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The authors made the following contributions. First Author: Conceptualization, Writing - Original Draft Preparation, Writing - Review & Editing; Ernst-August Doelle: Writing - Review & Editing, Supervision.

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## Abstract

15 One or two sentences providing a **basic introduction** to the field, comprehensible to a  
16 scientist in any discipline.

17 *Keywords:* keywords

18 Word count: X

The title

## Results

The aggregated data-set describes 316,835 observations of daily physical activity and sleep from 24,935 unique participants. Table ?? shows demographic information. A table of study characteristics can be found in supplementary materials.

### The effects of physical activity volume on sleep

We explored the effects of physical activity on sleep (RQ1) using mixed-effects models. We estimated the effect of physical activity volume on sleep by age, and the results are presented in Table 1 and Figure 1. There was no meaningful relationship between physical activity volume and sleep duration. However, a positive curvilinear relationship was observed between physical activity volume and sleep efficiency, onset, and regularity, which interacted with age. Sleep efficiency improved with greater physical activity volume, but improvements tapered off for older individuals. Physical activity volume and sleep onset had a positive association for younger individuals, but a negative association for older individuals, where sleep onset was reduced among those with the highest physical activity. There was a strong positive association between physical activity volume and sleep regularity, which was strongest among older participants. For participants aged 35 years and above, this link weakened among those with a physical activity volume greater than two standard deviations.

37 The effects of physical activity intensity on sleep

38 The effects of sleep duration on physical activity

39 The effects of sleep efficiency on physical activity

40 The effects of sleep onset on physical activity

41 The effects of sleep regularity on physical activity

Table 1

*Sleep on physical activity volume controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
Sleep duration				
(Intercept)	-0.37 [-0.94, 0.20]	0.29	-1.28	.291
Scale PA volume	0.03 [0.00, 0.07]	0.02	1.96	.050
Age	0.00 [-0.01, 0.00]	0.00	-0.29	.797
Scale PA volume <sup>2</sup>	0.00 [-0.01, 0.01]	0.00	0.11	.912
Scale PA volume:age	0.00 [0.00, 0.00]	0.00	0.92	.359
Age:scale PA volume <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.94	.349
Sleep efficiency				
(Intercept)	-0.90 [-1.29, -0.50]	0.20	-4.46	.001
Scale PA volume	0.23 [0.20, 0.27]	0.02	12.97	< .001
Age	0.01 [0.01, 0.01]	0.00	9.99	.002
Scale PA volume <sup>2</sup>	-0.02 [-0.03, -0.01]	0.00	-4.77	< .001
Scale PA volume:age	0.00 [0.00, 0.00]	0.00	-5.16	< .001
Age:scale PA volume <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.50	.617
Sleep onset				
(Intercept)	-0.98 [-1.50, -0.47]	0.26	-3.77	.060
Scale PA volume	0.11 [0.09, 0.14]	0.01	8.32	< .001
Age	0.02 [0.02, 0.02]	0.00	9.81	.007
Scale PA volume <sup>2</sup>	-0.01 [-0.02, -0.01]	0.00	-4.73	< .001
Scale PA volume:age	0.00 [0.00, 0.00]	0.00	-8.70	< .001
Age:scale PA volume <sup>2</sup>	0.00 [0.00, 0.00]	0.00	2.34	.034
Sleep regularity				
(Intercept)	-0.13 [-0.39, 0.13]	0.13	-0.96	.415
Scale PA volume	0.33 [0.29, 0.36]	0.02	19.10	< .001
Age	0.01 [0.00, 0.01]	0.00	5.07	.019
Scale PA volume <sup>2</sup>	-0.03 [-0.03, -0.02]	0.00	-5.74	< .001
Scale PA volume:age	0.00 [0.00, 0.00]	0.00	0.64	.540
Age:scale PA volume <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-3.33	.006

*Note.* Adjusted for SES, BMI, and sex.

