

BSS International Sleep Medicine Course 2026

15th - 18th September | Newcastle



British Sleep Society



UK Multidisciplinary Sleep Professionals



Nederlandse vereniging voor
SLAAP- EN WAAKONDERZOEK
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Effects of 'acute and chronic' sleep deprivation

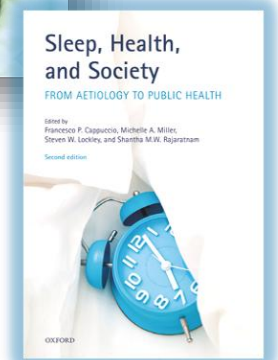
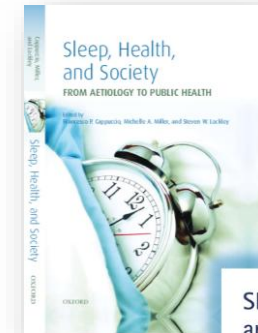
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Professor of Biochemical Medicine & Sleep Health & Society Programme Lead.

ISMIC 2026

**UNIVERSITY
OF WARWICK**



Conflict of Interest Disclosures for Speakers

☐

1. I do not have any potential conflicts to disclose.

☒

2. I wish to disclose the following potential conflicts of interest:

Type of Potential Conflict	Details of Potential Conflict
Grant/Research Support	NIHR (FOUND Trial NIHR203393) and Cephalon Research funding support. Professional Footballers' Association research funding
Consultant	
Speakers' Bureaus	
Financial support	
Other	Royalties from Oxford University Press for textbooks listed below.

☐

3. The material presented in this lecture has no relationship with any of these potential conflicts, **OR**

☒

4. This talk presents material that is related to one or more of these potential conflicts, and the following objective references are provided as support for this lecture:

1. Cappuccio FP, **Miller MA** & Lockley SW. *Sleep, health and society: from aetiology to public health*. Oxford University Press, 2010; September 23 2010. **See Slide 7**
2. Cappuccio FP, **Miller MA**, Lockley SW Rajaratnam S. *Sleep, health and society: from aetiology to public health*. Oxford University; July 2018.. **See Slide 7**

Overview: A. Chapter 6 (67-79)¹

➤ 5. EFFECTS OF SLEEP DEPRIVATION ON PHYSICAL HEALTH

5.1 | Effects of sleep deprivation on appetite and body mass homeostasis

5.2 | Sleep deprivation and type 2 diabetes

5.3 | Effects of sleep deprivation on cardiovascular vulnerability and hypertension

➤ 6. EFFECTS OF SLEEP DEPRIVATION ON IMMUNE FUNCTIONS

2. EFFECTS OF SLEEP DEPRIVATION ON EMOTIONAL STATE AND MOOD

➤ 3. EFFECTS OF SLEEP DEPRIVATION ON NEUROCOGNITIVE FUNCTIONS

➤ 3.1 | Sustained attention

➤ 4. EFFECTS OF SLEEP DEPRIVATION ON EXECUTIVE FUNCTIONING AND DECISION-MAKING

4.1 | Effects of sleep deprivation on learning and memory

4.2 | Effects of sleep deprivation on neurophysiological markers of brain functioning

➤ 7. OTHER EFFECTS OF SLEEP DEPRIVATION

Learning Objectives

By the end of this session, learners will be able to:

Identify

- Identify the two appetite-regulating hormones affected by sleep loss and explain how changes in their expression influence appetite and food cravings.

Describe

- Describe the relationship between sleep deprivation and metabolic syndrome and evaluate the extent to which sleep deprivation increases the risk of cardiovascular disease, stroke, and type 2 diabetes.

Identify

- Identify the key inflammatory markers affected by sleep deprivation and explain how insufficient sleep may influence adaptive immune function.

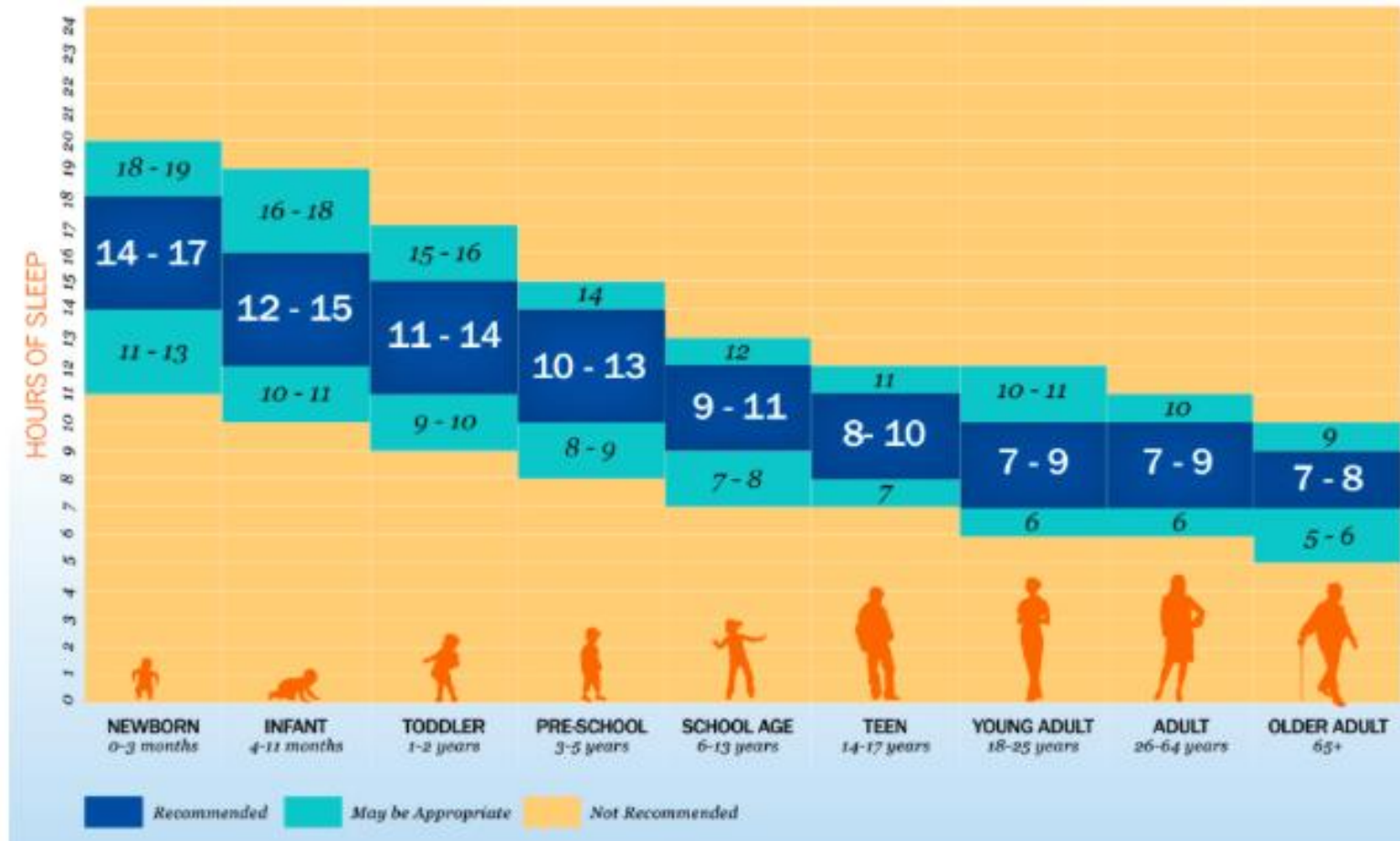
List

- List the negative effects of sleep deprivation on mood and identify the disorder in which sleep deprivation may temporarily alleviate mood-related symptoms.

Compare and contrast

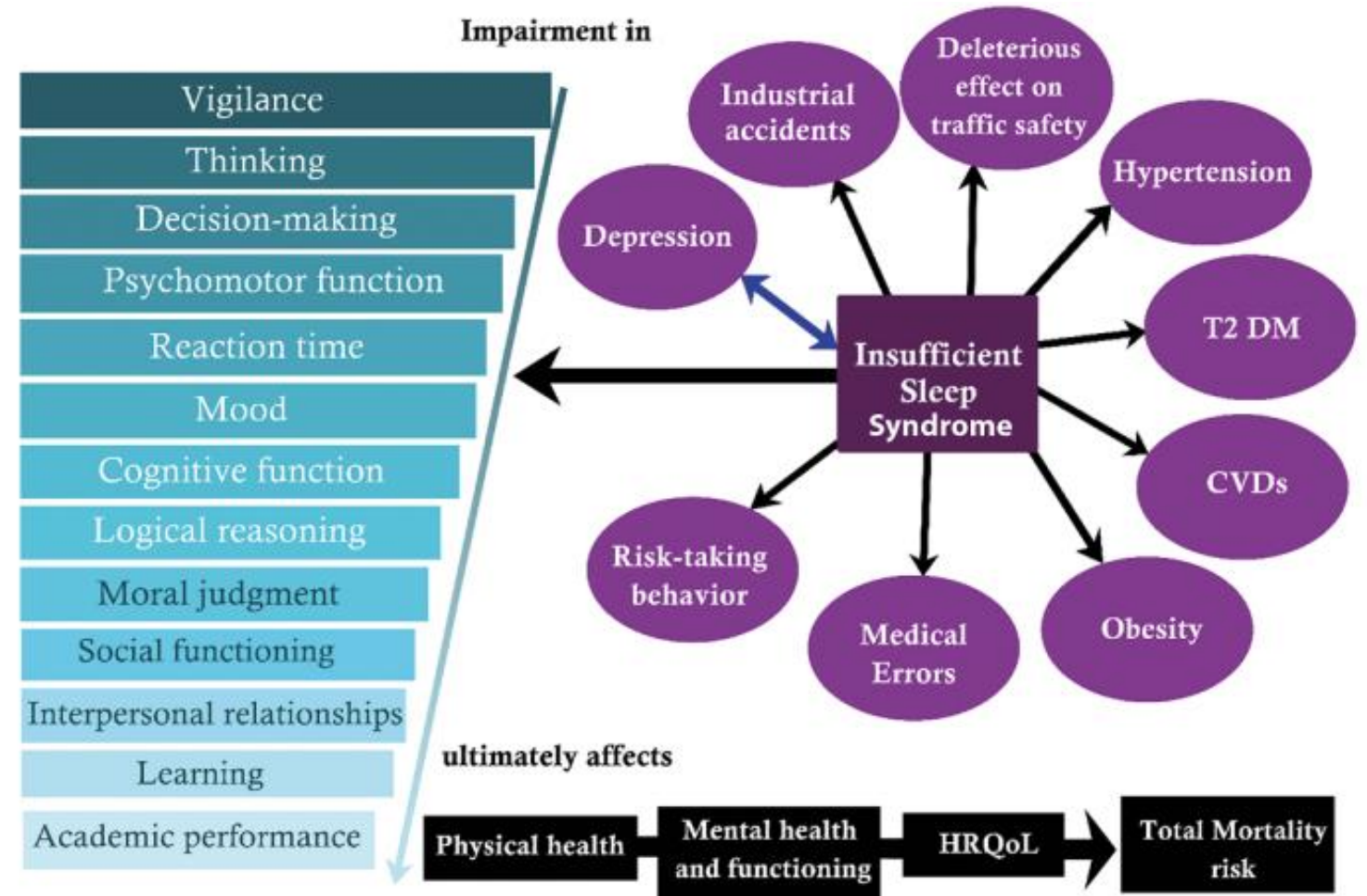
- Compare and contrast the effects of repeated partial sleep loss and total sleep deprivation on cognitive outcomes, including subjective alertness, sustained attention, and working memory.

