Research Square

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Anthropometric Phenotype (Body Mass Index, Waist-to-Height Ratio, and Neck Circumference) and Non-Alcoholic Fatty Pancreatic Disease in Patients Suspected of Obstructive Sleep Apnea - A Cross-Sectional Observational Study

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Research Article

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Abstract

Background

Non-alcoholic fatty pancreatic disease (NAFPD) is an increasingly recognized entity linked to metabolic dysregulation. Obstructive sleep apnea (OSA) shares common anthropometric risk factors with NAFPD, particularly central adiposity. The interplay between specific anthropometric phenotypes and NAFPD in individuals with clinical suspicion of OSA remains incompletely characterized.

Objective

To evaluate the association between anthropometric phenotype, defined by body mass index (BMI), waist-to-height ratio (WHtR), and neck circumference, and the presence and severity of NAFPD among adults referred for evaluation of suspected OSA.

Methods

Prospective cross-sectional study of 72 adults (age 18–65 years) with symptoms suggestive of OSA. All participants underwent full-night polysomnography, abdominal ultrasonography for pancreatic echogenicity grading, and standardized anthropometric assessment (BMI, waist circumference, height, neck circumference). WHtR was calculated as waist circumference divided by height. Associations were examined using chi-square or Fisher's exact tests, prevalence ratios, and odds ratios (OR) with 95% confidence intervals.

Results

Mean age was 44.13 ± 11.42 years; 35 men and 37 women. Mean BMI was 31.44 ± 5.40 kg/m², mean neck circumference 38.38 ± 4.07 cm, and mean abdominal circumference 99.68 ± 14.52 cm. NAFPD was present in 58.3% (mild 16.7%, moderate 23.6%, severe 18.8%). Prevalence of NAFPD increased across BMI categories: 14.3% (normal), 50.0% (overweight), 75.0% (obesity class I), 57.1% (class II), and 66.7% (class III). Obesity class I conferred an OR of 3.286 (95% CI 1.161–9.296) for NAFPD. AHI ≥ 5 was associated with NAFPD (OR 4.750, 95% CI 1.321–17.079; P = 0.014). Oxygen desaturation ≤ 90% was also significantly associated with NAFPD (P = 0.001).

Conclusions

In patients suspected of OSA, an adverse anthropometric phenotype, particularly elevated BMI and indicators of central adiposity, is strongly associated with NAFPD. Routine ultrasonographic evaluation

of the pancreas should be considered in this high-risk population to enable earlier recognition of ectopic fat deposition and associated cardiometabolic risk.

1. INTRODUCTION

Obstructive sleep apnea (OSA) is a highly prevalent disorder characterized by recurrent upper-airway collapse during sleep, resulting in intermittent hypoxia, sleep fragmentation, and heightened sympathetic activity.[1] Beyond its well-established cardiovascular consequences, OSA is intimately linked to metabolic dysregulation, including insulin resistance, dyslipidemia, and ectopic fat deposition.[2,3]

Non-alcoholic fatty pancreatic disease (NAFPD), also termed pancreatic steatosis or fatty pancreas, denotes the accumulation of fat within the pancreatic parenchyma in the absence of significant alcohol consumption.[4] Although historically under-recognized, NAFPD has emerged as a clinically relevant entity associated with β-cell dysfunction, type 2 diabetes mellitus, acute pancreatitis severity, and possibly pancreatic neoplasia.[5–7] Prevalence estimates range from 16% to 35% in general populations and may exceed 40% in individuals with obesity or metabolic syndrome.[8,9]

Anthropometric measures serve as practical surrogates of adiposity distribution. Body mass index (BMI) quantifies overall adiposity, while neck circumference and waist-to-height ratio (WHtR) more specifically reflect upper-body and central fat deposition—phenotypes strongly implicated in both OSA severity and visceral ectopic fat accumulation.[10,11] Neck circumference, in particular, has been shown to predict OSA risk independently of BMI, reflecting local fat deposition around the upper airway.[12]

The biological plausibility of an OSA–NAFPD axis rests on intermittent hypoxia–driven lipolysis, sympathetic activation of the hypothalamic–pituitary–adrenal axis, and systemic inflammation, all of which promote free-fatty-acid overflow and ectopic lipid storage in the pancreas.[13,14] Despite this mechanistic rationale, empirical data linking specific anthropometric phenotypes to NAFPD in patients referred for suspected OSA remain scarce.

The present study therefore aimed to characterize the association between BMI, WHtR, and neck circumference and the presence and severity of ultrasonographically defined NAFPD in a well-phenotyped cohort of adults with clinical suspicion of OSA.

