

**Title:** Cross-sectional and longitudinal associations between sleep duration, sleep quality and bone stiffness in European children and adolescents

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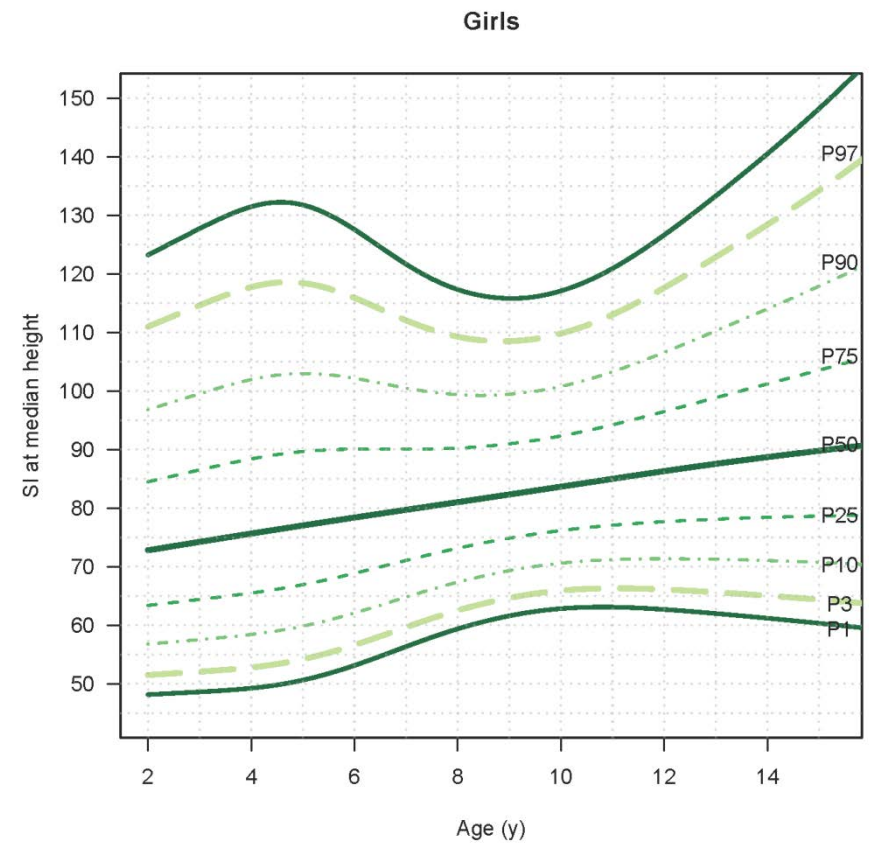
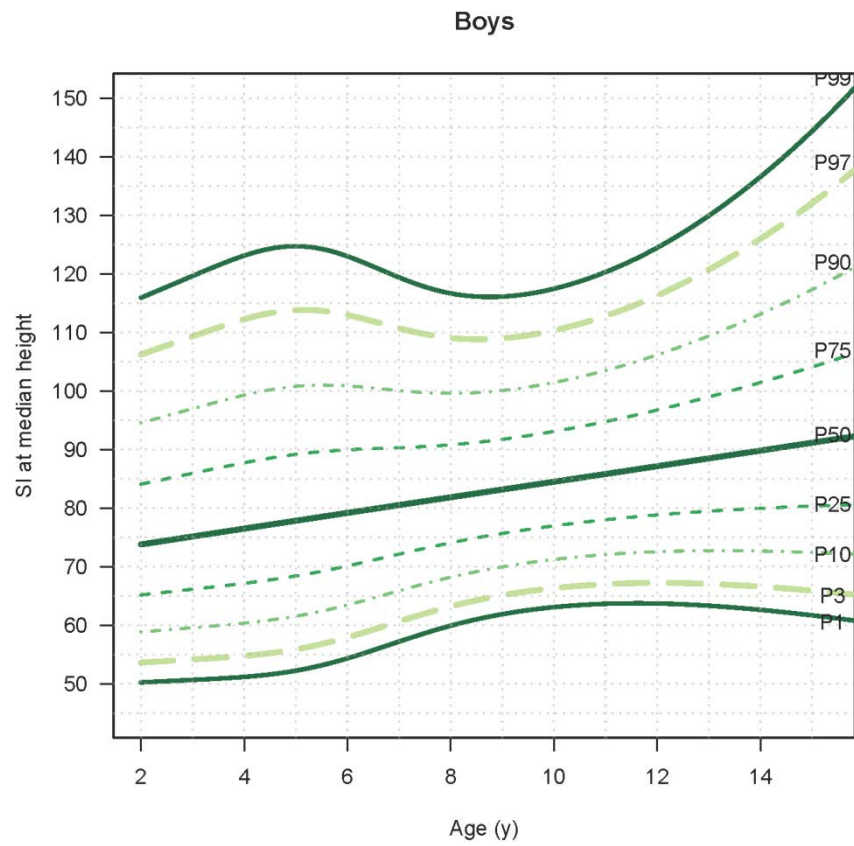
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**Fig. S1** Sex-specific reference curves for bone stiffness index (SI) percentiles by age (years) for average children based on 50<sup>th</sup> height percentile in the IDEFICS/I.Family study



