Age-Related Associations Between Chronotype and Sleep-Wake Cycles: A Longitudinal Big Data Analysis of Objective Sleep

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Introduction

- Circadian rhythms progressively delay throughout adolescence until older adulthood when it advances, mirroring childhood[1].
- Presently, it remains unclear whether sleep-wake patterns and diurnal preference (i.e., chronotype) diverge across the lifespan.
- Here, we examined whether self-reported chronotype was associated with the daily start of the sleep-wake cycle, indicated by objectively measured bedtime.

Materials & Methods

Data

- Data from 11,026 users (mean age: 45.3, 54% female) across 1,167,489 nights from the PSG-validated SleepScore mobile app.
- Chronotype was subjectively assessed with a 5-item questionnaire ranging from *strong morning type* to *strong evening type.*
- Bedtime was manually captured as the time a user started a sleep recording.

Analysis

- Simple linear regressions were used for this analysis.

Conclusion

- Unlike evening types, younger ages identifying as morning types had later bedtimes and older ages had earlier bedtimes.
- The degree of change in bedtimes across chronotypes was presumably driven by age-related changes in circadian rhythmicity.

Results

	Full Sample	Strong Morning	Slight Morning	Neither	Slight Evening	Strong Evening
Number of Users	11,168	1,760	2,258	2,254	2,479	2,417
Nights Recorded	1,185,757	205,172	257,920	234,762	245,966	241,937
Age (years)	45.4 ± 16.8	50.6 ± 16	48.1 ± 16.4	45.4 ± 16.8	43.2 ± 16.5	41.4 ± 16.5
Chronotype %	-	15.70	20.20	20.10	22.10	21.60
Bedtime	23:57 hr ± 96 mins	23:02 hr ± 85 mins	23:18 hr ± 78 mins	23:48 hr ± 87 mins	00:08 hr ± 81 mins	01:09 hr ± 102 mins
Wake Up Time	7:28 hr ± 84 mins	6:30 hr ± 70 mins	6:57 hr ± 65 mins	7:26 hr ± 72 mins	7:44 hr ± 70 mins	8:25 hr ± 91 mins
Total Sleep Time	346 mins ± 51 mins	341 mins ± 49 mins	350 mins ± 50 mins	349 mins ± 52 mins	348 mins ± 51 mins	338 mins ± 50 mins
Sleep Efficiency	79 ± 7	78 ± 7	79 ± 7	79 ± 7	79 ± 7	79 ± 7

Table 1. Demographic and average sleep-wake characteristics for all groups.

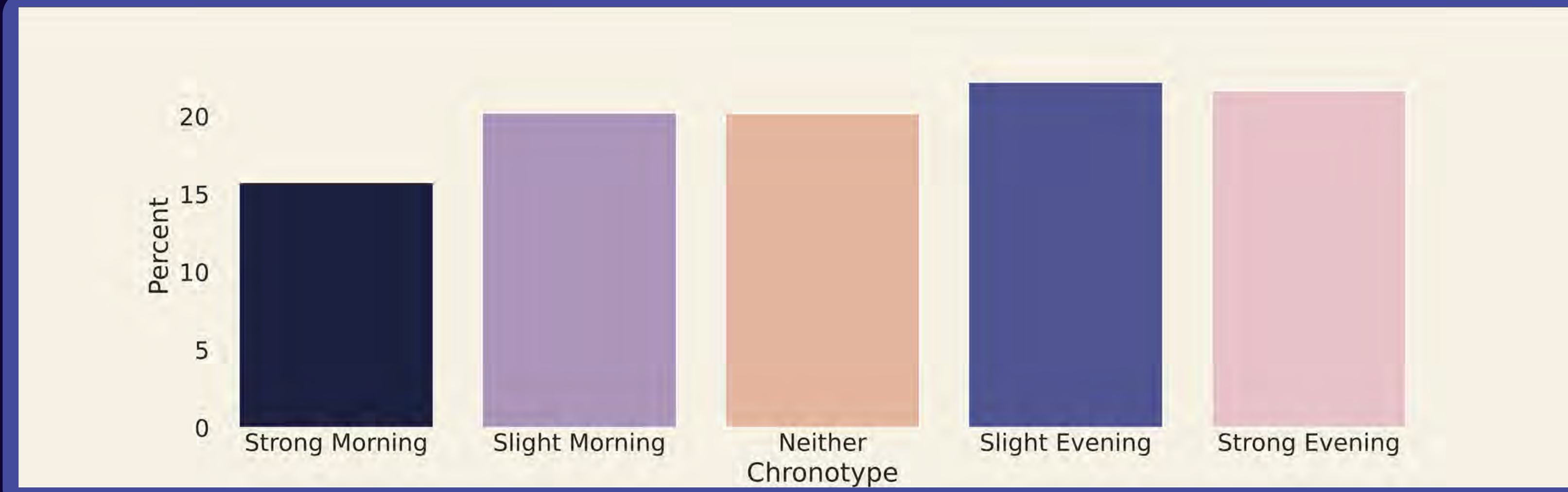

Figure 1. Histogram of distribution of users identifying as each chronotype group. A skew toward slight evening type (n=2147, 21.70%) compared to strong morning types (1560, 15.70%) was observed.

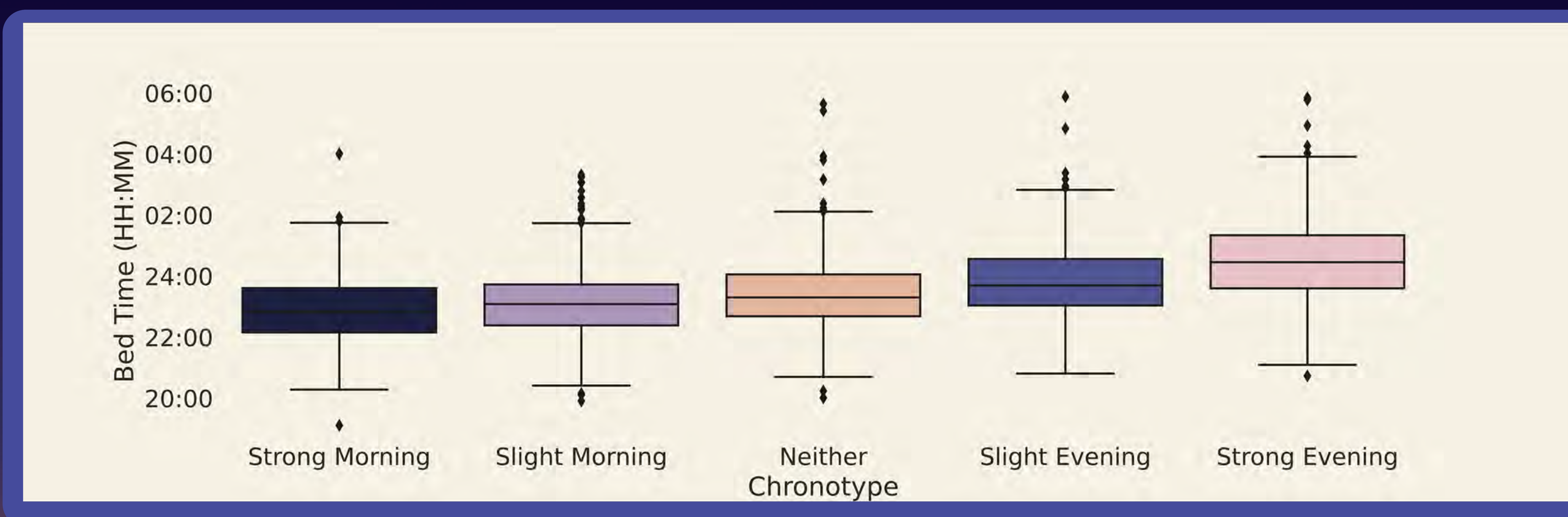

Figure 2. Box plots of mean bedtime for each chronotype group indicate that, as expected, average bedtimes were earliest for strong morning types (mean: 23:02 hrs ± 86 mins) and latest for strong evening types (mean: 01:10 hrs ± 102 mins).

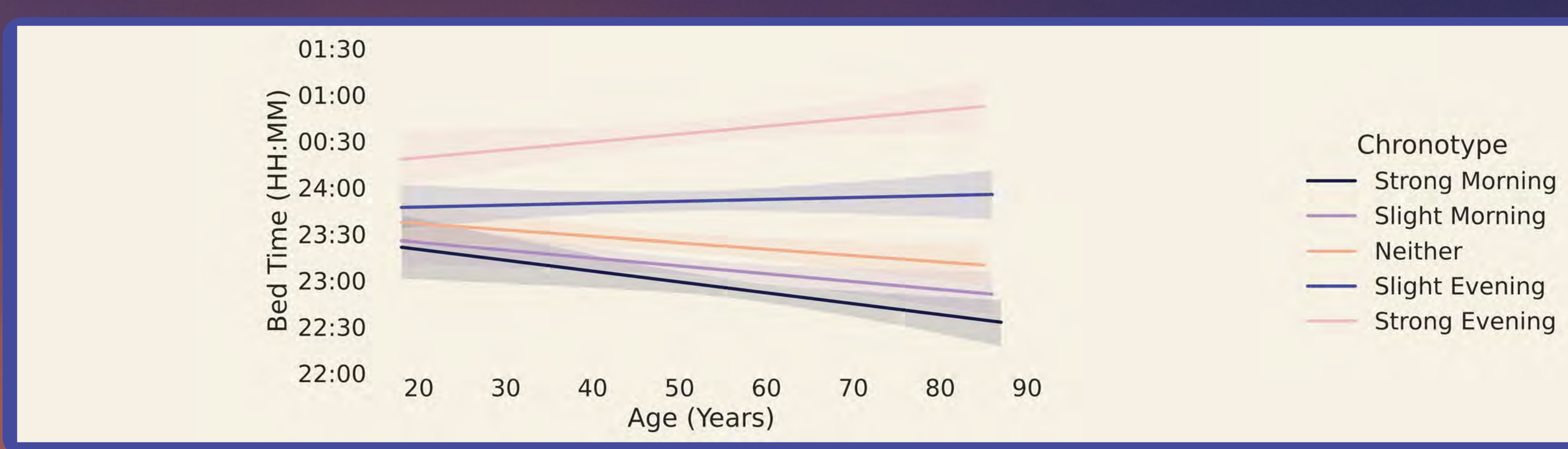

Figure 3. Linear regression analysis reveals a significant negative association between overall age and bedtime across chronotypes ($p<0.0001$). The degree of change in bedtimes across ages was largest for *definite morning types*, whereby average bedtime decreased from 23:38 hr ± 86 min at age 20 to 22:29 ± 88 min at age 80 ($\beta = -0.019$, $SE=0.002$, $p<0.00001$).

