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Original article

Prognostic performance of Predictive Index for Osteoporosis and Osteoporosis Self-Assessment Tool for Asians in the identification of individuals high-risk for osteoporosis

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ABSTRACT

Objectives: To compare Predictive Index for Osteoporosis (PIO) with Osteoporosis Self-Assessment Tool for Asians (OSTA) as a clinical tool for identifying the risk of osteoporosis in Filipino men 50–69 and Filipino women 50–65 years of age.

Methods: This was an analytic study that employed a cross sectional approach that included Filipino men and women seen at the Outpatient Charity Department or at the private clinics and who underwent dual energy X-ray absorptiometry. All subjects completed a structured questionnaire and their weight and height were obtained, from which their PIO and OSTA scores were computed.

Results: A total of 81 patients were included in the study. OSTA has an area under the curve of 0.712 which turns out to be significant (P = 0.0004), with a calculated likelihood ratio of 1.64. The receiver operating characteristic (ROC) curve of PIO showed that the optimal cut off is > 0.962 and the calculated likelihood ratio that this patient may have osteoporosis is 1.38. Comparing the sensitivity and specificity, the resulting P value of 0.2728 denotes that the area under the curve of the 2 tools is not significantly different.

Conclusions: The optimal cut-off point of OSTA and PIO to discriminate high-risk and low-risk patients for osteoporosis were 0.712 and 0.686, respectively, based on ROC analysis. The performance measures of OSTA and PIO did not vary significantly in predicting the risk for osteoporosis in Filipino adults.

1. Introduction

The incidence of osteoporosis is projected to significantly increase over the next few years given the aging population, with the numbers expecting to reach 65 000 by the year 2020 [1]. According to a report last 2003 by the National Nutrition Health Survey, 26% of women and 11.4% of men aged between 60 and 69 years are considered at high risk for osteoporosis [2].

The National Osteoporosis Foundation and Endocrine Society recommend dual energy X-ray absorptiometry (DXA) for men above 70 years old and for women older than 65 years [5]. Screening for men 50–69 years and women 50–65 years is recommended for DXA if they have any of the following significant risk factors [5]: low (less than 19 kg/m^2) body mass index (BMI), prior fracture as an adult, smoking, corticosteroid therapy, estrogen deficiency, maternal history of hip fractures [5]. DXA is the gold standard in the diagnosis of osteoporosis, however, it is not readily available, nor is it easily afforded to the general population.

In the recent Summary of the Consensus Statements on Osteoporosis Prevention, Diagnosis, and Treatment in the Philippines, they recommended Osteoporosis Self-assessment Tool for Asians (OSTA) to stratify the risk of an individual for osteoporosis when DXA is not available [5]. It is a simple tool whose formula includes the patient's age and body weight in the calculation [5].

Recent studies have cited smoking as another significant factor for developing osteoporosis [6]. Smoking was found to have an independent, dose-dependent effect on bone loss, which increases fracture risk [6]. This is why a new clinical tool, the Predictive Index

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for Osteoporosis (PIO), which include current smoking status, has been recently developed to identify the risk of osteoporosis in men under 70 years old [7]. In the study by Kim et al, a PIO score of 0.87 was the optimal cut off value, and a patient's PIO score above 0.87 indicated a need for bone mineral density screening [7].

In the Philippines, osteoporosis is often seen as a natural part of the aging process and many find the DXA work up for osteoporosis to be quite expensive. As such, due attention has not been given to its prevention and treatment, despite osteoporosis causing significant morbidity and mortality.

According to the Global Adult Tobacco Survey conducted in the Philippines in 2015, 22.7% of adult Filipinos smoke tobacco, 40.3% among men and 5.1% among women [20]. With the rising prevalence of smoking among both men and women and the recent findings of how smoking potentially adds to the lifetime risk of developing fractures, this simple PIO tool that incorporates smoking status to the patient's age and weight in the calculation may turn out to be a more sensitive indicator of osteoporosis risk.

