











# Adolescents' chronotype and its association with obesity-related outcomes: The EHDLA study

Miguel Angelo Duarte Junior<sup>1</sup>  | Arthur Eumann Mesas<sup>2</sup>  | Sitong Chen<sup>3</sup>  |  
 Júlio B. Mello<sup>4</sup>  | Jorge Olivares-Arancibia<sup>5</sup>  | Aamir Raof Memon<sup>3</sup>  |  
 Rodrigo Yáñez-Sepúlveda<sup>6</sup>  | Ran Bao<sup>7,8,9</sup>  | Lee Smith<sup>10</sup>  |  
 José Francisco López-Gil<sup>11</sup> 

<sup>1</sup>Department of Preventive Medicine and Public Health, School of Medicine, Universidad Autónoma de Madrid, Madrid, Spain

<sup>2</sup>Health and Social Research Center, Universidad de Castilla-La Mancha, Cuenca, Spain

<sup>3</sup>Institute for Health and Sport, Victoria University, Melbourne, Victoria, Australia

<sup>4</sup>eFiDac Research Group, School of Physical Education, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile

<sup>5</sup>AFySE Group, Research in Physical Activity and School Health, School of Physical Education, Faculty of Education, Universidad de las Américas, Santiago, Chile

<sup>6</sup>Faculty Education and Social Sciences, Universidad Andres Bello, Viña del Mar, Chile

<sup>7</sup>Centre for Active Living and Learning, University of Newcastle, Callaghan, New South Wales, Australia

<sup>8</sup>College of Human and Social Futures, School of Education, University of Newcastle, Callaghan, New South Wales, Australia

<sup>9</sup>Active Living Research Program, Hunter Medical Research Institute, New Lambton Heights, New South Wales, Australia

<sup>10</sup>Centre for Health, Performance and Wellbeing, Anglia Ruskin University, Cambridge, UK

<sup>11</sup>One Health Research Group, Universidad de Las Américas, Quito, Ecuador

## Correspondence

José Francisco López-Gil, One Health Research Group, Universidad de Las Américas, Quito, Ecuador.  
 Email: [josefranciscolopezgil@gmail.com](mailto:josefranciscolopezgil@gmail.com)

## Summary

**Objective:** This study aimed to assess associations between chronotype and obesity-related indicators in a sample of Spanish adolescents.

**Methods:** This cross-sectional study used data from The Eating Healthy and Daily Life Activities (EHDLA) Study, which included a representative sample of adolescents from Spain. A total of 820 adolescents (54.7% girls) aged 12–17 years were included in the analyses. The adolescents' chronotype was determined using the Morningness/Eveningness Scale in Children. Obesity-related indicators included body mass index, waist circumference, waist-to-height ratio, triceps and medial calf skinfolds, sum of skinfolds, and body fat percentage. Generalized linear models were used to examine the relationship between the Morningness-Eveningness score and chronotype status and the above-mentioned obesity-related indicators in adolescents. All analyses were adjusted for sex, age, socioeconomic status, sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, and energy intake.

**Results:** The morningness chronotype was associated with higher abdominal obesity (odds ratio [OR] = 1.67, 95% confidence interval (CI) 1.12 to 2.50;  $p = 0.001$ ), waist-to-height ratio (unstandardized beta coefficient [ $B$ ] = 0.01, 95% CI 0.01 to 0.05;  $p = 0.029$ ) and skinfold calves ( $B = 1.04$  95% CI 0.24 to 1.94;  $p = 0.011$ ), compared with the intermediate chronotype.

**Conclusion:** Adolescents with a morningness chronotype may be more prone to abdominal obesity than their counterparts with an intermediate chronotype. Effective intervention-related approaches can be applied to those with a morningness chronotype.