Reference
1. Fischer D, Lombardi DA, Marucci-Wellman H, Roenneberg T. (2017) Chronotypes in the US – Influence of age and sex. *PLoS ONE* 12(6): e0178782.

SleepScore Labs™

Comforter Designed for Warm Sleepers Improves Objectively-Measured Sleep for Adults in Midlife and Older

Sharon Danoff-Burg[1], Holly Rus[1], Morgan Weaver[1], Rodolfo Rodriguez, Jr.[1], Larisa Gavrilova[1]
[1]SleepScore Labs, Carlsbad, CA

Introduction

- This study examined effects of a comforter designed for warm sleepers used at home
- Bedding can aid in maintaining a comfortable thermal state in the sleep environment
- Research is needed to bring scientific rigor to document these benefits and their potential for promoting better sleep

Materials & Method

Sample & Design

- 31 healthy adults (96% female, mean age 46) who reported sleeping hot
- 6-week field study, within subjects, pre-post

Intervention

- Used cooling comforter (made of viscose from bamboo with Tencel/poly fill) with direct contact on skin for 3 weeks

Analysis

- Multilevel regression accounting for nested data (nights within subjects) and paired t-tests

Conclusion

- Sleeping with a cooling comforter can improve objectively-measured and self-reported sleep for ***hot sleepers aged 45 and older***
- In the full sample (ages 23-74), self-reported but not objectively-measured sleep improved

Results

Self-Report Results (*n*=1003 nights)

	Observed		Estimated		
	Original Bedding	Cooling Comforter	Constant	*beta*	*p*-value
Time to Fall Asleep (minutes)	20.79	22.41	20.73	1.05	0.489
Number of Times Woke Up	2.77	2.71	2.77	-0.07	0.515
Time Awake After Falling Asleep (minutes)	26.68	23.37	26.42	-2.85	0.198
Sleep Quality (0-100)	**56.45**	**59.83**	**56.29**	**3.28**	**0.006**
Feeling Well-rested in the Morning	**55.35**	**59.22**	**55.10**	**4.19**	**<0.001**

- **In the full sample (*n*=31), participants perceived better sleep quality and felt more rested in the morning when using the comforter**
- **Pre-post analyses revealed additional significant improvements in perceived sleep: sleeping hot fewer nights per week, better able to sleep through the night, improved sleep duration and sleep satisfaction**

Objective Results (*n*=423 nights)

	Observed		Estimated		
	Original Bedding	Cooling Comforter	Constant	*beta*	*p-value*
SleepScore (0-100)	**76.89**	**79.46**	**76.91**	**3.05**	**0.002**
BodyScore (0-100)	**80.1**	**82.47**	**79.66**	**3.31**	**0.002**
MindScore (0-100)	75.37	76.55	75.59	1.32	0.341
Total Sleep Time (minutes)	**362.17**	**374.31**	**363.23**	**16.79**	**0.010**
Sleep Onset Latency (minutes)	21.41	17.90	21.27	-2.33	0.173
Wake After Sleep Onset (minutes)	39.74	38.56	40.13	0.28	0.921
Time in Bed (minutes)	**431.06**	**442.43**	**432.49**	**17.89**	**0.017**
Light (minutes)	221.36	225.93	222.76	7.62	0.138
Deep (minutes)	**69.92**	**75.69**	**69.30**	**7.21**	**0.005**
REM (minutes)	70.89	72.69	71.31	1.89	0.527

- **In the subsample of participants 45 and older (*n*=15), objective measures showed increased time in bed, increased total sleep time, more deep sleep, and increased SleepScore and BodyScore**

Support
Blue Ridge Home Fashions

Sleep Score Labs™

Compliance to sleep recommendations: A big data analysis in users of a consumer sleep technology

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SleepScore Labs, Carlsbad, CA[1], University of Washington, School of Medicine, Seattle, WA[2]

Introduction

- The National Sleep Foundation has published sleep time duration and sleep quality recommendations across the life-span based on expert panel input.[1,2]
- These recommendations offer sleep guidance to millions of individuals.
- Many individuals are using commercially available sleep tracking devices to measure their sleep.
- We analyzed the data of SleepScore Max (SleepScore Labs) and S+ (ResMed) sleep measurement devices (both validated against PSG) to determine how well the users of these devices are sleeping.

Methods

- Sleep duration, sleep latency and sleep efficiency data of 40,892 users (5,513,369 nights) between 15 and 98 years old were used in this analysis, and averages per user were calculated.
- Within each age group (Young Adults (18-25), Adults (26-64) and Older Adults (65-98)), percentages of users meeting the classifications as published in the recommendations [1,2] were calculated.

	Young Adults (18-25)			Adults (26-64)			Older Adults (65-98)		
	+	?	-	+	?	-	+	?	-
Sleep Latency[2]	79.7%	14.2%	6.1%	84.8%	11.4%	3.8%	84.3%	14.2%	1.5%
Sleep Efficiency[2]	53.6%	43.8%	2.6%	58.3%	30.9%	10.8%	59.6%	29.6%	10.8%
Sleep Duration[1]	30.0%	40.2%	29.8%	27.3%	41.7%	31.0%	28.2%	63.9%	7.9%

Table 1: Proportion of users meeting the recommendation classifications per age group. + : Appropriate/Recommended, ? :Uncertain/ May be Recommended, and -: Inappropriate/Not Recommended.

Conclusions

- **30% or less users slept on average the recommended amount of hours.**
- **Slightly over half of the users showed the recommended sleep efficiency.**
- **At least 79.7% fell asleep within 30 minutes on average.**
- **These results show that sleep improvement campaigns need to focus on extending sleep duration and sleep hygiene to improve sleep efficiency.**

Results

Sleep Duration recommendations are least met on average, whereas Sleep Latency recommendations are frequently met.

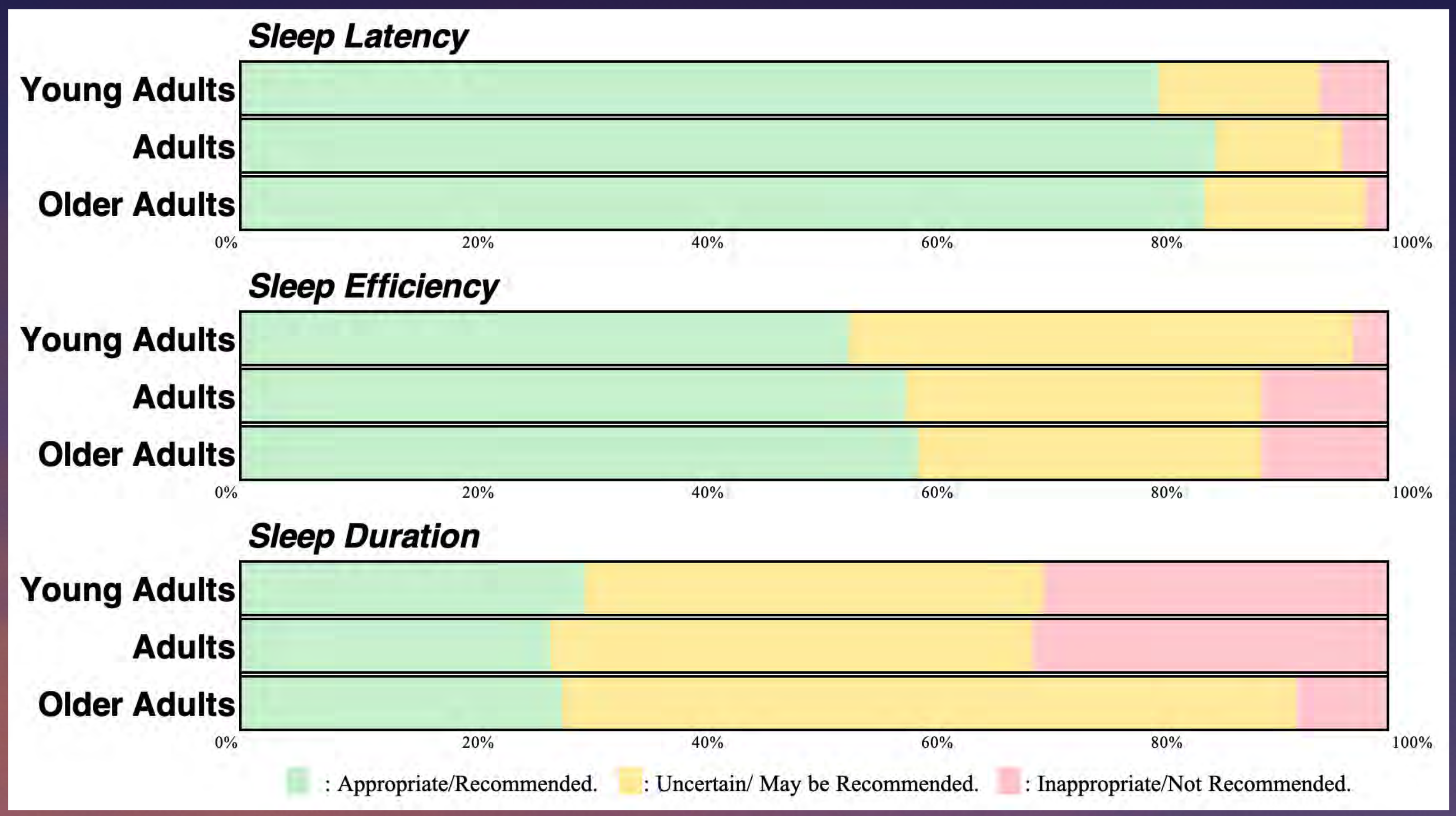


Figure 1: Proportion of users meeting the recommendation classifications for each of the sleep variables per age group.

References
[1]Hirshkowitz M, Whiton K, Albert SM, et al (2015). National sleep foundation's sleep time duration recommendations: methodology and results summary. Sleep Health, 1(1), 40–3.

[2]Ohayon, M, Wickwire, EM, Hirshkowitz, M, et al. (2017). National Sleep Foundation's sleep quality recommendations: First report. Sleep Health, 3(1), 6-19.

Sleep Score Labs™

Self-Reported Exercise and Objectively Measured Sleep: A Big Data Consumer Sleep Technology Analysis

Luke Gahan[1], Elie Gottlieb[1], Nathaniel Watson[2], Roy Raymann[1]
[1]SleepScore Labs, Carlsbad, CA [2]Department of Neurology, University of Washington School of Medicine, Seattle, WA

Introduction

- Exercise and sleep are bidirectionally associated, yet most epidemiological evidence has relied on self-reported sleep measurement and cross-sectional study designs[1].
- Here, we examined the association between self-reported exercise intensity and frequency with objectively measured sleep using consumer sleep technology.