The accuracy of PIO in the diagnosis of osteoporosis among Filipino men 50–69 years old and women 50–65 years old, as compared with DXA scan as the gold standard, is largely unknown. Furthermore, the comparability of the diagnostic accuracy of PIO and OSTA in diagnosing osteoporosis, with DXA scan as the gold standard, is unknown.

The general objective of this study is to compare the performance of PIO and OSTA as a clinical tool for identifying the risk of osteoporosis in Filipino men 50–69 years of age and Filipino women 50–65 years of age. Specifically, this study will determine the optimal cut off points of OSTA and PIO relative to the study population using receiver operating characteristic (ROC) analysis and determine the sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio, and diagnostic accuracy of OSTA and PIO for predicting high risk individuals for osteoporosis.

2. Methods

2.1. Study design

This analytic study employed a cross-sectional approach to compare the performance of PIO with OSTA as a clinical tool for identifying the risk of osteoporosis in Filipino men 50–69 and Filipino women 50–65 years of age.

2.2. Study setting and period

This study was conducted at the Outpatient Charity Department and at the private clinics at the Makati Medical Center and at The Center for Osteoporosis and Bone Health at Makati Medical Center from June 1, 2018 to November 30, 2018.

2.3. Study participants

2.3.1. Inclusion criteria

The following patients were included in this study:

1. Filipino men 50–69 years old and Filipino women 50–65 years of age
2. Patients who were seen at the Outpatient Charity Department, private clinics and at The Center for Osteoporosis and Bone Health at Makati Medical Center who underwent DXA

2.3.2. Exclusion criteria

The following patients were excluded from this study:

1. Previously diagnosed with osteoporosis
2. Previously treated with any of the following medications that could alter bone mineral density: bisphosphonates, calcitonin, selective estrogen receptor modulators, parathyroid hormone analogs, glucocorticoids
3. History of atraumatic fractures or history of diseases that may affect bone density such as bone diseases, hyperthyroidism, chronic renal failure, rheumatoid arthritis
4. Subjects with surgical pins or cement in their bones

2.4. Sample size

The estimated prevalence of osteoporosis by OSTA is 43.4%. The computation was as follows:

$$TP + FN = Z^2 * \frac{SN(1-SN)}{W^2} = 1.96^2 \frac{0.719(1-0.719)}{0.15^2} = 34.50$$

$$N(SN) = \frac{TP + FN}{P} = \frac{34.50}{0.43} = 80$$

Where:

Z value = 1.96 (95% confidence interval normal distribution)
W = Accuracy (0.15)
SN = Sensitivity (71.9%) - OSTA
P = Prevalence of Disease 43%
TP = True Positive
FN = False Negative
The final sample size was 80.

2.5. Clinical assessment tools

Osteoporosis Self-Assessment Tool for Asians.

The OSTA is a simple clinical tool to identify patients at increased risk for osteoporosis using weight in kilograms and age in years. It has been validated by different researches to be an effective screening tool in identifying patients with low bone mineral density (BMD) and risk for osteoporosis. It is calculated by using the formula: (body weight (kg) − age (year)) × 0.2, truncated to yield an integer. Those with an OSTA score of − 1 and below have an increased risk of having osteoporosis.

Predictive Index for Osteoporosis.

This new index was initially developed among Korean men under 70 years old to determine the risk of osteoporosis and who should undergo BMD screening by using weight in kilograms, age in years, and smoking status. It is calculated using the formula: {age in years (+10; for current smoker only)/weight in kilograms}.

2.6. Determination of clinical outcome and variables

This study used a purposive sampling method to achieve the minimum sample size of 76. Patients who were identified from the Outpatient Charity Department during consults and from the clinics of the endocrine consultants, and at The Center for Osteoporosis and Bone Health at Makati Medical Center who were scheduled for DXA from June 1, 2018 to November 30, 2018 were included in the study.

