of highly effective interventions to improve CPAP adherence from current levels. We had three objectives.

1) Describe the pre-treatment beliefs and cognitions, and personality traits predicting decision to purchase or start CPAP, or CPAP adherence at one month or more following treatment initiation, as targets for interventions, from the studies already completed
2) Specify the research that need to be done to identify new targets for interventions and clarify areas of uncertainty from previous studies
3) Identify areas in which further research is not required.

2. Methods

The review protocol was registered in the International Prospective Register for Systematic Reviews (PROSPERO), protocol number

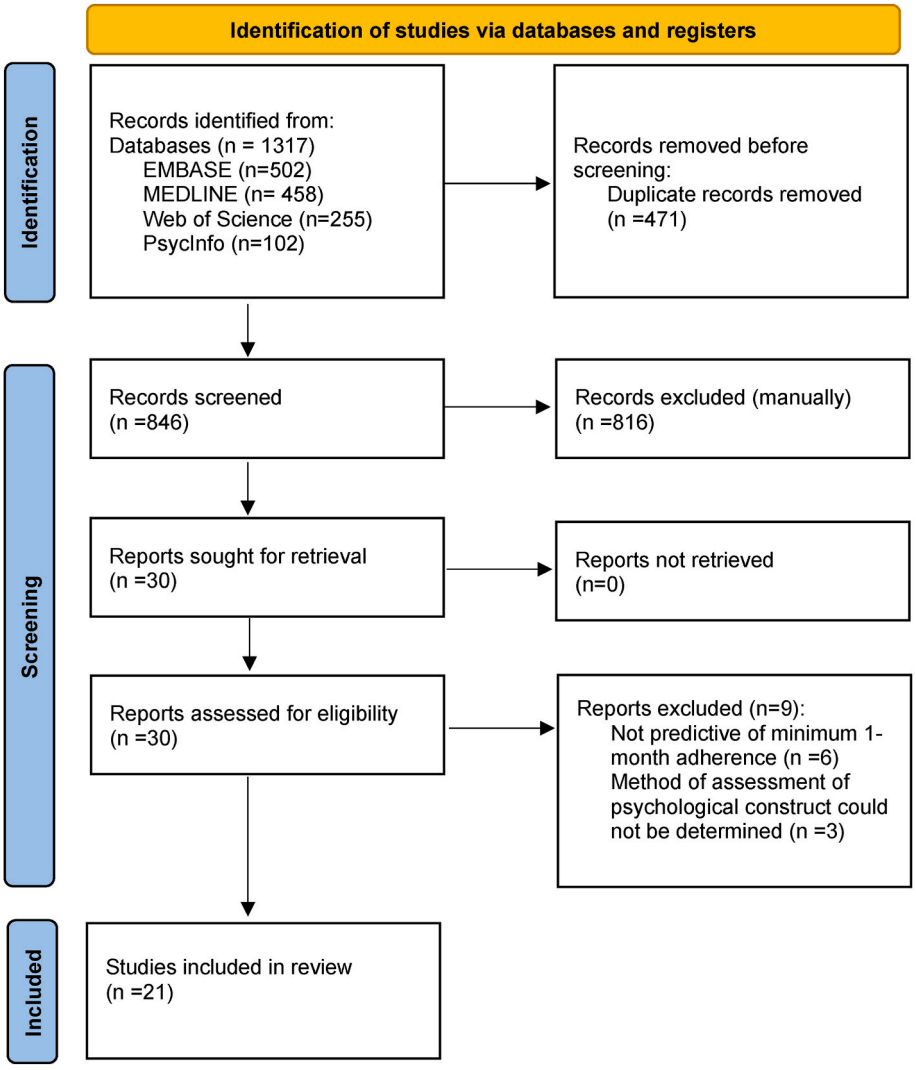

Fig. 1. PRISMA flow diagram of search and selection process.

[CRD42022368420]. The recommended Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol was followed.