Table 2

*Sleep on physical activity intensity controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
Sleep duration				
(Intercept)	-0.41 [-0.97, 0.15]	0.28	-1.44	.243
Scale PA intensity	0.09 [0.04, 0.13]	0.02	3.60	.001
Age	0.00 [0.00, 0.00]	0.00	0.14	.900
Scale PA intensity <sup>2</sup>	-0.01 [-0.03, 0.02]	0.01	-0.61	.542
Scale PA intensity:age	0.00 [0.00, 0.00]	0.00	-1.43	.165
Age:scale PA intensity <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.52	.604
Sleep efficiency				
(Intercept)	-1.00 [-1.41, -0.60]	0.21	-4.87	< .001
Scale PA intensity	0.13 [0.04, 0.22]	0.05	2.75	.062
Age	0.01 [0.01, 0.02]	0.00	10.22	.002
Scale PA intensity <sup>2</sup>	0.01 [-0.02, 0.04]	0.01	0.78	.436
Scale PA intensity:age	0.00 [0.00, 0.00]	0.00	-1.95	.113
Age:scale PA intensity <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-1.71	.088
Sleep onset				
(Intercept)	-0.96 [-1.49, -0.44]	0.27	-3.60	.065
Scale PA intensity	-0.04 [-0.07, -0.01]	0.02	-2.46	.015
Age	0.02 [0.02, 0.02]	0.00	9.64	.007
Scale PA intensity <sup>2</sup>	0.00 [-0.02, 0.02]	0.01	0.38	.703
Scale PA intensity:age	0.00 [0.00, 0.00]	0.00	-0.37	.714
Age:scale PA intensity <sup>2</sup>	0.00 [0.00, 0.00]	0.00	1.51	.143
Sleep regularity				
(Intercept)	-0.24 [-0.47, -0.02]	0.11	-2.09	.123
Scale PA intensity	0.30 [0.25, 0.34]	0.02	13.30	< .001
Age	0.01 [0.01, 0.01]	0.00	6.88	.004
Scale PA intensity <sup>2</sup>	-0.05 [-0.07, -0.02]	0.01	-3.48	.001
Scale PA intensity:age	0.00 [0.00, 0.00]	0.00	-6.20	< .001
Age:scale PA intensity <sup>2</sup>	0.00 [0.00, 0.00]	0.00	0.33	.743

*Note.* Adjusted for SES, BMI, and sex.

Table 3

*Physical activity by sleep duration controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
PA volume				
(Intercept)	0.37 [0.18, 0.57]	0.10	3.77	.022
Scale sleep duration lag	0.00 [-0.03, 0.04]	0.02	0.23	.825
Age	-0.01 [-0.01, -0.01]	0.00	-8.82	< .001
Scale sleep duration lag <sup>2</sup>	-0.01 [-0.02, 0.00]	0.01	-1.87	.061
Scale sleep duration lag:age	0.00 [0.00, 0.00]	0.00	-0.54	.605
Age:scale sleep duration lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.35	.739
PA intensity				
(Intercept)	0.90 [0.70, 1.10]	0.10	8.76	.005
Scale sleep duration lag	0.01 [-0.02, 0.04]	0.02	0.66	.544
Age	-0.02 [-0.03, -0.02]	0.00	-28.60	< .001
Scale sleep duration lag <sup>2</sup>	0.00 [-0.03, 0.03]	0.01	0.00	.998
Scale sleep duration lag:age	0.00 [0.00, 0.00]	0.00	0.38	.711
Age:scale sleep duration lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.82	.482

*Note.* Adjusted for SES, BMI, and sex.