How much sleep do we need?

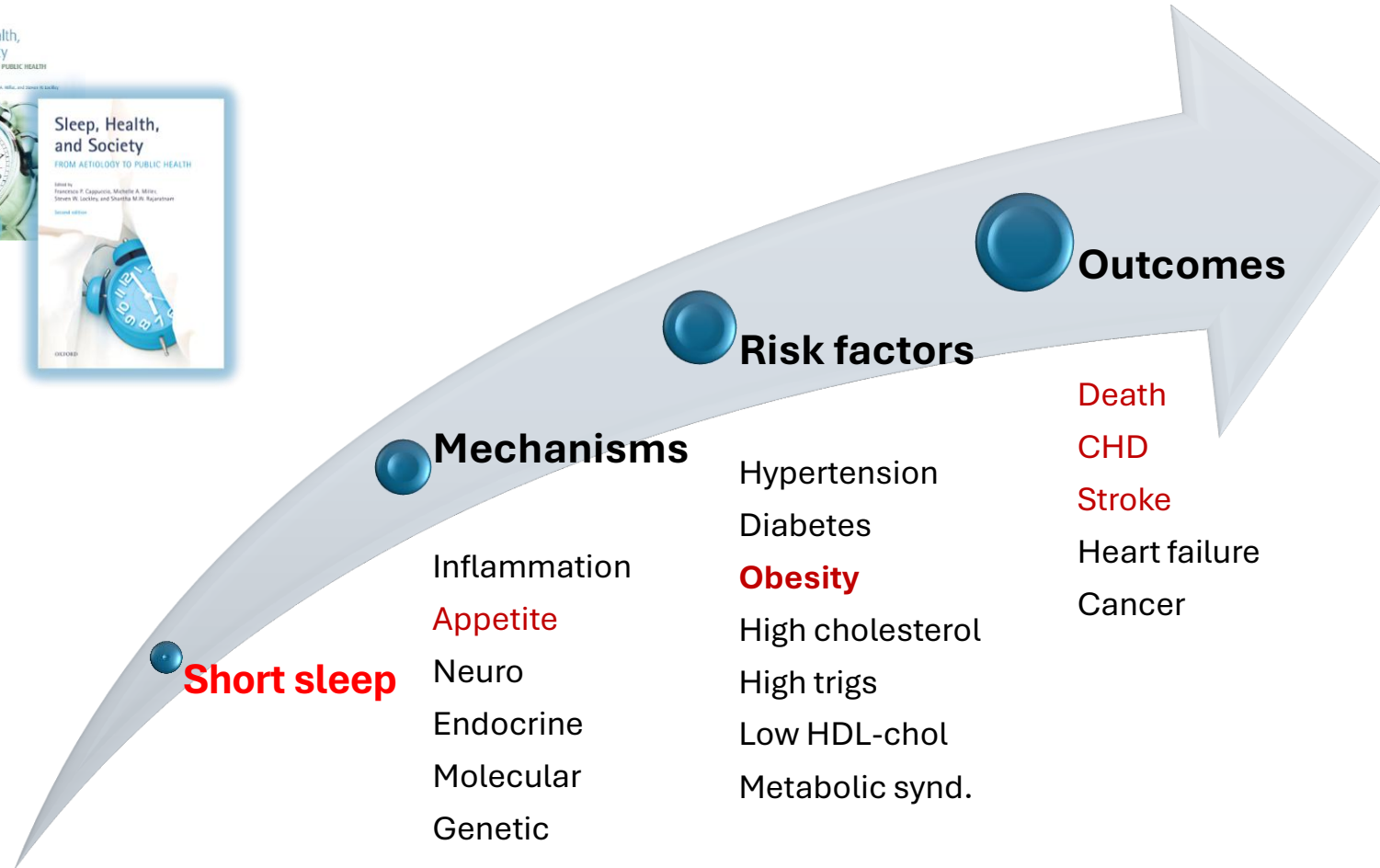


5. EFFECTS OF SLEEP DEPRIVATION ON PHYSICAL HEALTH

- 5.1 | Effects of sleep deprivation on appetite and body mass homeostasis
- 5.2 | Sleep deprivation and type 2 diabetes
- 5.3 | Effects of sleep deprivation on cardiovascular vulnerability and hypertension



5.1 EFFECTS OF SLEEP DEPRIVATION ON APPETITE AND BODY MASS HOMOSTASIS



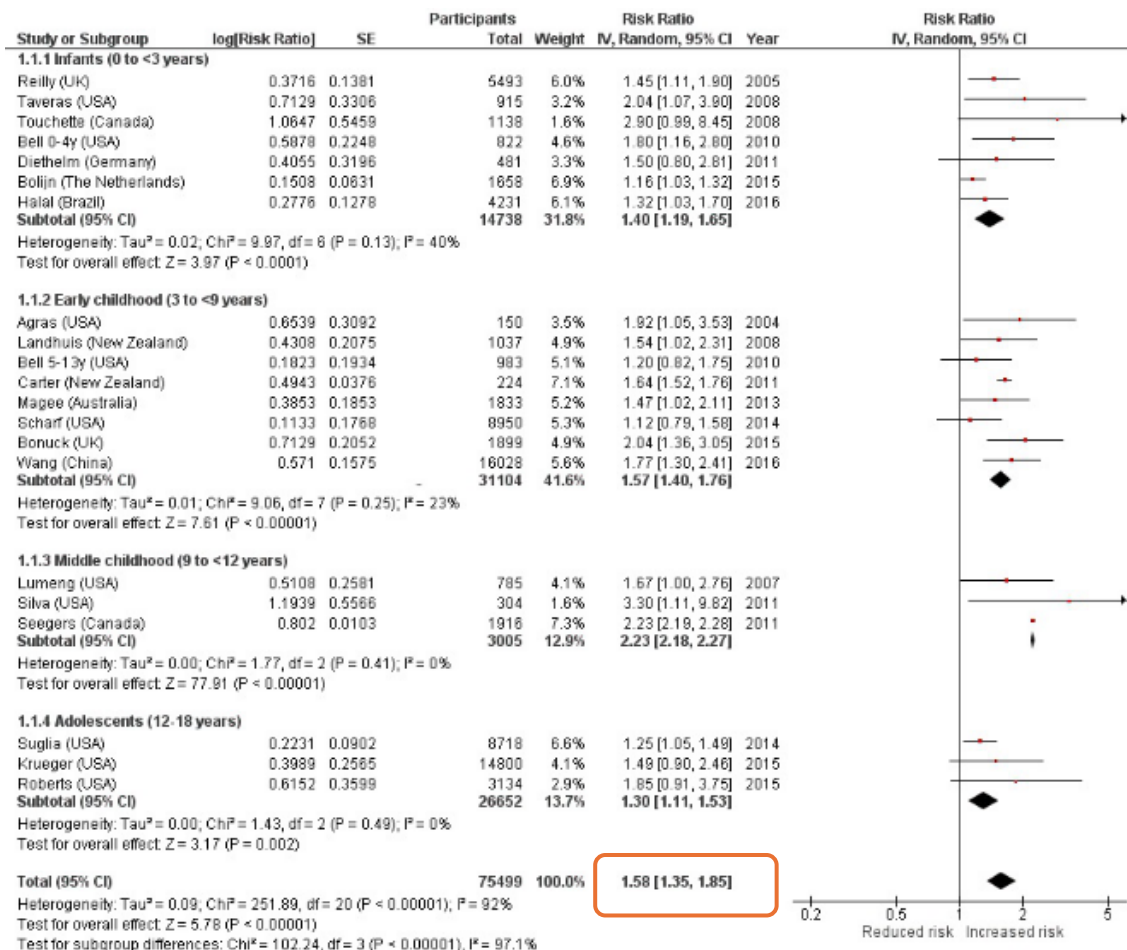
**Bradford-Hill
Criteria for
causality.**

The effect is
strong, consistent,
temporal sequence,
dose-response ,
biological plausibility,
reversible.

1. Cappuccio FP, **Miller MA** & Lockley SW. *Sleep, health and society: from aetiology to public health*. Oxford University Press, 2010; **September 23 2010**.
2. Cappuccio FP, **Miller MA**, Lockley SW Rajaratnam S. *Sleep, health and society: from aetiology to public health*. Oxford University; July 2018.

Short sleep and **incidence** of obesity in infants, children and adolescents

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58%
Increase risk

Appetite Control



Appetite: Regulated by metabolic, hormonal and neural mechanisms.



Arcuate nucleus in hypothalamus has two opposing neuronal circuits - (appetite - stimulating and appetite - inhibiting).

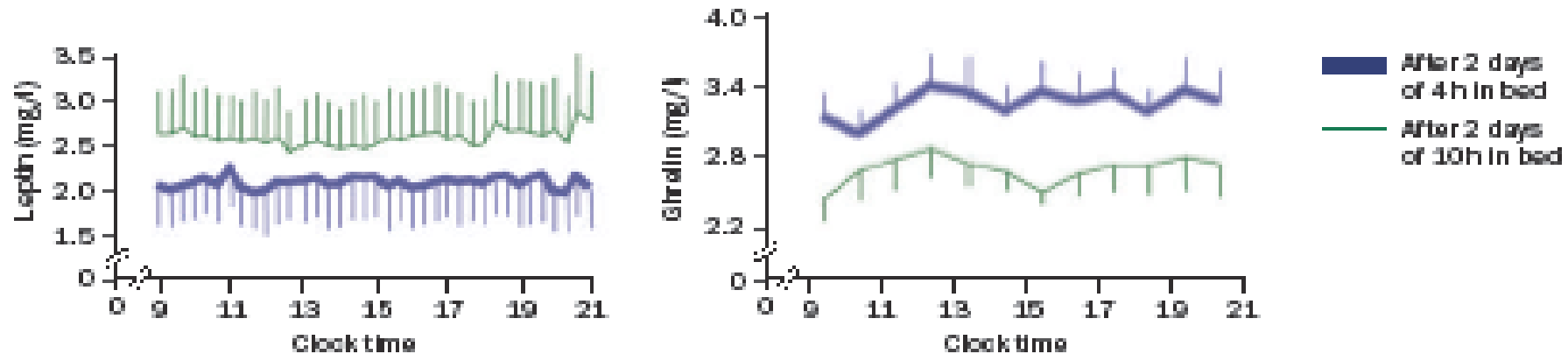


Two important signals are Leptin (from adipose tissue) and Ghrelin (from stomach).