2.1. Eligibility criteria

2.1.1. Inclusion criteria

Studies investigating beliefs, cognitions, and personality in adult patients with OSA (>18 years of age) in relation to:

1) CPAP uptake (agreement to purchase or start CPAP)
2) adherence/non-adherence/use of CPAP ≥1 month after starting CPAP

2.1.2. Exclusion criteria

Studies in which:

1. It was unclear precisely what belief, cognition or trait had been measured, and how, either from this, or previous, publications
2. The belief or cognition was measured after CPAP initiation, therefore outside the optimal time frame for targeting by an intervention to improve CPAP adherence. Personality traits could be measured at any point in relation to CPAP initiation as it was expected that personality would be stable over the short time frame of a study.
3. The sample population was not representative of a general OSA population e.g., selected for a specific concurrent condition such as dementia
4. The effect of an intervention on CPAP adherence was being investigated
5. The outcome was CPAP adherence at 1–3 weeks (at which point CPAP use may still be changing) [6].

2.1.3. Information sources

Studies were sourced from four databases: MEDLINE, EMBASE, PsycInfo, and Web of Science from inception of the databases until February 2022.

2.1.4. Search strategy

Following psychologist and librarian discussion, search terms were devised for databases. Twenty-eight free text and Medical Subject Headings (MeSH) terms were used to search in MEDLINE and revised accordingly for other databases (see Fig. S1 in Supplement). The search terms addressed various behavioural models and variables related to CPAP adherence or uptake in OSA patients. Key terms included synonyms for CPAP "adherence" and "compliance" in OSA, generic terms such as "illness beliefs" and specific terms for behaviour change and treatment adherence models such as the "self-regulatory model". The search was specified so that each result had to include a variation of each

Table 1
Assessment of included studies according to the adapted Newcastle-Ottawa Scale.

First author	Represent-ativeness of cohort	Selection of non-exposed cohort	Assessment of construct	Comparability of cohort	Assessment of outcome	Sufficient length of follow-up	Adequacy of follow-up	Statistical analyses	Total score (max 11) & rating
Borriboon	★	★	★	★★	★★	★			8 (L)
Bros	★	★		★★	★★	★	★		8 (L)
Brostrom	★	★	★★	★★	★	★			8 (L)
Copur		★	★★	★★	★★	★			8 (L)
Kreivi	★	★			★★	★	★	★	7 (L)
Moran	★	★	★★	★	★★	★		★	9 (H)
Olsen	★	★	★★	★★	★	★	★	★	10 (H)
Pelletier-Fleury	★	★	★★	★★	★	★			8(L)
Poulet	★	★	★★	★★	★	★	★		9(L)
Saconi	★	★	★★	★★	★	★	★	★	10 (H)
Sage	★	★		★★	★★	★	★	★	9(L)
Sampaio	★	★	★	★★	★★	★	★		9 (M)
Sampaio	★	★	★★	★★	★★	★	★		10(H)
Sawyer	★	★	★★	★★	★	★	★	★	10 (H)
Shahrabani	★	★		★★		★	★		6(L)
Skinner	★	★	★★	★★	★	★	★		9(L)
Stepnowsky		★	★★	★★	★★	★	★	★	10(H)
Tanahashi		★	★	★★	★	★	★		7(L)
Tzischinsky	★	★		★★		★	★		6(L)
Wallace	★	★	★★	★★	★★	★	★		10(H)
Wild	★	★	★★	★★	★	★	★		9 (L)

The total maximum score was 11, with scores for High quality (H), Moderate quality (M) and Low quality (L) as follows: 4-5, 3-4, ≤2 (Selection), 1-2, 1-2, 0 (Comparability), 4-5, 4-5, ≤3 (Outcome).

of the four following terms: OSA, CPAP, a psychological construct, and adherence. The results of the search were imported into the CADIMA software system, following which duplicates were manually removed and screened.

2.1.5. Selection process

The screening of search results via examination of titles, keywords, and abstracts was conducted independently by two authors (P.K, N.H), then full-text articles were reviewed for eligibility. Differences regarding study eligibility were discussed to reach consensus; if not achieved, a third reviewer (S.A.S) was consulted.

2.1.6. Data collection process

One author (P.K.) collected the data from each study which included: first author, publication year, participant characteristics (number of participants, mean age, gender, ethnicity), study characteristics (behavioural variables investigated, precise outcome measure) and key findings.

2.1.7. Quality assessment

Two authors (P.K., N.H.) independently evaluated study quality using the Newcastle-Ottawa Scale (NOS) [31] which was specifically adapted for this study (see supplement for details). The total maximum score NOS was 11, and the adjusted scores for good, fair, and poor quality respectively for each domain were therefore: 4–5, 3–4, ≤2 (S), 1–2, 1–2, 0 (C), 4–5, 4–5, ≤3 (O).

