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DOI: https://doi.org/10.3399/BJGPO.2021.0146

To access the most recent version of this article, please click the DOI URL in the line above.

Received 05 August 2021
Revised 11 October 2021
Accepted 13 October 2021

Author Accepted Manuscript

This is an 'author accepted manuscript': a manuscript that has been accepted for publication in BJGP Open, but which has not yet undergone subediting, typesetting, or correction. Errors discovered and corrected during this process may materially alter the content of this manuscript, and the latest published version (the Version of Record) should be used in preference to any preceding versions

Digital cognitive behavioural therapy for insomnia and primary care costs in England: an interrupted time series analysis

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Abstract

Background

Sleepio is an automated digital programme that delivers cognitive behavioural therapy for insomnia (dCBT-I). *Sleepio* has been proven effective in improving sleep difficulties. However, evidence for the possible impact of *Sleepio* use on health care costs in the United Kingdom has not previously been developed.

Aim

We sought to identify the effect of a population-wide rollout of *Sleepio* in terms of primary care costs in the National Health Service (NHS) in England.

Design and Setting

The study was conducted in the Thames Valley region of England, where access to *Sleepio* was made freely available to all residents between October 2018 and January 2020. The study relies on a quasi-experimental design, using an interrupted time series to compare the trend in primary care costs before and after the rollout of *Sleepio*.

Method

We use primary care data for people with relevant characteristics from nine general practices in Buckinghamshire. Primary care costs include general practice contacts and prescriptions. Segmented regression analysis was used to estimate primary and secondary outcomes.

Results

For the 10,704 patients included in our sample, the total saving over the 65-week follow-up period was £71,027. This corresponds to £6.64 per person in our sample or around £70.44 per *Sleepio* user. Secondary analyses suggest that savings may be driven primarily by reductions in prescribing.

Conclusion

Sleepio rollout reduced primary care costs. National adoption of *Sleepio* may reduce primary care costs by £20 million in the first year. The expected impact on primary care costs in any particular setting will depend on the uptake of *Sleepio*.

Keywords (MeSH terms)

primary health care, insomnia, health care costs, interrupted time series analysis, cognitive behavioral therapy, digital technology

How this fits in

Therapist-delivered cognitive behavioural therapy (CBT) is a recommended first-line treatment for insomnia, but it is difficult to access, and the majority of patients who present for GP management receive verbal advice or medications for sleep. *Sleepio* has been shown to be clinically effective in 12 randomised controlled trials and offers patients access to fully-automated digital CBT for insomnia at scale. The real-world impact of providing whole population access to digital CBT for insomnia has not

previously been determined in terms of health care costs. *Sleepio* was made freely available in a large region of England, and primary care costs were evaluated before and after rollout.

Introduction

In England, approximately 38% of people have symptoms of insomnia. The prevalence of diagnosed insomnia has increased over time and was 5.8% of the population in 2007[1]. Insomnia is commonly managed by general practitioners through verbal advice (100%), sleep hygiene education (89%), and medication[2]. Patients rarely receive access to first-line cognitive behavioural therapy (CBT) for insomnia[3,4]. This is due in part to a shortage of trained providers[5] and a lack of treatment awareness[2,6]. Digital CBT for insomnia (dCBT-I) offers a potential solution.

Sleepio is a standardised and fully automated (i.e., a standalone programme without the need for professional human input) digital therapeutic, which comprises the full range of cognitive and behavioural techniques used in CBT for insomnia[7]. It is designed for adults who want to improve their sleep and is available through a website and supporting app. There is a growing body of evidence to support the effectiveness of *Sleepio*. For example, Espie et al.[8] and Freeman et al.[9] demonstrated benefit in terms of the Sleep Condition Indicator and Insomnia Severity Index. Espie et al.[10] found benefits to functional health, well-being, sleep-related quality of life, and symptoms of anxiety and depression.