## KEYWORDS

chronobiology, excess weight, overweight, youth

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## 1 | INTRODUCTION

Child and adolescent obesity has emerged as a significant global health concern due to its increasing prevalence over recent decades.<sup>1</sup> For instance, the global prevalence of obesity in children and adolescents (5–19 years old) increased from 1.7% to 6.9% in girls and from 2.1% to 9.3% in boys between 1990 and 2022.<sup>2</sup> Consequently, it is estimated that 160–185 million children and adolescents have obesity.<sup>2,3</sup> Importantly, childhood obesity is associated with higher mortality and premature comorbidity rates, with adverse health effects that can persist into adulthood.<sup>4</sup> Excess weight status (e.g., overweight or obesity) can be due to an imbalance between energy intake (e.g., diet) and energy expenditure (e.g., physical activity),<sup>3</sup> which are substantially complex conditions. The development and perpetuation of obesity can be explained by the biosocioecological framework, which includes biological predisposition, socioeconomic status, and environmental factors.<sup>1</sup> Obesogenic environments, including availability of unhealthy foods, food marketing, excessive screen time, and low physical activity, contribute to excess weight.<sup>1</sup> Furthermore, biological heterogeneity factors also influence body weight regulation.<sup>1</sup> For example, the pathways controlling appetite and satiety, pleasure-seeking behaviours, and metabolic efficiency strongly affect body composition.<sup>1</sup> A growing body of evidence suggests sleep duration and quality may be related to weight status.<sup>3</sup> More recently, it has been proposed that chronotype may also play a role in the pathophysiology of obesity.<sup>5</sup>

Chronotype is the result of interplay from a number of external (e.g., light, time zone) and internal (e.g. circadian rhythm, suprachiasmatic nucleus, and specific genotype) factors.<sup>6,7</sup> The interaction of external and internal factors produces a process called entrainment of biological time, which has implications for preferences in the circadian rhythm and sleep. These different entrainment characteristics are referred to as different chronotype.<sup>7</sup> Chronotype is commonly assessed using self-reported measures that collect subjective data on sleep timing and preferences for performing activities and tasks. The classification of chronotypes is typically categorized as morningness, intermediate, or eveningness.<sup>7</sup> Adolescents are exposed to conflicts between social and biological time, given that they typically engage in activities early in the morning, irrespective of their chronotype. Indeed, sleep duration is shorter during adolescence compared to other life stages.<sup>8</sup> This divergence between biological and social timing may be a contributor potentially related to excess weight.<sup>8</sup>

Previous studies have pointed out the association between chronotype and excess weight status, including lower diet quality,<sup>9,10</sup> lower adherence to the Mediterranean diet,<sup>11</sup> and disrupted sleep.<sup>12</sup> Nevertheless, the association between chronotype and obesity-related indicators remains unclear, especially in adolescents.<sup>6,13–16</sup> For example, previous studies have found that chronotype was not associated with obesity-related indicators,<sup>12,14,17</sup> while one study found an association only in a specific age group (i.e., 12–15 years old),<sup>13</sup> or only in adults with sleep disorders (i.e., disrupted sleep).<sup>12</sup> Notably, physical activity, sedentary behaviours, sleep duration, and diet<sup>9,13</sup> are all related to weight status; however, these factors were not taken into account in previous studies.<sup>9,13</sup> Therefore, the present study

aimed to assess associations between chronotype and obesity-related indicators in a sample of Spanish adolescents.

## 2 | METHODS

### 2.1 | Study design and participants

This cross-sectional study used the secondary data from the Eating Healthy and Daily Life Activities (EHDLA) Study (Spain), which included a representative sample of adolescents from the *Valle de Ricote* (Region of Murcia, Spain). The methodology of the EHDLA study has been previously described.<sup>18</sup> Data collection was conducted during the 2021/2022 academic year. Of the initial 1378 participants, 119 (8.6%) were excluded due to missing data on key outcomes such as body mass index (BMI), waist circumference (WC), and skinfolds. In addition, participants were excluded due to missing data on the Morningness-Eveningness Scale for Children (MES-C)<sup>16</sup> (29.0%;  $n = 400$ ), overall sleep duration (2.3%;  $n = 32$ ), and Youth Activity Profile questionnaire (YAP-S)<sup>21</sup> (0.5%;  $n = 7$ ). Finally, a total of 820 adolescents (54.7% girls) aged 12–17 years were included in the present analyses.