3. Results

The PRISMA flowchart process of study selection is depicted in Fig. 1. The search identified 1317 articles, which after screening was reduced to 21 publications, although two studies pertained to the same cohort with different measures reported in the two manuscripts. The key characteristics of the 21 studies are summarised in Table S1 in the supplement.

3.1. Study characteristics

The studies were of a longitudinal observational design with a median sample size of 110 (220) participants. The median age of patients was 55 (5) years, and the majority of studies had a predominance of males with a median of 73 (30) % males, with the exception of Moran et al. [32]. Only six (29%) of the studies reported the ethnicity of their patients; of these, three had a majority white sample [33,34] or exclusively one ethnicity (Hispanic, Thai, and Japanese) [35–37]. Twelve studies investigated patients' beliefs and cognitions about their condition, treatment, and themselves at the time of starting CPAP, four studied personality, and five evaluated a combination of beliefs, cognitions, and personality. Three studies evaluated the decision to start CPAP or the intention to purchase CPAP. Of the other 18 studies of CPAP adherence, there were five different outcome measures with only three studies using the widely accepted adherence criteria.

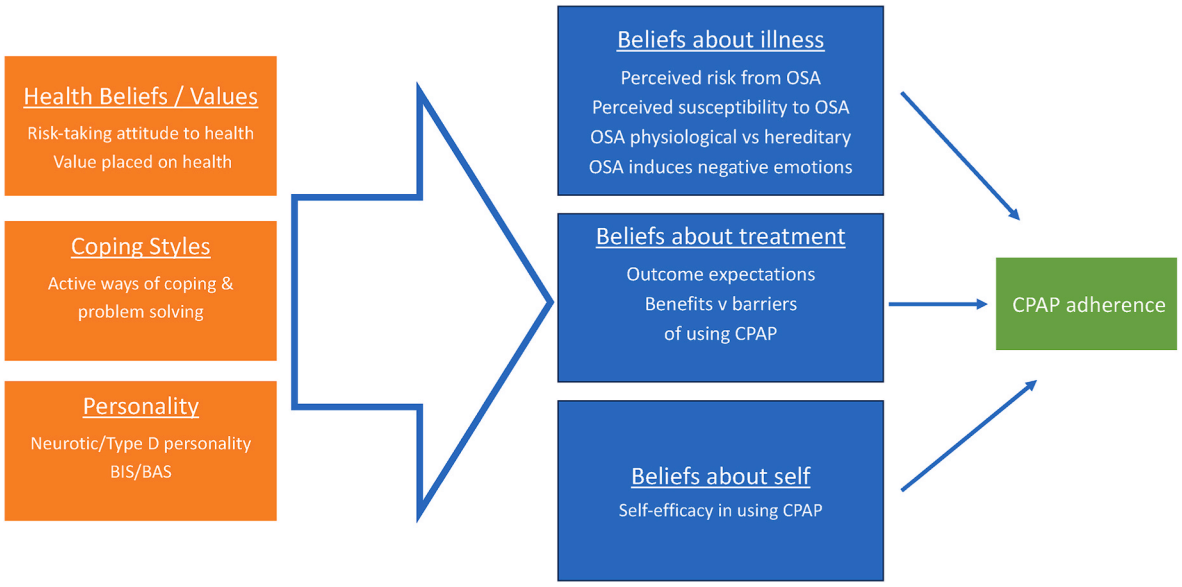

Fig. 2. Summary of relationships between personality, beliefs, and CPAP adherence in general and the results of the current review Abbreviations: BIS/BAS (Behavioural Inhibition System/Behavioural Activation System); CPAP: continuous positive airway pressure; OSA: obstructive sleep apnoea. The figure summarises how an individual's beliefs regarding an illness, treatment, and their own self, coping styles, and personality are likely to influence their adherence to treatment in general, and then within each category, the specific behavioural factors that predispose to poor adherence to CPAP therapy identified by this review.

