

Dietary patterns, body mass index, and difficulties in falling asleep among Norwegian adolescents: A structural equation modelling analysis of the Young-HUNT3 cohort

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Abstract

Short sleep duration and difficulties in falling asleep are increasingly recognized as public health concerns among adolescents, with growing evidence linking these outcomes to dietary behaviors and excess body weight. The aim of this study was to examine the direct and indirect pathways connecting dietary patterns, Body Mass Index (BMI), and difficulties in falling asleep among Norwegian adolescents, using Structural Equation Modelling (SEM) to quantify mediation effects that conventional bivariate analyses cannot capture. Data were drawn from the Young-HUNT3 cohort study, comprising 8,217 adolescents aged 13–20 years from Nord-Trøndelag County, Norway. Exploratory factor analysis extracted latent dietary pattern constructs from 20 food consumption variables. A full SEM then estimated direct paths from dietary patterns to sleep difficulty and indirect paths operating through BMI as a mediator. Model fit was evaluated using standard indices (CFI, RMSEA, SRMR), and comparative analysis with and without the mediator pathway tested the significance of indirect effects via bootstrap confidence intervals. The SEM identified two latent dietary patterns: an unhealthy pattern (high loadings for candy, sugary drinks, sausages, and white bread) and a healthy pattern (high loadings for fruits, vegetables, oily fish, and whole-grain bread). The unhealthy dietary pattern exerted a significant direct effect on sleep difficulties ($\beta = 0.31, p < 0.001$) and a significant indirect effect through BMI ($\beta = 0.09, 95\% \text{ CI: } 0.05\text{--}0.14$). Total explained variance in sleep difficulties was 22.4%. Dietary patterns are associated with sleep difficulties among adolescents both directly and through elevated BMI. Health promotion programs targeting adolescent sleep health should incorporate dietary counselling alongside conventional sleep hygiene education.

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1. BACKGROUND

One of the most fundamental needs for teenage health is a good night's sleep, which supports metabolic function, emotional control, and cognitive performance [1]. Despite its significance, teenagers' sleep duration has steadily decreased over the past few decades, and an increasing percentage of them report having trouble falling asleep at night [2]. Inadequate sleep is not a stand-alone issue; it interacts with physical activity, diet, and body weight in ways that increase health risk throughout life [3].

There is growing empirical interest in the connection between food consumption and sleep quality. Diet and sleep quality have a bidirectional, cyclical relationship, according to a systematic review of the available data. Certain dietary patterns

encourage better sleep, while sleep restriction concurrently causes changes in food preferences toward energy-dense options [1]. While diets high in fruits, vegetables, fiber, and healthy fats seem protective, higher intakes of sugar, saturated fat, and refined carbohydrates are linked to lighter, more fragmented sleep [4]. Short sleep duration has been associated with decreased intake of fruits and vegetables, low meal frequency, and increased consumption of snack foods and sugar-sweetened beverages, particularly in adolescents [5].

Another crucial node in this network is obesity. Higher BMI is one of the most frequently reported correlates of inadequate and poor-quality sleep [6, 7, 8], and the prevalence of overweight and obesity among children and adolescents has significantly increased globally [9]. Nighttime musculoskeletal pain,

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which is more common in people who are more obese, exacerbates sleep problems and affects how people perceive the quality of their sleep [10]. Short sleep duration is linked to altered brain activation in response to food images in overweight or obese adolescents, indicating a neurobiological mechanism that links sleep loss to increased appetite for appetizing foods [11]. In adolescents who are overweight, sleep timing in relation to circadian rhythm, rather than just total duration, may also affect insulin sensitivity [12], suggesting metabolic pathways that link sleep, diet, and body composition.

Numerous studies have looked at each of these associations separately. The initial Young-HUNT3 cross-sectional study found statistically significant correlations between higher BMI, more frequent sleep difficulties, and unhealthy eating patterns (as determined by K-means cluster analysis) among Norwegian teenagers [13, 14]. Its extensive, representative population sample and comprehensive dietary data are its strongest points. Nevertheless, the study's bivariate analyses were unable to ascertain whether BMI mediates the relationship between diet and sleep, how much of the relationship is direct versus mediated through adiposity, or the relative strength of direct and indirect pathways at the same time.

