A scoping review of sleep discrepancy methodology: what are we measuring and what does it mean?

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Introduction

- Sleep discrepancy is a common feature of insomnia disorder
- Sleep discrepancy has been investigated with diverse methods making it difficult to integrate findings across studies
- AIM: *How has sleep discrepancy has been conceptualised in the literature what methods have been used to investigate it?*

Method

- Scoping review methodology

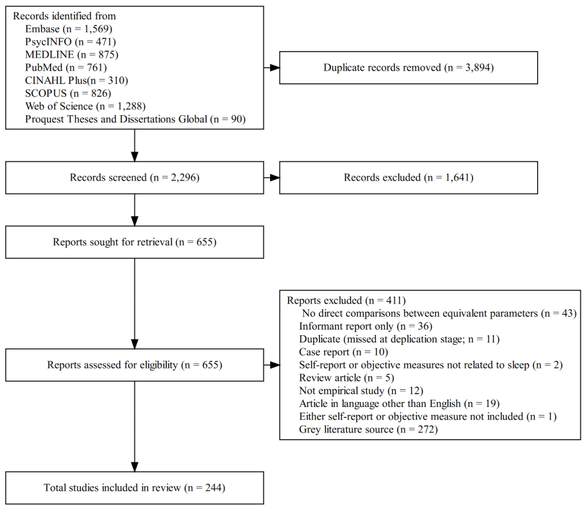

Figure 1: PRISMA flowchart

There are **different types** of **sleep discrepancy** and **significant problems** with how they have been investigated.

Results

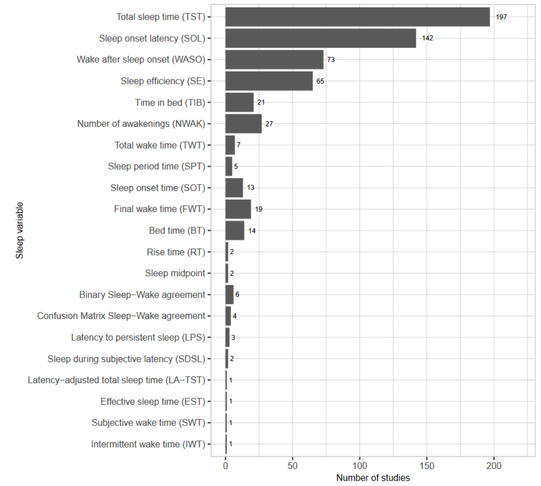

Figure 12: Sleep variables

- Approximately half (n = 128) of included studies calculated a derived index (e.g., self-report TST–objective TST) to operationalise sleep discrepancy
- 172 studies measured sleep discrepancy at the group level by directly comparing self-report and objective sleep

Conclusions

- Sleep discrepancy is mostly restricted to sleep states or sleep time and varies in its conceptual distance to sleep misperception

Objective sleep \ Self-report sleep	Self-report sleep state e.g., laboratory query	Episodic self-report e.g., morning questionnaire TST	Habitual self-report e.g., PSQI TST	Aggregate self-report e.g., weekly mean diary TST
Objective sleep state e.g., laboratory PSG	= Sleep misperception	n/a	n/a	n/a
Episodic objective e.g., single night PSG	n/a	Sleep time discrepancy	Discrepancy between habitual and episodic sleep	Not typically observed
Aggregate objective e.g., weekly mean actigraphy TST	n/a	Not typically observed	Global sleep discrepancy	Problematic (see section 5.6)

Figure 21: Sleep discrepancy matrix

- Conceptual and methodological problems
  i. Methodological heterogeneity
  ii. Objective SOL definitions
  iii. Operationalising with derived indices
  iv. Averaging across nights
  v. Correlations as concordance
  vi. Sleep quality discrepancy
  vii. Sleep diaries defining rest intervals

On the use of difference and ratio scores in sleep discrepancy research

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Introduction

- Sleep discrepancy is the discordance between self-report and objective measures of sleep
- Sleep discrepancy is often operationalised as a derived index (e.g., self-report TST – objective TST)
- Derived indices are associated with a range of conceptual and methodological problems

Method

- Archival data: Healthy Ageing Research Programme (N = 230; age 50+)
- Objective sleep using actigraphy with concurrent sleep diaries
- Questionnaires measures including the insomnia severity index.