3.2. Psychological constructs studied

3.2.1. Beliefs and cognitions

Elements of the Social Cognitive Theory (SCT) were investigated in seven studies and elements of the Health Belief Model (HBM) studied in four. Higher self-efficacy (SE, confidence) in using CPAP, higher outcome expectations (OE, positive expectations of the outcome) of using CPAP, and higher perceived risk (PR) of OSA, at the time of starting CPAP predicted greater use of CPAP at one month following CPAP initiation. SE explained 9% of the variance in CPAP use between individuals alone [34] and 19% when combined with race [33]. Only 18% of patients who went on to be adherent to CPAP at one year had scores of <20 on a novel SE scale when starting CPAP [38]. OE with PR explained 22% of the variance in CPAP use between individuals [39]. Patients who believed that they had inherited OSA were more likely to agree to start CPAP [40]. Patients who felt negative emotions towards their diagnosis and who did not attribute their OSA to risk factors such as poor diet or smoking were more likely to be non-adherent to CPAP [40]. A high perception of risk posed from OSA and a high perceived susceptibility to OSA predicted good CPAP adherence at one month later [39]. Patients' perceived benefits and barriers to CPAP use predicted both an intention to purchase CPAP and CPAP use one month later, with intention to purchase (but not benefits or barriers themselves) predicting decision to purchase CPAP six months later [41,42]. High OE of using CPAP were associated with both high adherence [39], and with moderate rather than high adherence [43].

3.3. Personality

3.3.1. Drive/motivation

BAS scores measure innate drive towards rewards and goals and BIS measures aversion away from unpleasant stimuli [44]. Higher BAS scores were associated with greater CPAP use and higher BIS scores with lower CPAP use (BIS: $r = -0.47$, $p = 0.01$ [45], BAS $r = 1.12$, $p = 0.016$ [32]).

3.3.2. Tendency towards negative affect (mood states)

High scores for neuroticism were associated with poorer CPAP adherence ($r = 0.472$, $p = 0.001$) [32], as was having a Type D (distressed) personality [46], both personality types having tendencies towards a negative affect, with an additional predisposition to be socially inhibited in the latter [47]. Patients with a non-Type D personality used CPAP for more than 1 hour a night longer than patients with a Type D personality, which is a clinically, as well as statistically, significant difference [(378 (116) minutes versus 292 (138) minutes, $p < 0.001$].

3.3.3. Attitude towards risk

Patients with DOSPERT questionnaire [48] scores indicating greater tolerance to risk-taking with one's health were significantly more likely to discontinue CPAP therapy than those with lower scores (HR 1.72, $p = 0.04$ [49]).

3.3.4. Coping

Active coping, by problem solving and seeking religious support, were positively associated with CPAP adherence; however, the variance in CPAP adherence accounted for was extremely small ($R^2 = 0.03$, $p < 0.05$) [34].

3.3.5. Study quality assessment

The assessment of study quality is shown in Table 1 below. None of the 21 studies scored the maximum score of 11. Thirteen (62%) were poor quality, one (5%) was fair/moderate quality, and seven (33%) were high quality. Study quality was largely compromised in areas of assessment of the psychological variable and statistical analysis. Five of 21 studies (24%) used questionnaires that had not been tested for validity and either had poor reliability (internal consistency where Cronbach's alpha <0.70) [38,41] or unknown reliability as this was not tested prior to use [42,50,51]. Sixteen of 21 studies (76%) did not give a measure of the predictive power the behavioural factor that they were investigating in isolation. Although all studies measured CPAP use objectively from the device, in eight of 21 (38%) studies, the counter gave a unit time where differentiation of duration of use from regularity was not possible and yet was necessary for optimal measurement of the study outcome. For example, in these studies, the counter would read 120 hours (h) which could be 4 h use over 30 days or 8 h use over 15 days.

4. Discussion

There have been 13 reviews over the last 26 years of the predictors of poor adherence to CPAP however, this is the first systematic review of the literature on behavioural factors predicting CPAP adherence. Therefore, we can discuss critically what is known so far, identify precisely where there are evidence gaps, and where there has been enough investment, so that we can move forwards with research that will best foster the development of interventions to improve CPAP adherence from current levels.

The relationship between health and illness beliefs and adherence to treatment is well described by a number of behavioural theories and models [52,53]. The decision to initiate treatment is strongly influenced by a patient's beliefs about their condition, the treatment, and their own self, for example, their perception of their own capabilities with regards to administering the treatment [52,53], However, once treatment is started, if a patient's experience and outcomes of treatment differ from their expectations, they will revise these beliefs, hence their use of treatment [52,53]. This is well illustrated by our recent modelling of CPAP use of 1000 patients demonstrating that 54% of patients change their use over the first month of treatment, particularly over the first two weeks. We describe "rising" and "upward drifting" users [6] analogous to Yi et al's "improver" group from modelling data from 301 patients [54]. We also describe "falling" and "downward drifting" users [6] demonstrating that patients revise their use and beliefs in the opposite directions also.