All patients who qualified were invited to participate in the study and asked to sign an informed consent form by the investigator. Patients who agreed to participate in the study were given a copy of their informed consent form. They were then asked to answer a 1 page questionnaire which took 10–15 min. The patients were advised that they may withdraw their consent to participate anytime during the course of the study. Results of the questionnaire

were disclosed to the patients. This correlated with their DXA results and they were subsequently advised to follow up with their attending physicians. This study was approved by the ethical review board of this institution (MMCIRB 2017–108) and followed the Declaration of Helsinki. All patients agreed to participate in this study and provided written informed consent. The participants who were eligible for the study were included after consent was given and the consent form completely filled up and signed. The consent form, which had both English and Filipino versions, contained the objectives and procedure of the study, which was explained by the investigators. The participants themselves signed the consent forms. The investigators answered any concerns and questions of the participants and made sure that the participants completely understood the content of the consent forms before signing. It was also made clear to the participants that they may withdraw their consent to participate at any time during the course of the study.

The questionnaire contained information on age, smoking history, alcohol consumption, and physical activity. Smoking history were quantified in terms of never smoked (less than 100 cigarettes per day), previous smoker, or current smoker; alcohol consumption in terms of 1–4 bottles per week or more than 4; physical activity quantified in terms of less than 150 min per week or more than 150 min per week. Patient's recent laboratory results of vitamin D, ionized calcium, urinalysis, fasting blood sugar, hemoglobin A1c were copied and recorded with the patient's permission. No additional laboratory results were requested, nor was it required for the patient to qualify for the study.

The investigator obtained the patient's anthropometric measurements which included their weight (kg), with the patient wearing light clothes and no shoes, and height (m). The patients' BMI was then calculated by dividing the weight by the square of height.

The investigator then computed the subject's PIO score using {age in years (+10; for current smoker only)/weight in kilograms} and the OSTA [(weight in kilograms − age in years) × 0.2][19].

The DXA machine measured lumbar spines (L1-L4), right femoral neck, left femoral neck. Osteoporosis was defined according to the World Health Organization Criteria with a T score ≤ -2.5 SD on DXA in the mean of lumbar spines (L1–4), femoral neck, or total femur [19].

2.7. Statistical analysis

Microsoft Excel (Microsoft Inc., Redmond, Washington, USA) was used for data entry and IBM SPSS software ver. 20.0 (IBM Co, Armonk, NY, USA) was used for data analysis. Descriptive statistics specifically median and interquartile range was used to present continuous data, while percentage was computed for categorical data.

Pearson's chi-squared test or Fisher's exact test, as appropriate, was used to compare the proportions of categorical data. The latter was used when more than or equal to 20% of the cells had an expected value of less than five or when any of the cells had an actual observation of equal to or less than one ($\leq$1). T-test was used to compare selected characteristics between groups. A probability P-value of less than 0.05 was considered statistically significant to reject the null hypothesis. Receiver operating characteristic curve analysis was used to compare PIO and OSTA in predicting osteoporosis risk against the standard DXA scan. The formula d [2] = (1−sensitivity) [2]+(1−specificity) [2] was used to determine the optimum cut-off point for the PIO and OSTA indices to determine the high and low risk. The sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio and diagnostic accuracy of the indices were computed. Furthermore, Z test of two proportions was used to compare the performance of PIO and OSTA.

2.8. Data handling

Codes using numbers was be assigned to each participant to secure privacy and confidentiality of data. All data entered in this study were treated with outmost confidentiality and shall be kept for a period of 5 years as reference, and will be shredded thereafter.

2.9. Provisions

The DXA for the charity and pay patients found eligible for the study were paid for by the patients. There were no risks involved in the participation of this study. DXA is a simple, quick, painless, noninvasive procedure which uses a very small dose of ionizing radiation to produce pictures of the bones.

The primary investigator shouldered the budget for the study. No drug company was involved in the conduct of the study, and the results was not used for commercial purposes.