Leptin appetite inhibiting (promotes satiety).

Ghrelin increases appetite and food intake.

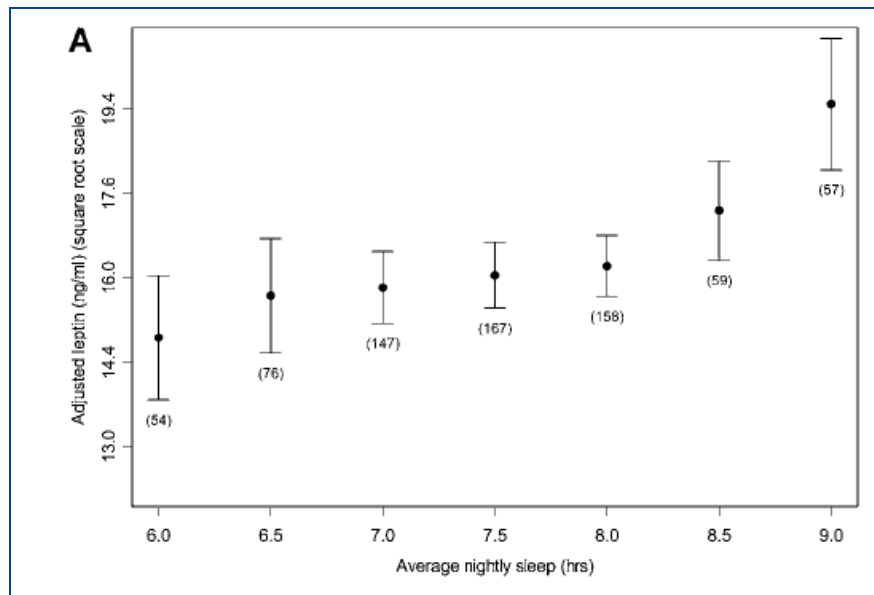
Effect of sleep duration on leptin and ghrelin levels



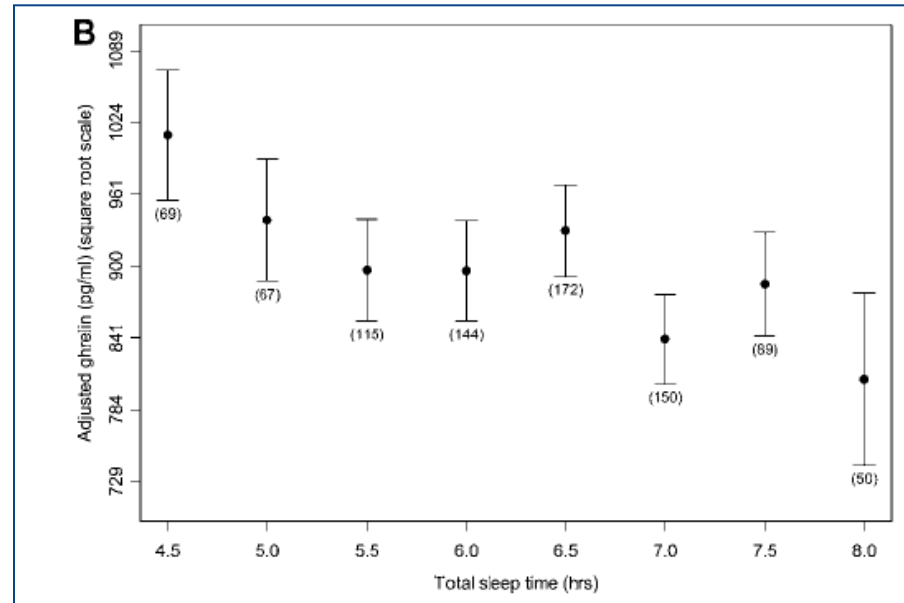
Mean (seM) leptin and serum plasma ghrelin levels in healthy individuals after 2 days with 4 h or 10 h sleep periods

Sleep and metabolic function

Leptin



Ghrelin



Sleep timing and dietary patterns.

- Students aged 9-15 years ($n = 119$, 11.7 ± 1.3 years, 76% female).

Mid sleep time

Early: $02:11 \pm 00:25$ ($n = 28$)

Late: $06:14 \pm 01:00$ ($n = 27$)

- Conclusion:** Children and adolescents who exhibit late sleep timing are more likely to make poorer dietary choices. Maybe important for obesity development.

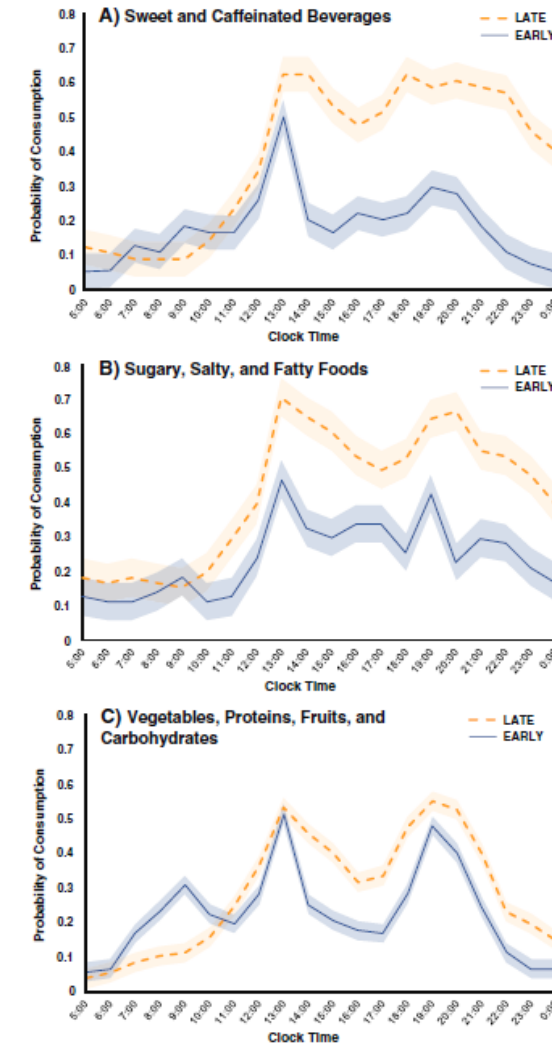


Fig. 2. Probability of consumption of (A) sweet and caffeinated beverages; (B) high energy-dense, nutrient-poor foods (i.e. sugary, salty, fatty foods); and (C) low energy-dense, nutrient-rich foods (i.e. carbohydrates, vegetables, proteins, and fruits) throughout the day by early/late sleep timing groups. Average probabilities and their 95% confidence intervals (shaded).

Thellman Sleep Health 2017 (269-275)

5.2 | SLEEP DEPRIVATION AND TYPE 2 DIABETES



Effects of short-term sleep deprivation

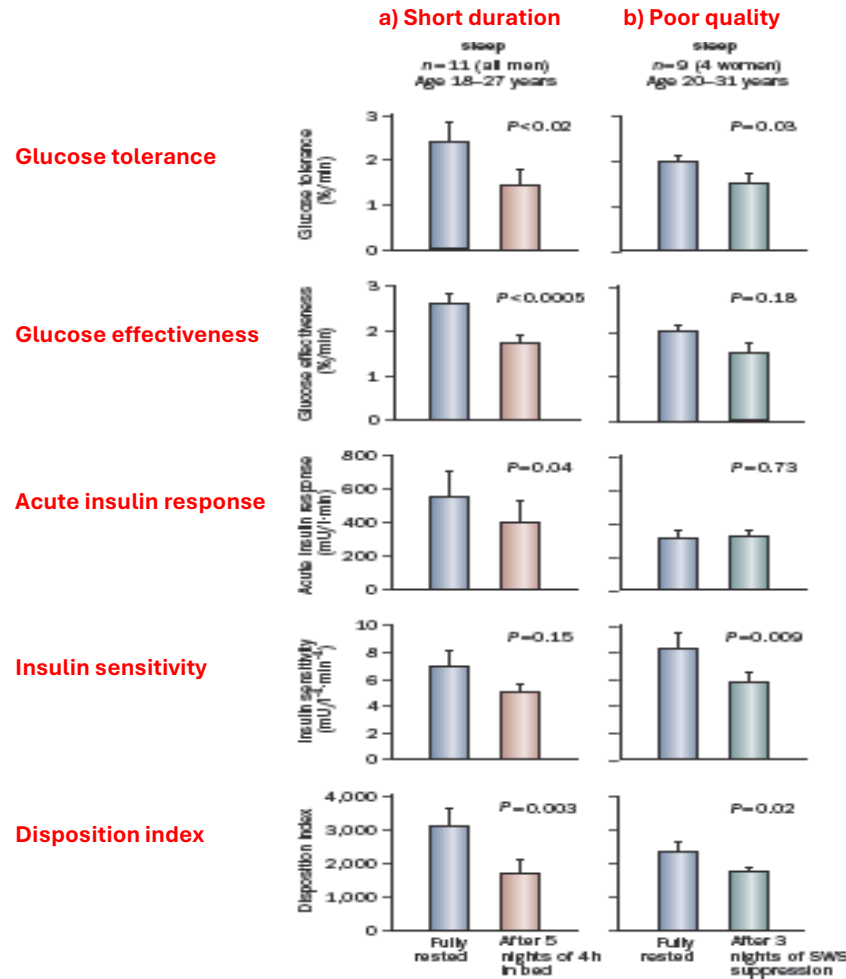


Effects of Long-term



Possible mechanisms

IV GTT in healthy individuals when fully rested and after sleep manipulations



- a) results when fully rested and after 5 nights of 4 h in bed
- b) results during baseline sleep and after 3 nights of suppression of slow-wave sleep

Plausible metabolic mechanisms

Short duration of sleep and incidence of type-2 diabetes

Exposure

Short sleep duration

Difficulty in initiating sleep

Difficulty in maintaining sleep

Author	Year	Country
Ayas	2003	USA
Biorkelund	2005	Sweden
Mallon (men)	2005	Sweden
Mallon (women)	2005	Sweden
Yaggi	2006	USA
Gangwisch	2007	USA
Hayashino	2007	Japan
Beihl (white)	2009	USA
Beihl (black)	2009	USA