The societal costs of insomnia are substantial[11], and evidence suggests that treatment can be cost-saving[12,13]. *Sleepio* has been shown to improve workplace productivity[14,15], and some evidence indicates that *Sleepio* is associated with reductions in self-reported prescribed sleep medication use[16]. However, its impact on health care service use and prescription costs is mostly unknown. Insomnia is a public health concern, with the costs associated with insufficient sleep estimated to be around £40 billion in the UK due to lost productivity[17]. Further costs are thought to be generated from increased health care expenditure and accident risk[12], with higher health care costs for people co-presenting with insomnia and comorbidities[18].

In England, *Sleepio* could be provided free-of-charge to the whole population, or to a subset of people who might need it, through National Health Service (NHS) funding. Real-world evidence can provide valuable insights beyond evidence generated in a trial setting.

This study sought to address the current gap in knowledge by using real-world data to evaluate the impact of providing public access to *Sleepio* in terms of i) primary care service use costs and ii) prescription costs. Our main objective was to identify whether providing access to *Sleepio* resulted in a change in the trend of total primary care costs from the perspective of the NHS in England.

Method

Intervention

The *Sleepio* programme consists of six 20-minute dCBT-I sessions over at least six weeks, with each session unlocked after at least one week. People in therapy can maintain a sleep diary to track progress, with advice tailored to the provided information. The sleep diary can be automatically populated with data from a wearable device. Patients can also access other online support tools, including an electronic library and user community.

As part of a two-year implementation experiment funded by Innovate UK, Big Health Ltd. provided access to *Sleepio* in partnership with the Oxford Academic Health Science Network (AHSN)[19]. Population rollout involved all adult residents of the Thames Valley region of England (including Oxfordshire, Berkshire, and Buckinghamshire) being granted permission to access *Sleepio* online free of charge. Eligibility was determined by the registrant's postcode, which must be entered when individuals first use *Sleepio*. Passive promotional activity, such as online and print advertising, was conducted throughout the region to encourage individuals to use *Sleepio*. Some employers in the region were also engaged and encouraged to promote *Sleepio* to their staff.

In this study, we focus on Buckinghamshire, where additional primary care engagement was employed. The *Sleepio* team worked with selected general practices to offer *Sleepio* to patients most likely to benefit from dCBT-I. This work involved evaluating different implementation strategies at population scale and included training, implementing digital prompts for GPs, and providing patient-centred resources to each practice. During the rollout period, additional awareness material was distributed, and practices were given tailored support.

Study design

This study adopts a before and after quasi-experimental design. We used an interrupted time series (ITS) approach to estimate the change in total primary care costs following the rollout of *Sleepio*. The ITS analysis controlled for baseline levels and trends in costs.

The cohort consisted of patients from nine general practices. Patients that we expected to be more likely to use *Sleepio* (based on criteria described below) were selected to reduce noise in the sample.

Our study design relies on two key assumptions. First, the primary care costs of people who do not use *Sleepio* are not affected by *Sleepio* rollout. Second, people who do not satisfy our selection

criteria do not use *Sleepio*. These assumptions imply that there would be no change in primary care use outside of our sample that is attributable to *Sleepio* rollout.

Data

EMIS Health is a software company that provides electronic patient record systems to general practices across the UK. Nine GP practices in Buckinghamshire were recruited, from which we aimed to extract data for at least 10,000 patients from the EMIS system.

We selected practices to represent a range of levels of deprivation. Patients needed to satisfy at least one of the following criteria within the extraction period:

1. A diagnosis of insomnia
2. A diagnosis of depression or anxiety disorder
3. Prescription of a hypnotic or anxiolytic medication
4. Referral to *Sleepio* by a GP

Individuals below the age of 18 years were excluded. The purpose of these criteria is to limit our sample to those we would anticipate might use *Sleepio*. We expected that insomnia diagnosis would rarely be coded in the data. Therefore, relevant prescribing (i.e., BNF chapter 4, section 1 drugs) was used as an inclusion criterion to identify people experiencing sleep problems.

Patient-level data were aggregated as patient-weeks, except for time-invariant patient characteristics. The data extraction period was 12 months before *Sleepio* rollout (from October 2017), up to 15 months after *Sleepio* rollout (to January 2020). This provided an adequate timeframe to capture seasonal effects within the ITS design. Notably, our timeframe incorporates three Christmas periods, which we anticipated would be a significant correlate for primary care service use. Data were extracted by an independent specialist provider (Interface Clinical Services Ltd.).