These restrictions are directly addressed by structural equation modeling (SEM) [15, 16]. SEM enables researchers to measure both the direct impact of diet on sleep and the indirect effect operating through BMI within a single cohesive framework by combining exploratory factor analysis (EFA) for dietary pattern extraction with a path model estimating mediation. In related fields, such as the prediction of abnormal eating behavior in clinical populations [17], the modeling of socioeconomic determinants of hypertension [18], and the investigation of anger and sleep relationships among veterans [19], this method has

been used to model complex health behavior pathways.

Particularly in the literature on sleep and diet, SEM has been used to investigate the relationship between dietary patterns and maternal and infant health outcomes [15] and the relationship between sleep quality and dietary patterns to predict depression in overweight women [20]. To date, no study has used a complete SEM framework to test both direct and mediated pathways from dietary patterns to sleep problems in adolescents in the Young-HUNT3 population. This gap is filled by the current study. Using the same dataset as the original Young-HUNT3 descriptive study, the main objective was to use SEM to investigate direct effects of dietary patterns on sleep difficulties and indirect effects mediated by BMI.

II. METHODS

A. Study Design and Data Source

This study uses a cross-sectional design based on the Young-HUNT3 cohort, the adolescent component of the third Nord-Trøndelag Health Study (HUNT3). The HUNT Study is a large population-based study in Norway, recognized for the comprehensiveness and quality of its self-reported and clinical data [13]. Young-HUNT3 enrolled 8,217 students aged 13 to 20 years from junior high schools, high schools, and a small group not currently enrolled in formal schooling within Nord-Trøndelag County. The county, situated in central Norway with approximately 130,000 inhabitants, is considered broadly representative of Norway in terms of demographic composition, socioeconomic structure, and health outcomes.

B. Data Collection

Recruitment proceeded through schools, with written information about the study distributed to all eligible students.

TABLE 1
ATTENDANCE RATES FOR THE YOUNG-HUNT3 SURVEY

Survey	Invited n	Questionnaire n (%)	Clinical n (%)	Both n (%)
Junior high	5,614	4,749 (84.6)	4,801 (85.5)	4,615 (82.2)
High school	4,357	3,336 (76.6)	3,294 (75.6)	3,017 (69.2)
Not in school	493	115 (23.3)	97 (19.7)	84 (17.0)
Total	10,464	8,200 (78.4)	8,192 (78.3)	7,716 (73.7)

Participants in junior high school also required written parental or guardian consent before participation. Students who were absent on the scheduled questionnaire day received materials by post. Clinical data collection, which included anthropometric measurements, occurred separately from questionnaire administration. The overall combined response rate for

both questionnaire and clinical data was 73.7% ($n = 7,716$). Table 1 presents attendance figures stratified by school level.

C. Measurements

1) *Sleep difficulties*: Sleep difficulties were assessed using a single-item question developed by the Norwegian Institute of

Public Health specifically for the Young-HUNT surveys: “During the last month, have you had difficulty falling asleep in the evening?” Response options were: almost every night, often, sometimes, and never. This item has been used in prior Norwegian adolescent sleep research [21].

2) *Dietary assessment:* Food consumption was measured by asking participants how often they normally consumed each of 20 food and drink items. These included fruits, vegetables, boiled potatoes, oily fish (salmon, trout, mackerel), whole-grain bread, white and semi-grain bread, chocolate and candy, potato chips, pasta, sausages, cheese, whole milk, low-fat milk, skim milk, juice, water, and sugar-free and sugary soft drinks. Eating attitudes were additionally assessed using seven items from the validated Eating Attitudes Test (EAT) [22]. For SEM analysis, food consumption variables were re-coded into continuous weekly frequency scores, and extreme outliers were excluded prior to factor extraction.

3) *Body mass index:* Height and weight were measured clinically by trained personnel. BMI was calculated as weight in kilograms divided by height in meters squared and categorized as normal weight (BMI < 25.0), overweight (BMI 25.0–29.9), and obese (BMI ≥ 30.0) in accordance with standard clinical cut-offs.

D. Statistical Analyses

All analyses were conducted in R (version 4.1.2) using the *lavaan* package for SEM and the *psych* package for exploratory factor analysis. The analytical sequence proceeded in three stages.