Before the data collection commenced, all parents/legal guardians were informed about the purpose of the current study and were required to provide signed consent forms. This study obtained ethical approval from the Bioethics Committee of the University of Murcia (ID: 2218/2018) and Ethics Committee of the Albacete University Hospital Complex and the Albacete Integrated Care Management (ID: 2021-85), and was conducted according to the guidelines of the Declaration of Helsinki.

### 2.2 | Procedures

#### 2.2.1 | Chronotype (independent variable)

A validated Spanish translation of the MES-C<sup>19</sup> was used to assess adolescent chronotype. The MES-C comprises 10 questions regarding adolescents' preferences for evening or morning, with 4 or 5 responses for each item. For example, "How alert are you in the first half hour you're up?", with the following response options: (a) out of it; (b) a little dazed; (c) okay; and (d) ready to take on the world. Adolescents were required to choose the response that most accurately describes their preference. Scores range from 10 to 43, with lower scores denoting a predilection for eveningness and higher scores for morningness. Participants were classified into eveningness ( $\leq 18$  points), intermediate (19–29 points), and morningness types ( $\geq 30$  points) based on MES-C scores using predefined cutoffs of 18 and 30 points.

#### 2.2.2 | Obesity-related indicators (dependent variables)

Body weight and height of the adolescents were measured with an electronic scale (Tanita BC-545, Tokyo, Japan; accuracy of 0.1 kg) and

a portable height rod (Leicester Tanita HR 001, Tokyo, Japan; accuracy of 0.1 cm). Subsequently, BMI was then calculated and classified as underweight, normal weight, overweight, obesity, and excess weight (i.e., overweight or obesity) according to the World Health Organization (WHO) age- and sex-specific cutoffs.<sup>20</sup> WC was measured at the level of the umbilicus using a constant tension tape (accuracy of 0.1 cm), and waist-to-height ratio (WHtR) was calculated. The cutoff for determining abdominal obesity was WHtR  $\geq 0.5$ .<sup>21</sup> Triceps and medial calf skinfolds were measured using calibrated steel callipers (Holtain, Crosswell, Crymych, United Kingdom; accuracy of 0.2 mm) to calculate the sum ( $\Sigma$ ) of skinfolds and body fat percentage using the Slaughter equations.<sup>22</sup>

### 2.2.3 | Covariates

Date of birth and sex were self-reported, and age was calculated from the date of birth. Socioeconomic status (SES) was assessed using the Family Affluence Scale (FAS-III).<sup>23</sup> Sleep time was assessed with the following questions: “What time do you usually go to bed?” and “What time do you usually get up?”. These questions were asked for both weekdays and weekends. Overall sleep duration was then

calculated. Information on physical activity and sedentary behaviour was obtained using the Spanish Youth Activity Profile (YAP-S) questionnaire.<sup>24</sup> The YAP-S is a self-administered questionnaire, requiring participants to recall questionnaire (previous their activities over the past week). It is divided into three sections: activity at school, activity out-of-school, and sedentary habits. Finally, adherence to the Mediterranean diet was evaluated using the Mediterranean Diet Quality Index for Children and Teenagers (KIDMED),<sup>25</sup> which ranges from  $-4$  to 12 points. Energy intake was assessed using a 45-item Food Frequency Questionnaire (FFQ), which collected information on the consumption of a variety of foods, including fruits, vegetables, legumes, nuts, dairy products, salted cereals, fish, eggs, poultry, red and processed meats, sweet cereals, sweets, sugar-sweetened beverages, and alcoholic beverages. The French food composition table *Répertoire général des aliments* (REGAL)<sup>26</sup> was used to calculate total energy intake.

### 2.2.4 | Statistical analysis

Density plots and quantile-quantile plots, along with the Shapiro–Wilk test were utilized to assess the normal distribution of variables.