Data were also collected from all individual users of *Sleepio*, either through the *Sleepio* website or the supporting iOS app. This sample cannot be linked to the EMIS sample. These data are used for descriptive purposes only, providing information on uptake across the region.

Analysis

Primary analysis

The primary outcome for the analysis is the average primary care costs per patient per week, where primary care costs include GP practice contacts and prescription costs. Unit costs were attributed to resource use using information from the Unit Costs of Health and Social Care[20]. According to the specific medicine, dose, and pack size, prescription costs were obtained from the BNF Online[21].

We employed a segmented regression analysis of the interrupted time series data to estimate the change in the trend of the primary outcome, such that the full model was estimated as

$$Y_{ijt} = \beta_0 + \beta_1 time_t + \beta_2 intervention_t + \beta_3 post_t + \beta_4 X_{ijt} + u_j + e_{ijt}$$

where Y_{ijt} is total primary care costs for individual i from practice j at time t; $time_t$ corresponds with the number of the week in the time series at time t; $intervention_t$ is a binary indicator for time t being before ($intervention = 0$) or after ($intervention = 1$) *Sleepio* rollout; $post_t$ corresponds to the number of weeks after the intervention at time t; X_{ijt} is a vector of patient-, practice-, and time-specific confounders; u_j represents a random error term at the level of the practice; and e_{ijt} represents unexplained variability.

In this model, β_0 estimates baseline costs at $t = 0$; β_1 estimates the pre-*Sleepio* trend in costs; β_2 estimates the immediate change in Y at the time of *Sleepio* rollout; and β_3 estimates the change in trend after *Sleepio* rollout compared with the pre-intervention trend. The post-intervention slope is estimated as $\beta_1 + \beta_3$. Seasonal effects are accounted for by including an indicator within X for the season in which week t falls, where weeks 10-22 of any calendar year are spring, 23-35 are summer, 36-48 are autumn, and 49 through to 9 are winter. β_4 estimates seasonal and other confounding effects. We assume the rollout period for *Sleepio* to span six weeks (this does not relate to the number of sessions that individuals complete, but rather to the time needed to make *Sleepio* accessible to the whole population).

The segmented regression analysis used a generalised linear model, with appropriate distributions and link functions fitted according to visual inspection of the data and use of a modified Park test and link tests. First-order autocorrelation was tested using the Durban-Watson test. Individual-level observations were drawn from practices, within which observations may be correlated. We implemented a multilevel regression model to account for clustering within practices.

Secondary analyses

We conducted four exploratory secondary analyses, as set out in Table 1. Two of our secondary analyses (A and B) focussed on prescriptions. These analyses could help health care commissioners to better understand the impact on costs and resource use characterised in our primary analysis. The budgetary implications of changes in prescription costs may differ from those associated with changes in GP contacts. The long-term prescription of nonbenzodiazepines (zolpidem and zopiclone, commonly known as z-drugs) for sleep problems is a concern in itself due to their side effects and lack of effectiveness[4].

For these analyses (A and B), we only included individuals who were – at any point in our follow-up period – referred to *Sleepio*. Reducing the size of the dataset in this way made it possible to more effectively control for individual-level variation and potentially identify effects directly attributable to *Sleepio* use.

Previous research on *Sleepio* has demonstrated benefits in terms of anxiety or depression symptoms and the potential for *Sleepio* to be particularly effective for people with anxiety or depression[9,10,22]. To contribute to this evidence base, we implemented our primary analysis with stratification according to the presence of a diagnosis of anxiety or depression.

To further test the robustness of our findings and the extent to which any treatment effect is attributable to *Sleepio* rollout, we conducted an analysis (D) whereby referral to *Sleepio* is the intervention. In this case, the control group is the population of patients who were never referred to *Sleepio*. We implemented an analysis similar to our primary analysis, using a hierarchical generalised linear model to evaluate the effect on primary care costs, in any given week, of having been referred to *Sleepio* by a GP. This approach is more susceptible to selection bias but could provide more precise identification of *Sleepio* patients and reduce noise in the sample.