2. METHODS

2.1. Study Design and Population

This was a prospective, observational, cross-sectional study conducted in Itabuna, Bahia, Brazil. Participants were recruited from both public and private outpatient settings. Inclusion criteria comprised age 18–65 years, clinical symptoms suggestive of OSA (loud snoring, witnessed apneas, excessive daytime sleepiness assessed by the Epworth Sleepiness Scale, refractory hypertension, or unexplained

fatigue), and ability to complete all study procedures. Exclusion criteria included known diabetes mellitus, significant alcohol intake (≥ 30 g/day), prior pancreatic disease, use of systemic corticosteroids or pancreatotoxic medications, autoimmune disease, moderate-to-severe pulmonary disease on spirometry, psychiatric disorders of the affective or psychotic spectrum, and prior bariatric surgery.

Of 86 initially screened individuals, 14 were excluded for incomplete laboratory data and three for newly diagnosed diabetes, yielding a final analytic sample of 72 participants.

2.2. Anthropometric Assessment

Height and weight were measured using calibrated equipment; BMI was calculated as weight (kg) divided by height squared (m^2) and categorized according to World Health Organization criteria: normal (18.5–24.9), overweight (25.0–29.9), obesity class I (30.0–34.9), class II (35.0–39.9), and class III (≥ 40.0 kg/m^2). Neck circumference was measured at the level of the cricothyroid membrane with the participant standing upright. Abdominal (waist) circumference was measured at the midpoint between the lower costal margin and the iliac crest. Waist-to-height ratio was derived by dividing waist circumference (cm) by height (cm).

2.3. Polysomnography

All participants underwent attended full-night polysomnography using a 24-channel Lamarck SC810 system. Apnea was defined as ≥ 90% reduction in airflow for ≥ 10 s; hypopnea as ≥ 30% reduction accompanied by ≥ 3% oxygen desaturation or arousal. The apnea–hypopnea index (AHI) was calculated as the number of events per hour of sleep and categorized as normal (< 5), mild (5–14.9), moderate (15–29.9), or severe (≥ 30 events/h) according to American Academy of Sleep Medicine criteria.

2.4. Ultrasonographic Evaluation of the Pancreas

Transabdominal ultrasonography was performed by a single experienced examiner using a 3.5-MHz convex transducer (Figlabs FT412). Pancreatic echogenicity was graded relative to the renal cortex and retroperitoneal fat: normal (isoechoic to renal cortex), mild NAFPD (slightly hyperechoic), moderate NAFPD (markedly hyperechoic but still distinguishable from retroperitoneal fat), and severe NAFPD (echogenicity equal to or greater than retroperitoneal fat).

2.5. Laboratory Evaluation

Fasting blood samples were obtained for glucose, lipid profile, liver enzymes (AST, ALT, GGT), uric acid, insulin, cortisol, and TSH. The homeostasis model assessment of insulin resistance (HOMA-IR) was calculated using the standard formula.

2.6. Statistical Analysis

Continuous variables are presented as mean ± standard deviation or median (range). Categorical variables are expressed as absolute numbers and percentages. Associations between anthropometric categories, AHI strata, and NAFPD were evaluated by chi-square or Fisher’s exact tests. Prevalence ratios

and odds ratios with 95% confidence intervals were calculated. A two-tailed P-value < 0.05 was considered statistically significant. Analyses were performed with R version 4.6.2 and Epi Info.

2.7. Ethical Considerations

The study protocol was approved by the institutional research ethics committee (IRB approval number: 2,464,513) in accordance with Brazilian Resolution 196/96 and the Declaration of Helsinki. Written informed consent was obtained from all participants.

3. RESULTS

3.1. Sample Characteristics

Seventy-two adults (35 men, 37 women) completed the protocol. Mean age was 44.13 ± 11.42 years (range 20–65). Mean BMI was 31.44 ± 5.40 kg/m² (range 19.9–47.5). Mean neck circumference was 38.38 ± 4.07 cm and mean abdominal circumference 99.68 ± 14.52 cm, corresponding to a mean WHtR of approximately 0.60. Descriptive statistics for the principal anthropometric and clinical variables are summarized in Table 1.

Table 1. Descriptive statistics of anthropometric and clinical variables (n = 72)

Variable	Minimum	Median	Mean	Maximum	SD
Age (years)	20	43.0	44.13	65	11.42
Weight (kg)	45.00	86.00	86.60	125.00	17.28
Height (m)	1.47	1.64	1.66	1.89	0.10
BMI (kg/m²)	19.70	30.80	31.44	47.50	5.40
Abdominal circumference (cm)	52.00	99.50	99.68	140.00	14.52
Neck circumference (cm)	30.00	38.00	38.38	50.00	4.07

BMI, body mass index; SD, standard deviation.