Materials & Methods

Data

- Data from 2,262 users across 343,308 nights
- Users aged 16-90 (mean: 47.3 +/- 16.0) were included in the study. 63.5 % of users were male
- Self-reported questionnaires were used to capture the average:
  - Exercise intensity – 3 point scale
  - Exercise frequency – days per week, 5 point scale

Analysis

- Linear regression modelling was used for analysis
- Models were adjusted for age and gender

Conclusion

- Self-reported exercise frequency and intensity were associated with improved objective sleep metrics across the board
- Self-reported exercise intensity appears to have a stronger relationship with enhanced sleep than exercise frequency

Results

Parameter	Exercise Frequency			Exercise Intensity		
	Beta	SE	p	Beta	SE	p
TST (mins)	3.3	0.838	<0.001	4.908	1.886	<0.001
Sleep Efficiency. (%)	0.50	0.116	<0.001	1.16	0.255	<0.001
WASO (%)	-1.2	0.429	0.007	-3.282	0.965	0.001
SOL (mins)	-0.423	0.163	0.001	-0.852	0.272	<0.001

Table 1. Linear regression analysis results for Exercise Frequency and Exercise Intensity. Compared with Total Sleep Time (TST), Sleep Efficiency (Sleep Eff.), Wake-After-Sleep-Onset (WASO) and Sleep Onset Latency (SOL)

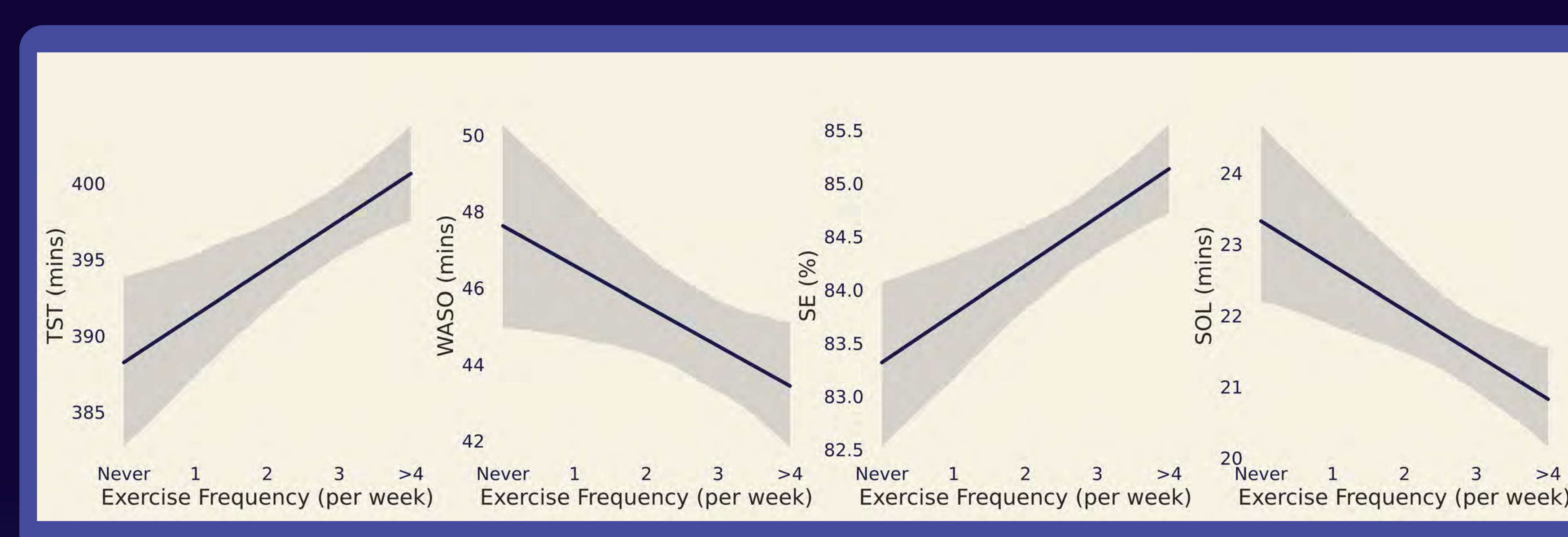


Fig 1. Regression fit for exercise frequency with respect to TST, WASO, S.E. & SOL. Exercise frequency is reported as times per week. 95% CI shown in grey

Fig 2. Regression fit for exercise intensity with respect to TST, WASO, S.E. & SOL. 95% CI shown in grey

Reference
1. Banno, M., Harada, Y., Taniguchi, M., Tobita, R., Tsujimoto, H., Tsujimoto, Y., & Noda, A. (2018). Exercise can improve sleep quality: a systematic review and meta-analysis. PeerJ, 6, e5172

Gender-specific differences in self-reported factors attributed to sleep disruption

Michael Ruder[1], Luke Gahan[1], Roy Raymann[1], Nathaniel Watson[2], Elie Gottlieb[1]
[1]SleepScore Labs [2]Department of Neurology, University of Washington School of Medicine, Seattle, WA

Introduction

- Although men exhibit shorter total sleep times across the lifespan, nighttime awakenings are more prevalent in women[1,2] .
- Sleep may be disrupted by several factors (e.g., social influences, external sensory stimuli, somatic cues) yet the relative gender-specific burden of these disruptors remains unclear.
- The purpose of the present study was to examine the occurrence of self-reported disruptors in males and females of equal ages.

Materials & Methods

Data

- Data from 79,262 users were included in the analysis
- 50% of users were female, mean age 42.4 ± 15.1.
- In-app questionnaires were used to capture self-reported sleep disturbances.

Analysis

- Age and gender balancing was used for sample generation.
- Fisher's exact test was to test for statistical significance.

Conclusion

- Women reported higher rates of regular sleep disruption for every cause.
- These findings highlight the role of gender in sleep-health reporting behaviors, yet major research gaps remain in both the treatment and prevention of sleep disruption in women.

Results

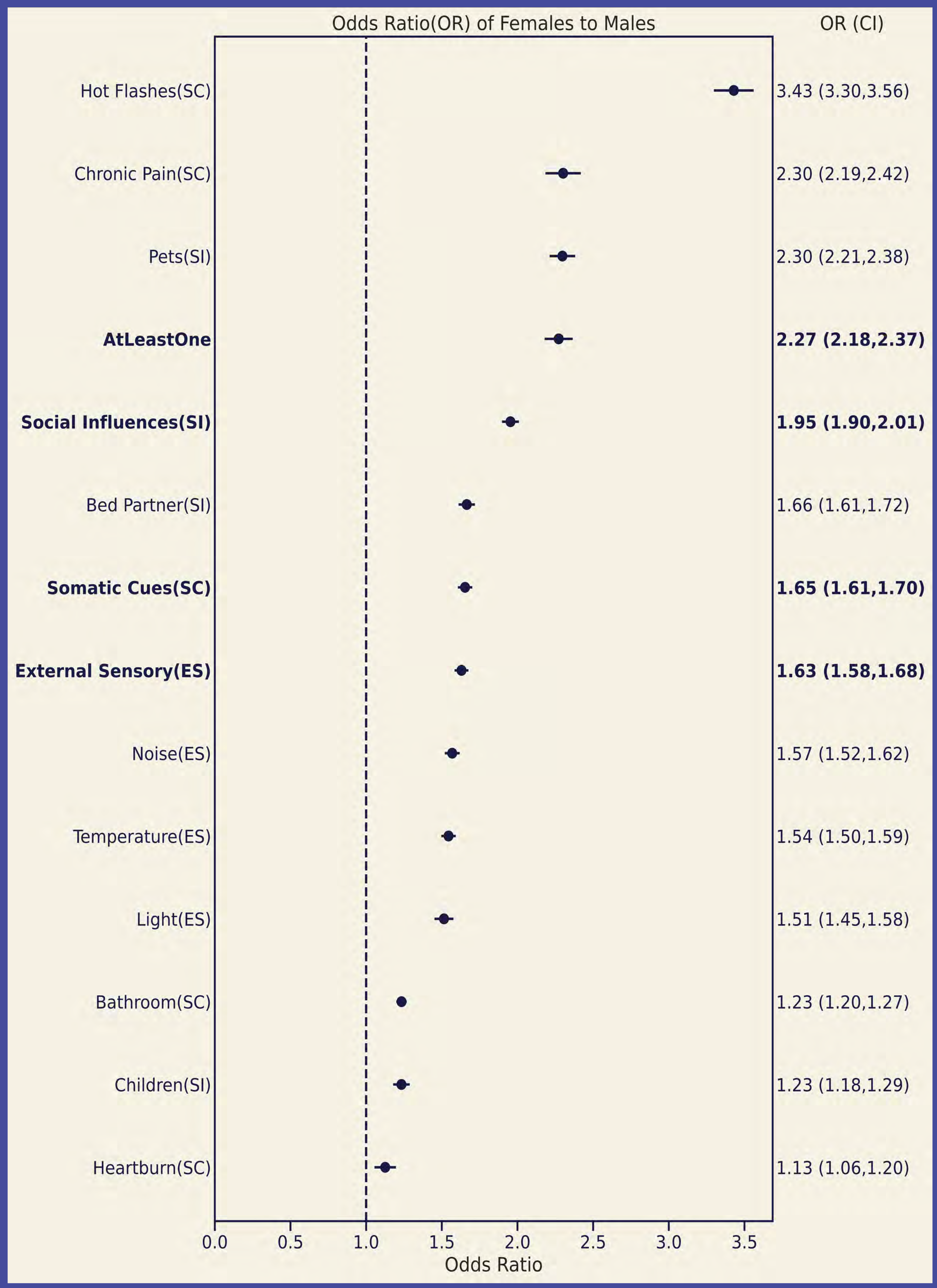


Figure 1. Odds ratios of self-reported sleep disruptors. Categories of multiple disruptors are bolded. Abbreviations following each individual (non-bolded) disruptor reflect the category in which they are grouped. **SI:** Social Influences (Bed Partner, Children, Pets). **SC:** Somatic Cues (Bathroom, Chronic Pain, Heartburn, Hot Flashes). **ES:** External Sensory (Noises, Temperature, Light).

References
1: Jonasdottir SS, Minor K, Lehmann S. (2021). Gender differences in nighttime sleep patterns and variability across the adult lifespan: a global-scale wearables study. *SLEEP,* 12;44(2).
2: Mallampalli, M. P., & Carter, C. L. (2014). Exploring sex and gender differences in sleep health: a Society for Women's Health Research Report. *Journal of women's health,* 23(7).