Results

The analysis included 1,252,368 person-week observations from 10,704 people over 117 weeks. 64.41% of the sample identified as female. We observed age in 5-year bands (except for 18-25 year olds and those over 90). The median age band was 50-55 years; 50% of the sample were aged 35-65.

Table 2 shows the number of people in each practice and the number recorded as being referred to *Sleepio* at least once within each practice, of which there were 1,008 people in total.

Across the sample, 1,655 (15%) people had at least one record of an insomnia diagnosis, and 5,515 (52%) had at least one diagnosis of anxiety or depression. Inclusion criteria prescriptions (hypnotics or anxiolytics) were received by 3,001 (28%) people, with 1,919 (18%) receiving at least one hypnotic prescription and 1,502 (14%) receiving at least one anxiolytic prescription.

In October 2018, the total number of patients registered with the nine practices in our study was 129,865, and the total population of Buckinghamshire was around 540,059[23]. Table 3 illustrates the estimated number of *Sleepio* patients for different population sizes, based on the number of people recorded as being referred by their GP in the EMIS data and the actual number of patients recorded by *Sleepio* within the full 117 weeks of the study.

The EMIS data only included referrals recorded by GPs, while the *Sleepio* data included all referral routes. *Sleepio* data relating to the nine practices rely on patients self-reporting GP referral. An individual's county is determined by their postcode provided in *Sleepio*. We assume the Thames Valley region to be formed of the three counties of Buckinghamshire (including Milton Keynes), Oxfordshire, and Berkshire.

Primary analysis

The regression results from the primary analysis are shown in Table 4. We report several models as a sensitivity analysis of alternative specifications.

All models except Model 5 are hierarchical generalised linear models using a quasi-gamma distribution with a variance function of $V(\mu) = \mu^2$ and log link. Model 5 is an ordinary least squares linear regression model. Our preferred model is that which exhibited superiority in statistical tests and provided the most convincing predictions visually.

A positive coefficient for *Time* shows that primary care costs increase over time, prior to *Sleepio* rollout. A negative coefficient for *Intervention* implies that the immediate impact of *Sleepio* rollout (during the six-week rollout period) is to reduce primary care costs. A negative coefficient for *Post* shows that the effect of *Sleepio* rollout was to reduce the trend shown by the coefficient on *Time*. If the negative coefficient for *Intervention* is smaller than the positive coefficient for *Time*, it implies that the upward trend in primary care costs continues after *Sleepio* rollout, but at a slower rate.

The regression results imply three key overall findings. First, there is a slight increasing trend in primary care costs over time. Second, *Sleepio* rollout has a small but statistically significant negative

impact on costs during the initial six-week rollout period. Third, *Sleepio* rollout mitigates the trend of increasing primary care costs.

Comparison between the alternative model specification reveals that seasonal adjustment is critical; accounting for seasonal effects reverses the direction of effect for *Intervention* and results in statistical significance for *Post*.

Our preferred model results show that the absolute difference in mean weekly costs per person, associated with *Sleepio* rollout, is a saving of £0.16 at week 65. This corresponds to £6.64 per person over the 65-week follow-up period, including the initial rollout period. The 95% confidence interval for this estimate is a saving of between £4.60 and £8.67. Across the observed sample of 10,704 people, *Sleepio* rollout reduced primary care costs by £71,027 (95% confidence interval £49,291 to £92,762).

Table 5 presents projections for average cost savings for different populations over different durations, based on our preferred model specification. The projections assume that, beyond our observation period (i.e., 65 weeks), primary care costs return to the trend observed before *Sleepio* rollout (represented by the coefficient for *Time* in Table 4).

Table 5 includes estimates per *Sleepio* user, based on the uptake estimates in Table 3, which assumes a growing population of users with growth at the rate observed in our study. Economic evaluations and decision analyses often rely on estimating effects at the individual level, which our study does not observe. Therefore, to inform future research, we provide alternative projections based on changes over time at the individual level. These projections are based on the assumption that *Sleepio* rollout is equivalent to treatment exposure at the individual level, such that those people identified as *Sleepio* users become *Sleepio* users at the point of the rollout. These projections assume a return to pre-rollout trends and no new users after year 1, such that year 1 savings for projected new users are subtracted from projected cumulative savings. In this case, the two-year savings per user would be £88.48 (£138.00 *minus* £49.52). The three-year savings would be £139.59 (£228.07 *minus* £88.48). Rather than projecting a growing saving over time as trends diverge, this approach assumes a shift to the pre-rollout trend to converge on an annual saving of £90.07 per user in the long term. Based on existing evidence, these effects might be expected to be maintained for up to three years[24].