Combined effect: $p=0.024$

Heterogeneity: $I^2=58\%$, $p=0.015$
Publication bias: Egger's test $p=0.14$

Author	Year	Country
Nilsson	2004	Sweden
Kawakami	2004	Japan
Mallon (men)	2005	Sweden
Meisinger (men)	2005	Germany
Meisinger (women)	2005	Germany
Hayashino	2007	Japan

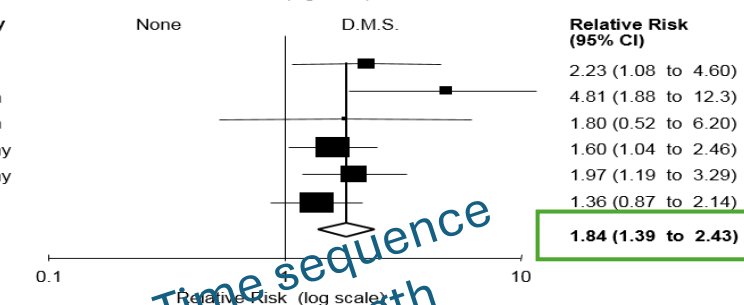
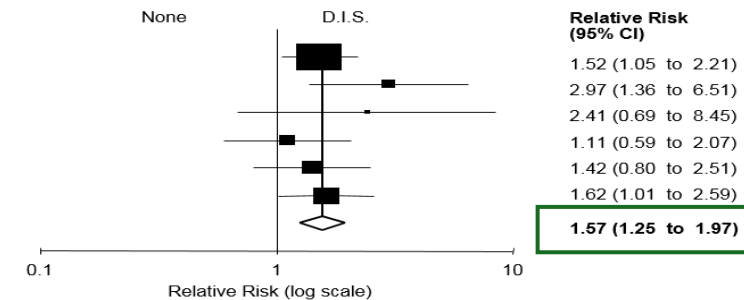
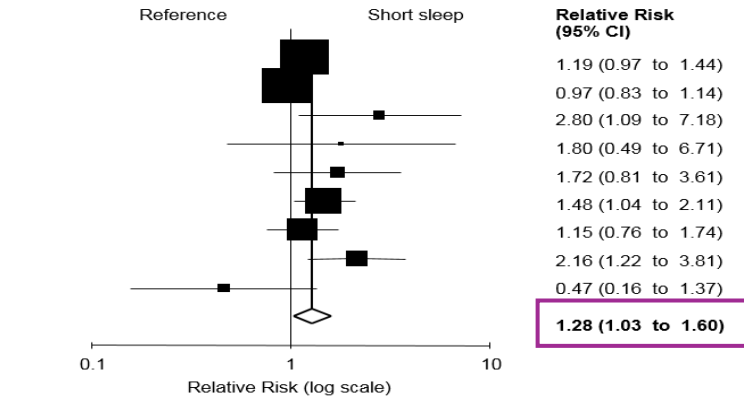
Combined effect: $p<0.0001$

Heterogeneity: $I^2=0\%$, $p=0.50$
Publication bias: Egger's test $p=0.37$

Author	Year	Country
Kawakami	2004	Japan
Mallon (men)	2005	Sweden
Mallon (women)	2005	Sweden
Meisinger (men)	2005	Germany
Meisinger (women)	2005	Germany
Hayashino	2007	Japan

Combined effect: $p<0.0001$

Heterogeneity: $I^2=22\%$, $p=0.27$
Publication bias: Egger's test $p=0.15$

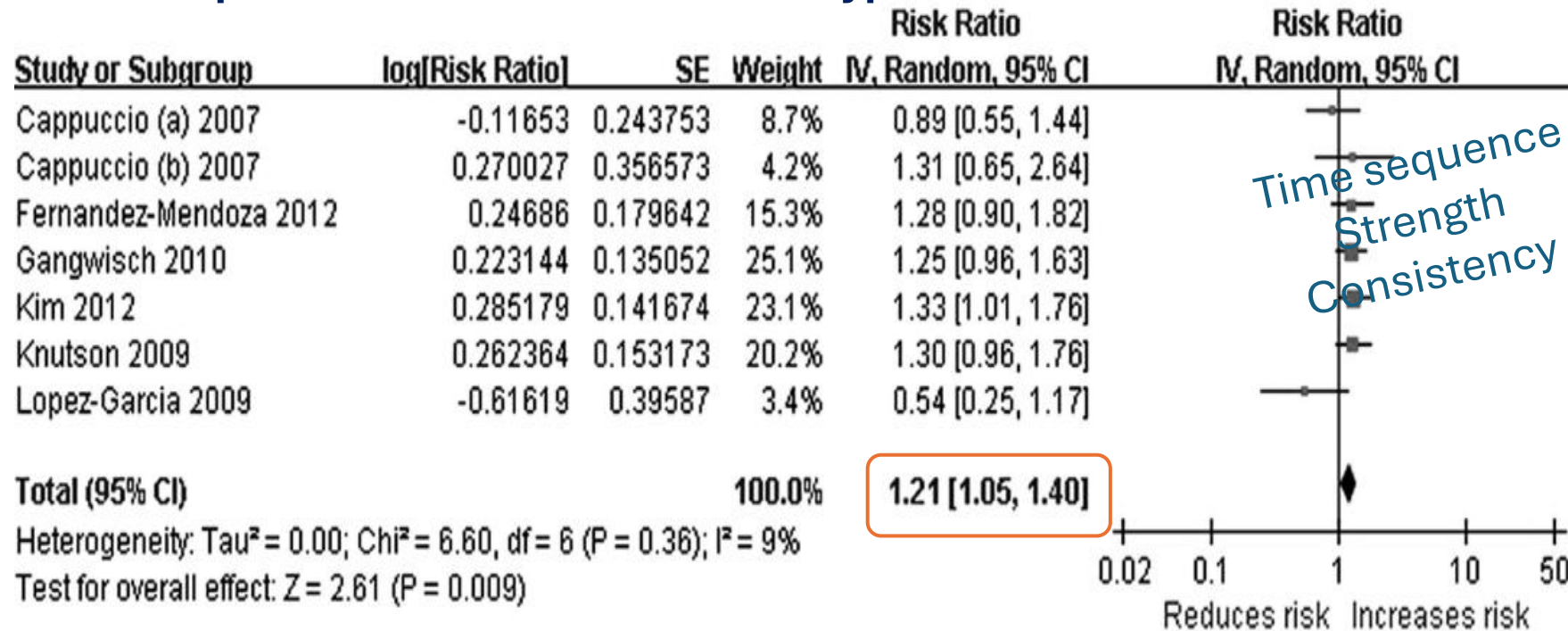


Time sequence
Strength
Consistency

Cappuccio FP et al. *Diabetes Care*; 2010; 33: 414-20

5.3 | EFFECTS OF SLEEP DEPRIVATION ON CARDIOVASCULAR VULNERABILITY AND HYPERTENSION

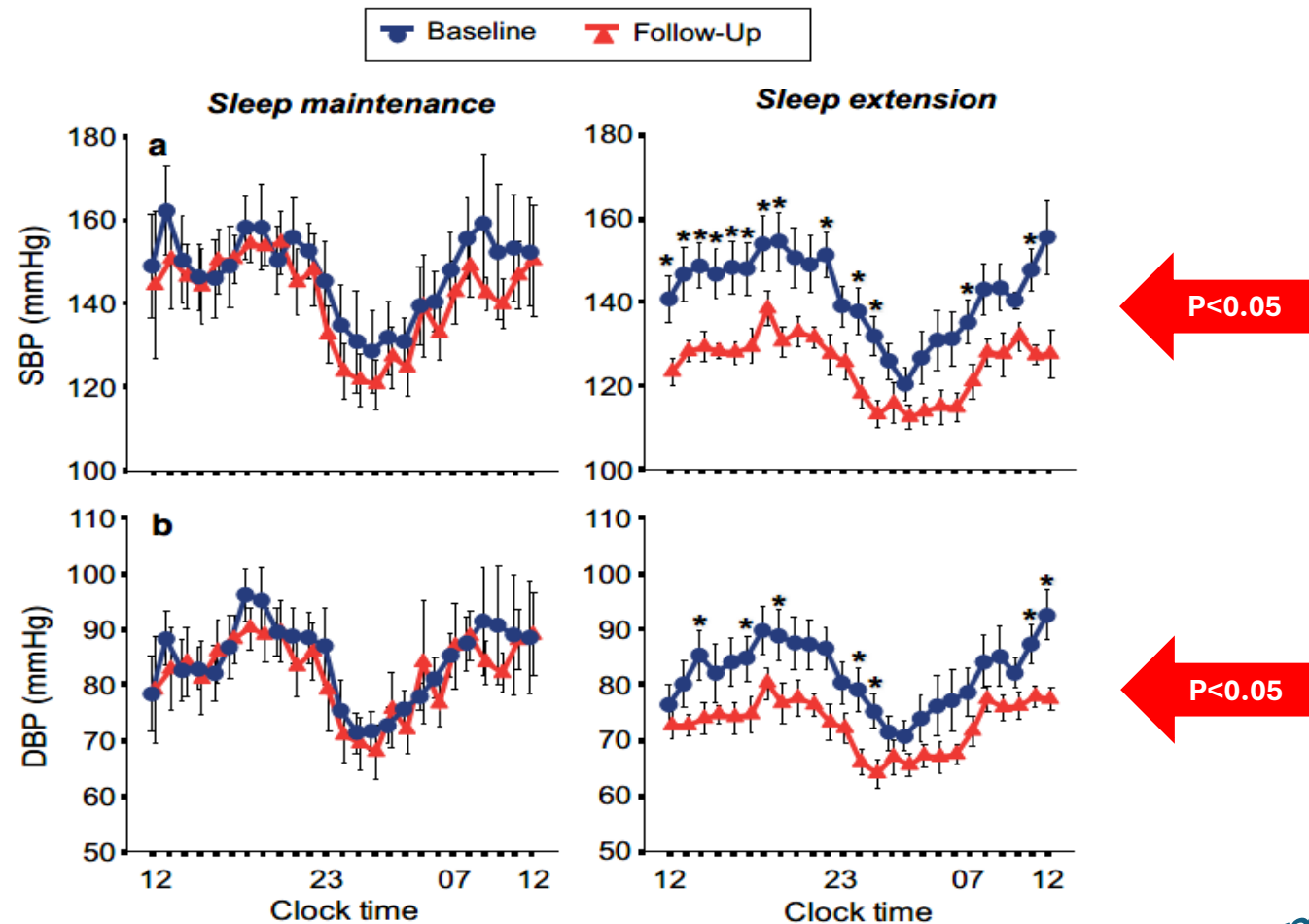
Short sleep duration and incidence of hypertension¹



Short duration of sleep has an effect on blood pressure very early in life².