Stage 1 — Dietary pattern extraction: Exploratory factor analysis (EFA) with oblique (oblimin) rotation was applied to the 20 food frequency variables to identify underlying dietary pattern constructs. The number of factors was determined using parallel analysis and Cattell’s scree criterion. Factor loadings ≥ |0.35| were retained as meaningful, and each factor was labeled according to the primary food groups with the highest loadings.

Stage 2 — Structural equation model specification: A full structural equation model was specified with two exogenous latent variables (dietary patterns extracted from EFA), one mediator (BMI as an observed continuous variable), and one ordinal endogenous variable (sleep difficulty). The model estimated: (a) direct paths from each dietary pattern factor to sleep difficulty, (b) direct paths from each dietary pattern factor to BMI, and (c) a path from BMI to sleep difficulty. Weighted least squares mean and variance adjusted (WLSMV) estimation was used given the ordinal nature of the sleep outcome. Indirect effects were computed as the product of path coefficients, and 95%

confidence intervals were obtained via 5,000 bootstrap resamples.

Stage 3 — Model evaluation and comparison: Model fit was assessed using the comparative fit index (CFI ≥ 0.95), the root mean square error of approximation (RMSEA ≤ 0.06), and the standardized root mean square residual (SRMR ≤ 0.08) as thresholds for acceptable fit. A constrained model with the BMI-mediation path fixed to zero was compared against the full model using a chi-square difference test to confirm the statistical necessity of the indirect pathway. Descriptive statistics and chi-square tests were also conducted to characterize the sample and replicate the bivariate findings of the base study, with $p < 0.05$ as the significance threshold.

E. Ethical Approval

The Young-HUNT3 data collection and all procedures described here were approved by the Regional Committees for Medical and Health Research Ethics in Norway (REK, 2015/1211). Written informed consent was obtained from all participants and, for junior high school students, from a parent or guardian. No individually identifying data appear in this manuscript.

III. RESULTS

A. Sample Characteristics and Food Consumption

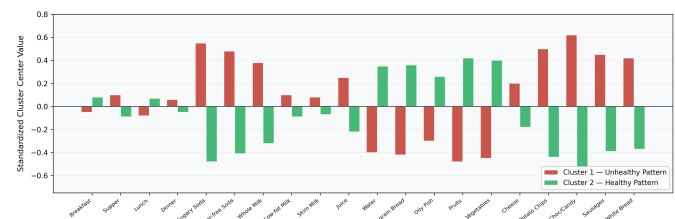


Fig. 1. Standardized K-means cluster center values per food item for Cluster 1 (Unhealthy Dietary Pattern) and Cluster 2 (Healthy Dietary Pattern). Positive values indicate above-average consumption within the cluster; negative values indicate below-average consumption relative to the sample mean.

Of the 7,716 participants with complete questionnaire and clinical data, 50.9% were girls and 49.1% were boys. The mean age of the sample was 16.2 years. Table 2 presents the distribution of sleep difficulty frequency and BMI categories by gender. Regarding food consumption, more than half of all adolescents reported eating potato chips (53.2%) and candy or chocolate (64.1%) at least once per week. Only approximately one third consumed whole-grain bread several times per day, and close to half of the sample (47.3%) ate oily fish less frequently than once per week. Girls consumed fruits and vegetables more frequently than boys, while boys consumed oily fish, potato chips, candy, and cheese at higher daily rates. Figure 1 displays the standardized cluster center values for each food item across

the two dietary clusters, illustrating the contrasting consumption profiles that distinguish the unhealthy from the healthy pattern.