**Table S1** Results of Pearson's correlations (95% confidence intervals) between co-variables, sleep characteristics and bone stiffness index

	Daytime napping duration	Nocturnal sleep duration	Sleep quality score (0-3)	Bone stiffness index
<i>Baseline</i>				
Age	-0.33(-0.35,-0.30)	-0.33(-0.35,-0.30)	-0.04(-0.06,-0.01)	0.13(0.10,0.16)
Weight (kg)	-0.20(-0.22,-0.17)	-0.31(-0.34,-0.29)	-0.10(-0.13,-0.07)	0.14(0.11,0.17)
Height (cm)	-0.28(-0.30,-0.25)	-0.29(-0.32,-0.27)	-0.01(-0.03,0.02)	0.15(0.13,0.18)
Body mass index	-0.09(-0.12,-0.07)	-0.24(-0.27,-0.22)	-0.16(-0.19,-0.13)	0.06(0.03,0.09)
Screen time (hours/week)	-0.04(-0.07,-0.01)	-0.26(-0.29,-0.23)	-0.14(-0.16,-0.11)	-0.02(-0.05,0.01)
Sports club (hours/week)	-0.14(-0.17,-0.11)	-0.08(-0.10,-0.05)	0.06(0.03,0.09)	0.11(0.08,0.14)
Daytime napping duration (10 min/day)	1	-0.08(-0.10,-0.05)	-0.004(-0.03,0.02)	0.05(0.02,0.08)
Nocturnal sleep duration (hours/day)	-0.08(-0.10,-0.05)	1	0.17(0.15,0.20)	0.02(-0.004,0.05)
Sleep quality score (0-3)	-0.004(-0.03,0.02)	0.17(0.15,0.20)	1	0.12(0.09,0.15)
<i>Follow-up</i>				
Age	0.14(0.07,0.21)	-0.48(-0.53,-0.42)	-0.33(-0.39,-0.27)	0.46(0.41,0.51)
Weight (kg)	0.09(0.02,0.15)	-0.30(-0.37,-0.24)	-0.19(-0.26,-0.13)	0.43(0.37,0.48)
Height (cm)	0.07(-0.001,0.13)	-0.39(-0.45,-0.33)	-0.25(-0.31,-0.19)	0.42(0.36,0.47)
Body mass index	0.08(0.01,0.14)	-0.15(-0.22,-0.09)	-0.16(-0.22,-0.09)	0.30(0.24,0.36)
Screen time (hours/week)	0.04(-0.03,0.11)	-0.22(-0.28,-0.16)	-0.14(-0.21,-0.08)	0.11(0.05,0.18)
Sports club (hours/week)	-0.05(-0.11,0.02)	-0.01(-0.08,0.06)	0.05(-0.02,0.11)	0.17(0.11,0.24)
Daytime napping duration (10 min/day)	1	-0.10(-0.17,-0.03)	-0.07(-0.14,-0.01)	0.09(0.02,0.15)
Nocturnal sleep duration (hours/day)	-0.10(-0.17,-0.03)	1	0.31(0.25,0.37)	-0.25(-0.31,-0.19)
Sleep quality score (0-3)	-0.07(-0.14,-0.01)	0.31(0.25,0.37)	1	-0.15(-0.21,-0.08)

**Table S2** Cross-sectional associations between sleep characteristics and bone stiffness index percentiles in 2009/10

	Model 1		Model 2		Model 3	
	$\beta$ (95%CI)	p-value	$\beta$ (95%CI)	p-value	$\beta$ (95%CI)	p-value
Sex						
Boys vs. girls (reference)	/	/	-0.02(-1.49,1.44)	0.97	0.04(-1.44,1.51)	0.96
Age	/	/	0.09(-0.36,0.55)	0.69	-0.12(-0.60,0.35)	0.61
Family socioeconomic status						
Low vs. high (reference)	/	/	-0.02(-2.97,2.93)	0.99	1.56(-1.42,4.53)	0.30
Medium vs. high (reference)	/	/	0.56(-1.17,2.30)	0.52	1.09(-0.65,2.83)	0.22
Daylight duration	/	/	0.49(0.17,0.81)	0.003	0.50(0.18,0.82)	0.003
BMI z-scores	/	/	2.69(2.02,3.35)	p<0.001	2.76(2.10,3.42)	p<0.001
Screen time	/	/	/	/	-0.14(-0.25,-0.04)	0.009
Sports club	/	/	/	/	1.15(0.78,1.53)	p<0.001
Nocturnal sleep duration z-scores	0.08(-0.80,0.96)	0.86	0.42(-0.46,1.30)	0.35	0.26(-0.63,1.14)	0.57
Daytime napping	0.62(0.28,0.95)	p<0.001	0.74(0.38,1.10)	p<0.001	0.78(0.43,1.14)	p<0.001
Sleep quality						
Poor vs. good (reference)	-0.79(-2.46,0.88)	0.35	-0.69(-2.35,0.97)	0.41	-0.44(-2.09,1.22)	0.61