SleepScore Labs™

Use of an Adjustable Bed Base Improves Sleep Quality and Duration

Sharon Danoff-Burg[1], Holly Rus[1], Colin Burke[1], Morgan Weaver[1], Rodolfo Rodriguez, Jr.[1]
Kiara Carmon[1], Duvia Lara Ledesma[1], Elie Gottlieb[1]
SleepScore Labs[1]

Introduction

- This study compared sleep in an inclined position on an adjustable bed base to participants' prior sleep on their original base
- The positional adjustment of a bed can potentially contribute to better sleep and alleviation of discomfort associated with a variety of medical conditions
- Most studies have focused on inclined sleep for therapeutic purposes, leaving need for understanding the impact among healthy individuals

Materials & Method

Sample & Design

- 26 healthy adults (61% female, mean age 40)
- 8-week field study, within subjects, pre-post

Intervention

- Used Mattress Firm 600 Adjustable Base with head and/or feet inclined (not flat) for 4 weeks

Analysis

- Multilevel regression accounting for nested data (nights within subjects) and paired t-tests

Conclusion

- Sleeping at in incline on an adjustable bed base can improve sleep and perceived comfort
- Objectively improved sleep outcomes were supported by self-report, showing multifaceted benefits of the adjustable base on sleep

Results

Objective Results (*n*=939 nights)

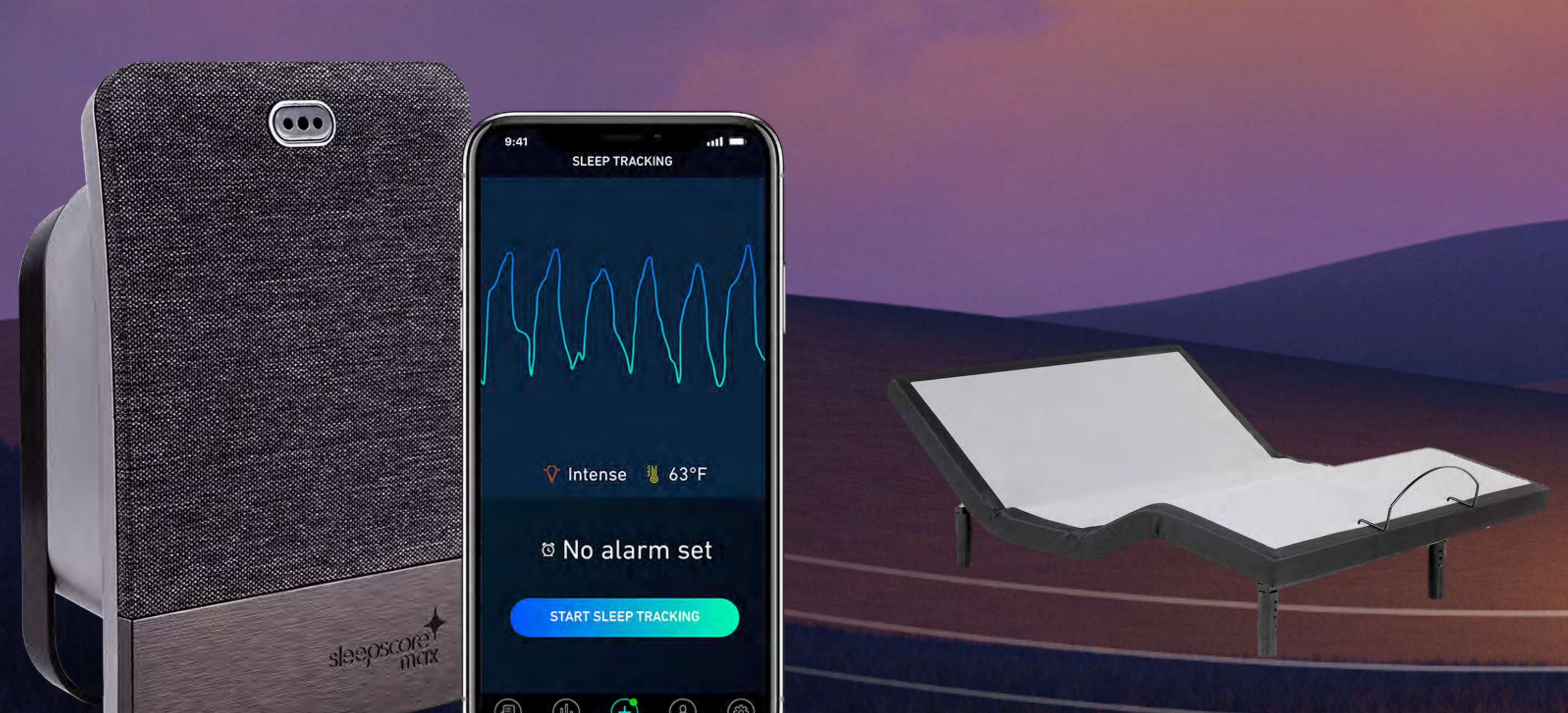
	Observed		Estimated		
	Original Base	MFRM 600	Constant	*beta*	*p*-value
SleepScore (0-100)	**80.53**	**83.30**	**80.39**	**2.73**	**0.001**
BodyScore (0-100)	**82.34**	**83.53**	**81.94**	**1.60**	**0.039**
MindScore (0-100)	**77.82**	**80.69**	**77.83**	**2.94**	**0.002**
Total Sleep Time (minutes)	**387.24**	**407.72**	**388.23**	**16.17**	**0.001**
Sleep Onset Latency (minutes)	20.24	21.08	20.28	0.63	0.621
Number of Awakenings	**4.80**	**4.64**	**4.89**	**-0.32**	**0.034**
Wake After Sleep Onset (minutes)	**40.85**	**38.16**	**41.46**	**-3.91**	**0.046**
Time in Bed (minutes)	**453.61**	**474.50**	**455.11**	**15.04**	**0.003**
Sleep Efficiency	0.85	0.86	0.85	0.01	0.196
Sleep Maintenance	**0.905**	**0.914**	**0.904**	**0.01**	**0.014**
Light (minutes)	234.62	247.29	236.56	7.36	0.052
Deep (minutes)	77.98	81.10	77.12	3.68	0.056
REM (minutes)	**74.64**	**79.33**	**74.60**	**5.07**	**0.009**
% Wake After Sleep Onset	**10%**	**9%**	**10%**	**-1.03**	**0.015**

- **Objective sleep measurements showed increased time in bed, total sleep time, and REM; less WASO in duration and proportion of the night; better sleep maintenance; and improvements in SleepScore, MindScore, and BodyScore**

Self-report Results (*n*=1139 nights)

	Observed		**Estimated**		
	Original Base	MFRM 600	Constant	*beta*	*p*-value
Comfort in Bed (0-100)	**61.99**	**77.04**	**61.79**	**15.85**	**<0.001**
Time to Fall Asleep (minutes)	**20.97**	**17.35**	**20.98**	**-3.89**	**0.004**
Number of Times Woke Up	**2.47**	**2.19**	**2.47**	**-0.26**	**0.037**
Time Awake After Falling Asleep (minutes)	**29.11**	**24.67**	**29.14**	**-5.91**	**0.016**
Sleep Quality (0-100)	**59.33**	**71.84**	**59.24**	**12.58**	**<0.001**
Feeling Well-rested in the Morning	**56.81**	**70.72**	**56.67**	**14.51**	**<0.001**

- **Participants perceived greater comfort and improvements in time to fall asleep, number of awakenings, time awake after initially falling asleep, sleep quality, and feeling well-rested.**
- **Pre-post analyses revealed additional significant improvements in perceived sleep: falling asleep in the preferred amount of time, ability to sleep through the night, sleep duration, and sleep satisfaction**



Support
Mattress Firm

In-Person Expert Pillow Fitting Process Improves Sleep Quality and Duration

Holly Rus[1], Sharon Danoff-Burg[1], Morgan Weaver[1], Rodolfo Rodriguez, Jr.[1]
Larisa Gavrilova[1], Colin Burke[1], Kiara Carmon[1], Duvia Lara Ledesma[1], Elie Gottlieb[1]
[1]SleepScore Labs

Introduction

- This study examined the sleep of participants using pillows selected during an in-store pillow fitting process compared to their original pillows
- The myriad of anecdotal clams about the benefits of different pillow types may complicate consumers' ability to find a pillow that can support better sleep
- Services that provide personalized recommendations may address this problem

Materials & Method

Sample & Design

- 17 healthy adults (71% female, mean age 38)
- 9-week field study, within subjects, pre-post with 1-week adjustment period

Intervention

- Guided through Mattress Firm in-store pillow fitting process to be paired with personalized pillow

Analysis

- Multilevel regression accounting for nested data (nights within subjects) and paired t-tests

Conclusion

- Being fit for a pillow through an in-person, expert pillow fitting process can improve sleep
- Objectively improved sleep outcomes were supported by self-report, showing multifaceted benefits of the fitted pillow on sleep

Results

Objective Results (*n*=722 nights)

	Observed		Estimated		
	Original Pillow	New Pillow	Constant	*beta*	*p*-value
SleepScore (0-100)	**71.69**	**75.13**	**72.10**	**2.53**	**0.003**
BodyScore (0-100)	**73.90**	**76.54**	**74.17**	**1.88**	**0.031**
Total Sleep Time (minutes)	**354.87**	**371.09**	**355.14**	**12.91**	**0.010**
Sleep Onset Latency (minutes)	24.40	25.07	24.33	1.29	0.386
Wake After Sleep Onset (minutes)	61.98	56.56	60.66	-3.18	0.192
Time in Bed (minutes)	**448.34**	**461.13**	**447.40**	**11.59**	**0.034**
Sleep Efficiency	0.80	0.81	0.80	0.01	0.088
Sleep Maintenance	**0.85**	**0.87**	**0.86**	**0.01**	**0.009**
Light (minutes)	236.84	244.43	236.34	6.47	0.114
Deep (minutes)	**56.31**	**61.86**	**56.61**	**4.23**	**0.017**
REM (minutes)	61.71	64.80	62.03	2.16	0.247
% Wake After Sleep Onset	**15%**	**13%**	**14%**	**-1.29**	**0.009**

- **SleepScore improved, participants spent more time in bed, slept longer, spent a lower proportion of the night awake, and had better sleep maintenance**
- **Participants got more deep sleep and showed improved BodyScore**

Self-report Results (*n* =756 nights)

	Observed		Estimated		
	Original Pillow	New Pillow	Constant	*beta*	*p*-value
Comfort in Bed (0-100)	**59.98**	**66.60**	**59.15**	**8.51**	**<0.001**
Pillow Comfort (0-100)	**55.26**	**70.07**	**55.01**	**15.55**	**<0.001**
Time to Fall Asleep (minutes)	19.75	20.30	19.97	-0.14	0.912
Time Awake After Falling Asleep (minutes)	**29.29**	**24.37**	**29.99**	**-5.66**	**0.020**
Sleep Quality (0-100)	**57.75**	**62.16**	**57.05**	**6.35**	**<0.001**
Feeling Well-rested in the Morning	**55.58**	**60.67**	**55.14**	**7.00**	**<0.001**

- **Participants perceived increased pillow and overall bed comfort, improved ability to sleep through the night, fewer awakenings, less time spent awake, better overall sleep quality, and feeling more well-rested in the morning**

Support
Mattress Firm

Sleep Score Labs™

Use of a Diffused Fragrance Before Bed May Contribute to Improved Objective and Perceived Sleep