Effect on incidence of hypertension associated mainly with a reduction in Slow Wave Sleep³

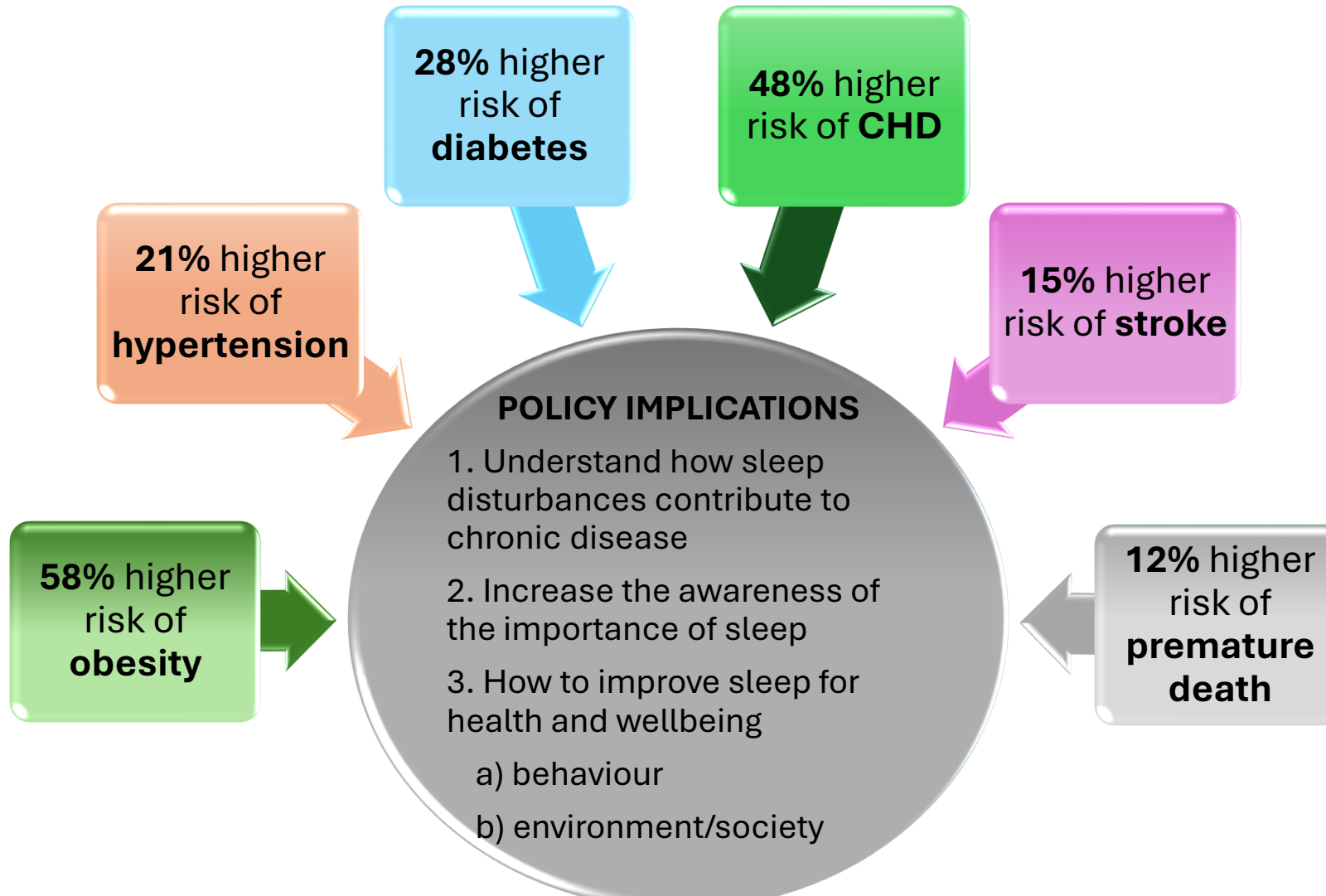
Systolic and diastolic BP at baseline and follow-up in the sleep maintenance group (n=9) and sleep extension group (n=13)



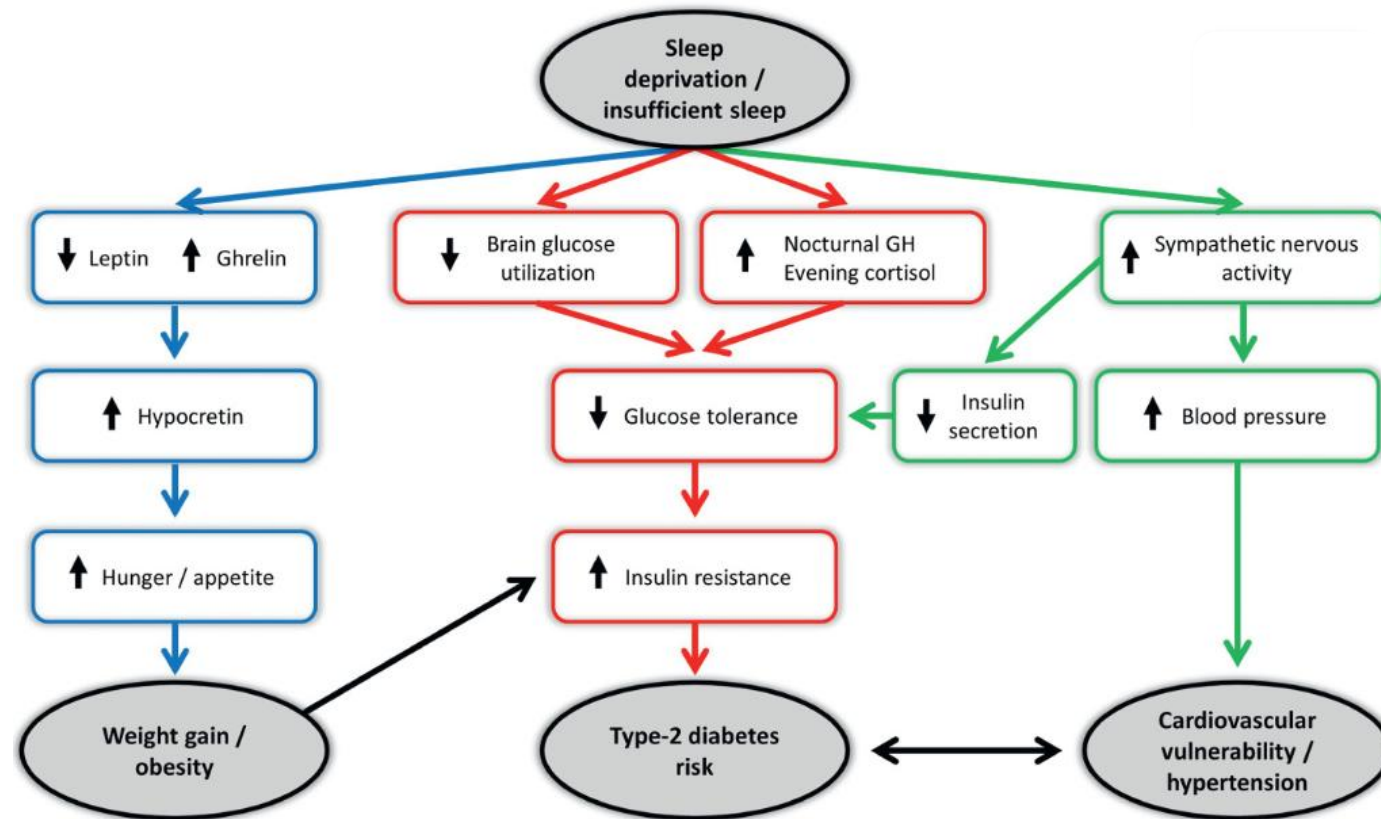
Short term RCT
Reversible effect

Short duration of sleep is associated with..

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5.1 EFFECTS OF SLEEP DEPRIVATION ON APPETITE AND BODY MASS HOMOSTASIS



6 | EFFECTS OF SLEEP DEPRIVATION ON IMMUNE FUNCTION

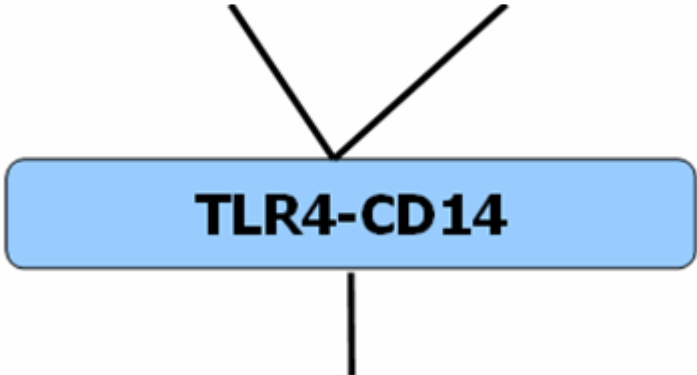


Acquired Immunity (adaptive Immunity/specific Immunity)

Occurs in response to infection, called **ADAPTIVE** as the immune system must adapt itself to previously unseen molecules.

Innate Immunity

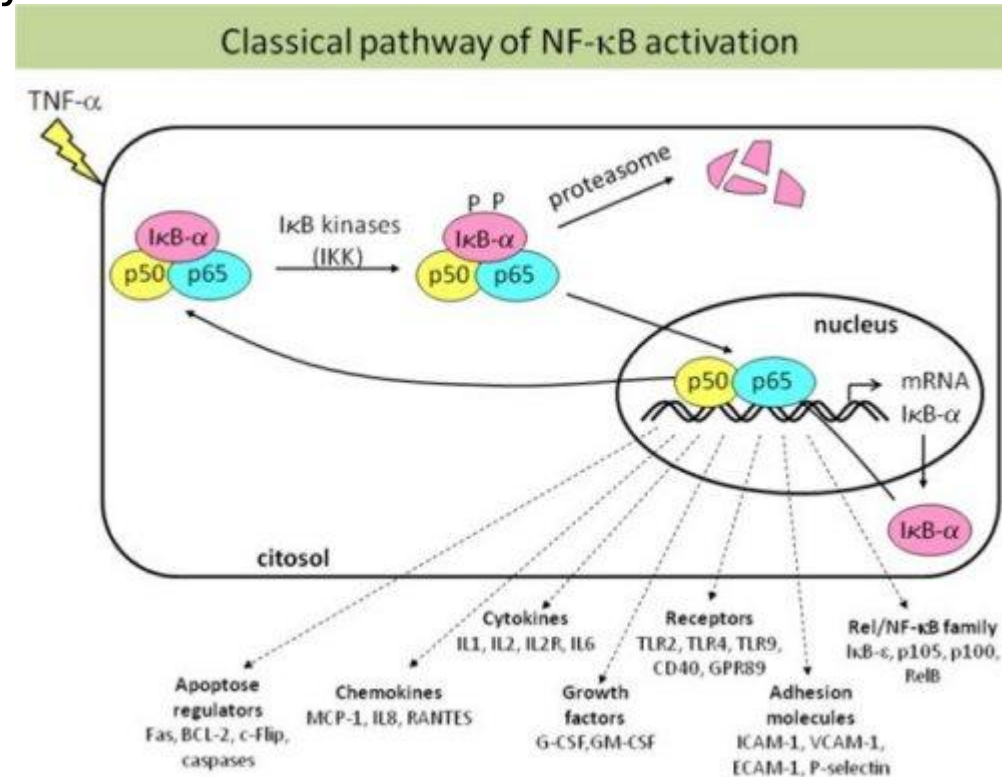
Prevents entry of micro-organisms into tissues or eliminates them prior to the occurrence of disease.