Difference score problems

- **Directionality** identified effects exist through the full range of a difference score

Table 2: Linear and piece-wise regressions of ISI scores on dTST

	Estimate	95% CIs	Standard Error	t-value	p-value
Linear regression					
Intercept	6.28	[6.03 , 6.54]	0.13	48.2	p < .001
dTST	-0.01	[-0.014 , -0.007]	0.002	-5.76	p < .001
Piecewise regression					
Intercept	6.08	[5.79 , 6.36]	0.145	42	p < .001
dTST	-0.014	[-0.018 , -0.01]	0.002	-6.99	p < .001
U1 dTST	0.043	[0.021 , 0.065]	0.011	3.76	p < .001
Break-point	45.1642	[21 , 69.4]	NA	NA	

Muggeo's score test for one or two changes in the slope of regression (Muggeo 2016) is statistically significant, observed value = 2.026, p = 0.043

- **Implicit constraints** components equal magnitude opposite in sign

$$ISI = b_0 + b_1(sTST - oTST) + \epsilon$$
$$= b_0 + (1)b_1 sTST + (-1)b_1 oTST + \epsilon$$

Table 3: Regression with an additive and difference score model

	Estimate	95% CI [LL, UL]	Standard Error	t-value	p-value
Difference score model					
Intercept	6.28	[6.03 , 6.54]	0.13	48.2	p < .001
dTST	-0.01	[-0.014 , -0.007]	0.002	-5.76	p < .001
Additive model					
Intercept	12.2	[10.6 , 13.8]	0.816	14.9	p < .001
oTST	-0.002	[-0.006 , 0.003]	0.002	-0.715	.475
sTST	-0.013	[-0.016 , -0.009]	0.002	-6.96	p < .001

A statistically significant reduction in R^2 from the additive (R^2 = 0.059) to the difference score model (R^2 = 0.023) is observed (F =53.7, p < .001)

There are **significant problems** with the use of **difference** and **ratio scores** in **sleep discrepancy** research.

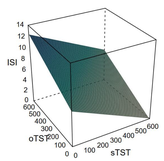


Figure 2: Difference score plot

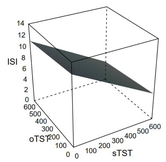


Figure 3: Additive model plot

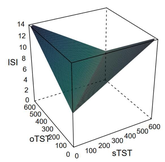


Figure 5: Absolute difference score model

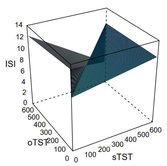


Figure 4: Unconstrained piecewise regression

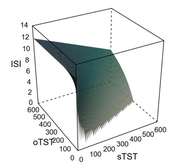


Figure 6: Ratio regression plot

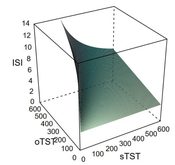


Figure 7: Inverted ratio regression plot

Absolute difference score problems

- **Directionality** full-range symmetrical distribution may not be present
- **Implicit constraints** components equal in magnitude opposite in sign, pattern reverses at X = Y, no combined main effect of predictors

$$ISI = b_0 + b_1(1 - 2W)(sTST - oTST) + \epsilon$$
$$= b_0 + b_1 sTST - b_1 oTST - 2b_1 WsTST + 2b_1 WoTST + \epsilon$$

$$ISI_{sTST>oTST} = b_0 + b_1 sTST + b_1 oTST - 2b_4 WsTST + 2b_5 WoTST + \epsilon$$
$$= b_0 - (1)b_1 sTST + b_1 oTST + \epsilon$$

$$ISI_{sTST\leq oTST} = b_0 + b_1 sTST + b_1 oTST - 2b_4 0sTST + 2b_5 0oTST + \epsilon$$
$$= b_0 + b_1 sTST - (1)b_1 oTST + \epsilon$$