Multiple beliefs (mental acceptance of certain ideas) and cognitions (mental representations of internal or external input) are likely to impact CPAP adherence concurrently, as is the case in adherence to other treatments [55,56]. In addition, personality, which determines an individual's characteristics, behaviour and thought [27,57], would naturally be expected to influence on CPAP adherence via its effects on beliefs and thoughts. Personality can also affect relationship building [58], hence social support, which may also influence CPAP use indirectly, as social support generally facilitates treatment adherence [59,60]. We can then summarise the results of this systematic review within the framework of what is known more generally about the relationships between personality, values about health, coping styles, and treatment adherence schematically in Fig. 2. The only modifiable factors accounting for a significant degree of variance in CPAP adherence were self-efficacy (9%) and benefits and barriers of using CPAP (23%). These are the only two credible targets for an intervention to improve CPAP adherence, which is a disappointing output from more than two decades of research.

5. Limitations of studies to date

The current literature has not used the most appropriate behavioural models. All but one of 16 studies which investigated beliefs and cognitions (excluding the four studies of personality traits only) used one of the social cognitive (learning) models. Eight studied elements from the Social Cognitive Theory (SCT) [61], five using the same (SEMSA) questionnaire and four used the Health Belief Model (HBM) [62]. There was further duplication because the SCT and HBM overlap, e.g., the perceived risk (of OSA) in the SCT is equivalent to perceived severity (of OSA) in the HBM. Furthermore, these studies used similar populations in size and type, thus there was little scientific gain from conducting so many of these studies. The authors appeared unfamiliar with the models themselves with Borriboon et al. misinterpreting perceived severity (HBM) to mean severity of symptoms and using the Functional Outcomes of Sleep Questionnaire Score as the instrument. Meanwhile, more relevant behavioural models have been neglected. The Common-Sense Model of Self-Regulation (CSM), described in 1980, has been the most widely used framework for describing and understanding the behaviours for managing illness threats, including taking of treatment. However, it has only been studied twice, once in relation to agreement to start CPAP by one of the current review authors in Ref. [40] and once in relation to CPAP adherence, where only the brief 8-item version of the revised 56-item questionnaire was used [63]. Models that are highly effective predicting adherence to medication such as the Necessity Concerns Framework (NCF), developed in 1999, have not been tested to see if they predict adherence to CPAP [56]. The NCF posits that a patient's adherence to medication reflects their judgements about personal need for treatment (necessity beliefs) versus the possibility of adverse effects. It would be expected that would be some overlap between beliefs that predict adherence to medication and CPAP. Last but not least, the COM-B model/Behaviour Change Wheel is a framework developed from a systematic review of 19 different frameworks of behaviour change [64]. It proposes that capability, opportunity, and motivation (COM) are necessary for a behaviour change to occur and has, for example, accounted for 47% of the variance in adherence to COVID-19 prevention measures [65,66]. It has yet to be assessed in the context of CPAP adherence.

The second major limitation is that the statistical methodology of most of these studies, and study design of many, is poor. Few studies with an adequate sample size had conducted multiple regression analyses and even then, few reported the contribution of each belief individually so that it is clear for only six of the 18 behavioural factors studied (33%) what degree of predictive capacity they yield. It is therefore unclear whether any sizeable effect would result from targeting the other 12 beliefs with an intervention. Yet reviews have reported these variables in either the same manner as those of which their predictive value is clear, or in proportion to the number of studies that have demonstrated their association with CPAP adherence. Sample sizes have also often been too small for the number of factors tested. Also, most studies did not report the ethnicity of their samples, and those that did had little diversity which may have limited the spectrum of beliefs and cognitions.

Thirdly, the majority of studies have not attempted to study the *in vivo* situation by investigating multiple behavioural factors (personality, beliefs, cognitions, and potential moderators such as mood) in a single study. The value of this type of approach can be seen in Ref. [67] to explain the different aspects of social distancing behaviour in 2025 individuals during the first lockdown of the COVID-19 pandemic in the UK [67].