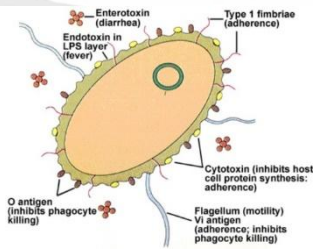


TLR4-CD14

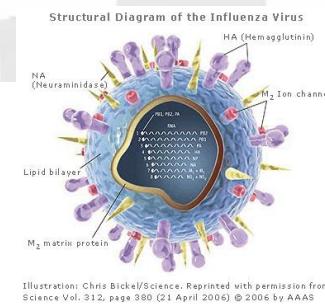
NF-κB signalling

- NF-κB inhibitor (IκB) removed by stimuli (e.g. TNF-α, bacteria, oxidants etc)
- Active NF-κB translocated to nucleus.
- Induces transcription of more than 200 genes.
- NF-κB may upregulate many genes involved in sleep regulation. NF-κB binding domains have been found in the promoter region of these genes (e.g. NO synthase).
- Feedback loops present.





Bacterial & Viral infections



Gram-negative bacteria.

Induce biphasic NREM response.

- Initial phase: NREM sleep intensity increases & REM inhibited
- Second phase: REM still inhibited but duration of NREM progressively decreases.

Both killed bacteria and bacterial wall components (muramyl peptides, endotoxin (lipopolysaccharide (LPS)) can induce NREM changes.

Influenza virus.

Viral infection is associated with:

- Formation of double-stranded (ds) viral RNA.
- Large increases in NREM sleep
- Induction of inflammatory cytokines e.g. interleukin-1 (IL-1).

Viral infections & sleep disturbances

- Viral mechanisms implicated in certain conditions e.g., chronic fatigue syndrome & sudden infant death syndrome*.

Sleep and vaccination

- Young healthy adults have reduced response to hepatitis A vaccination when sleep deprived**.

* Krueger et al Crit Rev Immunol 1994; 14:355-79.

**Lange et al Psychosom Med 2003; 65:831-5

Immune modulation of sleep

- Typical manifestations of inflammatory disorders include fatigue and sleepiness.
- Increased circulating cytokines in acute phase response.
- Interleukin-1beta (IL-1B) and TNF-alpha lead to increase in NREM.
- Fulfil criteria of a Sleep Response Substance (SRS).

Sleep Response Substance (SRS)

- i. Should enhance sleep if injected
- ii. If inhibited, should reduced sleep.
- iii. Their level in the brain should vary with sleep propensity
- iv. Should act on sleep regulatory circuits
- v. Should be altered in pathological states that are associated with enhanced sleepiness.

Sleep and cellular immunity

Type 1: Defence mediated - Pro-inflammatory.

e.g. IL-2, interferon-gamma, IL-12

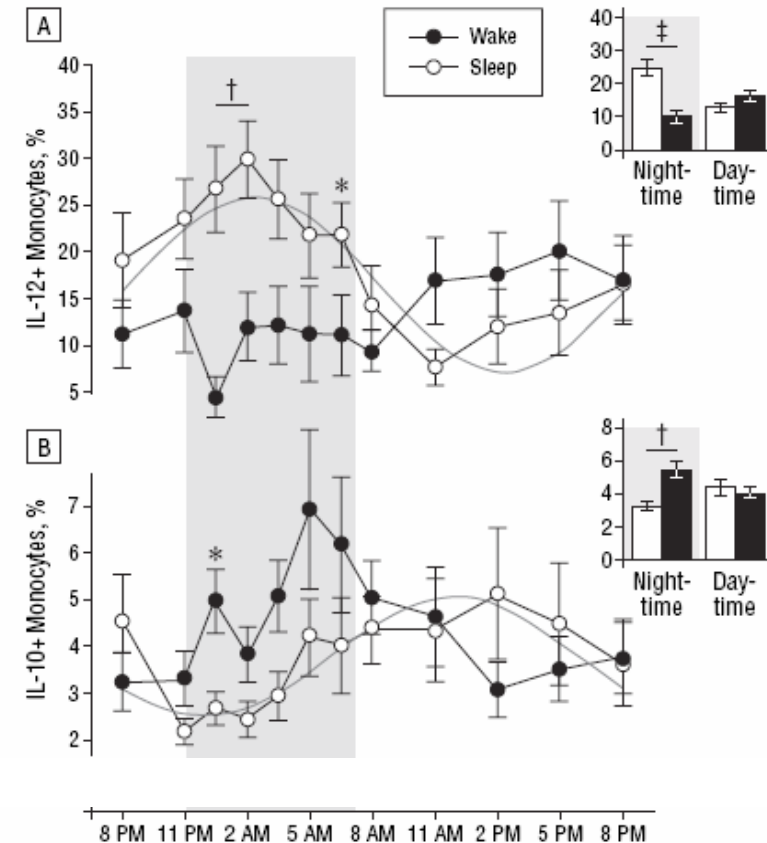
➤ Excess leads to inflammation and tissue damage

Type 2: Anti-inflammatory - moderate Type 1 effects

e.g. IL-4, IL-10.

➤ Excess leads to susceptibility to infection and allergy.

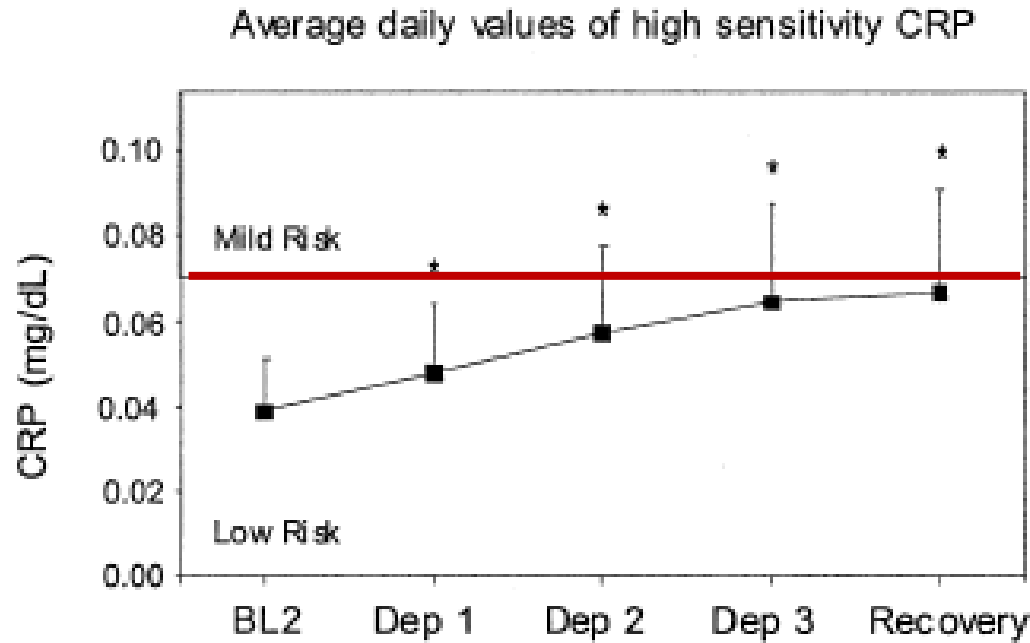
- Sleep regulates the balance between Type 1 and Type 2 activity



Lange et al. Arch Intern Med 2006; 166:1695-1700

Besedovsky et al. Pysiol Rev 2019; 99:1325-1380

Short-term sleep deprivation and Hs-CRP¹



10 subjects undergoing acute total sleep deprivation (88h).

Short-term partial sleep deprivation (10 days 4.2hours) also led to increase hs-CRP.

Low- and mild-risk quintiles CRP line from 5,000 apparently healthy Americans.
BL baseline; Dep deprivation.

Longitudinal data from Whitehall II study (n= 5,003): Each hour decrease in sleep duration was associated with an 8.1% increase in CRP and 4.5% increase in interleukin-6²

1. Meier-Ewert et al. JACC 2004; 43:678–83
2. Ferrie, J. E et al (2013). American Journal of Epidemiology, 178, 956-961.

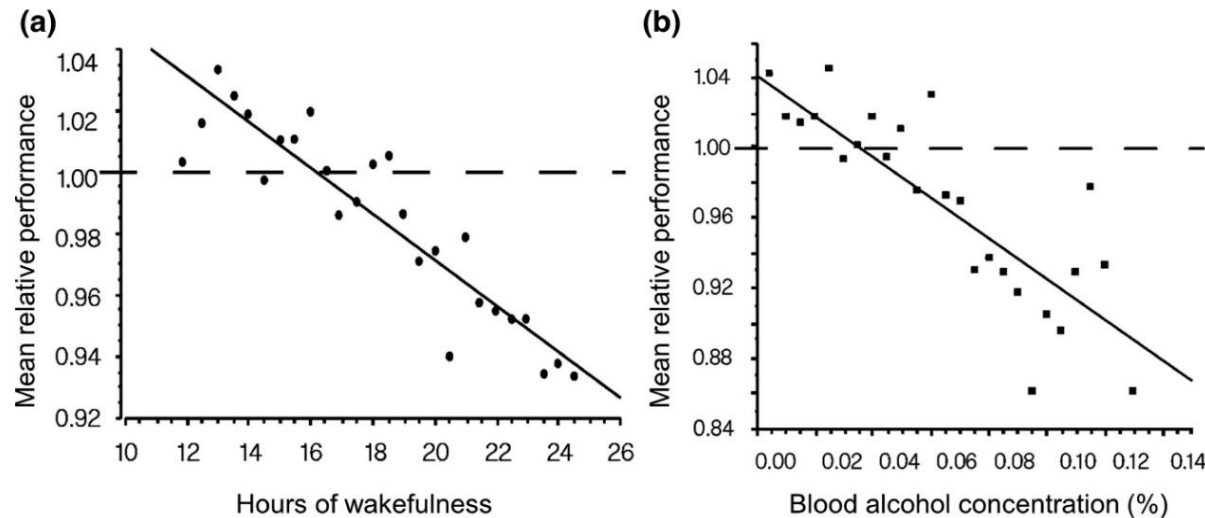
2. EFFECTS OF SLEEP DEPRIVATION ON EMOTIONAL STATE AND MOOD

- The regulation of sleep, affective state, and mood is closely related.
- Chronic restriction of sleep (5 hr per night for 1 week) resulted in robust cumulative impairment of emotional well-being, including increased sleepiness, fatigue, confusion, tension, and total mood disturbance¹.
- Evidence suggests that mood disorders are typically associated with disturbed sleep².
- Insomnia is a powerful predictor of depression, suggesting that non-depressed insomniacs have a roughly twofold risk to later develop depression³.