Table 5: Absolute diffference score and unconstrained piecewise regression

	Estimate	95% CI [LL, UL]	Standard Error	t-value	p-value
Absolute difference model					
Intercept	6	[5.62 , 6.38]	0.194	30.9	p < .001
absTST	0.014	[0.009 , 0.019]	0.003	5.57	p < .001
Unconstrained piecewise model					
Intercept	8.98	[6.06 , 11.9]	1.49	6.02	p < .001
sTST	0.004	[-0.009 , 0.017]	0.007	0.612	.541
oTST	-0.012	[-0.026 , 0.002]	0.007	-1.66	.097
W	4.31	[0.221 , 8.4]	2.08	2.07	.039
W*sTST	-0.018	[-0.032 , -0.004]	0.007	-2.48	.013
W*oTST	0.01	[-0.006 , 0.027]	0.008	1.26	.209

The R^2 from the absolute difference score model (R^2 = 0.03) was reduced more than two-fold from the unconstrained piecewise regression (R^2 = 0.072) a difference that was statistically significant (F =11.2, p < .001).

Ratio score problems

- **Directionality** identified effects exist through the full range of a difference score
- **Arbitrary designation of numerator/ denominator**

$$\frac{\partial I\hat{S}I}{\partial sTST} = [\frac{\partial}{\partial sTST} b_1 sTST][\frac{1}{oTST}]$$
$$= \frac{b_1}{oTST}$$

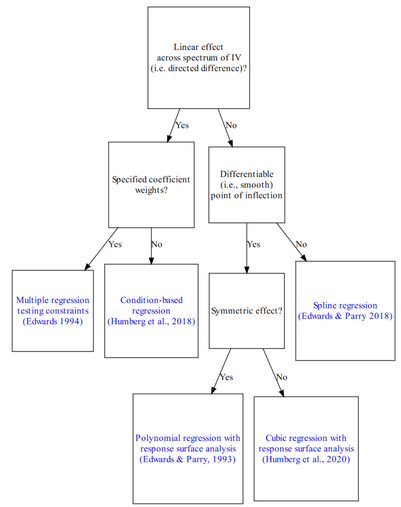
$$\frac{\partial I\hat{S}I}{\partial sTST} = [\frac{\partial}{\partial oTST} b_1 oTST^{-1}][sTST]$$
$$= [-b_1 oTST^{-2}][sTST]$$
$$= \frac{-b_1 sTST}{oTST^2}$$

Table 7: Ratio model comparisons

	Estimate	95% CI [LL, UL]	Standard Error	t-value	p-value
rTST regression					
Intercept	11.9	[10.3 , 13.6]	0.843	14.2	p < .001
rTST	-5.42	[-7.08 , -3.76]	0.847	-6.4	p < .001
Inverse rTST score regression					
Intercept	3.09	[1.94 , 4.24]	0.584	5.29	p < .001
Inverted rTST	3.36	[2.31 , 4.4]	0.532	6.31	p < .001

- **Implicit constraints**

Solutions



Insomnia and sleep discrepancy: an investigation with cubic response surface analysis

pilot study

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Response surface analysis revealed **sleep discrepancy** was not associated with **insomnia symptom severity** in older men.

Introduction

- Sleep discrepancy is often operationalised as a derived index (e.g., self-report TST – objective TST)
- Cubic regression with response surface analysis solves many problems associated with the use of difference and ratio scores in operationalising sleep discrepancy
- Hypothesis:
  i. Discrepancy effect (H1.1)
  ii. Discrepancy effect is asymmetric in the expected direction (H1.2)
  iii. Linear level effect (H1.3)

Method

- Data from MrOS 1,022 community-dwelling men aged 65+ years.
- Total sleep time (TST) from single-night polysomnography (PSG)
- Self reported TST from morning questionnaire
- Insomnia severity index (ISI) to measure insomnia symptom severity

$$Z = b_0 + b_1X + b_2Y + b_3X^2 + b_4XY + b_5Y^2 + b_6X^3 + b_7X^2Y + b_8XY^2 + b_9Y^3$$