Table 4

*Physical activity by sleep efficiency controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
PA volume				
(Intercept)	0.36 [0.18, 0.55]	0.09	3.82	.019
Scale sleep efficiency lag	0.06 [0.00, 0.12]	0.03	2.11	.114
Age	-0.01 [-0.01, -0.01]	0.00	-8.37	.001
Scale sleep efficiency lag <sup>2</sup>	0.01 [0.00, 0.02]	0.01	1.28	.270
Scale sleep efficiency lag:age	0.00 [0.00, 0.00]	0.00	-1.15	.293
Age:scale sleep efficiency lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.39	.720
PA intensity				
(Intercept)	0.90 [0.73, 1.07]	0.09	10.11	.003
Scale sleep efficiency lag	0.05 [0.01, 0.09]	0.02	2.28	.060
Age	-0.02 [-0.03, -0.02]	0.00	-22.87	< .001
Scale sleep efficiency lag <sup>2</sup>	0.01 [0.00, 0.01]	0.00	1.78	.076
Scale sleep efficiency lag:age	0.00 [0.00, 0.00]	0.00	-0.78	.451
Age:scale sleep efficiency lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.39	.712

*Note.* Adjusted for SES, BMI, and sex.



Table 5

*Physical activity by sleep onset controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
PA volume				
(Intercept)	0.40 [0.18, 0.61]	0.11	3.64	.031
Scale sleep onset lag	0.03 [0.01, 0.06]	0.01	2.39	.017
Age	-0.01 [-0.01, -0.01]	0.00	-11.12	< .001
Scale sleep onset lag <sup>2</sup>	-0.03 [-0.06, 0.01]	0.02	-1.59	.218
Scale sleep onset lag:age	0.00 [0.00, 0.00]	0.00	-2.17	.032
Age:scale sleep onset lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	0.74	.508
PA intensity				
(Intercept)	0.92 [0.74, 1.11]	0.10	9.70	.003
Scale sleep onset lag	0.01 [-0.05, 0.08]	0.03	0.44	.692
Age	-0.02 [-0.03, -0.02]	0.00	-34.44	< .001
Scale sleep onset lag <sup>2</sup>	-0.01 [-0.02, 0.00]	0.01	-1.66	.098
Scale sleep onset lag:age	0.00 [0.00, 0.00]	0.00	0.04	.972
Age:scale sleep onset lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.27	.791

*Note.* Adjusted for SES, BMI, and sex.

Table 6

*Physical activity by sleep regularity controlling for SES, gender and BMI*

Term	$\beta$ [95% CI]	SE	t	p
PA volume				
(Intercept)	0.33 [0.13, 0.53]	0.10	3.23	.041
Scale sleep regularity lag	0.21 [0.18, 0.23]	0.01	16.87	< .001
Age	-0.01 [-0.01, -0.01]	0.00	-10.74	< .001
Scale sleep regularity lag <sup>2</sup>	0.02 [0.01, 0.04]	0.01	3.02	.012
Scale sleep regularity lag:age	0.00 [0.00, 0.00]	0.00	-6.68	< .001
Age:scale sleep regularity lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	-0.62	.557
PA intensity				
(Intercept)	0.89 [0.72, 1.07]	0.09	10.05	.003
Scale sleep regularity lag	0.11 [0.08, 0.14]	0.02	6.84	.002
Age	-0.02 [-0.03, -0.02]	0.00	-30.01	< .001
Scale sleep regularity lag <sup>2</sup>	0.00 [-0.01, 0.02]	0.01	0.40	.696
Scale sleep regularity lag:age	0.00 [0.00, 0.00]	0.00	-2.65	.029
Age:scale sleep regularity lag <sup>2</sup>	0.00 [0.00, 0.00]	0.00	0.03	.973

*Note.* Adjusted for SES, BMI, and sex.