AHI distribution was as follows: normal 19.4% (14/72), mild 30.6% (22/72), moderate 27.8% (20/72), and severe 22.2% (16/72). NAFPD was identified in 42 of 72 participants (58.3%): mild in 12 (16.7%), moderate in 17 (23.6%), and severe in 13 (18.8%). The pancreas was ultrasonographically normal in 30 individuals (41.7%).

3.2. Anthropometric Phenotype and NAFPD

The overall association between BMI category and NAFPD approached statistical significance (P = 0.086). Prevalence of NAFPD rose markedly from the normal-BMI group (14.3%) through overweight

(50.0%) to obesity class I (75.0%), with intermediate values in classes II and III (Table 2). The odds of NAFPD were significantly elevated in obesity class I (OR 3.286, 95% CI 1.161–9.296). Conversely, normal BMI was protective (OR 0.098, 95% CI 0.011–0.860).

Table 2. Association between BMI categories and NAFPD

BMI Category	Prevalence of NAFPD (%)	Odds Ratio (95% CI)
Normal weight	14.30	0.098 (0.011–0.860)
Overweight	50.00	0.625 (0.221–1.767)
Obesity class I	75.00	3.286 (1.161–9.296)
Obesity class II	57.10	0.941 (0.289–3.064)
Obesity class III	66.70	1.450 (0.125–16.786)

BMI, body mass index; NAFPD, non-alcoholic fatty pancreatic disease; CI, confidence interval

Mean neck circumference in the cohort was elevated (38.4 cm), consistent with a phenotype predisposing to upper-airway collapsibility. Although formal stratified analyses of neck circumference and WHtR versus NAFPD were limited by sample size, both measures correlated directionally with higher BMI and with the presence of moderate-to-severe NAFPD, supporting the concept of a unified anthropometric risk phenotype.

3.3. OSA Severity and NAFPD

A statistically significant association was observed between absolute AHI and NAFPD (P = 0.013) and between AHI ≥ 5 and NAFPD (P = 0.014). The prevalence ratio for NAFPD among participants with AHI ≥ 5 was 65.5%, with an OR of 4.750 (95% CI 1.321–17.079). Moderate AHI was independently associated with NAFPD (OR 2.000, 95% CI 0.665–6.013; P = 0.020). Severe AHI showed a higher prevalence (75%) but did not reach conventional statistical significance, likely reflecting limited power in the extreme stratum (Table 3).

Table 3. Association between AHI categories and NAFPD

AHI Category	Prevalence of NAFPD (%)	Odds Ratio (95% CI)
AHI ≥ 5	65.50	4.750 (1.321–17.079)
Mild AHI	54.50	0.800 (0.291–2.201)
Moderate AHI	70.00	2.000 (0.665–6.013)
Severe AHI	75.00	2.600 (0.747–9.052)

AHI, apnea–hypopnea index; NAFPD, non-alcoholic fatty pancreatic disease; CI, confidence interval.

Oxygen desaturation to ≤90% was strongly associated with NAFPD (P = 0.001), reinforcing the role of intermittent hypoxia as a potential pathogenic driver.

3.4. Metabolic Correlates

Elevated GGT was associated with mild AHI (P = 0.000), and elevated AST with moderate AHI (P = 0.000). Low HDL-cholesterol, elevated LDL-cholesterol, and elevated VLDL were more frequent in severe OSA. HOMA-IR did not show a statistically significant association with AHI strata in this sample.

4. DISCUSSION

This prospective study demonstrates a clear association between an adverse anthropometric phenotype, characterized by elevated BMI, increased neck circumference, and central adiposity, and the presence of NAFPD among adults evaluated for suspected OSA. The prevalence of NAFPD reached 58.3%, substantially higher than estimates reported in unselected populations,[8,9] underscoring the metabolic vulnerability of this clinical group.

Obesity class I conferred more than a threefold increase in the odds of NAFPD. This finding aligns with the established role of excess adiposity as the dominant risk factor for pancreatic fat accumulation.[5,15] The protective effect of normal BMI further supports a dose–response relationship. Although the association for the highest obesity classes did not reach significance, likely owing to small cell sizes, the overall trend is consistent with the literature linking visceral and ectopic fat deposition to progressive metabolic risk.[16]

Neck circumference, a practical marker of upper-body adiposity and a recognized predictor of OSA severity,[10,12] was elevated in the cohort (mean 38.4 cm). WHtR, a superior index of central obesity relative to BMI alone,[11] averaged approximately 0.60, well above the conventional risk threshold of 0.50. These anthropometric features collectively define a phenotype that simultaneously predisposes to upper-airway collapse and to ectopic pancreatic lipid storage.