Holly Rus[1], Sharon Danoff-Burg[1], Morgan Weaver[1], Rodolfo Rodriguez, Jr[1], Larisa Gavrilova[1], Elie Gottlieb[1], Stephen Lillford[2], Roy Raymann[1]
[1]SleepScore Labs, [2]Reckitt

Introduction

- This study examined if a diffused fragrance used before bedtime would contribute to sleep improvement in healthy females
- Existing evidence on the sleep-promoting properties of fragrance has been anecdotal or based on clinical research
- In-home testing offers insight into the effectiveness of a product under real-life conditions, yielding more ecologically valid results

Materials & Method

Sample & Design

- 26 women (mean age 36)
- 9-week field study, within subjects, counterbalanced with and without product for 3 weeks each

Intervention

- After baseline, used diffused fragrance at home for at least 1 hour before going to bed

Analysis

- Multilevel regression accounting for nested data (nights within subjects) and paired t-tests

Conclusion

- Using the diffused fragrance before bed may contribute to sleep improvement
- Objectively improved sleep outcomes were supported by self-report, showing multifaceted benefits of the diffused fragrance on sleep
- No significant negative impacts were seen on sleep in the objective and self-report measures

Results

Objective Results (*n*=835 nights)

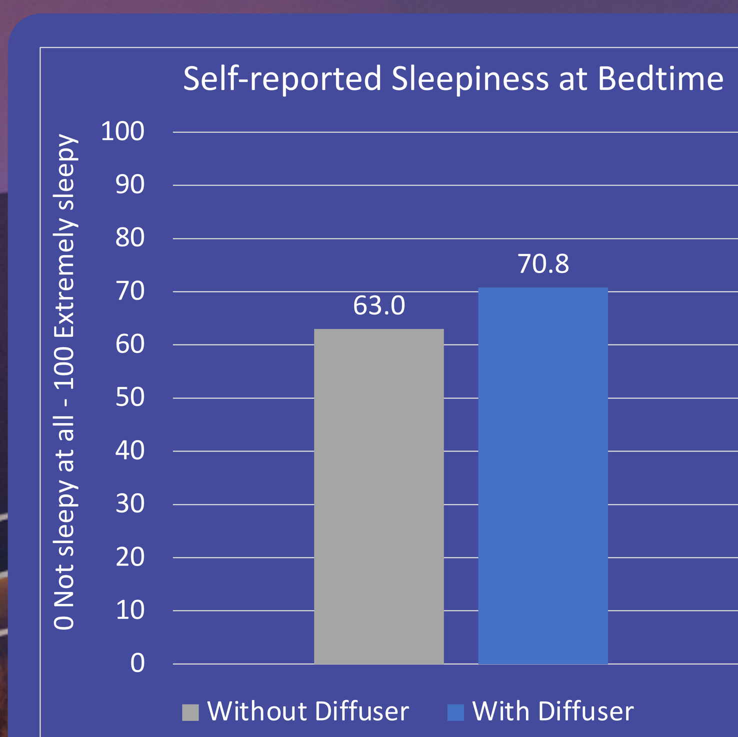
	Observed		Estimated		
	Without Diffuser	With Diffuser	Constant	*beta*	*p*-value
BodyScore (0-100)	**83.28**	**84.32**	**83.30**	**1.323**	**0.043**
Total Sleep Time (minutes)	417.08	417.05	417.76	-0.269	0.954
Sleep Onset Latency (minutes)	24.56	26.80	24.90	1.119	0.381
Number of Awakenings	**4.44**	**4.09**	**4.43**	**-0.363**	**0.006**
Wake After Sleep Onset (minutes)	**37.60**	**33.55**	**37.35**	**-3.484**	**0.037**
Sleep Efficiency	0.86	0.86	0.86	0.004	0.276
Sleep Maintenance	**0.92**	**0.93**	**0.92**	**0.007**	**0.033**
Light (minutes)	258.24	254.15	258.51	-4.493	0.228
Deep (minutes)	**78.49**	**82.48**	**78.52**	**4.794**	**0.010**
REM (minutes)	80.35	80.42	80.73	-0.564	0.777
% Light Sleep	57%	56%	57%	-0.710	0.141
% Deep Sleep	**18%**	**19%**	**17%**	**1.294**	**0.003**
% REM Sleep	17%	18%	18%	0.132	0.734
% Wake After Sleep Onset	**8%**	**7%**	**8%**	**-0.716**	**0.033**

- **Deep sleep improved along with improvements related to sleep consistency: fewer awakenings, less time awake, better sleep maintenance**

Self-report Results (*n* =886 nights)

	Observed		Estimated		
	Without Diffuser	With Diffuser	Constant	*beta*	*p*-value
Time to Fall Asleep (minutes)	23.44	23.08	23.48	-0.650	0.595
Number of Times Woke Up	**2.75**	**2.06**	**2.69**	**-0.606**	**<0.001**
Time Awake After Falling Asleep (minutes)	**25.44**	**17.95**	**25.27**	**-7.114**	**<0.001**
Sleep Quality (0-100)	**55.63**	**61.49**	**56.14**	**5.209**	**<0.001**
Global Vigor – Bedtime (0-100)	**45.36**	**48.33**	**45.44**	**2.779**	**<0.001**
Global Affect – Bedtime (0-100)	**64.46**	**67.86**	**64.95**	**2.592**	**0.004**
Global Vigor – Morning (0-100)	52.90	53.95	53.39	0.506	0.625
Global Affect – Morning (0-100)	**65.00**	**67.91**	**65.39**	**2.187**	**0.005**

- **Participants felt sleepier at bedtime, felt they woke up less often and spent less time awake after falling asleep, reported better sleep quality, and experienced better mood at bedtime and in the morning**



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Prevalence And Correlates of Sleep Disorders Among Users of Consumer Sleep Technology

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Introduction

- The prevalence of sleep disorders and associations with objectively measured sleep-wake dysfunctions vary widely across populations.
- Using consumer sleep technology, we examined the self-reported prevalence and objective sleep variable correlations of four sleep disorders.

Materials & Method

Data

- Data from 33,429 users across 1,842,282 nights
- Users aged 16-99 (mean: 46.6 +/- 16.9) were included in the study.
- 55.1% of users were female.
- Subjective sleep disorders we ascertained by asking:
  - ***"Which of the following disorders has a healthcare professional diagnosed you with?"***
  - ***Users with the no disorder(n=23,660), Apnea/SDB (n=5287), Insomnia (n=3974), PLM/RLS (.n=2288) and Narcolepsy (n=267) were included***

Analysis

- Sleep variables were averaged per user and linear regression modelling was used for analysis.
- Users with disorders were compared with those who reported no sleep issues.

Conclusion

- Self-reported sleep disorders were associated with poorer sleep.
- Results suggest that consumer sleep trackers (CSTs) could play a role in screening for disorders.
- CSTs could also be used to encourage users to seek care in clinical sleep medicine settings.

Results

Disorder	Total Sleep Time (mins)			Sleep Efficiency (%)			WASO (mins)		
	Beta	SE	p	Beta	SE	p	Beta	SE	p
Intercept	414.574	0.9	<0.001	92.279	0.131	<0.001	9.413	0.469	<0.001
Age	-1.135	0.019	<0.001	-0.28	0.003	<0.001	1.17	0.01	<0.001
Gender [M]	-18.36	0.612	<0.001	-2.281	0.089	<0.001	7.914	0.319	<0.001
Apnea/SDB	-9.398	0.913	<0.001	-1.396	0.133	<0.001	3.06	0.465	<0.001
Insomnia	-5.449	0.984	<0.001	-1.396	0.143	<0.001	2.192	0.5	<0.001
RLS/PLM	-8.799	1.26	<0.001	-2.441	0.183	<0.001	6.711	0.641	<0.001
Narcolepsy	-23.481	3.482	<0.001	-2.956	0.506	<0.001	6.863	1.774	<0.001

Table 1 Regression analysis results for Total Sleep Time (TST), Sleep Efficiency (SE) and Wake After Sleep Onset (WASO)

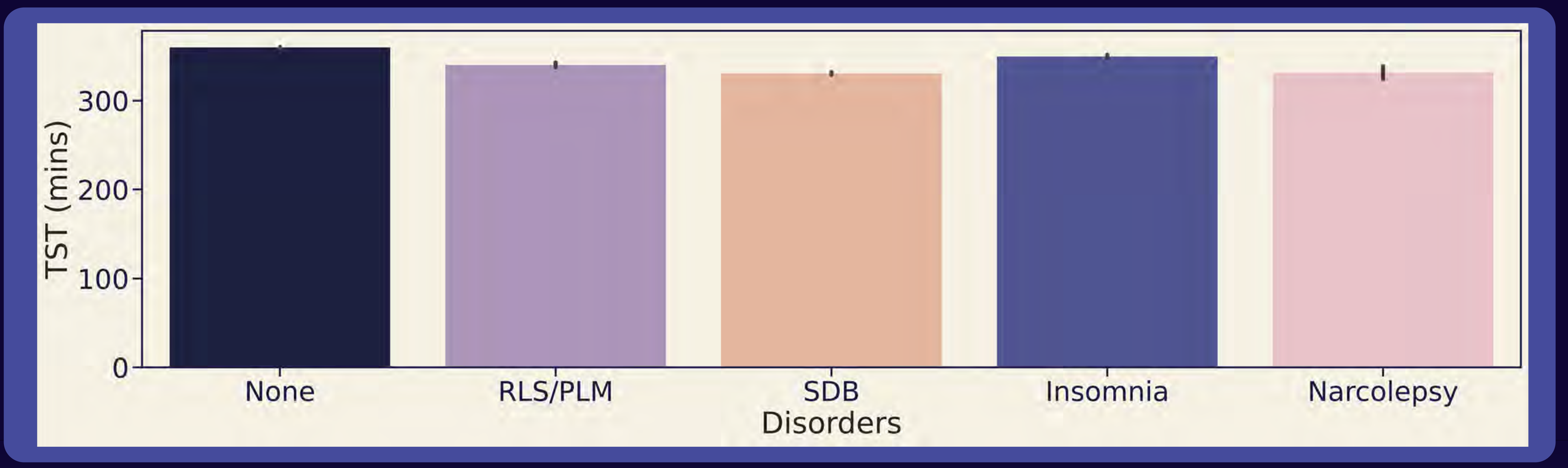

Figure 1 Total Sleep Time (TST) sample means for the No Disorder, RLS/PLM, SDB, Insomnia and Narcolepsy