Fourthly, in treatment adherence studies it would be usual to collect qualitative data on patients' perceived barriers and facilitators of the behaviour change, as the (predominantly quantitative) data obtained from questionnaires, would not be sufficient to inform development of interventions. However, patient interviews have not been conducted in any of the studies in this review.

Lastly, a key class of variable that may influence CPAP adherence, "personal values", may have been omitted from these studies. While personality traits are considered descriptors of an individual (e.g., "agreeable" or "neurotic"), personal values are considered distinct and independent of personality, being described instead as motivations ("to be independent", "maintain family security") [68]. As already discussed, motivation has an important role in influencing behaviour. Therefore, there is a clear rationale for investigating personal values, in particular ones such as self-direction (independence of thought and action) or security of self and family in relation to use of treatments like CPAP.

Our conclusions concur with previous reviews, in particular [16,18] which highlight the limitations in the statistical methods of previous studies with [18] offering valid proposals for the design for future studies. One review entitled "A systematic review of CPAP adherence across age groups: clinical and empiric insights for developing CPAP adherence interventions" in 2011 [14] provided a comprehensive overview of the challenges in the field but did not include a search strategy and evaluation of study quality that would define present-day systematic reviews.

Practice Points.

1. Several (18) pre-treatment beliefs and cognitions about OSA and CPAP and personality traits predict adherence to CPAP; however, the clinical relevance of all but six remain unknown because their power to predict CPAP adherence was not quantified.
2. Two beliefs and two personality traits explain a significant (≥9%) degree of variance in CPAP adherence between individuals, consistent with them being clinically relevant predictors of adherence to CPAP.
3. The two beliefs identified to be significant predictors of CPAP adherence can be targeted for modification by behavioural interventions, with the expectation that patient adherence to CPAP will improve. Personality traits, although not modifiable in the short-term, can be utilised in tools to identify patients at particularly high-risk of becoming non-adherent to CPAP.
4. When interpreting the study findings, the poor overall study quality should be borne in mind: 13/21 (62%) were poor quality and only 7/21 (33%) were high quality.

Research Agenda.

1. Future studies should include large cohorts with good representation across ages, genders, and ethnicities.
2. These should utilise new behaviour change frameworks, models that have been successful in explaining medication adherence and other adherence behaviours, as these are likely to perform better at explaining patient adherence to CPAP than classical social cognitive theories.
3. Personality traits, coping styles, personal values, beliefs, cognitions, and their mediators and moderators, should be studied together to understand "*in vivo*" relationships. The data should be analysed using powerful statistical methods such as modelling to develop understanding of which variables predict CPAP adherence, their relative contribution, and how they interact.
4. There is also need for high-quality qualitative data on patients' perceived barriers and facilitators to CPAP use. This can be done by purposive sampling of smaller patient subsets from larger cohorts. Selection can based on illness beliefs identified from a patient's quantitative data, or based on their early behaviour in relation to CPAP use which predicts a particular propensity for non-adherence to CPAP in the longer-term.

6. Limitations of this review

We were strict in our inclusion and exclusion criteria which may have resulted in under-reporting of beliefs, cognitions, and personality traits with relevance to CPAP adherence. However, this was done to align with the review's aims. Firstly, by excluding studies where the scale or questionnaire used to measure the belief, cognition or aspect of personality was not accessible, we may have excluded a psychological variable of value. However, it would be impossible to assess the quality of the assessment tool, nor target an undefined variable in a behavioural intervention, and therefore it did not fulfil this review's aim. We also excluded studies that evaluated the association of beliefs, cognitions and personality with CPAP adherence measured before one month when CPAP use is not stable and does not correlate with long-term use [6,69], as our aim was to identify behavioural factors that influence CPAP adherence long-term and not transiently. We also restricted our search strategy to beliefs and cognitions measured at the time of starting CPAP, and not following initiation, as intervening with pre-treatment beliefs is the most feasible approach in many healthcare systems as patients are in contact with healthcare professionals at this time. Patients may not attend follow up following treatment initiation, and this is more than two and a half times more common in patients who are non-adherent to CPAP than adherent [70]. Furthermore, pre-treatment beliefs and cognitions are key to CPAP adherence, having an independent effect to beliefs and cognitions that arise subsequently, as we have discussed earlier. We also did not include the studies investigating the influence of affect (an individual's experience of feeling, emotion, or mood) or an anxiety or depressive disorder on CPAP adherence, as other reviews have covered these topics. Also, as anxiety and depression would not be targeted by behavioural interventions to improve CPAP adherence, these studies did not fit our review's aim. We did not perform a meta-analysis of the behavioural factors which had been measured in more than one study, such as self-efficacy. This is because the data were very heterogeneous; in particular because the variable being measured in each study was different as a result of different scales (selected from different behavioural models) and therefore conducting a meta-analysis would not have been appropriate.