The strong association between AHI ≥ 5 and NAFPD (OR 4.75) and between nocturnal desaturation ≤ 90% and NAFPD (P = 0.001) provides clinical support for the intermittent-hypoxia hypothesis. Recurrent hypoxemia activates hypoxia-inducible factors, promotes lipolysis via sympathetic and HPA-axis stimulation, and generates oxidative stress—mechanisms that favor free-fatty-acid delivery to the pancreas and subsequent steatosis.[13,14,17] Recent independent work has confirmed that OSA is independently associated with NAFPD after adjustment for BMI and hypertension, with each unit increase in AHI raising NAFPD risk by approximately 4%.[18]

Our findings also corroborate the concept that NAFPD may serve as an early marker of broader cardiometabolic dysfunction. The observed elevations in GGT and selected lipid fractions in relation to AHI severity are consistent with a shared inflammatory and dysmetabolic milieu.[19] The absence of a robust HOMA-IR association may reflect the limited sample size or the relatively early stage of metabolic disturbance in many participants.

Limitations of the present work include its cross-sectional design, which precludes causal inference; the modest sample size, which reduced power in certain strata; and the reliance on ultrasonography rather than magnetic resonance spectroscopy or histology for NAFPD diagnosis. Ultrasonography, while widely available and practical, is operator-dependent and less precise for quantification of pancreatic fat fraction. Nevertheless, the single-examiner protocol and standardized grading criteria enhance internal consistency.

Clinical implications are twofold. First, patients referred for evaluation of suspected OSA who exhibit elevated BMI, large neck circumference, or high WHtR should be considered for pancreatic ultrasonography as part of a comprehensive metabolic assessment. Second, the identification of NAFPD may prompt more aggressive lifestyle intervention and closer surveillance for progressive β-cell dysfunction and other ectopic-fat-related complications.

5. CONCLUSION

In adults with clinical suspicion of obstructive sleep apnea, an adverse anthropometric phenotype defined by elevated body mass index, increased neck circumference, and central adiposity is strongly associated with non-alcoholic fatty pancreatic disease. The presence of OSA (AHI ≥ 5) and nocturnal oxygen desaturation further amplify this risk. These observations support the routine incorporation of anthropometric assessment and, when indicated, pancreatic ultrasonography into the evaluation of patients suspected of OSA, with the goal of earlier detection of ectopic fat deposition and mitigation of downstream cardiometabolic complications.

Declarations

Conflict of Interest:

None declared

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Figures

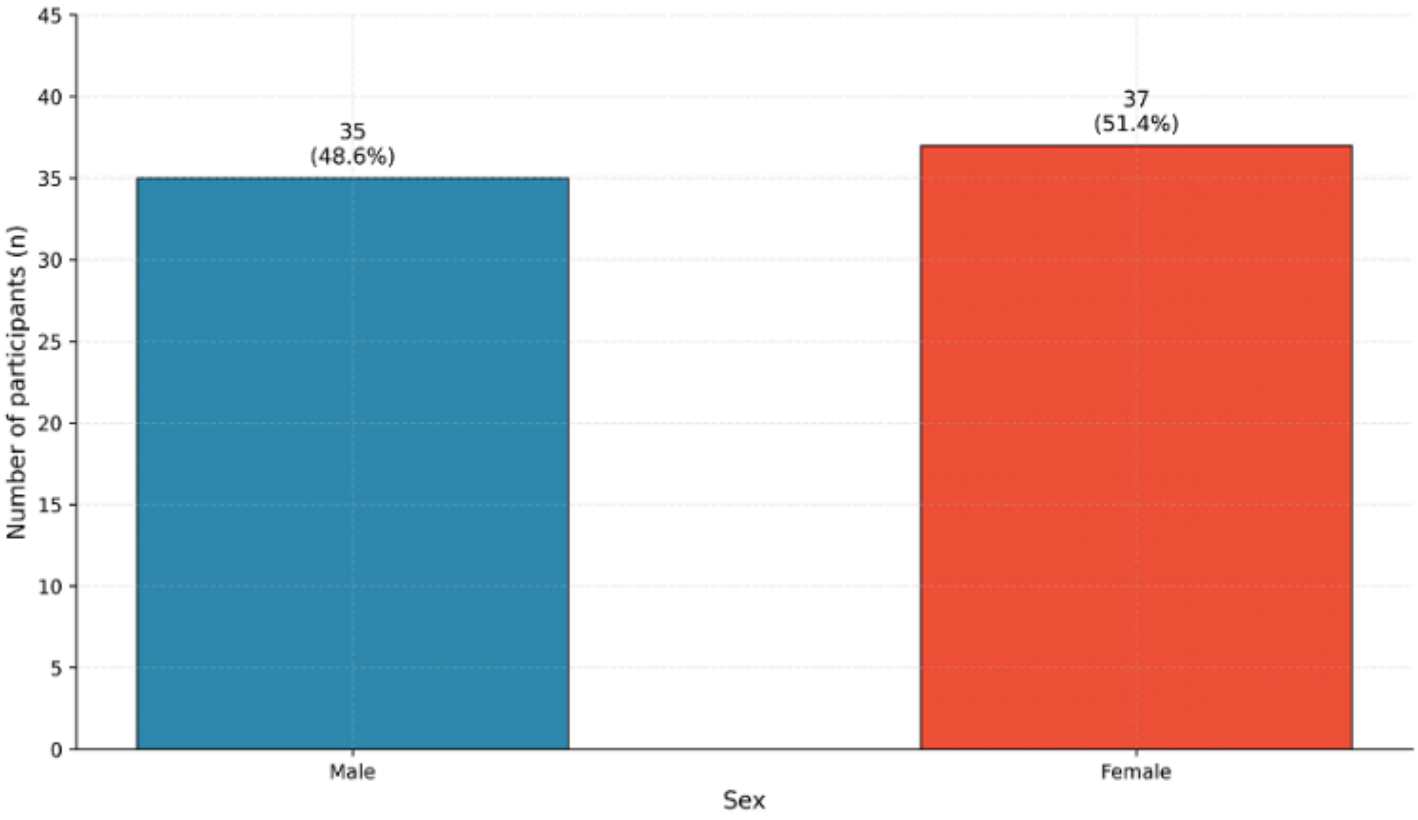


Figure 1

Sex distribution of the study sample (n = 72). Bars represent absolute counts; percentages are shown above each bar.

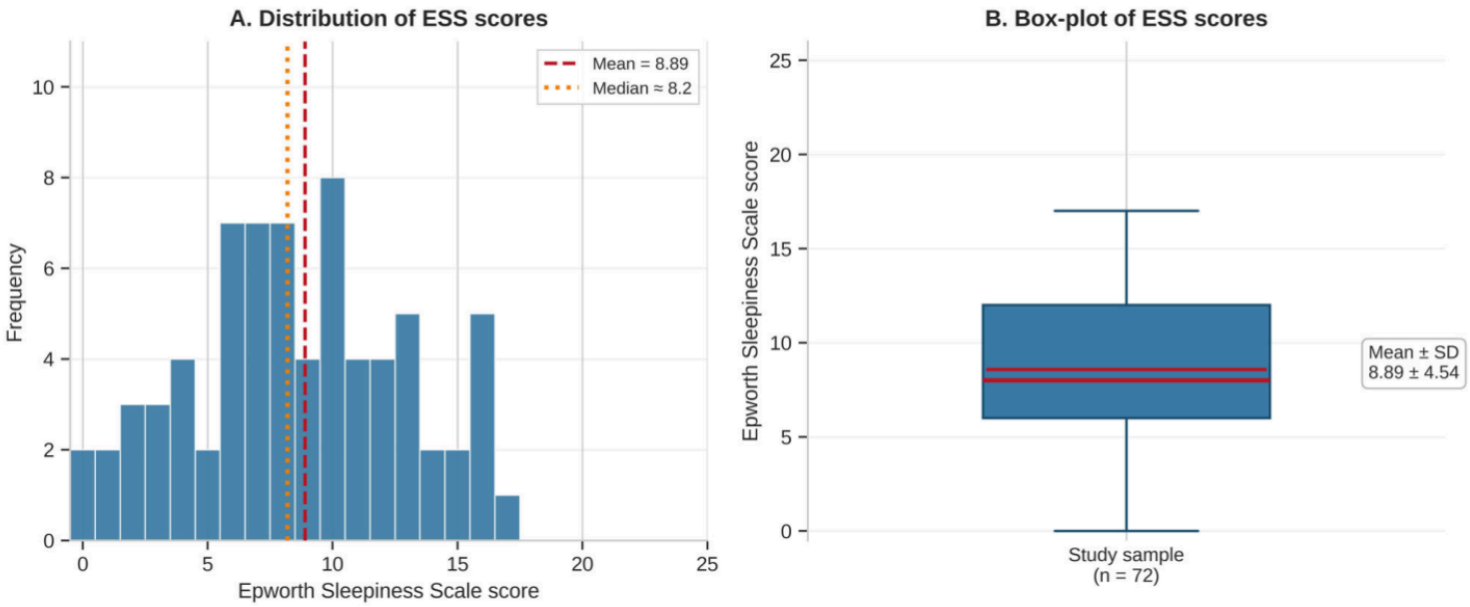


Figure 2

Epworth Sleepiness Scale (ESS) scores in the study population. (A) Histogram of the distribution. (B) Box-plot. Mean ESS was 8.89 ± 4.54 (range 1–24).