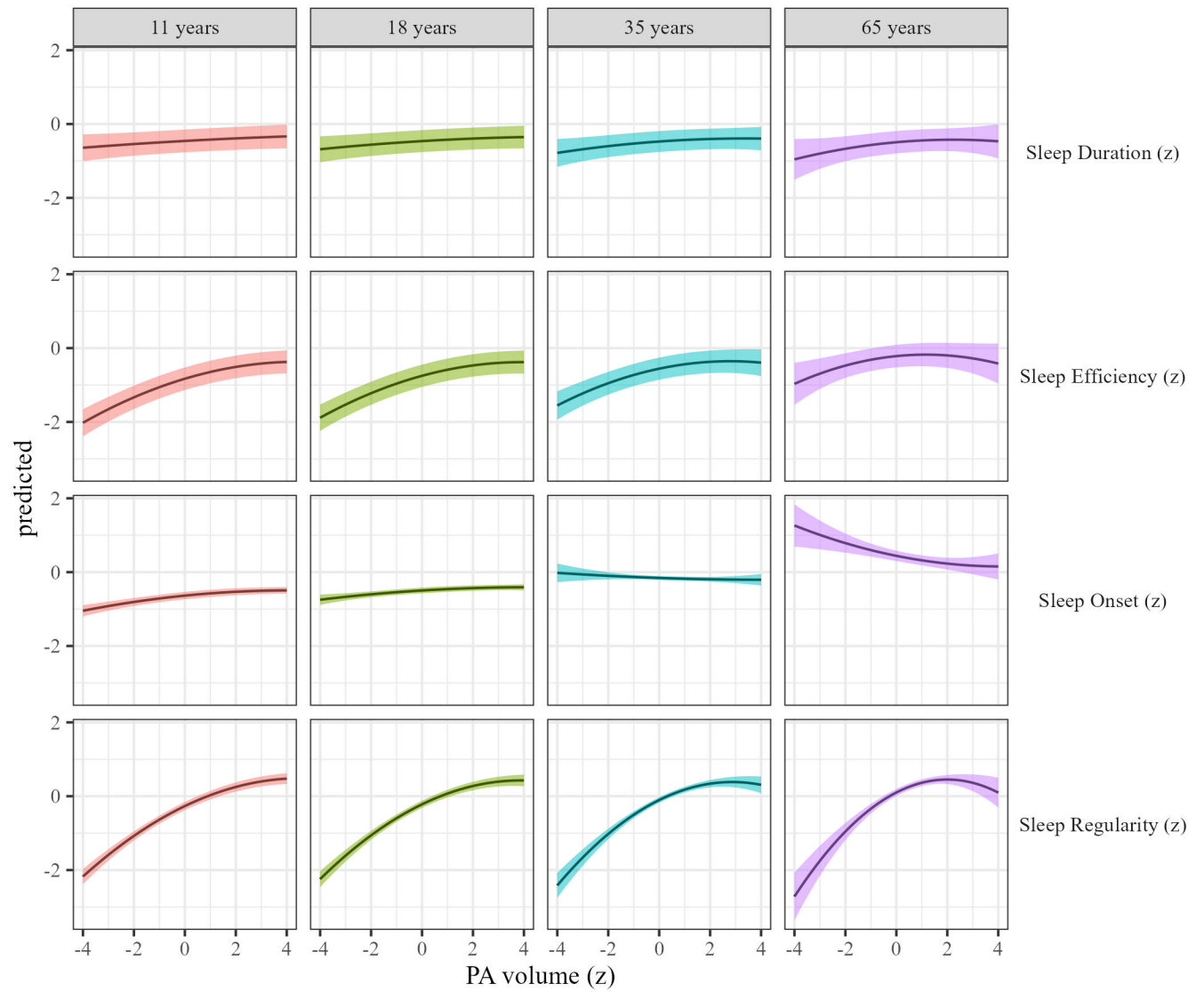


Figure 1. Sleep metrics on Physical activity volume