7. Focus for future research

Going forward, there several evidence gaps that need to be filled. As also surmised by Olsen et al. quantitative studies need to be large [18]. Modelling of longitudinal patterns of CPAP use generally requires participant numbers in the hundreds with sample size calculations dependent on a number of factors specific to the type of modelling [71]. In addition, our work and others modelling data on CPAP use from large cohorts demonstrates that there are multiple patient subgroups based on their CPAP usage with the least prevalent groups accounting for only 5% of cohorts [6,54,72]. To have adequate quantitative data on beliefs from these smaller groups, it would therefore be necessary to have a few hundred patients at a minimum. Good representation of ages, genders and ethnicities is essential for future research as it would be important to understand whether particular beliefs and cognitions are more prevalent in certain groups, and whether this mediates the increased rate of non-adherence in certain groups, for example, non-white individuals [73].

Before any large quantitative study can be conducted, careful selection of what needs to be measured and how this needs to be measured is required. Newer behavioural models with efficacy in explaining adherence behaviours, adapted using qualitative data from patients should be utilised to develop the appropriate assessment tools.

The statistical analysis for future studies must be rigorous. Collection of data on a significant number of inter-related variables and longitudinal data should enable powerful statistical techniques such as modelling, as also previously highlighted by Olsen et al. [18]. This should enable a more detailed description of adherence behaviour, and its contributory factors and context. Studies should include purposive sampling of smaller subsets of patients for interview selected either because of their behaviour and/or their beliefs/cognitions/personality.

Agreement between researchers to use the same outcome measure in studies would facilitate comparison and incremental learning between studies, enhancing the chances of scientific advances, a case also made by Weaver et al. [5]. An American Thoracic Society statement in 2023 argued that a more patient-centred approach would be to reduce the CPAP adherence threshold to 2 h [74]. On the counter side, important outcomes, such as hospitalisations and death, are poorer with each hour less *per* night of CPAP use from 7 h down to 4 h supporting the argument that the current adherence threshold should be raised [4,75]. The

threshold is not important but consistency is; perhaps then an agreement of adhering to the current accepted criteria of a minimum of 4 h for at least 70% of nights should be implemented in the spirit of fostering research.

Poor adherence to CPAP remains a major obstacle to good outcomes for patients with OSA. The efficacy of behavioural interventions in improving patient adherence to CPAP within research settings is testament to the importance of patients' beliefs and cognitions about their condition and treatment, however interventions suitable for implementation in healthcare systems have been lacking, to date. At present, the current literature of pre-treatment beliefs, cognitions and personality traits that determine CPAP, on which current interventions are based, is sparse and largely not high quality. We recommend a fresh approach to research in the field. Large longitudinal studies using questionnaires based on newer models of behaviour change and treatment adherence are required to collect data on multiple beliefs, barriers and facilitators of CPAP use for modelling analysis. Purposive sampling of patients for interviews to collect qualitative data will provide in-depth understanding. Such high-quality studies should provide quality evidence for highly effective theory-and evidence-based interventions to improve patient adherence to CPAP.

Author contributions

P Kasetti: Literature search, data collection (abstract and full-text article screening), data analysis, data interpretation, production of figures and writing of original draft as well as editing later drafts and revision for submission. N F Husain: Data collection (abstract screening and full-text article screening), data analysis and editing later drafts for submission.T. C. Skinner: Study design, data interpretation, reviewing and editing of the manuscript.K. Asimakopoulou: Study design, data interpretation, reviewing and editing of the manuscript.J. Steier: Supervision of study, reviewing and editing of the manuscript.S. A. Sathyapala: Study conception, Literature search, study design, project administration, data analysis, data interpretation, supervision, writing of original draft and revising manuscript and revision for submission.

Funding

Internal funding from Imperial College London.

Declaration of competing interest

None to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2024.101910.

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