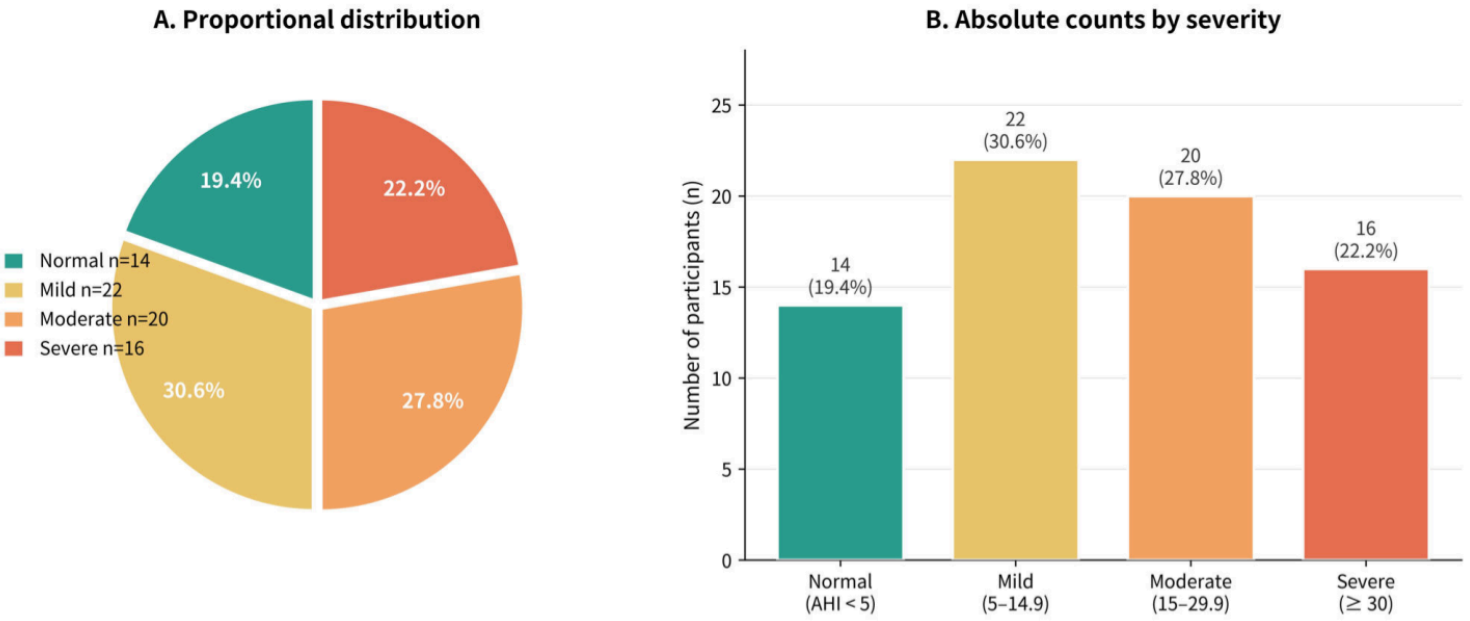


Figure 3

Distribution of apnea–hypopnea index (AHI) severity categories (n = 72). (A) Proportional distribution (pie chart). (B) Absolute counts by severity category.