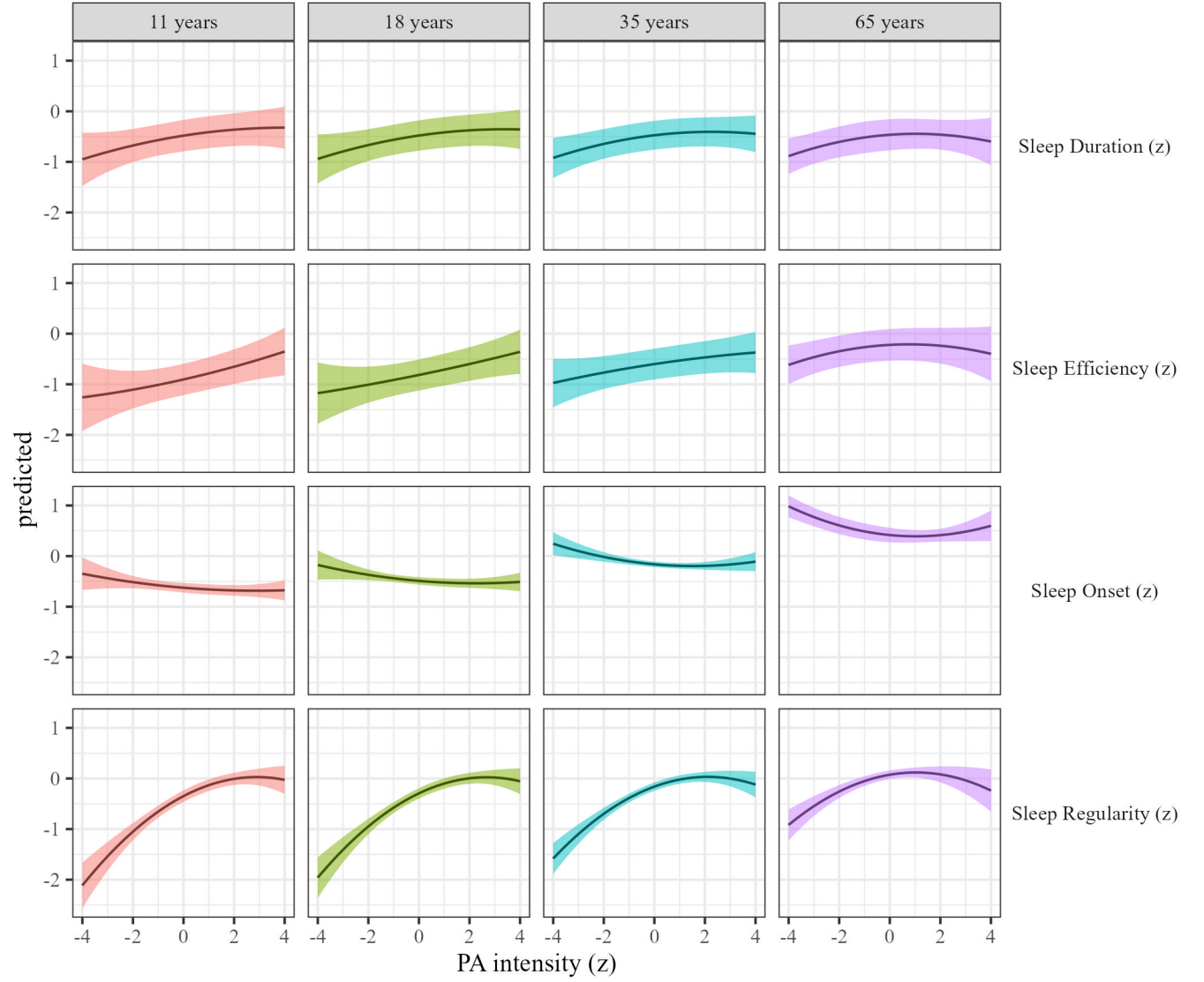


Figure 2. Sleep metrics on Physical activity intensity

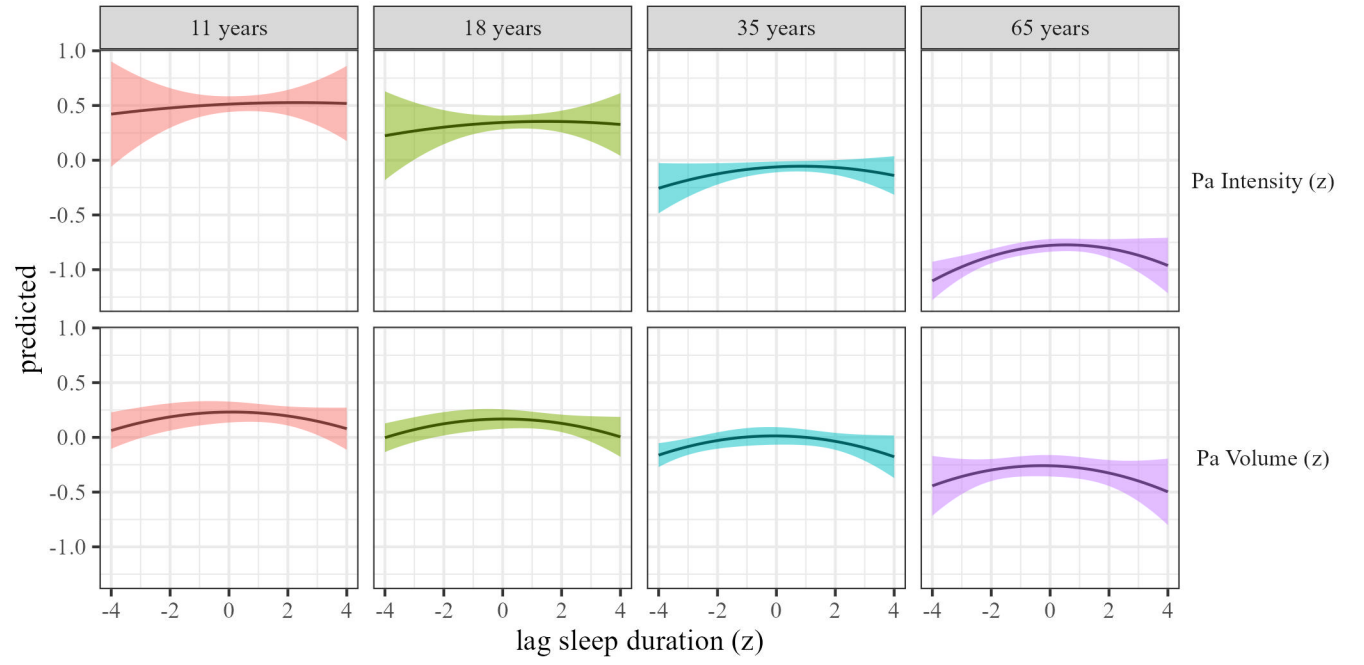