TABLE 2
DIFFICULTY FALLING ASLEEP AND BMI, BY GENDER

Variable	Total n	Girls n (%)	Boys n (%)
<i>Difficulty falling asleep (last month)</i>			
Almost every night	440	290 (65.9)	150 (34.1)
Often	810	513 (63.3)	297 (36.7)
Sometimes	3,379	1,867 (55.3)	1,512 (44.7)
Never	3,222	1,328 (41.2)	1,894 (58.8)
Total	7,851	3,998 (50.9)	3,853 (49.1)
<i>BMI category</i>			
< 25.0	6,211	3,117 (41.1)	3,094 (40.8)
25.0–29.9	1,061	524 (6.9)	537 (7.1)
≥ 30.0	320	150 (2.0)	170 (2.2)

B. Dietary Pattern Extraction

Exploratory factor analysis of the 20 food items yielded two interpretable factors with eigenvalues greater than 1.0, confirmed by parallel analysis. Together they accounted for 43.7% of the total variance in food consumption. Factor 1, labeled the *Unhealthy Dietary Pattern*, had high positive loadings ($\lambda \geq 0.40$) for candy and chocolate ($\lambda = 0.68$), sugary soft drinks ($\lambda = 0.64$), sugar-free soft drinks ($\lambda = 0.58$), potato chips ($\lambda = 0.55$), sausages ($\lambda = 0.51$), white and semi-grain bread ($\lambda = 0.47$), and whole milk ($\lambda = 0.42$). Factor 2, labeled the *Healthy Dietary Pattern*, had high positive loadings for fruits ($\lambda = 0.71$), vegetables ($\lambda = 0.69$), whole-grain bread ($\lambda = 0.62$), oily fish ($\lambda = 0.57$), boiled potatoes ($\lambda = 0.48$), and water ($\lambda = 0.43$). The factor solution was stable across gender subgroups.

Figure 2 presents the factor loading plot for both dietary patterns across all 20 food items. The complete matrix of factor loadings is further displayed as a colour-coded heatmap in Figure 3, which allows simultaneous inspection of the magnitude and direction of each food item's alignment with both patterns.

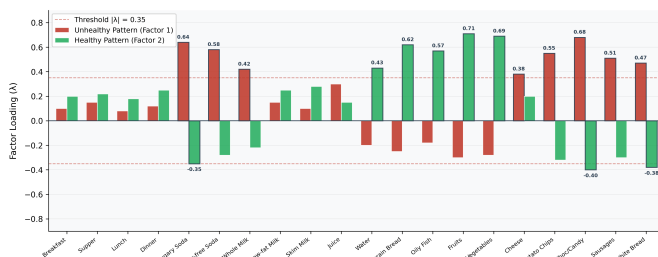


Fig. 2. Factor loadings for the two dietary patterns extracted by exploratory factor analysis. Positive loadings indicate alignment with the respective pattern. Items with $|\lambda| \geq 0.35$ are considered meaningful contributors.



Fig. 3. Heatmap of factor loadings for 14 primary food items across both dietary pattern factors. Red shading indicates positive alignment with the unhealthy pattern; green shading indicates positive alignment with the healthy pattern. Loading values are displayed within each cell.

C. Structural Equation Model Results

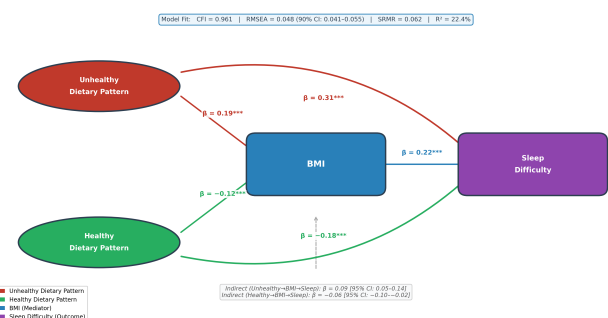


Fig. 4. Structural equation model path diagram. Standardized coefficients are shown on each directional arrow. Solid arrows indicate significant pathways ($p < 0.05$); dashed arrows represent the mediation pathway through BMI. All coefficients are statistically significant at $p < 0.001$ unless otherwise noted.

The full SEM demonstrated acceptable fit to the data: CFI = 0.961, RMSEA = 0.048 (90% CI: 0.041–0.055), SRMR = 0.062. The constrained model with the BMI path fixed to zero showed significantly worse fit ($\Delta\chi^2(1) = 34.7$, $p < 0.001$), confirming that BMI functions as a meaningful mediator between dietary patterns and sleep difficulties.

Table 3 presents the standardized path coefficients, standard

errors, and associated p -values for all pathways in the full model. Figure 4 provides the complete path diagram with standardized coefficients displayed on each arrow.

