



Cross-Site Femoral Neck T-score Assessment via Optimized Gaussian Process Regression: Leveraging Lumbar Metrics, Clinical and Biochemical Markers, and Engineered Features

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Abstract

As the global population transitions toward an aging demographic, osteoporosis and osteopenia have emerged as critical health concerns. Although dual-energy X-ray absorptiometry (DEXA) remains the gold standard for assessing bone density, site-specific scans, particularly for the femoral neck, can be restricted by equipment limitations or patient physical conditions in remote areas. This research addresses this gap by proposing a Gaussian process regression (GPR) framework to infer the femoral neck T-score, leveraging lumbar spine metrics (L1-L4 and total lumbar) as the primary axial predictors.

Utilizing a clinical dataset, preprocessing and feature selection were executed in MATLAB. This process identified 12 independent variables, comprising 10 clinical and biochemical markers alongside two engineered features: bone index and mineral interaction. By employing the T-score representation, the model standardized the target variable, thereby enhancing its capacity to capture complex cross-site correlations. The GPR-based approach provided a probabilistic framework that not only predicted the T-score but also quantified the uncertainty of the predictions.

The model demonstrated exceptional performance, yielding a coefficient of determination (R^2) of 0.89 and a mean absolute error (MAE) of 0.03, which indicates a strong correlation with the DEXA ground truth. These findings suggest that the proposed framework serves as a reliable, non-invasive alternative for site-specific bone health assessments. Consequently, it has the potential to reduce the necessity for multiple comprehensive scans in underserved regions.

Keywords: *Osteoporosis, Osteopenia, Gaussian Process Regression, Femoral Neck*