Figure 3. Physical activity by sleep duration

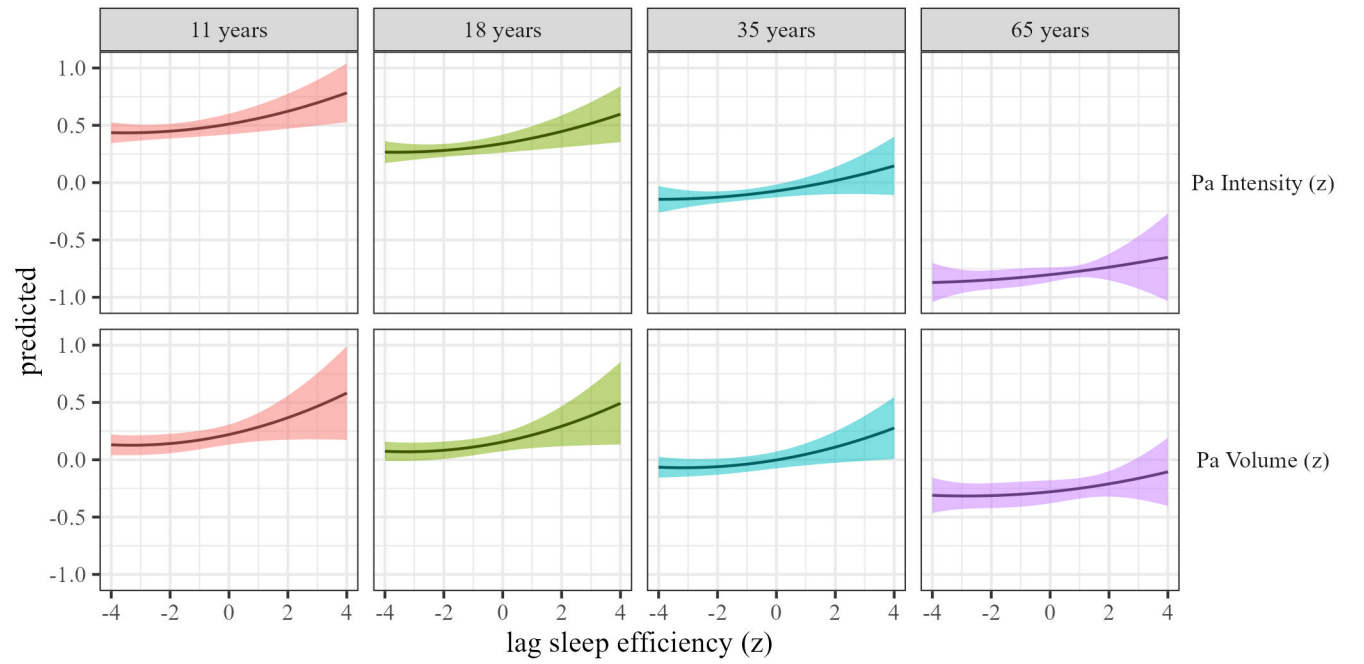