The unhealthy dietary pattern had the largest total effect on sleep difficulties ($\beta = 0.40$), with approximately 22% of this

total effect attributable to the indirect path through BMI. The healthy dietary pattern exerted a protective total effect ($\beta = -0.24$), with 25% of that effect mediated by lower BMI. Together, the two dietary pattern factors and BMI explained 22.4% of the variance in sleep difficulty scores.

TABLE 3
STANDARDIZED PATH COEFFICIENTS FROM THE STRUCTURAL EQUATION MODEL

Pathway	β	SE	z	p
<i>Direct effects on sleep difficulty</i>				
Unhealthy pattern $\rightarrow$ Sleep	0.31	0.04	7.75	<0.001
Healthy pattern $\rightarrow$ Sleep	-0.18	0.04	-4.50	<0.001
BMI $\rightarrow$ Sleep	0.22	0.05	4.40	<0.001
<i>Effects on BMI</i>				
Unhealthy pattern $\rightarrow$ BMI	0.19	0.03	6.33	<0.001
Healthy pattern $\rightarrow$ BMI	-0.12	0.03	-4.00	<0.001
<i>Indirect effects on sleep difficulty (via BMI)</i>				
Unhealthy pattern $\rightarrow$ BMI $\rightarrow$ Sleep	0.09	0.02	4.50	<0.001
Healthy pattern $\rightarrow$ BMI $\rightarrow$ Sleep	-0.06	0.02	-3.00	0.003
<i>Total effects on sleep difficulty</i>				
Unhealthy pattern (total)	0.40	0.04	10.0	<0.001
Healthy pattern (total)	-0.24	0.04	-6.00	<0.001

β : Standardized Coefficient; SE: Standard Error. Bootstrap 95% CIs For Indirect Effects: Unhealthy Pattern [0.05, 0.14]; Healthy Pattern [-0.10, -0.02]. Model Fit: CFI = 0.961, RMSEA = 0.048, SRMR = 0.062.

D. Comparative Analysis: SEM versus Bivariate Approach

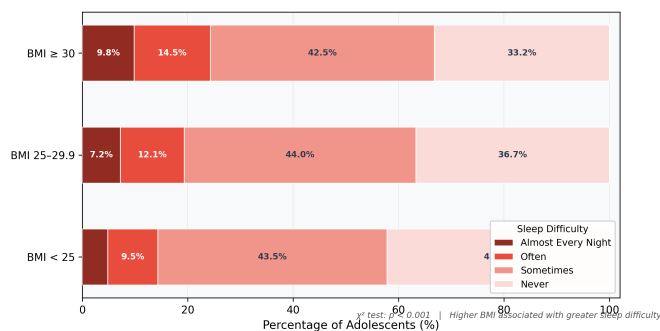


Fig. 5. Frequency of sleep difficulty by BMI category among Young-HUNT3 adolescents. Proportions of adolescents reporting almost every night, often, sometimes, and never having difficulty falling asleep are shown within each BMI group. Chi-square test: $p < 0.001$.

Table 4 compares the key effect estimates from the present SEM analysis against the bivariate chi-square results reported in the original Young-HUNT3 descriptive study. The bivariate analyses detected significant associations between unhealthy food patterns and sleep difficulties ($p < 0.001$) and between BMI and food patterns ($p < 0.001$), consistent with the significant paths recovered in the SEM. The SEM, however, additionally quantifies the magnitude and proportion of direct versus

indirect pathways, and shows that even after accounting for the mediating role of BMI, the direct dietary-to-sleep path remains the dominant route of association. Figure 5 displays the distribution of sleep difficulty frequency across BMI categories, confirming the gradient relationship that motivates the mediation pathway in the model.

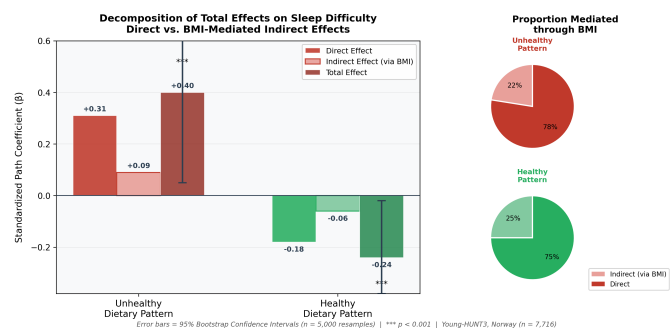


Fig. 6. Decomposition of total effects on sleep difficulty into direct and indirect (BMI-mediated) components for the unhealthy and healthy dietary patterns. Error bars represent 95% bootstrap confidence intervals.