**TABLE 1** Descriptive characteristics of participants ( $N = 820$ ).

	Eveningness ( $\leq 18$ points)	Intermediate (19–29 points)	Morningness ( $\geq 30$ points)	All
Participants, $n$ (%)	50 (6.1)	569 (69.4)	201 (24.5)	820 (100.0)
Sex (girls)	33 (66.0)	335 (58.9)	87 (43.3)	455 (55.5)
Age (years)	13.0 (2.0)	14.0 (2.0)	14.0 (3.0)	14.0 (2.0)
FAS-III (score)	8.5 (2.8)	8.0 (3.0)	8.0 (3.0)	8.0 (3.0)
Overall sleep duration (minutes)	454.3 (88.9)	497.1 (72.9)	510.0 (68.6)	497.1 (68.6)
YAP-S physical activity (score)	2.3 (0.9)	2.6 (0.9)	2.8 (0.8)	2.6 (0.8)
YAP-S sedentary behaviors (score)	3.0 (0.8)	2.6 (0.8)	2.4 (0.8)	2.6 (0.8)
KIDMED (score)	4.5 (2.8)	7.0 (3.0)	8.0 (3.0)	7.0 (3.0)
Energy intake (kcal)	2898.4 (1577.3)	2605.1 (1483.1)	2449.9 (1388.5)	2581.9 (1487.4)
BMI ( $\text{kg}/\text{m}^2$ )	21.9 (7.2)	21.6 (5.7)	21.8 (7.0)	21.7 (6.0)
BMI (z-score) <sup>a</sup>	0.07 (2.20)	$-0.03$ (1.87)	0.07 (2.29)	0.00 (1.98)
Excess weight (%) <sup>a</sup>	15 (30.0)	137 (24.1)	59 (29.4)	211 (25.7)
Obesity (%) <sup>a</sup>	7 (14.0)	44 (7.7)	22 (10.9)	73 (8.9)
WC (cm)	68.8 (20.9)	70.6 (12.7)	72.0 (14.5)	71.0 (13.4)
WHtR (unit)	0.44 (0.10)	0.44 (0.07)	0.45 (0.10)	0.44 (0.0)
Abdominal obesity (%) <sup>b</sup>	13 (26.0)	97 (17.0)	57 (28.4)	167 (20.4)
Skinfold triceps (mm)	16.0 (7.8)	15.0 (9.0)	16.0 (11.0)	15.0 (9.6)
Skinfold calf (mm)	16.8 (9.8)	15.0 (10.0)	16.0 (13.0)	15.0 (10.0)
$\Sigma$ Skinfolds (mm)	30.0 (18.0)	32.0 (22.2)	32.0 (18.7)	31.0 (19.0)
Body fat (%) <sup>c</sup>	24.6 (11.1)	23.4 (11.8)	24.6 (15.3)	23.7 (12.6)

Note: Data are expressed as the median (interquartile range) or count (percentages).

Abbreviations: FAS-III, Family Affluence Scale-III; YAP-S, Spanish Youth Active Profile; KIDMED, Mediterranean Diet Quality Index in children and adolescents; BMI, body mass index; WC; waist circumference; WHtR, waist-to-height ratio.

<sup>a</sup>According to the World Health Organization.<sup>20</sup>

<sup>b</sup>Using a cut-off point of waist-to-height ratio  $\geq 0.5$ .<sup>21</sup>

<sup>c</sup>According to Slaughter's formula.<sup>22</sup>

Categorical variables were described using counts ( $n$ ) and percentages (%), while continuous variables were summarized with the median and interquartile range (IQR). Since there was no interaction between sex and MESC (score) concerning obesity-related indicators ( $p > 0.05$  for all), both girls and boys were analysed together. To determine the relationship between the MESC score or chronotype (i.e., morningness, intermediate, or eveningness) and obesity-related indicators, generalized linear regression models with a Gaussian distribution (for continuous outcomes) or binomial distribution (for dichotomous outcomes) were conducted. These models were carried out using robust methods (i.e., “KS2014” or “Mqlc” methods), which offer numerous advantages in addressing heteroscedasticity and outliers. Unstandardized beta coefficients ( $B$ ) or odds ratios (OR), and their 95% confidence interval (CI) for each outcome were computed. Models for BMI (or its derivatives) were adjusted for several covariates, including sex, age, socioeconomic status, overall sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, and energy intake. The remaining outcomes were further adjusted for BMI. All statistical analyses were executed using R statistical software (version 4.4.0). A significance level of  $p < 0.05$  was employed.