Footnote: Model 1: unadjusted model only with a random effect for country

Model 2: Model 1 + adjusted for sex, age, family socioeconomic status, BMI z-scores and daylight duration

Model 3: Model 2 + adjusted for screen time and time spent at sports club

**Table S3** Longitudinal associations between sleep characteristics and bone stiffness index percentiles in 2013/14

	Model 1		Model 2		Model 3	
	$\beta$ (95%CI)	p-value	$\beta$ (95%CI)	p-value	$\beta$ (95%CI)	p-value
Sex						
Boys vs. girls (reference)	/	/	-3.42(-6.49,-0.34)	0.03	-4.22(-7.43,1.02)	0.01
Age	/	/	4.44(3.23,5.65)	p<0.001	4.06(2.83,5.30)	p<0.001
Pubertal status						
Pre-pubertal vs. pubertal (reference)	/	/	-4.26(-8.17,-0.34)	0.03	-4.59(-8.45,-0.72)	0.02
Family socioeconomic status						
Low vs. high (reference)	/	/	-5.08(-12.04,1.88)	0.15	-3.02(-9.93,3.89)	0.39
Medium vs. high (reference)	/	/	-3.86(-7.30,-0.42)	0.03	-3.16(-6.60,0.27)	0.07
Daylight duration	/	/	1.03(0.45,1.62)	0.001	1.00(0.42,1.57)	0.001
BMI z-scores	/	/	4.14(2.63,5.65)	p<0.001	4.39(2.88,5.90)	p<0.001
Baseline bone stiffness index percentiles			0.45(0.39,0.51)	p<0.001	0.43(0.37,0.50)	p<0.001
Average screen time	/	/	/	/	0.02(-0.22,0.26)	0.88
Average sports club	/	/	/	/	1.89(1.14,2.63)	p<0.001
Baseline nocturnal sleep duration z-scores	-1.84(-4.10,0.43)	0.11	-0.57(-2.46,1.32)	0.55	-0.43(-2.30,1.44)	0.65
Baseline daytime napping	-2.51(-3.71,1.32)	p<0.001	-1.20(-2.20,-0.19)	0.02	-1.06(-2.05,-0.07)	0.04
Follow-up nocturnal sleep duration z-scores	-0.40(-2.37,1.57)	0.69	-0.63(-2.27,1.02)	0.46	-0.73(-2.35,0.89)	0.38
Follow-up daytime napping	1.24(0.41,2.08)	0.004	0.78(0.07,1.48)	0.03	0.84(0.14,1.53)	0.02
Sleep quality <sup>b</sup>						
Poor vs. good (reference)	2.92(-1.45,7.29)	0.19	-1.28(-5.02,2.46)	0.50	-1.29(-4.98,2.40)	0.49

Footnote: Model 1: unadjusted model only with a random effect for country

Model 2: Model 1 + adjusted for bone stiffness index percentiles at baseline, sex, age, family socioeconomic status, pubertal status, BMI z-scores and daylight duration at follow-up

Model 3: Model 2 + adjusted for average screen time and time spent at sports club at both surveys

**Table S4** Interaction terms of meeting sleep guidelines and sleep quality with screen time and sports club on bone stiffness index percentiles

	Cross-sectional models		Longitudinal models	
	$\beta$ (95%CI)	p-value	$\beta$ (95%CI)	p-value
Baseline total sleep duration <sup>a</sup> * screen time	0.03(-0.20,0.27)	0.78	-0.52(-1.02,-0.03)	0.04
Baseline total sleep duration <sup>a</sup> * sports club	0.70(-0.21,1.61)	0.13	0.48(-1.45,2.41)	0.63
Baseline sleep quality <sup>b</sup> * screen time	-0.03(-0.22,0.17)	0.78	0.22(-0.18,0.62)	0.28
Baseline sleep quality <sup>b</sup> * sports club	-0.64(-1.33,0.05)	0.07	1.02(-0.40,2.44)	0.16
Follow-up total sleep duration <sup>a</sup> * screen time	/	/	-0.31(-0.76,0.13)	0.17
Follow-up total sleep duration <sup>a</sup> * sports club	/	/	-0.38(-2.01,1.26)	0.65
Follow-up sleep quality <sup>b</sup> * screen time	/	/	0.13(-0.29,0.54)	0.55
Follow-up sleep quality <sup>b</sup> * sports club	/	/	-0.38(-1.85,1.08)	0.61

Footnote: All cross-sectional models were adjusted for sex, age, family socioeconomic status, screen time, time spent at sports club, BMI z-scores and daylight duration, with a random effect for country

All longitudinal models were adjusted for bone stiffness index percentiles at baseline, sex, age, family socioeconomic status, pubertal status, BMI z-scores and daylight duration at follow-up as well as average screen time and time spent at sports club at both surveys

<sup>a</sup> Based on the sleep recommendation from the National Sleep Foundation, adequate sleep duration as reference

<sup>b</sup> Good sleep quality as reference