Secondary analyses

Table 6 shows the key coefficients for our secondary analyses that maintained the segmented regression analysis approach, as summarised in Table 1. All analyses included seasonal adjustment,

age, gender, diagnoses, and practice random effects. Analysis A and Analysis B used a Poisson distribution with a log link. Analysis C used the same model specification as our primary analysis.

The coefficient for the pre-existing increasing trend in prescription costs (0.005) is greater than that for overall costs (0.002), as is the coefficient for the impact of *Sleepio* on the trend (-0.004 compared with -0.002). The coefficients for Analysis A can be used to estimate a reduction in prescription costs at 65-week follow-up of £8.62 per person (£5.40 in the first year), suggesting that our primary analysis's observed reductions in prescription costs may significantly explain savings. Analysis B shows that *Sleepio* had a small but statistically significant impact in achieving a downward trend in the prescription of z-drugs. Analysis C supports the notion that *Sleepio* may be more effective in reducing costs among people diagnosed with anxiety or depression (n=5,515). The average saving per person in this group, over 65 weeks, was £9.27.

Our final analysis (D), treating *Sleepio* referral as the intervention, identified a negative but statistically non-significant effect. This is likely due to a selection bias, whereby individuals who use *Sleepio* may be more likely to have higher levels of resource use, all else equal. An exploratory analysis of the insomnia subsample did not identify any statistically significant findings. This may be due to difficulty with coding insomnia or a lack of power associated with the sample size.

Discussion

Summary

Our analysis's main findings show that the rollout of *Sleepio* in the Thames Valley region reduced average primary care costs, including general practice contacts and prescriptions.

Over the observed follow-up period, the average saving in our sample was £6.64 per person. Assuming that people outside of our sample were not affected by the rollout of *Sleepio*, this corresponds to a saving of £71,027 across the nine practices.

Our secondary analyses suggest that reductions in prescription costs are a significant driver in reducing overall primary care costs. This is partly explained by reductions in the prescription of z-drugs, which may include both off-label and on-label use. Data from *Sleepio* suggest that around 26% of people referred to *Sleepio* would start CBT (according to Big Health operational data from the Thames Valley experiment). Based on these figures, the saving per patient associated with prescription costs may be £21 in the first year (£5.40/0.26), around half of the per-user saving identified across the whole sample.

The reduction in costs observed in the subsample of people diagnosed with anxiety or depression (n=5,515) was greater than the average saving across the whole sample. Future research should explore the potential for cost savings in different categories of expenditure and different populations.

Strengths and limitations

A strength of our analysis is that the primary and secondary outcomes and analytical approach were determined before the data were analysed. The preferred model was selected on the basis of predictive ability and fit for the primary outcome.

Our main findings are robust across a variety of model specifications. The observed direction of effect on the trend in costs is not sensitive to seasonal effects or individuals' characteristics. This supports the generalisability of our findings. Practices with different proportions of people with the diagnoses observed in our data might, therefore, expect to observe similar impacts for the subpopulation that satisfies our inclusion criteria.

The inclusion of seasonal effects and practice random effects was important in demonstrating a statistically significant impact of *Sleepio* rollout. However, the direction of effect for the trend in costs was not undermined by their exclusion. Our evidence suggests that the cost savings were not driven by any single practice, supporting our findings' generalisability. However, we did observe variation by practice, and commissioners should consider the characteristics of providers and patients that might act as barriers or facilitators to changes in service use[19].

It is important to note that our study is not a cost-effectiveness analysis, and our estimates do not include other potential cost impacts associated with *Sleepio* rollout. In particular, our analysis does not attribute any direct cost to *Sleepio* rollout or use. The advantage of this is that our analysis is independent of *Sleepio* pricing. The relevance of our study will not be undermined by changes in the price of *Sleepio* licences.