### 3 | RESULTS

The characteristics of the sample are provided in Table 1. Most participants (69.4%) were classified as intermediate chronotype. The median (IQR) MESC score in morningness, intermediate and eveningness chronotype was 32 (IQR = 3), 25 (IQR = 4), and 17 (IQR = 3) points, respectively. The overall proportion of excess weight, obesity, and abdominal obesity was 25.7%, 8.9%, and 20.4%, respectively.

Table 2 shows the association between MESC score and obesity-related indicators. We identified an association between WHtR ( $B = 0.001$ , 95% CI 0.0001 to 0.001;  $p = 0.029$ ), skinfold calves ( $B = 0.09$ , 95% CI 0.01 to 0.16;  $p = 0.029$ ), sum of skinfolds ( $B = 0.14$ , 95% CI 0.01 to 0.27;  $p = 0.030$ ) and body fat % ( $B = 0.09$ , 95% CI 0.004 to 0.17;  $p = 0.040$ ) and abdominal obesity (OR = 1.10, 95% CI 1.02 to 1.18;  $p = 0.010$ ).

Table 3 depicts the results of generalized linear models assessing the relationship between chronotype status and obesity-related indicators among adolescents. The morningness chronotype was associated with a higher WHtR ( $B = 0.01$ , 95% CI 0.01 to 0.05;  $p = 0.029$ ) and skinfold calves ( $B = 1.04$  95% CI 0.24 to 1.94;  $p = 0.011$ ), compared to intermediate. Moreover, adolescents identified as morningness chronotype had a 1.67-fold increased likelihood of abdominal obesity compared to those identified as intermediate chronotype.

### 4 | DISCUSSION

One of the key findings of this study was the identified association between the MESC score and several obesity-related indicators, such as the WHtR, abdominal obesity, calf skinfold, sum of skinfolds, and %

**TABLE 2** Generalized linear models assessing the relationship between Morningness-Eveningness score and obesity-related indicators among adolescents.

Outcomes	Predictor	
	MESC (per one point)	
	B (95% CI)	p
BMI (kg/m <sup>2</sup> ) <sup>d</sup>	0.02 (−0.06 to 0.09)	0.640
BMI (z-score) <sup>a,d</sup>	0.004 (−0.02 to 0.03)	0.755
Excess weight status (yes) <sup>a,d</sup>	OR: 1.02 (0.98 to 1.05)	0.407
Obesity status (yes) <sup>a,d</sup>	OR: 1.02 (0.96 to 1.08)	0.498
Waist circumference (cm) <sup>e</sup>	0.07 (−0.003 to 0.14)	0.060
Waist-to-height ratio (unit) <sup>e</sup>	0.001 (0.0001 to 0.001)	<b>0.029</b>
Abdominal obesity (yes) <sup>b,e</sup>	OR: 1.10 (1.02 to 1.18)	<b>0.010</b>
Skinfold triceps (mm) <sup>e</sup>	0.06 (−0.01 to 0.13)	0.082
Skinfold calves (mm) <sup>e</sup>	0.09 (0.01 to 0.16)	<b>0.029</b>
∑ Skinfolds (mm) <sup>e</sup>	0.14 (0.01 to 0.27)	<b>0.030</b>
Body fat (%) <sup>c,e</sup>	0.09 (0.004 to 0.17)	<b>0.040</b>

Note: Data expressed as unstandardized beta coefficients ( $B$ ) and 95% confidence intervals (CIs) from generalized linear models with Gaussian distribution, and odds ratios (OR) and 95% CIs from generalized linear models with binomial distribution. Bold indicates statistical significance ( $p < 0.05$ ).

Abbreviations: BMI, body mass index; MESC, Morningness-Eveningness scale in children; WC; waist circumference.