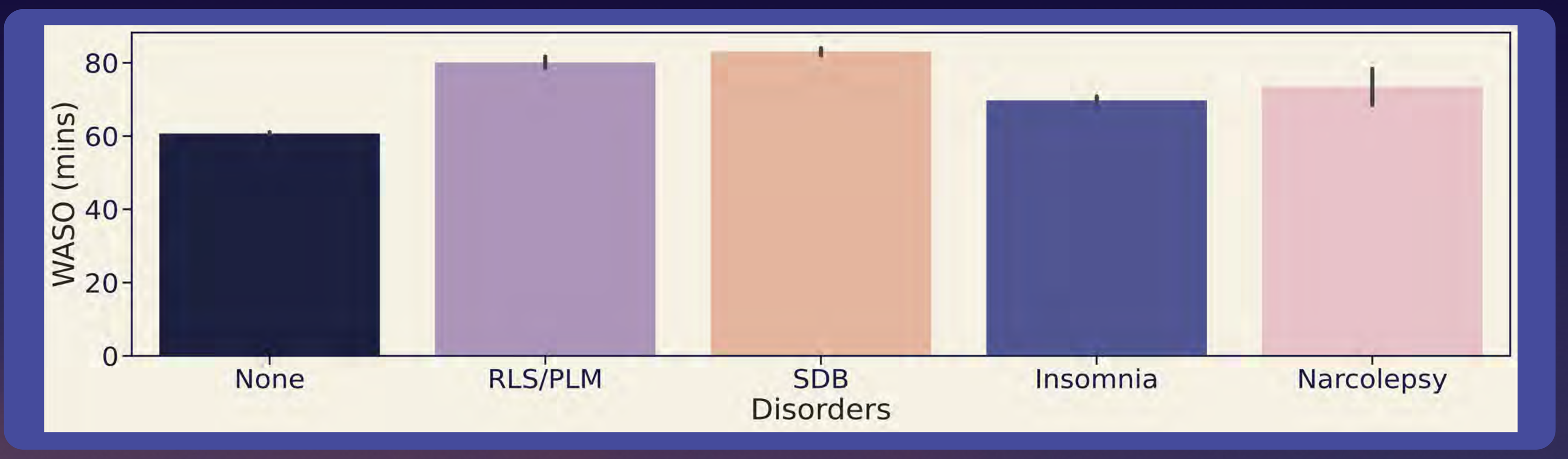

Figure 2 Wake After Sleep Onset (WASO) sample means for the No Disorder, RLS/PLM, SDB, Insomnia and Narcolepsy

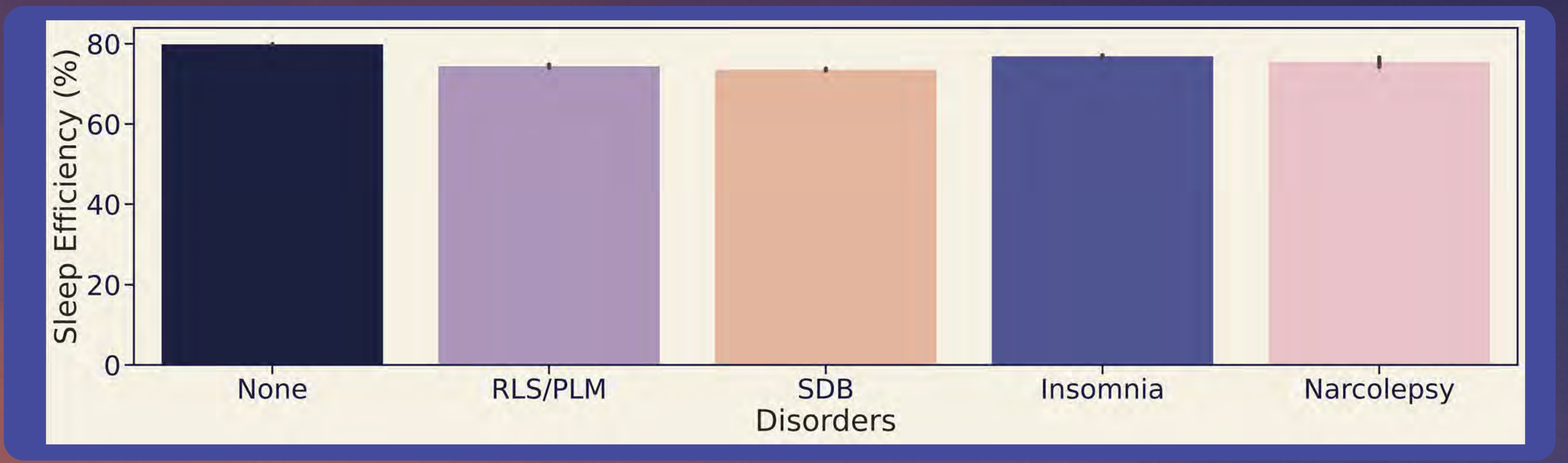

Figure 3 Sleep efficiency sample means for the No Disorder, RLS/PLM, SDB, Insomnia and Narcolepsy

Social Jetlag and Increased BMI: A Population-Based Study Using a Contactless Sleep Measurement Application

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Introduction

Social jetlag involves delayed bed and wake times on weekends relative to weekdays. Resulting circadian rhythm disruption, sleep disturbance, and shortened sleep have untoward consequences for human health and performance. Elevated BMI is associated with habitual short sleep and circadian disruption, as seen in shift workers. Studies assessing the relationship between social jetlag and BMI often rely on self-reported sleep patterns, or measure sleep objectively with a worn device for short periods of time. We assessed the relationship between social jetlag and BMI in a novel manner using longitudinal, ecologically valid assessments (measured in subjects typical home environment) using the PSG-validated contactless, sonar-based SleepScore mobile application.

Materials & Methods

A total of 357 individuals across 130,120 nights monitored their sleep with the contactless SleepScore mobile application (mean age 56, range 18-85, 48.6% females). Social jetlag was determined in a well-established manner by subtracting the mean objective sleep midpoint on weekdays from the mean objective sleep midpoint on weekends. Body mass index (BMI) was self-reported and defined as kg/m^2. BMI < 18.5 was underweight, <25 was normal, <30 was overweight and ≥ 30 was obese. Chronotype was subjectively assessed with a 5-item question ranging from definitely morning-type to definitely evening-type. Chronotype, age and gender were included in the analysis as confounds.

Results

Mean BMI was 27.4 kg/m^2 (range 15.8-63.7, SD=6.5) with 2.9% underweight, 38.7% normal weight, 32% overweight, and 26.5% obese. Mean social jetlag was 26.6 min (95% CI 22.2 – 31.0) with 23% strong morning-type, 22.1% slight morning-type, 19.8% neither, 17.2% slight evening-type and 18% strong evening-type. Linear regression revealed a significant association between social jetlag and BMI (ß=0.025, SE=0.012, $p<0.05$) after adjustment for subject age, gender and chronotype. Thus, for every one-minute increase in social jetlag, there was a 0.025 kg/m2 increase in BMI. For expository purposes, a social jetlag of 60 minutes would increase BMI by 1.5 kg/m2.

Conclusion

In our population-based sample of individuals using a sonar-based contactless consumer sleep technology to objectively measure sleep we found a positive association between a well-validated measure of social jetlag and BMI, such that increased social jetlag portended increased BMI. This is consistent with previous reports demonstrating the untoward effect of social jetlag on human health and metabolism. The longitudinal and ecologically valid nature of our sleep measurement adds to the veracity of our growing understanding of the problem with social jetlag.

Figures

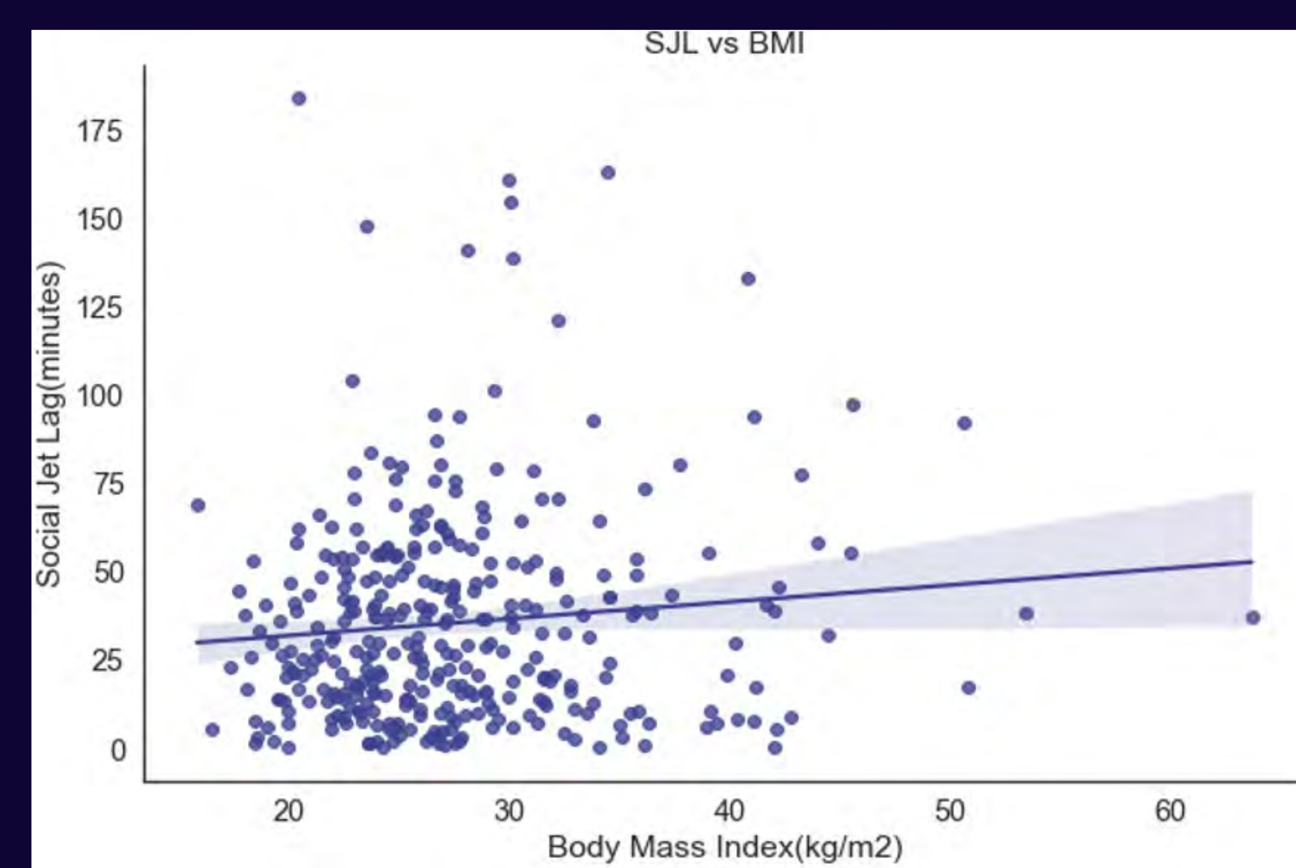

Figure 1. BMI as a function of social jetlag.