- Rising ridge congruence surface $b_1 = b_2$, $b_4 = -2 * b_3$, $b_5 = b_3$, $b_7 = -3 * b_6$, $b_8 = 3 * b_6$, $b_9 = -b_6$

- b_3 discrepancy effect (H1.1) must be significantly positive
- b_6 direction & presence of asymmetry (H1.2) must be significantly negative
- u_1 ($b_1 + b_2$) linear level effect (H1.3) must be significantly negative

Results

	$\hat{b}_o$	$\hat{b}_1$	$\hat{b}_2$	$\hat{b}_3$	$\hat{b}_4$	$\hat{b}_5$	$\hat{b}_6$	$\hat{b}_7$	$\hat{b}_8$	$\hat{b}_9$	$\hat{u}_1$	$\Delta\chi^2$	R^2
Asymmetrical congruence model													
Estimate	0.03	-0.099	-0.099	-0.026	0.053	-0.026	8e-04	-0.003	0.003	-8e-04	-0.199	10.2	0.028
p-value	.392	< .001	< .001	.068	.068	.068	.839	.839	.839	.839	< .001	.117	
Full cubic model													
Estimate	0.084	-0.22	0.055	-0.035	0.033	-0.023	0.014	-0.06	0.051	-0.007			0.039
p-value	.055	< .001	.418	.072	.363	.478	.163	.016	.05	.658			

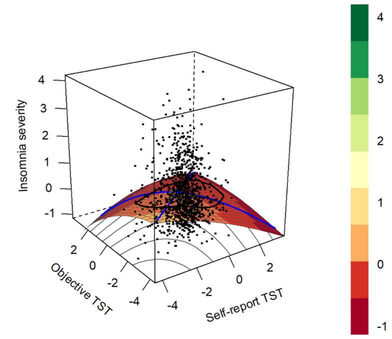

Figure 4.2: Response surface for asymmetric rising ridge discrepancy model

Table 3: Model comparisons

Model	k	df	χ^2	χ^2diff	AIC	cfi	R^2	R^2adj
cubic	9	0	0		2838	2838	0.039	0.031
full	5	4	6.22	6.31	2836	2836	0.033	0.028
IA	3	6	7.29	1.08	2833	2833	0.032	0.029
additive	2	7	7.65	0.29	2831	2831	0.032	0.03
diff	1	8	27.1	17.5	2849	2849	0.013	0.012
null	0	9	40.6	12.4	2860	2860	0	0

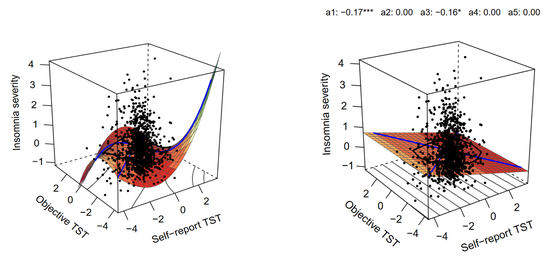

Figure 5: Cubic regression model

Figure 7: Response surface for additive model

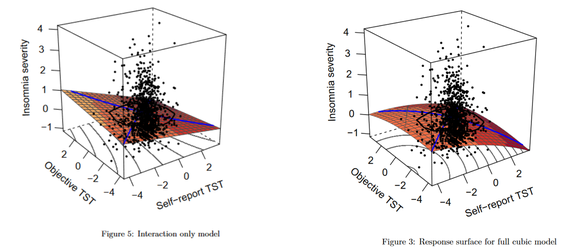

Figure 5: Interaction only model

Figure 3: Response surface for full cubic model

Conclusions

- Response surface analysis is a useful alternative to derived indices for investigating sleep discrepancy
- Discrepancy in sleep time parameters can be importantly different to misperception
- Emphasis on perception of sleep quantity rather than sleep misperception per se
  - Experiments with hypnotics
  - Low self-report + objective as different phenotype
- Results to be replicated in pre-registered study