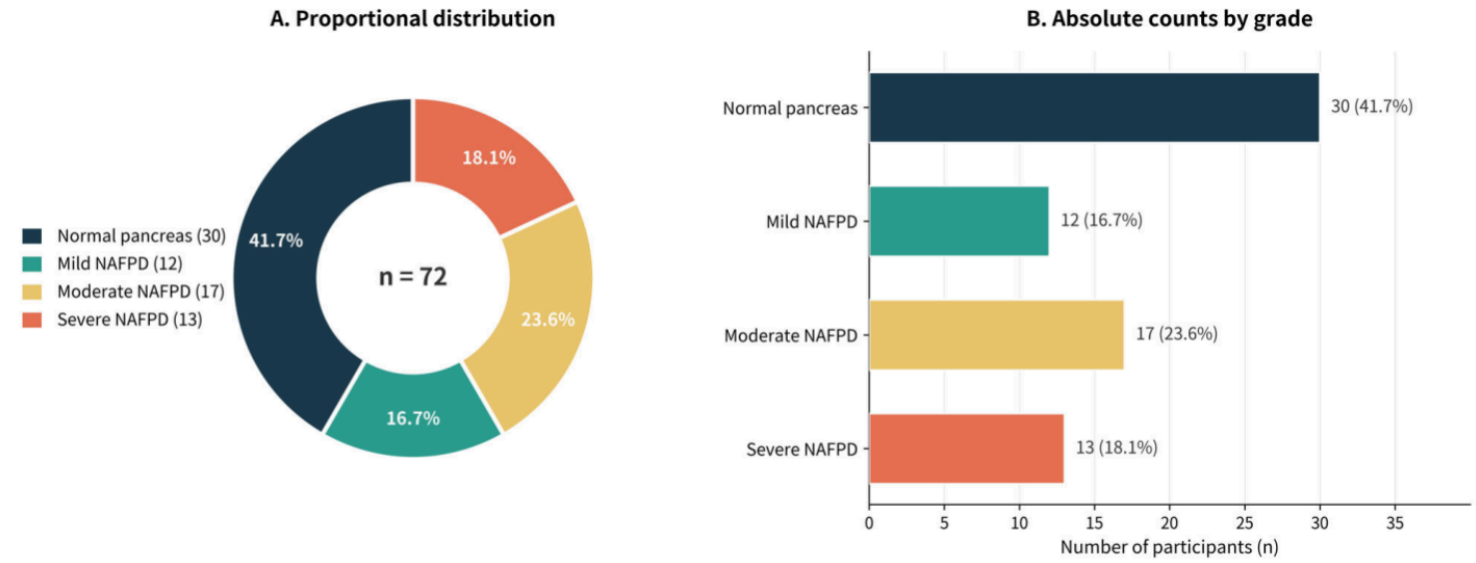


Figure 4

Distribution of non-alcoholic fatty pancreatic disease (NAFPD) severity grades. (A) Proportional distribution (donut chart). (B) Absolute counts by grade.