<sup>a</sup>According to the World Health Organization.<sup>20</sup>

<sup>b</sup>Using a cut-off point of waist-to-height ratio  $\geq 0.5$ .<sup>21</sup>

<sup>c</sup>According to Slaughter's formula.<sup>22</sup>

<sup>d</sup>Adjusted for sex, age, socioeconomic status, sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, and energy intake.

<sup>e</sup>Adjusted for sex, age, socioeconomic status, sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, energy intake, and body mass index.

body fat. Each unit increase in the MESC score was associated with higher odds of having abdominal obesity. Additionally, in comparison to individuals with intermediate chronotype, those with morningness chronotype had higher WHtR and skinfold calves scores, as well as a higher chance of having abdominal obesity. Conversely, eveningness chronotype was not associated with any obesity-related indicators among adolescents, in comparison with intermediate chronotype. Although our study did not find an association between chronotype and BMI, our results indicate that a morning chronotype is linked to other more robust obesity-related indicators, even after adjusting for several potential confounders.

Chronotype changes throughout the lifespan,<sup>8</sup> and adolescents tend to adopt an evening chronotype.<sup>7</sup> However, the intermediate chronotype was the most common in our sample and in previous studies.<sup>12,17,27</sup> Regarding associations between chronotype and obesity-related indicators, our results suggest that morningness chronotype is linked to obesity-related indicators. These findings are in line with previous studies.<sup>27,28</sup> For instance, Zerón-Ruggerio and colleagues<sup>28</sup> pointed out that young adult females ( $n = 133$ ; 18 to

**TABLE 3** Relationship between chronotype status and obesity-related indicators among adolescents.

Dependent variables	Independent variable				
	MESC status				
	Eveningness ( $\leq 18$ points)		Intermediate (19–29 points)	Morningness ( $\geq 30$ points)	
	B (95% CI)	p		B (95% CI)	p
BMI ( $\text{kg}/\text{m}^2$ ) <sup>d</sup>	0.47 (–0.90 to 1.86)	0.502	1 (Reference)	0.10 (–0.66 to 0.86)	0.798
BMI (z-score) <sup>a,d</sup>	0.15 (–0.30 to 0.59)	0.522	1 (Reference)	0.01 (–0.23 to 0.26)	0.932
Excess weight status (yes) <sup>a,d</sup>	OR: 1.39 (0.71 to 2.06)	0.345	1 (Reference)	OR: 1.27 (0.87 to 1.63)	0.251
Obesity status (yes) <sup>a,d</sup>	OR: 1.70 (0.65 to 4.47)	0.281	1 (Reference)	OR: 1.26 (0.68 to 2.35)	0.454
Waist circumference (cm) <sup>e</sup>	0.12 (–1.26 to 3.92)	0.869	1 (Reference)	0.66 (–0.10 to 1.41)	0.090
Waist-to-height ratio <sup>e</sup>	0.002 (–0.01 to 0.01)	0.611	1 (Reference)	0.01 (0.01 to 0.05)	<b>0.029</b>
Abdominal obesity (yes) <sup>b,e</sup>	OR: 2.13 (0.72 to 3.54)	0.293	1 (Reference)	OR: 1.67 (1.12 to 2.50)	<b>0.001</b>
Skinfold triceps (mm) <sup>e</sup>	–0.47 (–1.75 to 0.80)	0.467	1 (Reference)	0.12 (–0.58 to 0.94)	0.736
Skinfold calves (mm) <sup>e</sup>	–0.40 (–1.84 to 1.04)	0.588	1 (Reference)	1.04 (0.24 to 1.94)	<b>0.011</b>
$\sum$ Skinfolks (mm) <sup>e</sup>	–0.94 (–3.39 to 2.45)	0.456	1 (Reference)	1.18 (–0.18 to 2.54)	0.088
Body fat (%) <sup>c,e</sup>	–0.50 (–2.14 to 1.15)	0.555	1 (Reference)	0.75 (–0.16 to 1.66)	0.106

Data expressed as unstandardized beta coefficients (B) and 95% confidence intervals (CIs) from generalized linear models with Gaussian distribution, and odds ratios (OR) and 95% CIs from generalized linear models with binomial distribution. In generalized linear regressions with binomial distribution, the reference group is “No”.

