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AI-driven bone mineral density prediction from chest x-rays and its association with obstructive sleep apnea

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Abstract

With an increasing aging population, the prevalence of chronic comorbidities is on the rise. The potential relationship between obstructive sleep apnea (OSA) and osteoporosis has garnered significant attention. Most studies examining the association between these two conditions have relied on dual-energy X-ray absorptiometry (DXA) to evaluate bone mineral density (BMD). Although DXA is considered the gold standard for BMD assessment, it does not reflect overall skeletal health.

The limitations of conventional measurements are particularly pronounced in patients with multisystemic diseases, such as OSA. To address these limitations, we applied VeriOsteo™OP software to predict lumbar spine BMD and T-scores from chest X-ray (CXR) images. In addition, we examined the relationship between these bone health metrics and OSA. A total of 70,395 patients who underwent CXR examinations at Tungs' Taichung MetroHarbor Hospital from 2017 to 2022 were included. Eligible samples were selected based on the presence of an OSA ICD-10-CM diagnosis code along with DXA results.

By incorporating variables, such as gender, age, Body Mass Index (BMI), and T-score, we used multiple machine learning models, including logistic regression, random forest, and XGBoost, to analyze the risk for OSA. The results indicated that when the BMI range was controlled, the predictive contribution of the T-score became significant. For some models, the area under the curve (AUC) reached over 85% in both the training and validation datasets. This suggests a notable association between T-score and OSA, which is maintained when confounding variables such as BMI are controlled.

This study highlights the potential of artificial intelligence (AI) technology using CXR imaging for osteoporosis screening. Combining CXR with machine learning models enables the assessment of OSA risk and offers a cost-effective, radiation-free screening tool with promising clinical applications.

Materials

Data resources

This was a cross-sectional, retrospective study that included patients who underwent CXR examination at Tungs' Metro Harbor Hospital from January 2017 to December 2022. Initially, 70,395 CXR-PA images were collected, and the image dataset was subsequently transformed into a tabular dataset. The tabular data consisted of X-ray PA view images taken from 2017 to 2022, which were analyzed using VeriOsteo™OP software to obtain BMD and T-scores. The data were sourced from the electronic medical record system of Tungs' Metro Harbor Hospital and spanned a six-year data collection period to ensure that the data was diverse and representative. The data used in this study were accessed on February 1, 2024, from the database of Tungs' Metro Harbor Hospital. This study was conducted in accordance with the principles of the Declaration of Helsinki and followed current scientific guidelines. As the data were fully anonymized to protect patient confidentiality, the requirement for informed consent was waived.

Inclusion and exclusion criteria

To ensure data quality and the reliability of the results, multiple exclusion criteria were established. First, patients had to meet at least one of the following conditions: (1) having a diagnosis of OSA confirmed by the ICD-10-CM code G47.33, or (2) having undergone a DXA scan. The diagnosis code G47.33 was assigned based on clinical judgment by physicians, and patients did not undergo polysomnography (PSG). Patients meeting either condition were included in the dataset (n = 5,480), whereas patients with missing BMI data were excluded (n = 607). Further exclusions included those with abnormal BMI values below 18.5 or above 60 (n = 147) and those under 50 years or over 85 years of age (n = 269). The final dataset consisted of 4,457 patients, which was used for preliminary and subgroup analyses (Fig 1).

Step 1: Introduction

1
- Taiwan is projected to become a super-aged society by 2025, with increasing elderly-related diseases like obstructive sleep apnea (OSA) and osteoporosis.
- OSA and osteoporosis are often comorbid and need integrated clinical attention.
- OSA-related intermittent hypoxia may promote bone loss.
- AI is being applied to predict BMD and T-scores from chest X-rays.

Step 2: Materials

2 **Data resources**
- This is a cross-sectional, retrospective study using data from Tungs' Metro Harbor Hospital (2017–2022).
- CXR images were analyzed using VeriOsteo™OP to obtain BMD and T-scores.
- Data were de-identified; informed consent was waived.

3 **Ethical Approval**
- Approved by the IRB of Tungs' Taichung MetroHarbor Hospital (IRB No. 112069).
- Written informed consent was obtained from all participants.

4 **Inclusion/Exclusion Criteria**
- Inclusion: OSA diagnosis (ICD-10-CM G47.33) or DXA data.
- Exclusion: Missing BMI, extreme BMI (<18.5 or >60), age <50 or >85.
- Final sample: 4,457 patients.

5 **BMD & T-score Detection**
- VeriOsteo™OP (Acer Medical Inc.) version 1.00.3000 used.
- AI analyzed thoracolumbar (T12–L1) regions from CXR.
- Performance validated against DXA measurements.

Step 3: Methods

6 **Independent variable and outcome variable**
- Variables: Gender, age, BMI, BMD, T-score.
- T-score categories per IOF:
- Normal: T-score > −1.0
- Low Bone Mass: −2.5 < T-score ≤ −1.0
- Osteoporosis: T-score ≤ −2.5

7 **Statistical Analysis**
- Qualitative data: Chi-square test for gender, T-score groups.
- Quantitative data: t-test for age, BMI, BMD, T-score.
- Significance set at $\alpha = 0.05$.
- Software: Python 3.10.12 with SciPy 1.13.1.

8 **Machine Learning**

- Data split 9:1 (training:validation), 10-fold cross-validation.
- Models: Logistic Regression, Random Forest, XGBoost.
- Evaluated using ROC curve and AUC.

Supplementary material:

9 The complete source code, data processing scripts, and additional resources supporting this study are available at Zenodo via the following DOI: https://doi.org/10.5281/zenodo.15300281.

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