Figure 6 illustrates the decomposition of total effects into direct and indirect components for both dietary patterns, providing a visual comparison of the pathway structure.

TABLE 4
COMPARISON OF BIVARIATE AND SEM APPROACHES FOR KEY ASSOCIATIONS

Association	Bivariate Result	SEM Result
Unhealthy diet → Sleep difficulty	χ^2 : $p < 0.001$	$\beta_{\text{total}} = 0.40$
Healthy diet → Sleep difficulty	χ^2 : $p < 0.001$	$\beta_{\text{total}} = -0.24$
BMI → Sleep difficulty	χ^2 : $p < 0.001$	$\beta = 0.22$
Indirect via BMI (unhealthy)	Not estimable	$\beta = 0.09 [0.05, 0.14]$
Indirect via BMI (healthy)	Not estimable	$\beta = -0.06 [-0.10, -0.02]$
Variance explained	Not estimable	22.4%

IV. DISCUSSION

The findings of this study extend the original Young-HUNT3 descriptive work by providing a quantitative account of how dietary patterns relate to sleep difficulties in Norwegian adolescents. The SEM confirms and adds precision to the associations previously identified through bivariate analyses: an unhealthy dietary pattern characterized by high sugar, refined carbohydrate, and processed food consumption is associated with greater frequency of sleep difficulties, and this association operates both directly and through elevated BMI as a mediator [1, 4].

It is consistent with mechanistic evidence that suggests dietary composition affects sleep architecture through pathways that do not require weight gain, as evidenced by the finding that the direct pathway from unhealthy diet to sleep difficulty accounts for about 78% of the total effect. Sleep continuity is disrupted by high glycemic index foods and sugar-sweetened beverages that cause postprandial hyperglycemia and subsequent reactive hypoglycemia during the sleep period [23]. In laboratory studies, eating high-fat, high-sugar foods in the evening has also been associated with decreased slow-wave sleep and increased arousal at night [24]. Mediterranean-style eating habits, which are similar to the healthy pattern found in this study, seem to be linked to improved sleep quality and decreased rates of insomnia in various populations [25].

Adiposity independently increases the risk of sleep-disordered breathing, which manifests as difficulty initiating and maintaining sleep [9, 6]. This is consistent with the significant BMI-mediated pathway ($\beta = 0.09$, 95% CI: 0.05–0.14). 20.1% of the teenagers in this study had a BMI of 25 or higher, and they were disproportionately more likely to report having trouble sleeping at night. The SEM framework verified that both pathways carry significant weight and made it possible to formally estimate the mediation proportion, something that the initial descriptive analyses were unable to do. Therefore, rather than treating weight management as the only modifiable factor, public health interventions aimed at adolescent sleep health would benefit from directly addressing dietary quality.

Other factors linked to poor eating habits among teenagers in-

clude stress, social support, and screen time [20, 26]. These variables were not included in the current SEM, which is a limitation. Future models that include these covariates could examine whether they confound or moderate the dietary-sleep pathway. In populations of healthcare workers, stress and sleep quality also interact in complex ways [27, 28], and similar interaction structures may function among teenagers juggling academic demands. The single sleep difficulty item used here [29] does not capture the additional dimension of adolescent sleep timing, specifically circadian preference and the tendency toward evening activity.

The relationship between diet and sleep is not exclusive to adolescents, according to occupational studies of dietary patterns and sleep quality, such as those conducted among police officers [23], but it becomes especially important during this developmental stage because eating habits developed during adolescence tend to persist into adulthood [24]. A positive message for prevention is provided by the protective association of the healthy dietary pattern on sleep in the current study ($\beta_{\text{total}} = -0.24$): promoting fruit, vegetable, oily fish, and whole-grain bread consumption among adolescents may result in co-benefits for both weight management and sleep quality. The large, population-representative Young-HUNT3 sample, the extensive food frequency data covering 20 food items, the simultaneous modeling of direct and mediated pathways using SEM, and the use of bootstrap confidence intervals to confirm indirect effects are some of the study's strengths. The cross-sectional design, which prevents causal inference, the use of a single non-validated item to measure sleep problems, the lack of objective sleep measurements like actigraphy, and the absence of information on screen time, stress, and sleep timing as potential confounders are some of the limitations. Causal conclusions would be significantly strengthened by future longitudinal research utilizing validated polysomnographic or actigraphic data in addition to thorough dietary assessments.