Note: Bold indicates statistical significance ( $p < 0.05$ ).

Abbreviations:  $\sum$ , sum; BMI, body mass index; MESC, Morningness-Eveningness scale in children; WC, waist circumference.

<sup>a</sup>According to the World Health Organization.<sup>20</sup>

<sup>b</sup>Using a cut-off point of waist-to-height ratio  $\geq 0.5$ .<sup>21</sup>

<sup>c</sup>According to Slaughter's formula.<sup>22</sup>

<sup>d</sup>Adjusted for sex, age, socioeconomic status, sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, and energy intake.

<sup>e</sup>Adjusted for sex, age, socioeconomic status, sleep duration, physical activity, sedentary behaviour, adherence to the Mediterranean diet, energy intake, and body mass index.

25 years old) with habits of early-bed and early-rise showed a higher BMI and WC compared to those with late bedtime and late wake-up habits. Similarly, Arslan et al.<sup>27</sup> ( $n = 850$ ; mean age  $21.67 \pm 2.83$  years) suggested that participants with a morning chronotype had higher BMI values than their counterparts with other chronotypes. Moreover, in their study, a 1-unit increase in the Morningness-Eveningness Questionnaire (MEQ) scores of university students resulted in a higher BMI. However, in contrast to our results, several studies found that the evening chronotype is more likely to have overweight and obesity.<sup>6,14,29</sup>

The discrepancies observed across studies may have several potential explanations. First, most studies reporting an association between evening chronotype and obesity used BMI as a measure rather than body composition or other more robust indicators (e.g., WC, WHtR).<sup>14</sup> Thus, we did not find associations between MESC score or chronotype and BMI. Second, potential confounders possibly explain different findings regarding chronotype and indicators related to obesity. Previous studies have reported an association between chronotype and physical activity,<sup>14,30</sup> sedentary behaviour,<sup>30</sup> screen time,<sup>29</sup> and eating disorders.<sup>14</sup> Considering that lifestyle factors can explain the association between chronotype and obesity,<sup>14</sup> we have adjusted our analyses by potential confounders (i.e., sex, age, socioeconomic status, sleep duration, physical activity, sedentary

behaviour, adherence to the Mediterranean diet, and energy intake) previously associated with chronotype. Nonetheless, differences in analysis adjustments can explain disagreement in the findings of associations between chronotype and obesity-related indicators. Finally, the use of different tools to evaluate chronotype is a challenge to understanding the real role of chronotypes in indicators related to obesity. A previous study reported a high correlation between different chronotype questionnaires.<sup>7</sup> However, correlations decrease when corrected by sleep-debt and for age and sex. Furthermore, some questionnaires classify chronotype only as morning and afternoon, others as morningness, intermediate and eveningness, and there are still other classifications such as later and early chronotype.<sup>6,30</sup> These different classifications make it difficult to compare studies.

Concerning factors related to chronotype, McMahon et al.<sup>12</sup> found associations between evening chronotype and higher blood pressure using a crude model. However, the associations were attenuated to the null in a model adjusted by sex and physical activity. Similarly, in a study on adolescents ( $n = 69$ ; 14–17 years old), Malone et al.<sup>29</sup> indicated that the associations between school night sleep duration and BMI z-scores were not significant after adjusting for sex, fruit/vegetable consumption, screen time, daytime naps, and social jet lag. Therefore, given the influence of different lifestyle factors on the association between chronotype and obesity-related indicators,

the discrepancies in analysis adjustments may explain the lack of consensus in the literature on this topic.