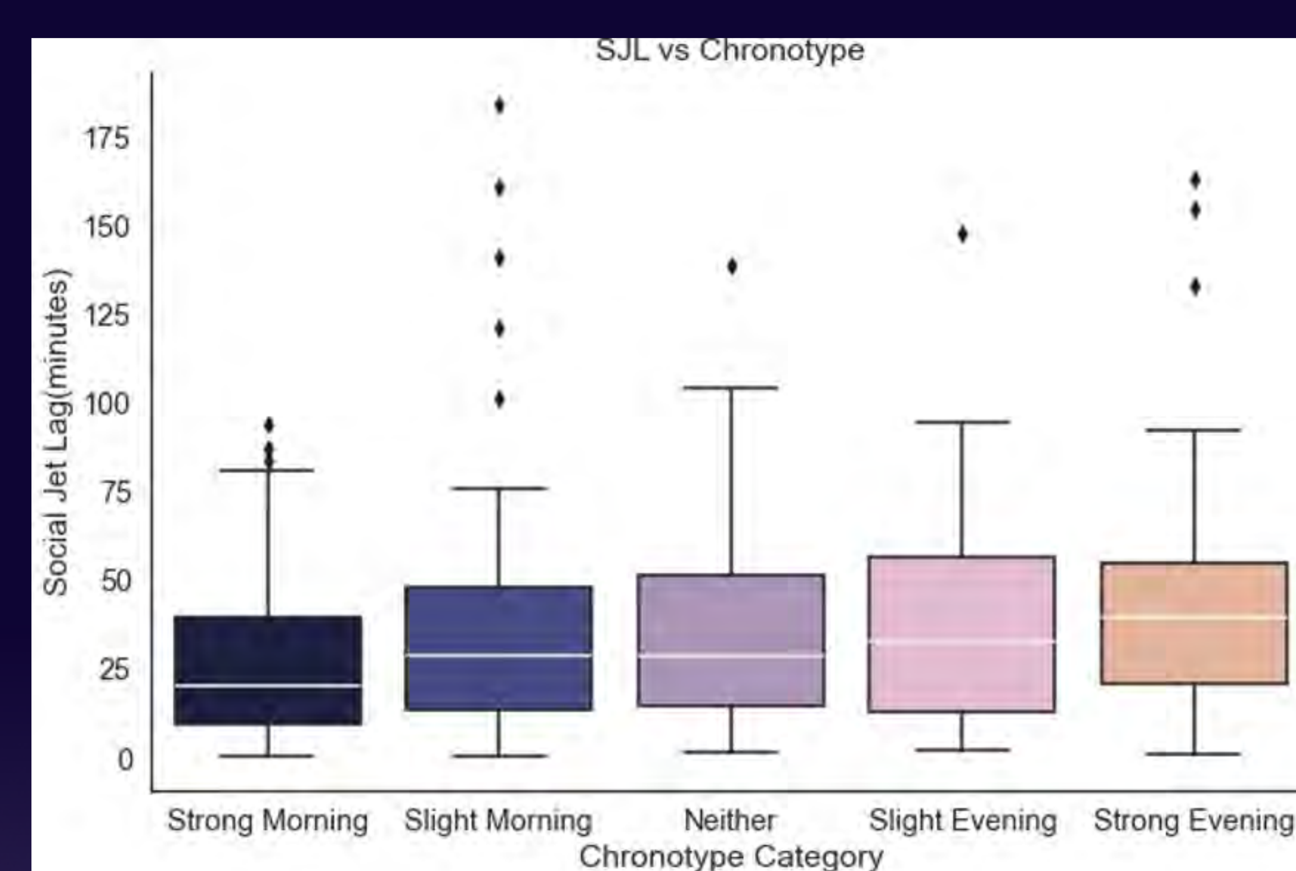

Figure 2. Chronotype as a function of social jetlag.

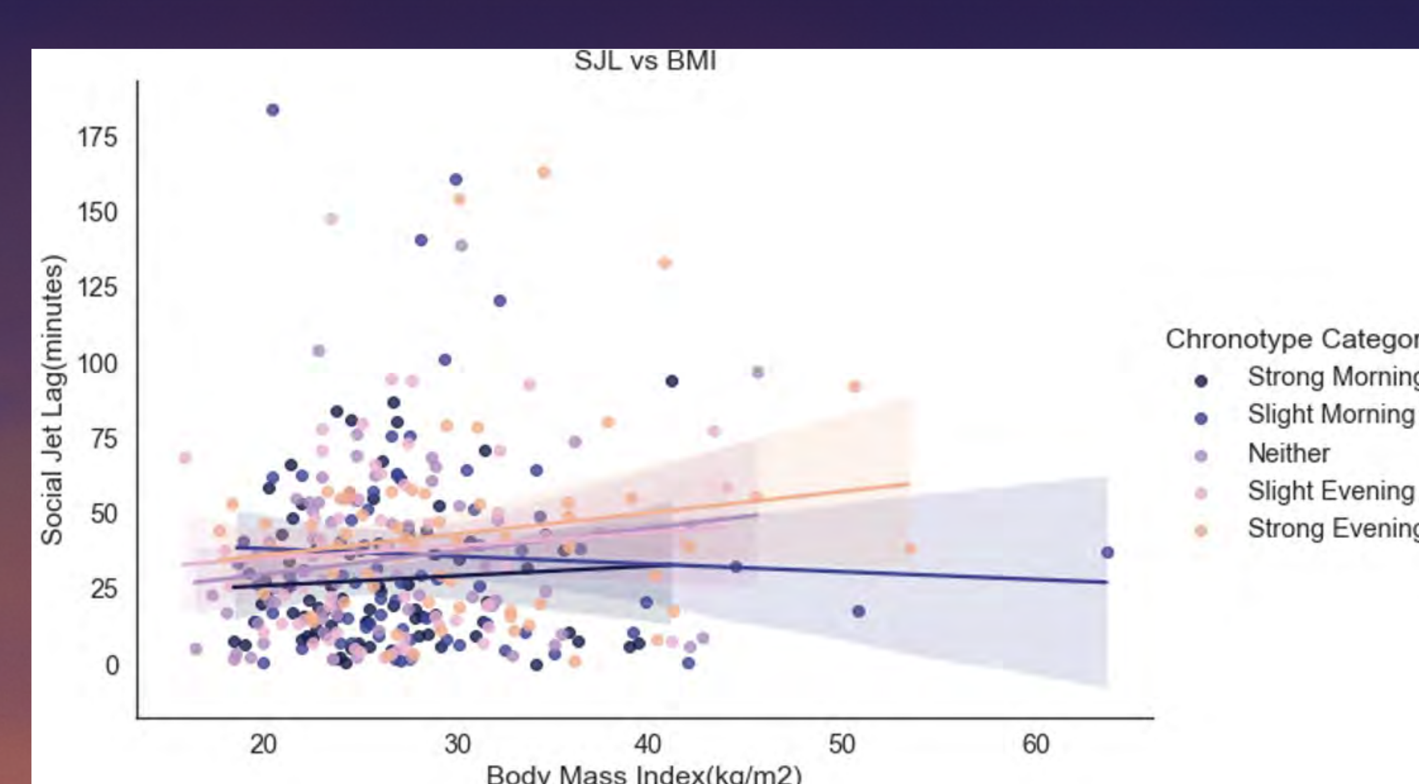

Figure 3. BMI as a function of social jetlag according to chronotype.

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Social Jetlag Decreases Across The Lifespan: A Longitudinal Big Data Analysis of Objective Sleep

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Introduction

- Social jetlag, the misalignment of social and circadian time, is highly prevalent (>50%)[1] and associated with adverse endocrine, behavioral, and cardiovascular risk profiles[2].
- Changes in social Zeitgebers across the lifespan may impact the severity of social jetlag, particularly following retirement.
- Here, we examined associations between:
  1. Age as a continuous measure and social jetlag
  2. Work cessation and social jetlag

Materials & Methods

Data

- Data from 2,446 users (mean age: 52 ± 15.8, 52% female) across 473,113 nights from PSG-validated SleepScore mobile app.
- Social jetlag was expressed in minutes and defined as the difference between midsleep times on week and weekend days from total recording periods.

Analysis

- Simple linear regressions were used for this analysis.
- Sub-group analyses on older adults were performed, serving as proxies for pre- and post-retirement.

Conclusion

- Social jetlag decreased across the lifespan, with a >40% reduction following the average age of retirement.
- The reduction, but not extinction, of social jetlag suggests that social Zeitgebers beyond work hours affect sleep timing in older adulthood.

Results

	Full Sample	Pre-Retirement	Post-Retirement
Number of Users	1033	599	434
Nights Recorded	105019	63702	41317
Age (years)	52.2 ± 15.8	60.5 ± 2.8	69.9 ± 2.8
% Female	56.7	55.1	59.3
Social Jetlag (mins)	31.1 ± 64.3	36.1 ± 53.7	20.4 ± 49.2
Total Sleep Time (mins)	342.7 ± 35.7	343.6	341.2
Sleep Efficiency	78.2 ± 7.1	75.8 ± 6.1	72.4 ± 6.3
Bed Time	23:34 Hours ± 79 mins	23:33 Hours ± 84 mins	23:26 Hours ± 73 mins
Wake Time	7:28 Hours ± 84 min	7:24 Hours ± 85 mins	7:30 Hours ± 82 mins

Table 1. Demographic and sleep-wake characteristics for all users, pre-retirement, and post-retirement groups.