1. **Dinges et al., 1997**
2. **Krause et al., 2017**
3. **Baglioni et al., 2011**

3. EFFECTS OF SLEEP DEPRIVATION ON NEUROCOGNITIVE FUNCTIONS

3.1 Sustained attention



Deterioration of cognitive performance and its association with prolonged wakefulness and blood alcohol levels in healthy individuals

(a) mean relative performance levels with time awake ($p < 0.05$, $R^2 = 0.92$), and
(b) performance deterioration with increasing blood alcohol concentrations up to 0.13% ($p < 0.05$, $R^2 = 0.69$). Mean error bars $\pm$ SE.

4. EFFECTS OF SLEEP DEPRIVATION ON EXECUTIVE FUNCTIONING AND DECISION-MAKING



Sleep loss: Adversely impacts higher-order cognitive skills including working memory, decision-making, expectation of reward, adapting and revising plans, divergent thinking, reasoning, behavioural inhibition, and problem-solving¹.



Sleep deprivation prompted healthy volunteers to take more risks in a gambling tasks compared with when they were well-rested.



FUNCTIONAL
Neuroimaging studies have highlighted that sleep-deprived individuals show differences within brain-reward circuitry during risky decision-making².

1. [Goel et al., 2009](#)
2. [Venkatraman, Chuah, Huettel, & Chee, 2007](#)

4.1 Effects of sleep deprivation on learning and memory

Sleep likely promotes the consolidation of memories, (i.e., the transformation of newly encountered labile information into stable representations integrated in pre-existing networks).

See also Chapter A. 5

Research suggests SWS is important in this process

7. OTHER EFFECTS OF SLEEP DEPRIVATION: Road Traffic Accidents

Crash driver 'suffering
sleep disorder'



Croydon tram crash: Drivers 'fell asleep' on fatal line

By Ed Thomas and Noel Titheradge
BBC News

24 April 2017 | London

f t b e Share



Four drivers have admitted falling asleep while operating trams in Croydon, where seven people were killed after a tram derailed in November 2016.

Drivers said a safety device, known as "a dead man's handle", failed to activate and stop their trams.

Tram Operations Ltd, which runs the line, said driver fatigue was monitored and controls were "fully functional".

© BBC

Sleep disorder 'danger' of HGVs

About one in
six British
HGV drivers
suffers from
a form of a
sleep
disorder
requiring
medical help



BBC

Selby disaster was
'sleep related'



Goel et al., 2009; Rajaratnam & Arendt, 2001

Global disasters

Oil slick



Nuclear reactor explosion



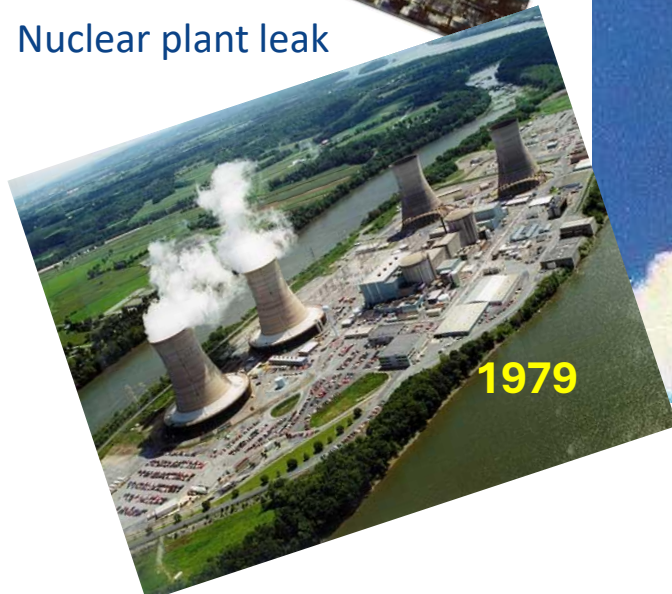
Space shuttle explosion



Chemical toxics release



Nuclear plant leak



7. OTHER EFFECTS OF SLEEP DEPRIVATION

Performance judgement and risk of harm to others

The occurrence of insufficient sleep can reflect lifestyle choices, overwhelming occupational, family, or social demands, or medical problems.

Screening for sleep disorders in almost 5,000 American Police Officers revealed a >40% prevalence of at least one type of sleep disorder¹

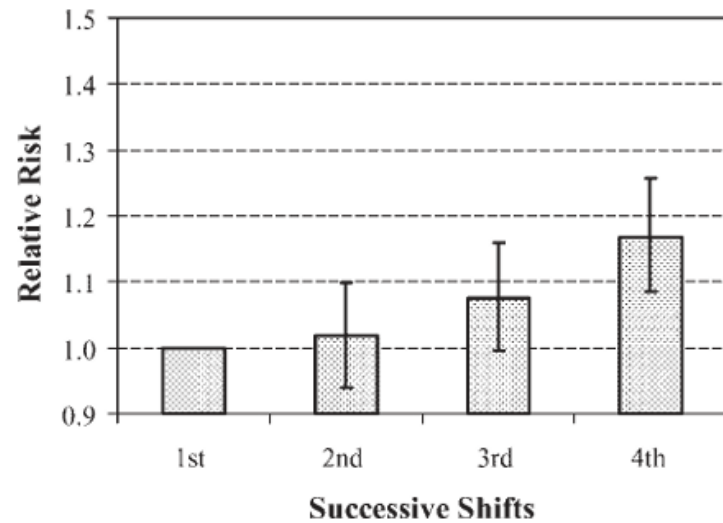
The bad sleep quality was significantly associated with adverse performance, safety and health outcomes.

In a separate study a police officer was quoted as saying

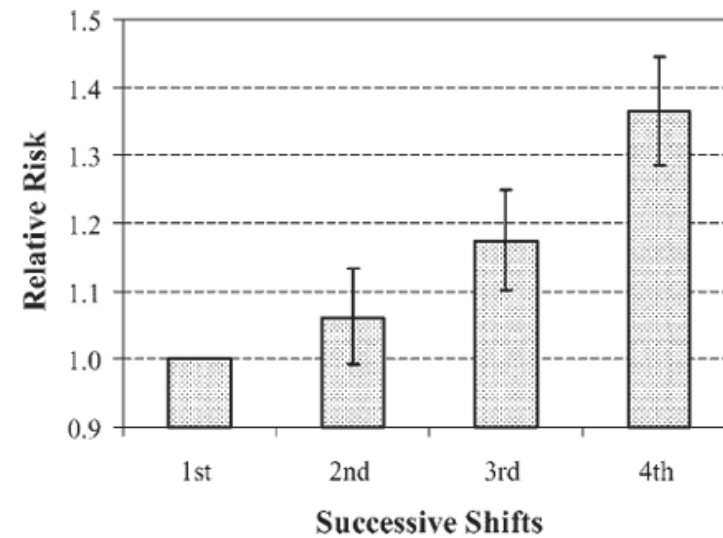
“One accidental discharge was due to poor sleep. It could have been horrible.”²

1. Rajaratnam et al., 2011.
2. Howarth. Master's Thesis 2023; unpublished observation.

Shift work: Impact of the Components of Long Work Hours on Injuries and “Accidents”



The relative risk over four successive morning/day shifts (error bars are 95% CIs)

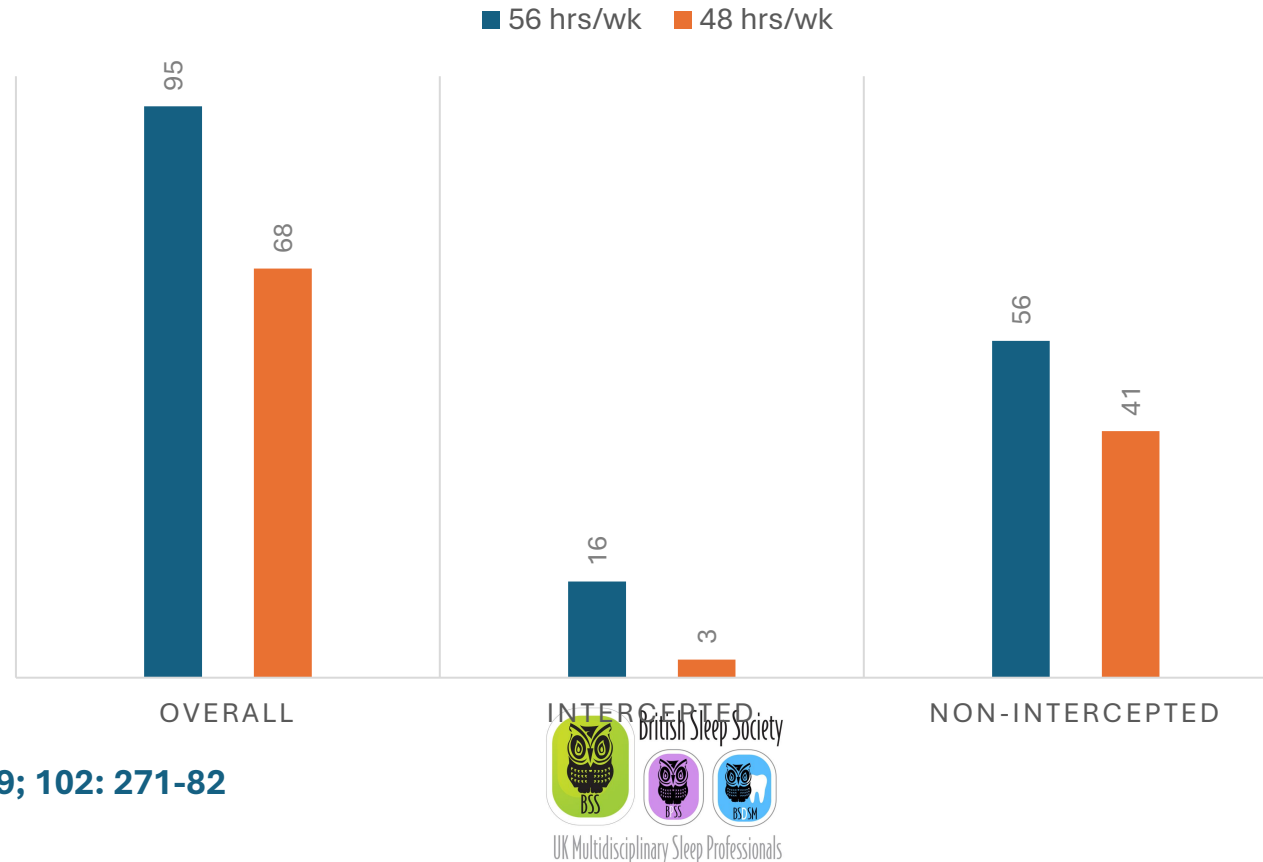


The relative risk over four successive night shifts (error bars are 95% CIs).