Figure 4. Physical activity by sleep efficiency

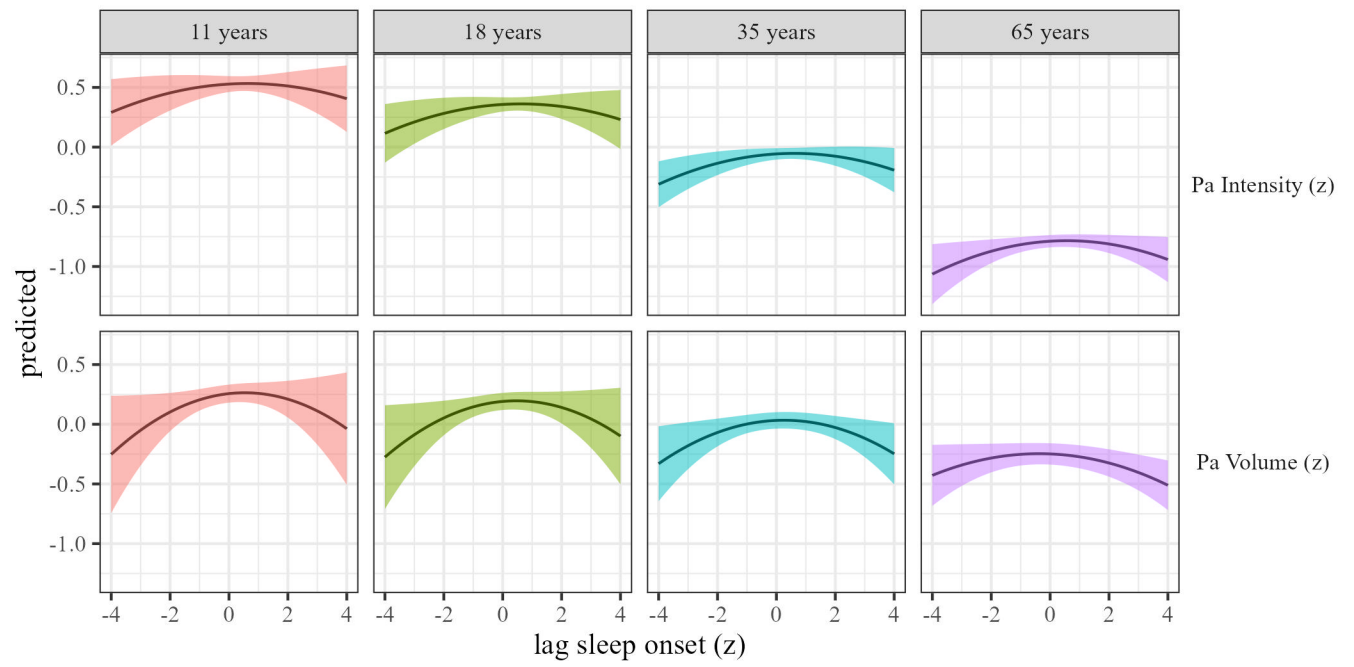


Figure 5. Physical