In this sense, sleeping is an important factor in this relationship. Considering that adolescents are required to adhere to school schedules, they may get an insufficient amount of sleep on nights preceding typical school days.<sup>31</sup> Roennemberg et al.<sup>7</sup> suggest that insufficient sleep on workdays is more common in the evening chronotype. Although we have adjusted our analysis by sleep duration, other sleep factors are important. For example, McMahon<sup>12</sup> reported an association between sleep-disrupting and anthropometric measures, mainly among those with morningness chronotype. Therefore, sleep quality, rather than sleep duration, maybe a moderator factor in the association between chronotype and obesity-related indicators. In addition, Malone et al.<sup>29</sup> reported that morningness/eveningness chronotype did not moderate the association between sleep duration and BMI z-scores among adolescents ( $n = 69$ ; 14 to 17 years old).

Diet is another important factor in this relationship. Although previous studies have not found a difference in daily energy intake between morning and evening chronotype,<sup>9,32</sup> it has been suggested that chronotype may influence the timing of food intake and the nutritional composition of meals.<sup>9,10</sup> Moreover, an important point in this relationship is a misalignment between chronotype and dietary intake throughout the day. Previous studies suggested that individuals with a morning chronotype consumed a higher amount of energy and nutrients at breakfast and those with an evening chronotype at dinner.<sup>9,10</sup> Notwithstanding, these associations were exactly the opposite in a study by Muñoz et al.<sup>9</sup> among participants with excess weight. Similarly, Zerón-Ruggerio et al.<sup>28</sup> suggested that breakfast is the meal most closely associated with sleep timing, while dinner timing is not influenced by sleep timing. Additionally, the same authors reported that participants with habits of early-bed and early-rise, showed the shortest time elapsed between dinner and the midpoint of sleep, and this time is associated with higher values of BMI and WC<sup>24</sup>. Therefore, these findings showed that the alignment between meals and sleep/wake cycles also could influence on obesity-related indicators.

#### 4.1 | Strengths and limitations

The strengths of this study include, firstly, the assessment of chronotype using the MESC, which has been validated and translated into Spanish. Also, adjustment for several potential confounders minimizes confounding effects and strengthens the validity of associations between chronotype and obesity-related outcomes. A key practical application of our findings is that chronotype may be associated with certain obesity-related indicators in adolescents. Therefore, we recommend that future studies expand beyond BMI measurements and consider including chronotype as a variable when examining lifestyle factors related to adolescent health. However, some limitations should be considered when interpreting our findings. This is a cross-sectional study, thus, evidence of an association can be established but not causality. Additionally, the use of questionnaires requires

caution in interpreting the results because of social desirability and recall biases. For example, sleep duration was estimated based on the time variables bedtime (i.e., time one gets into bed) and get-up time (i.e., time one gets out of bed), and therefore may refer to time in bed rather than explicit sleep duration. Finally, although we used questionnaires validated for the Spanish population and controlled for confounding variables, the risk of bias is inherent in the use of self-reported measures.

## 5 | CONCLUSION

Adolescents with a morningness chronotype may be more prone to have abdominal obesity than their counterparts with an intermediate chronotype. Furthermore, the importance of body composition in anthropometric measurements is highlighted, so as not to limit nutritional status to BMI. Finally, consistent associations were identified after controlling by potential confounders, physical activity, sedentary behaviour, sleep, and diet. Therefore, we suggest that chronotype may be considered a variable in studies analysing behaviours related to obesity-related outcomes.

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### CONFLICT OF INTEREST STATEMENT

The authors of this paper declare that they have no known financial interests or personal relationships that could have influenced the work reported in this study.

### ORCID

Miguel Angelo Duarte Junior  <https://orcid.org/0000-0002-6367-557X>

Arthur Eumann Mesas  <https://orcid.org/0000-0002-0088-8607>

Sitong Chen  <https://orcid.org/0000-0002-8975-7565>

Júlio B. Mello  <https://orcid.org/0000-0002-3013-1760>

Jorge Olivares-Arancibia  <https://orcid.org/0000-0002-7186-3941>

Aamir Raoof Memon  <https://orcid.org/0000-0002-3203-418X>

Rodrigo Yáñez-Sepúlveda  <https://orcid.org/0000-0002-9311-6576>

Ran Bao  <https://orcid.org/0000-0003-2638-5343>

José Francisco López-Gil  <https://orcid.org/0000-0002-7412-7624>

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