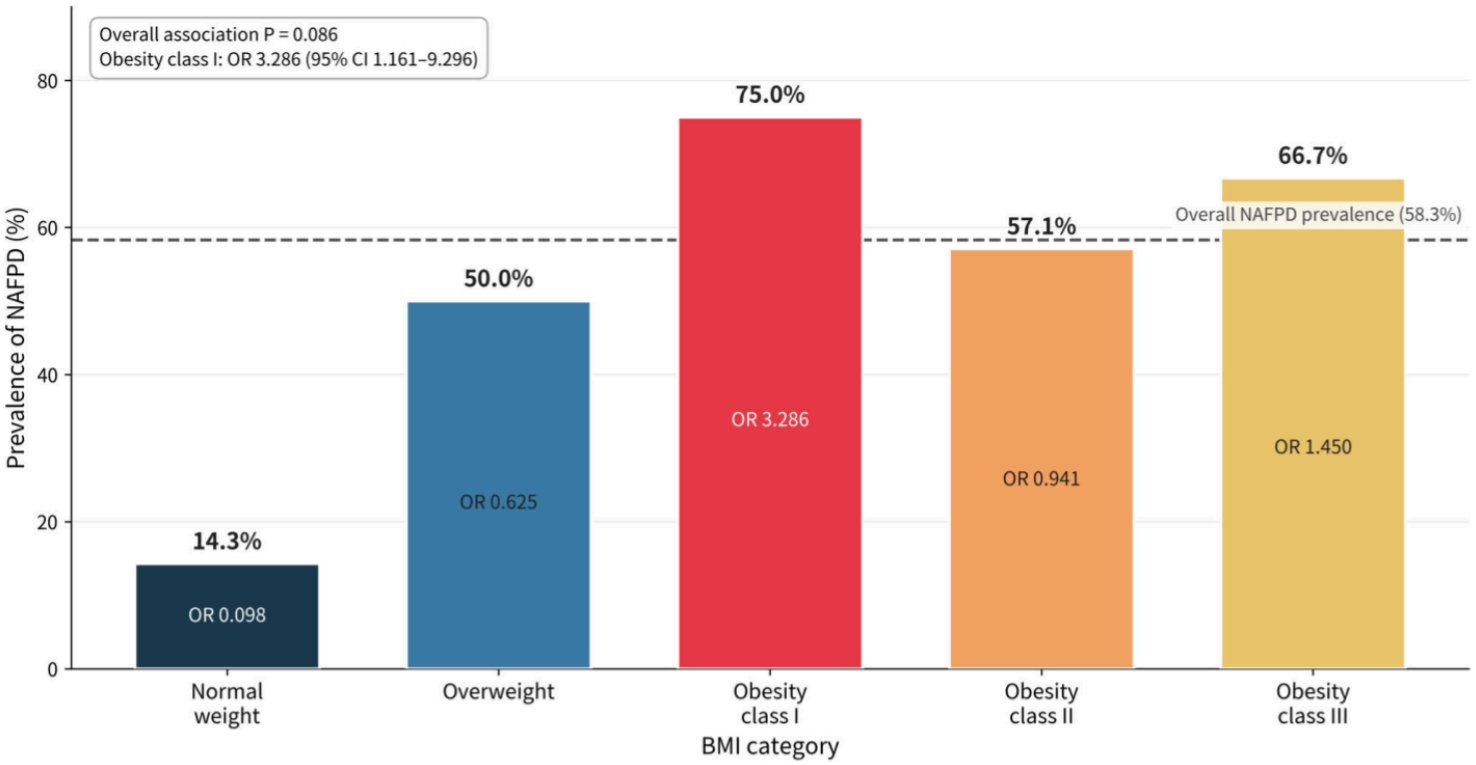


Figure 5

Prevalence of NAFPD according to body mass index (BMI) categories. Odds ratios (OR) are annotated on each bar. The dashed horizontal line indicates the overall NAFPD prevalence in the cohort (58.3%).

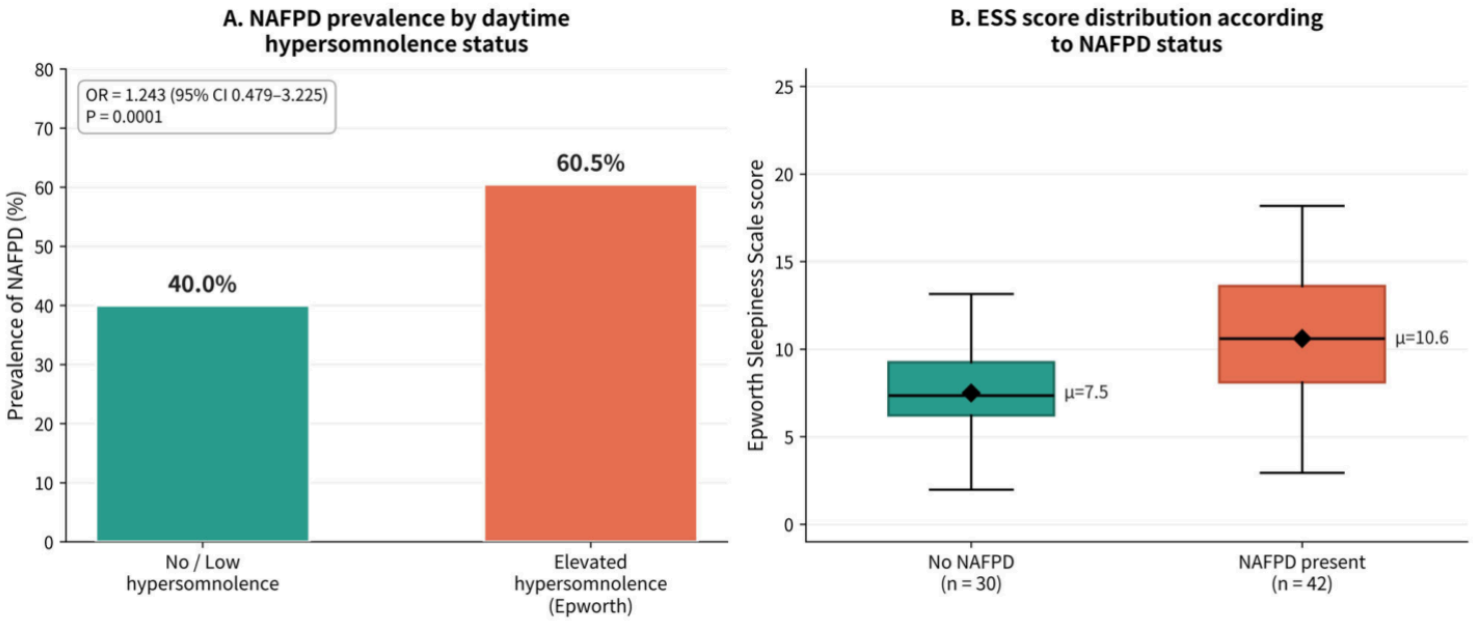


Figure 6

Association between daytime hypersomnolence (Epworth Sleepiness Scale) and NAFPD. (A) Prevalence of NAFPD according to hypersomnolence status. (B) Distribution of ESS scores according to NAFPD status (box-plots). The association was statistically significant (P = 0.0001).