In practice, access to *Sleepio* may be priced on the basis of initiation of dCBT-I rather than initial registration by a user or referral by a GP. A limitation of our analysis is that we cannot identify which individuals in our EMIS data sample initiated dCBT-I.

We are unable to describe our sample in detail due to the limited availability of personally identifiable data, as agreed with participating practices. This makes it difficult to assess the representativeness of the sample. As a result, our extrapolations to the national level are speculative; we are not able to weight our observations according to the characteristics of the

population as a whole, which may be particularly important in considering the uptake of a digital technology [25].

We are also unable to observe any changes in resource use in areas outside of Buckinghamshire, where primary care engagement was based on passive promotional activity and not used to drive uptake. As shown in Table 3, a lower level of uptake was observed in these areas. This has implications for implementation strategies and related costs. Further work could evaluate the resource impact of *Sleepio* rollout in alternative settings, such as when delivered as an adjunctive intervention for those with poor sleep through the Improving Access to Psychological Therapies (IAPT) programme.Our analysis does not provide estimates of any impact on referrals to secondary care or resources used in settings other than GP practices. Due to the pre-specification of our primary outcome and the development of our model to suit these data, there was limited scope for us to explore different aspects of resource use without suffering from over-testing. The design of our analysis also limits the extent to which we can estimate the magnitude of the impact on resource use relating to GP contacts compared to that associated with prescription costs.

Optimal sample specifications for identifying statistically significant effects in interrupted time series analyses are difficult to estimate reliably[26]. One limitation of our study is that we did not conduct simulations before commencing data collection to specify a sample size. The sample size was determined on the basis of practicality and our expectations about uptake and the variability in health care costs. Nevertheless, the total number of observations is likely to provide reliable estimates[27].

An alternative study design may have enabled us to overcome several of the limitations described here. Observation of a contemporaneous comparator, such as practices outside of the rollout area, would have enabled us to account for unobserved causes of variation in health care costs. However, we were not able to establish the necessary contacts and agreements to support such a design.

Comparison with existing literature

To our knowledge, no studies have evaluated the real-world health care cost impact of providing CBT for insomnia at population scale. Previous health economic evaluations of CBT-I have focused on evaluations using data from controlled trials[28], which may not be generalisable to primary care settings where GPs manage insomnia[2]. Our analysis supports previous research showing that dCBT-I can reduce prescribing[16].

Implications for research and practice

The rollout of *Sleepio* in the Thames Valley resulted in lower primary care costs across nine practices within one year. Providing NHS patients in England with access to *Sleepio*, while encouraging GPs to refer patients with sleep problems to register for *Sleepio*, is likely to result in fewer GP attendances and fewer prescriptions in the population. Therefore, these savings will partially or entirely offset direct costs associated with the adoption of Sleepio.

Funding

This study was funded by Oxford AHSN and by Big Health Ltd. Innovate UK funded the wider project in the Thames Valley through the Digital Health Technology Catalyst programme.

Ethical approval

This study involved no randomisation, did not require changes to accepted treatment standards within the NHS, and did not involve primary data collection. The study was retrospectively reviewed by the Joint Research Office study classification group at Oxford University Hospitals NHS Foundation Trust and classified as service evaluation, such that it did not require research ethics board approval. The study received permission from Buckinghamshire Clinical Commissioning Group's Medicines Management Assurance Committee.

All *Sleepio* participants agreed to a privacy policy when they registered for *Sleepio* and consented to Big Health Ltd. using health information for research purposes. This allows for non-identifiable health information only to be published in aggregate form for academic research. Collection and analysis of data within the *Sleepio* programme was approved by the Medical Sciences Interdivisional Research Ethics Committee, University of Oxford (Ref R72295/RE001).

The study used no identifiable information. As per the study's data-sharing agreements, the data cannot be made available to other researchers.

Competing interests

CS, EB, and AC are employees of the Office of Health Economics, which has received consultancy income from the developers of *Sleepio* and from Oxford Academic Health Science Network (AHSN). CBM is employed by Big Health and is salaried by the company. TM, JR, and MW are employees of Oxford AHSN and Oxford University Hospitals NHS Foundation Trust.