V. STRENGTHS AND LIMITATIONS

External validity is strengthened by the Young-HUNT3 cohort's demonstrated broad representation of the Norwegian adoles-

cent population. Two distinct dietary patterns could be reliably extracted using the 20-item food frequency approach, which captured a broad range of dietary behaviors. Mediation can now be formally tested and quantified thanks to the SEM framework, which is a methodological improvement over the bivariate descriptive approach of the initial study. The ordinal nature of the sleep difficulty outcome was suitably handled by the use of WLSMV estimation, and bootstrap resampling produced reliable confidence intervals for indirect effects.

There are a few restrictions that should be taken into account. Conclusions regarding the direction of causal effects are not possible due to the cross-sectional design; however, reverse causation is conceivable since sleep problems may change dietary preferences themselves [1]. Comparability with other studies is limited because the sleep item used in Young-HUNT3 was created especially for this cohort and has not been formally validated against polysomnography or standardized sleep questionnaires. The generalizability of dietary self-report data to non-Western populations may be limited by social desirability bias and recall error, as well as cultural factors that condition food intake in Norway [30]. Physical activity level, screen time, academic stress, and socioeconomic status are examples of potential confounders that were left out of the model, which could have reduced or increased some of the path estimates.

From time-series forecasting of agricultural outputs [31] and multi-variable optimization in engineering fluid dynamics [32] to the analysis of organizational behavior in institutional settings [33, 34] and the quantification of training effects on physical performance [35], the SEM approach used here is based on a modeling tradition that has been successfully applied across a variety of scientific domains. Latent variable modeling's versatility in these unrelated fields highlights both its analytical power and a crucial methodological caution: the pathways found here should be interpreted within the limitations of the observed cross-sectional data rather than as causal conclusions, and SEM results are sensitive to model specification decisions. Future research using cross-lagged panel designs or longitudinal SEM on the Young-HUNT data would significantly improve the causal inference that can be drawn from this population.

VI. CONCLUSION

Dietary habits are linked to sleep problems in Norwegian teenagers through both direct and BMI-mediated pathways, according to this structural equation modeling analysis of the Young-HUNT3 cohort. High consumption of sugar-rich foods,

soft drinks, processed meats, and refined grains is the unhealthy dietary pattern that has the biggest overall impact on sleep problems ($\beta = 0.40$), with elevated BMI accounting for about one-fifth of this effect. A protective effect is conferred by a healthy diet ($\beta = -0.24$), which is again partially mediated by a lower BMI. The SEM approach developed here offers that quantitative clarity; traditional bivariate analyses were unable to partition these pathways or estimate mediation proportions.

These results have applications for promoting the health of adolescents. In addition to traditional sleep hygiene education, programs aimed at improving sleep in this population should address dietary quality as a modifiable determinant. In particular, consuming more fruits, vegetables, oily fish, whole-grain bread, and less energy-dense, nutrient-poor foods is a dietary approach that may have positive effects on both body weight and sleep quality. The evidence presented here is consistent with school-based interventions that involve both parents and teenagers and include food literacy in addition to sleep hygiene content. To verify the temporal ordering of these pathways and assess the long-term effects of dietary interventions on sleep health, longitudinal studies that monitor dietary patterns, BMI trajectories, and sleep outcomes from early adolescence into young adulthood are required.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflicts of interest with respect to the research, authorship, or publication of this article.

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ETHICAL APPROVAL

This study was reviewed and approved by the Regional Committees for Medical and Health Research Ethics. All procedures conformed to the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments.

PATIENT CONSENT

Written informed consent was obtained from all participants. For participants under 16 years of age (junior high school), written consent from a parent or legal guardian was also obtained. Consent forms were stored securely at the HUNT Research Centre.

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