All subjects eligible to be included in the study did not receive any monetary assistance from the investigator as part of recruitment. Exclusion from this study did not result to denial of medical service to the patient.

3. Results

Ninety-five patients were interviewed but fourteen were excluded from the study due to one of the following: history of bisphosphonates intake (alendronate), hyperparathyroidism, steroid intake, presence of surgical pins. Consequently, a total of 81 patients were included in the study whose age ranged from 50 to 69 years old with a mean age of 61 years old.

Table 1 below shows the demographic and clinical characteristics of study population dichotomized according to BMD status. Normal or osteopenia group (n = 48) and osteoporosis group (n = 33) did not vary significantly in terms of age, gender, smoking history, alcohol consumption, and physical activity. Patients diagnosed with osteoporosis on DXA was found to have lower BMD at less than 21 compared to those with normal BMD or osteopenia. OSTA and PIO were also significantly different between the 2 groups. The mean OSTA index was 1.8 ± 2.5 in the normal or osteopenia group and −0.1 ± .72 in the osteoporosis group, which was found to be significantly different with a lower score for those with osteoporosis. The mean PIO index was 0.9 ± 0.2 in the normal or osteopenia group and 1.1 ± .0.3 in the osteoporosis group, which was found to be significantly different with a higher score for those in the osteoporosis group (Table 2).

OSTA is significantly correlated with BMD, with a coefficient of −0.341. This denotes that a lower OSTA will likely increase the likelihood of osteoporosis as diagnosed by the BMD on DXA. On the other hand, PIO is significantly correlated with osteoporosis based on BMD, where a higher PIO will likely result to higher chances of osteoporosis.

The optimal cut-off point to determine the high risk and low risk patients for osteoporosis relative to OSTA was derived from ROC analysis (Fig. 1). Consequently an optimal cut off point of 0.71 was generated. This has true positive cumulative rate of 54.55% (95% CI 36.35%–71.89%) and true negative of 66.67% (95% CI 51.59%–79.60%) (Fig. 2).

Odds ratio of less than 1 denotes that a lower OSTA will likely result to higher likelihood of osteoporosis. On the other hand, odds ratio of 47.43 denotes that a high PIO will likely result to a higher likelihood of having osteoporosis (Table 3).

Table 4 shows the performance measures of OSTA as a predictor

Table 1
Demographic and clinical characteristics of the study population according to bone mineral density status.

Variable	Normal or Osteopenia (n = 48)	Osteoporosis (n = 33)	P-value
Age (yr), mean ± SD [1]	60.5 ± 6.2	61.7 ± 6.8	0.4146
Gender, n (%)			
Male	24 (50.0)	18 (54.5)	0.6893
Female	24 (50.0)	15 (45.5)	
BMI, n (%)			
< 21	4 (8.3)	8 (24.2)	0.0491*
≥ 21	44 (91.7)	25 (75.8)	
Smoking, n (%)			
Never Smoked	32 (66.7)	26 (78.8)	0.4898
Previous Smoker	5 (10.4)	2 (6.1)	
Current Smoker	11 (22.9)	5 (15.2)	
Alcohol consumption, n (%)			
No Alcohol consumption	36 (75.0)	29 (87.9)	0.1551
Drinks Alcohol 1–4 times/week	12 (25.0)	4 (12.1)	
Drinks Alcohol more than 4 times/week	0 (0.0)	0 (0.0)	
Physical activity, n (%)			
Less than 150 min per week	47 (97.9)	33 (100.0)	1.0000
More than 150 min per week	1 (2.1)	0 (0.0)	
Comorbidities, n (%)			
Prostatomegaly	1 (2.1)	0 (0.0)	0.4070
Hypertension	8 (16.7)	2 (6.1)	0.1565
Dyslipidemia	2 (4.2)	1 (3.0)	0.7914
Parkinson's Disease	0 (0.0)	1 (3.0)	0.2278
Diabetes mellitus	20 (42.6)	7 (21.2)	0.0483*
Osteoporosis Self-Assessment Tool for Asians, mean ± SD	1.8 ± 2.5	−0.1 ± .72	0.0018*
Predictive Index for Osteoporosis, mean ± SD	0.9 ± 0.2	1.1 ± .0.3	0.0014*

* Statistically significant.
SD, Standard Deviation; BMI, body mass index.