Acknowledgements

Earlier versions of this analysis were shared with stakeholders and presented at academic meetings. We are grateful for comments received at the winter 2020 meeting of the Health Economists' Study Group and ISPOR Europe 2019. An earlier version of this manuscript was published at medRxiv. The reported results in earlier versions may differ following refinements to the analysis.

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Analysis	Population	Intervention	Outcome
A	People referred to *Sleepio* by their GP	*Sleepio* rollout	Total prescription costs
B	People referred to *Sleepio* by their GP	*Sleepio* rollout	Count of z-drug prescriptions
C	People with a diagnosis of anxiety or depression	*Sleepio* rollout	Total primary care costs
D	Whole sample	*Sleepio* referral	Total primary care costs

TABLE 1: OVERVIEW OF SECONDARY ANALYSES

Practice	EMIS data		
	Sample size	Referred to *Sleepio*	
1	2,391	220	9.20%
2	812	87	10.71%
3	1,849	171	9.25%
4	295	33	11.19%
5	757	64	8.45%
6	1,511	138	9.13%
7	454	79	17.40%
8	2,351	148	6.30%
9	285	68	23.86%
Total	10,704	1,008	9.42%

TABLE 2: GP PRACTICE SAMPLES

	Population size	Estimated patients based on EMIS data		Estimated patients based on *Sleepio* data	
EMIS sample	10,704	1,008	9.42%	Unknown	
Nine practices	129,865	1,008†	0.78%‡	1,220	0.94%
Buckinghamshire	540,059	4,192‡	0.78%‡	3,134	0.58%
Thames Valley	2,300,000	17,940‡	0.78%‡	12,374	0.54%
England	55,980,000	434,512‡	0.78%‡	302,292‡	0.54%†

TABLE 3: ESTIMATED NUMBER OF SLEEPIO PATIENTS BY POPULATION (†EXTRAPOLATED FROM OBSERVATION; ‡ASSUMED FROM EXTRAPOLATION)

	Preferred model	Model 2	Model 3	Model 4	Model 5
Time	0.002***	0.002***	0.002***	0.001***	0.004
Intervention	-0.038***	-0.036***	-0.033***	0.033***	0.263***
Post	-0.002***	-0.002***	-0.002***	-0.000	-0.003
Seasonal adjustment	YES	YES	YES	NO	NO
Age bands	YES	YES	NO	NO	NO
Gender	YES	YES	NO	NO	NO
Diagnoses	YES	NO	NO	NO	NO
Practice random effects	YES	YES	YES	YES	NO

TABLE 4: FULL SAMPLE REGRESSION COEFFICIENTS (SIGNIFICANCE LEVELS: * < 0.001; ** < 0.01; * < 0.05)**

Sample	1 year	65 weeks	2 years†	3 years†
Per person (95% CI)	£4.66 (£3.20 – £6.13)	£6.64 (£4.60 – £8.67)	£13.00 (£9.15 – £16.84)	£21.48 (£15.22 – £27.75)
Per *Sleepio* user*	£49.52	£70.44	£138.00	£228.07
Nine practices	£49,930	£71,027	£139,144	£229,967
Buckinghamshire	£207,640	£295,374	£578,648	£956,347
Thames Valley	£884,298	£1,257,936	£2,464,343	£4,072,885
England	£21,523,042	£30,617,071	£59,979,956	£99,130,468

TABLE 5: PROJECTED REDUCTION IN PRIMARY CARE COSTS ASSOCIATED WITH SLEEPIO ROLLOUT (†PROJECTION BEYOND THE OBSERVED PERIOD; *9.42% OF OUR SAMPLE BASED ON GP REFERRALS; CI: CONFIDENCE INTERVAL)

	Analysis A (prescription costs)	Analysis B (z-drugs)	Analysis C (anxiety/depression sample)
Time	0.005***	0.002*	0.003***
Intervention	0.013	0.222***	-0.046***
Post	-0.004***	-0.003**	-0.003***

TABLE 6: SECONDARY ANALYSIS REGRESSION COEFFICIENTS