activity by sleep onset

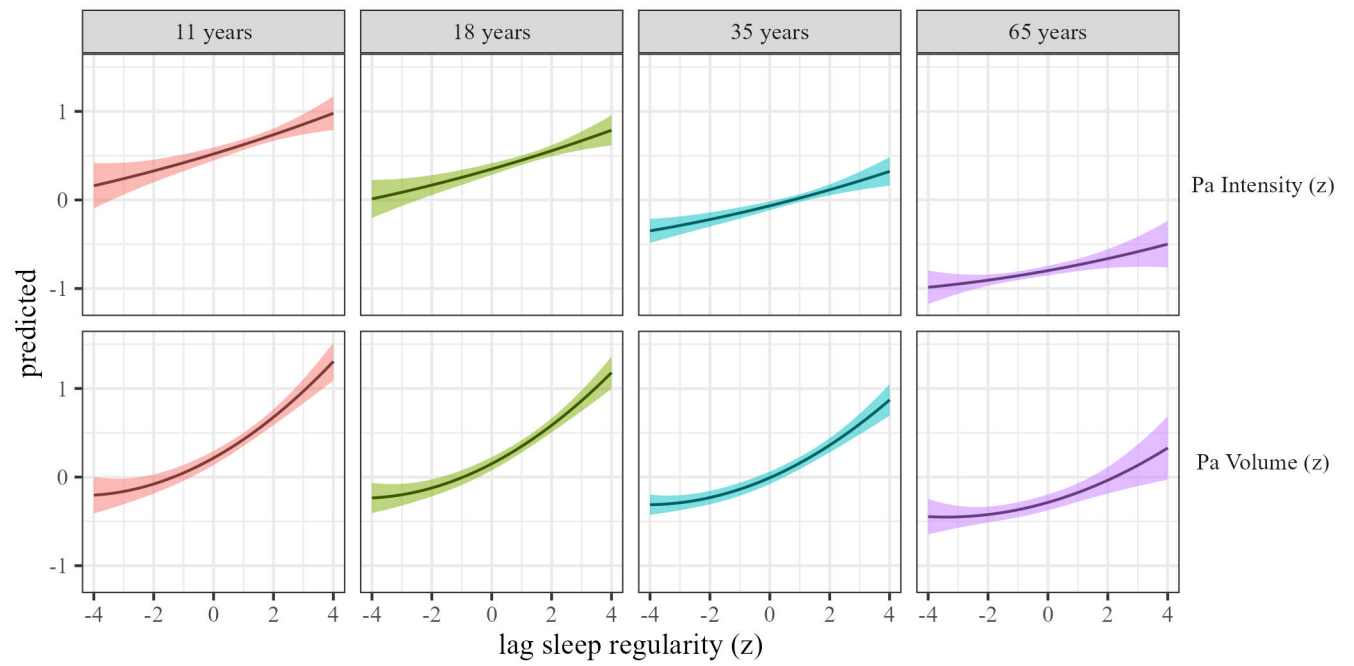


Figure 6. Physical activity by sleep regularity