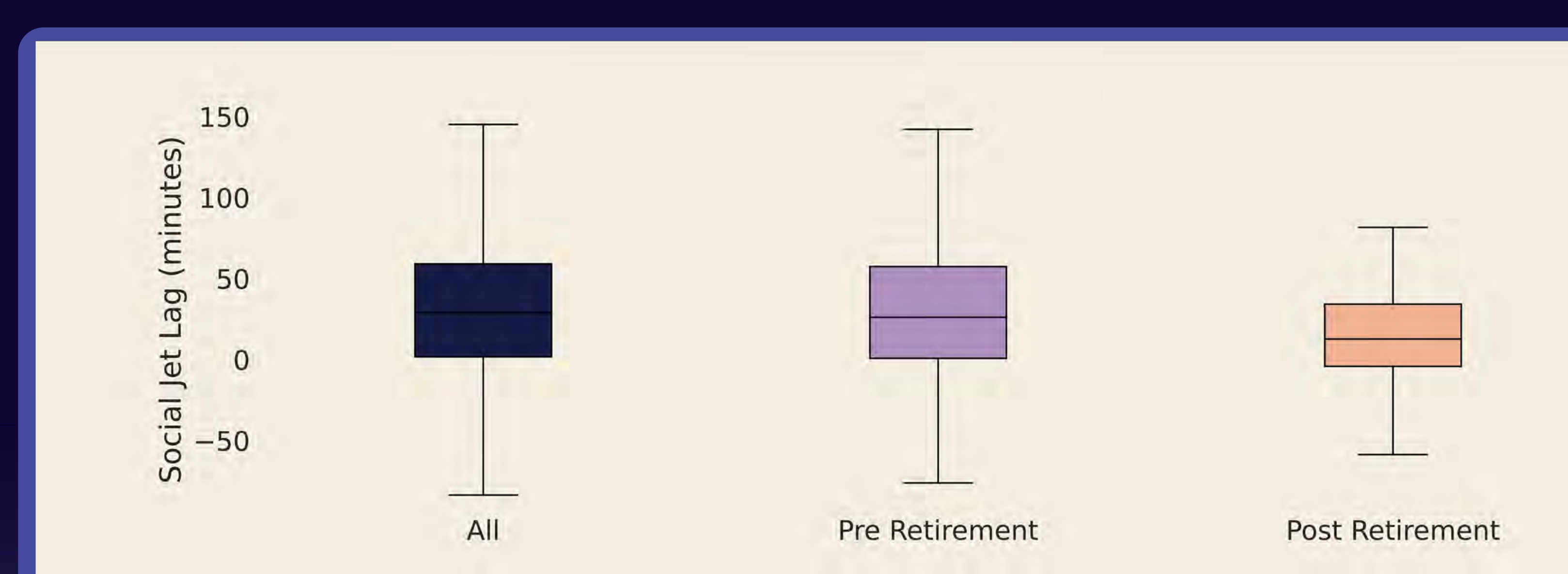

Figure 1. Box plots of mean social jetlag in minutes and 95% confidence intervals for all users and a subgroup of older adults, serving as a proxy for pre-retirement (n=604, age range: 54-64, mean age: 60.5 ± 2.8) and post-retirement (n=428, age range: 65-75, mean age: 70±2.8). Post-retirement age was associated with a reduction in social jetlag (β = -15.31, SE = 3.78, p<0.001).

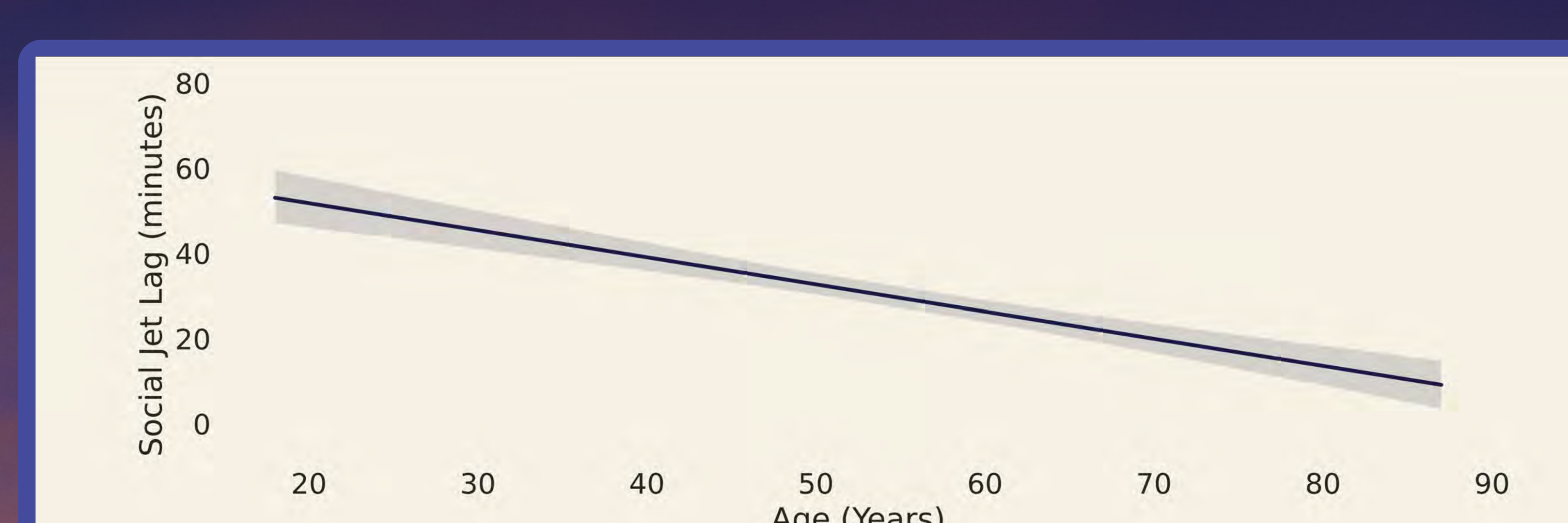

Figure 2. Linear regression reveals a significant negative association between overall age and social jetlag, whereby older age is associated with a reduction in social jetlag (β = -0.64, SE = 0.08, p<0.001).

References
1. Roenneberg et al., (2012). Social jetlag and obesity. *Curr Biol*, 22:939-943.
2. Rutters et al., (2014). Is social jetlag associated with an adverse endocrine, behavioral, and cardiovascular risk profile? *J Biol Rhythms*, 29:377-383.

Towards interpreting consumer sleep data: Distributions of sleep scores

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Introduction

- Consumer sleep measurement technology has become widely available to the public.
- Most consumer sleep electronics have implemented easy-to-interpret but novel sleep metrics that capture sleep quality.
- Here, we provide reference values for the parameters SleepScore, BodyScore and MindScore as included in the SleepScore Labs non-contact radio-frequency sleep measurement devices.

Methods

- SleepScore is calculated using objectively measured total sleep time, sleep onset latency and sleep stage durations, normalized for age and sex, conform Ohayon et al (2004), ranging from 0-100.
- BodyScore reflects the amount of deep sleep, normalized for age and sex, ranging from 0-100.
- MindScore reflects the amount of REM, normalized for age and sex, ranging from 0-100.
- Data from 40,862 S+ (ResMed) and SleepScore Max (Sleep-Score Labs) users (18 -98 years old) were used to calculate distribution statistics.

	Mean	1st Quartile	2nd Quartile	3rd Quartile	Mode
SleepScore	81±11	73	81	88	89
BodyScore	81±10	73	80	86	84
MindScore	78±10	72	79	84	83

Table 1: Descriptive statistics across 40,862 S+ and Max users, aged between 18 and 98 years old, average age 53±15 years.

Conclusions

- **SleepScores, BodyScores and MindScores presented to an average consumer will mostly show them a number in the low 70 to high 80 range.**
- **This distribution was intentionally created as being left-skewed to prevent triggering anxiety that may contribute to orthosomnia.**
- **Despite the intent to create a normalized score that would not be impacted by age, the data show a slight increase of scores by age.**
- **The presented reference values should be taken into account when interpreting these sleep scores.**

Results

Nightly scores range from 0-100, and most scores fall within the 70 to 90 range (see Table 1). An increase of the values could be observed with increasing age (see Figure 1).

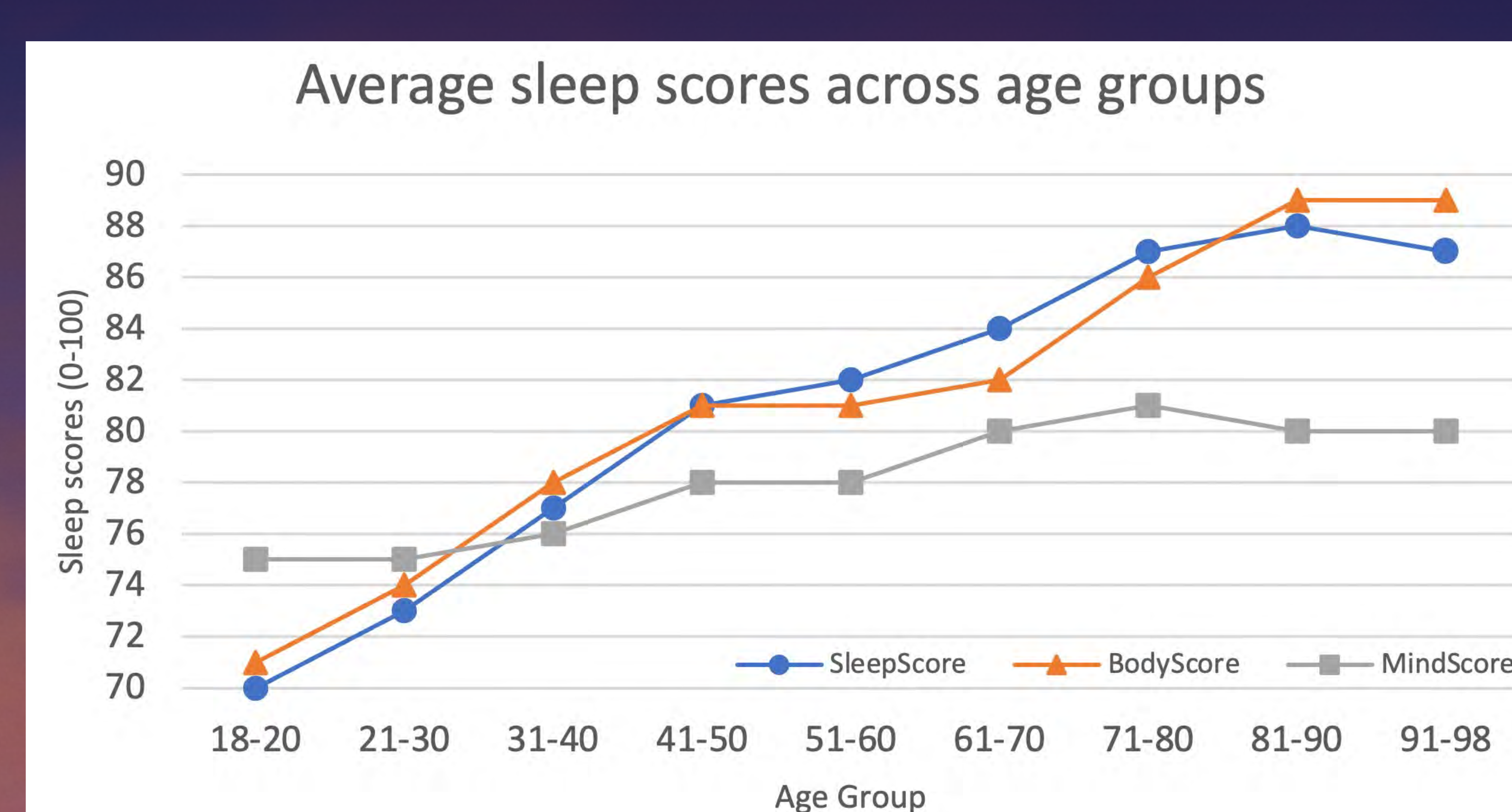

Figure 1: Average SleepScore, BodyScore and MindScore across age groups.

References
Ohayon MM, Carskadon MA, Guilleminault, C, & Vitiello MV (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. Sleep, 27(7), 1255-1273.