Shift work: Medical Errors

Adverse events and error rates for Junior doctors:
Traditional (56h per week) v Intervention (48h per week) rotas

Total sleep Time
Traditional rota
 $6.75 \pm 0.40h$



Total sleep Time
Intervention rota
 $7.26 \pm 0.36h$

International Agency for Research on Cancer



IARC MONOGRAPHS CLASSIFICATION OF NIGHT SHIFT WORK

Night shift work is **PROBABLY
CARCINOGENIC TO HUMANS (Group 2A)**

Limited evidence in humans. Sufficient
evidence in experimental animals.



The *IARC Monographs* classification indicates
the level of certainty that an agent can
cause cancer (*hazard identification*).



Positive associations
have been observed
between night shift
work and cancers of the:



Breast



Prostate

Colon and
rectum

Night shift work includes both working at night and
working in a job that involves rapidly crossing many
time zones.

Specific types of workers



Nurses

Factory
workersFlight
attendantsAirplane
pilots

Higher percentages of night shift workers are seen in



Health care

Manufacturing

Retail,
service sector

Transport

Public Health: Consequences of 'less' sleep

- 20% of road deaths are related to fatigue
- Someone who sleep less than 6 hours per night takes an additional 6 days off work per year compared to a worker sleeping 7-9 hours

RAND report : Quantifying the Economic Costs of Insufficient Sleep

The U.S. sustains by far the highest economic losses (up to \$411 billion a year, which is 2.28 per cent of its GDP) and the UK (up to \$50 billion (£40.2 billion), 1.86 per cent of its GDP).

Small changes to sleep duration could have a big impact on the economy. For example, if individuals that slept under six hours started sleeping six to seven hours then this could add \$29.9 billion to the UK economy

[Why Sleep Matters: Quantifying the Economic Costs of Insufficient Sleep | RAND](https://www.rand.org/randeurope/research/projects/2016/the-value-of-the-sleep-economy.html)

<https://www.rand.org/randeurope/research/projects/2016/the-value-of-the-sleep-economy.html>

Key Points

- Important negative health outcome measures associated with insufficient sleep (e.g., obesity, type 2 diabetes, hypertension).
- Several components of immune system altered after sleep restriction.
- Sleep deprivation increases sleepiness, impairs mood states and emotional processing, and contributes to altered risk-taking and decision-making behaviour.
- Insufficient sleep has been associated with elevated mortality, enhanced accident risk, and a generally increased incidence of errors.

Policy



Institute for Policy

Modernising Shift Working Practices

Organisational practices to reduce negative health and safety effects of shift working

Key Policy Recommendations

Consistently embed evidence-based protections for shift-workers into existing employment legislation, requirements and practices.

Employers:

1. Design working rotas to minimise disruption to circadian rhythms.
2. Provide education and training for shift workers on the risks associated with shift working.
3. Provide working environments that support employees to engage in behaviours that reduce their risks of sleepiness, fatigue and disease.
4. Modernise workplace health assessments and empower shift workers to detect and treat any negative health effects associated with shift working.

Legislators and Regulators:

5. Embed these recommendations into existing requirements and working laws.

Public Health Organisations and Charities:

6. Prioritise shift working as a public health focus.

The Impacts of Shift Working

As the deleterious short-term and long-term effects associated with shift working are becoming more apparent, employers are well positioned to ensure their workforce is protected and well equipped to mitigate the risks.

- Over a quarter of the UK working population are shift workers (ONS, 2022). A growing body of evidence indicates that night shift working can increase the risk of developing serious health conditions as well as workplace accidents.
- Since 2007, the World Health Organization has placed night shift work in the second highest cancer-risk class; '2A: probably carcinogenic to humans' (IARC, 2020).
- It is estimated that the risk of developing type 2 diabetes is 44% higher among shift workers compared with non-shift workers in the UK (Vetter, C. et al., 2018).
- The risk of suffering heart disease is 37% higher for night shift workers, when compared with non-shift workers in the UK (Wang, N. et al., 2021).
- Sleepiness and fatigue are common negative effects of night shift working. These are linked to higher levels of traffic collisions and major workplace accidents, as well as decreased patient safety in hospitals (Mitchell, H., 2024).
- Sleep deprivation, which is especially common amongst shift workers, is estimated to cost the UK economy more than £37 billion annually (RAND, 2016).



Parliamentary event briefing

Fighting Fatigue: Addressing Shift Work, Sleep and the Public Health Burden

Date: Wednesday 10 June | 17:00-18:30

Location: House of Commons, Committee Room 15

Host: Ian Lavery MP, Chair, APPG on Occupational Health

This briefing has been developed by researchers from University of Warwick as a pre-parliamentary event brief, and incorporates contributions from the Society of Occupational Medicine, alongside insights generated through a preceding webinar "Shift Work, Sleep and Public Health: From Evidence to Action"; and stakeholder discussions involving researchers, employers, occupational health professionals, trade unions, and individuals with lived experience of shift work. These events were made possible with the contribution of the Health Spotlight Programme at the University of Warwick.

Contact:

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University of Warwick
Email: talar.moukhtarian@warwick.ac.uk



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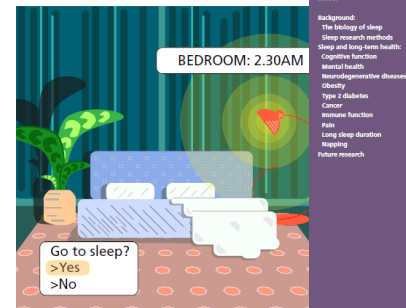
HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTbrief

Number 29, September 2018

Sleep and Long-Term Health

By Lev Tankelevitch & Sarah Burr



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Cover page image: Lef Apollonidis

HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 586 September 2018

Shift Work, Sleep and Health



Overview

- Shift work (working outside regular daytime hours) is common in many safety-critical and other sectors, including transportation and healthcare.
- Shift work can disrupt sleep and circadian timing, essential biological processes that affect many aspects of physical and mental health and performance.

- [Sleep and Long-Term Health - POSTbrief 29](#)
- [Sleep and Health - POSTnote 585](#)
- [Shift Work, Sleep and Health - POSTnote 586](#)



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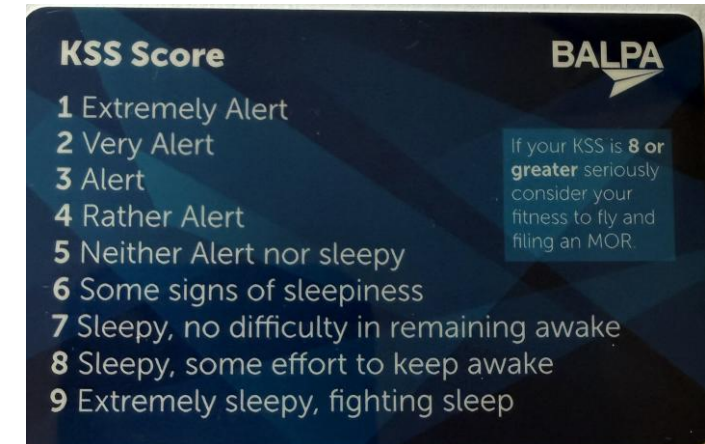
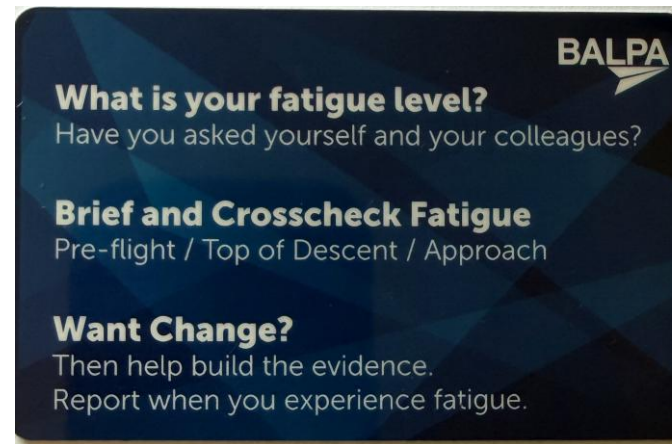
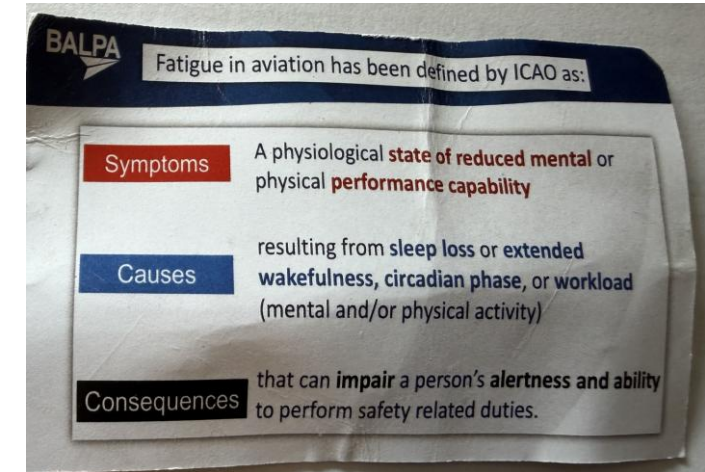
Sleep and Health



Overview

- Sleep is affected by physical and mental health and environmental and social factors.
- Short-term sleep disruptions increase the risk of workplace and driving accidents.
- Long-term sleep disruptions are associated with a range of poor health outcomes.

Guidelines British Airline Pilots' Association



SLEEP, HEALTH & SOCIETY[©]

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