Table 2
Correlations between Osteoporosis Self-assessment Tool for Asians, Predictive Index for Osteoporosis, and bone mineral density.

Variable	Correlation coefficient	P-value
OSTA vs PIO	−0.9021	0.0001*
OSTA vs BMD	−0.341	0.0018*
PIO vs BMD	0.35	0.0014*

* Statistically significant.
OSTA, Osteoporosis Self-assessment Tool for Asians; PIO, Predictive Index for Osteoporosis; BMD, bone mineral density.

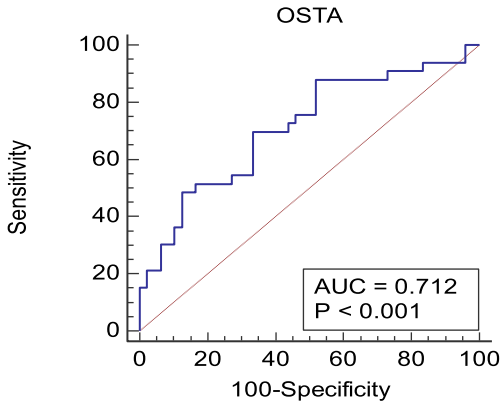

Fig. 1. Receiver operating characteristic curve of Osteoporosis Self-assessment Tool for Asians for predicting osteoporosis.
AUC, area under the curve; OSTA, Osteoporosis Self-assessment Tool for Asians.

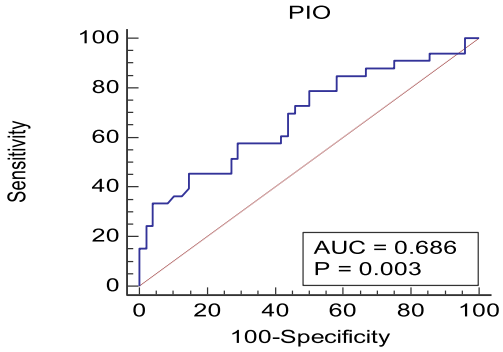

Fig. 2. Receiver operating characteristic curve of Predictive Index for Osteoporosis for predicting osteoporosis.
AUC, area under the curve; PIO, Predictive Index for Osteoporosis.

Table 3
Logistic regression analysis of Osteoporosis Self-assessment Tool for Asians, Predictive Index for Osteoporosis, and osteoporosis.

Variable	Odds ratio	95% CI OR	P-value
OSTA	0.7137	0.57–.90	0.0042*
PIO	47.43	3.34–674.42	0.0044*

*Statistically significant.
OSTA, Osteoporosis Self-assessment Tool for Asians; PIO, Predictive Index for Osteoporosis; CI, confidence interval; OR, odds ratio.

for osteoporosis. Out of the 33 patients with osteoporosis, 18 are correctly classified based on OSTA Cut-off value of 0.71. Furthermore, out of 48 patients without osteoporosis, 32 of them were correctly classified by OSTA.

The sensitivity of OSTA, or the probability that the index will give a positive result when a patient has osteoporosis, was 54.55% (95% CI 36.35%–71.89%). The specificity of OSTA, or the probability that the model will give a negative result when a patient does not have osteoporosis, was 66.67% (95% CI 51.59%–79.60%). However,

Table 4
Performance measures of Osteoporosis Self-assessment Tool for Asians for predicting osteoporosis.

Diagnostic Level	Osteoporosis	Normal or Osteopenia	Total
≥ 0.71	18	16	34
< 0.71	15	32	47
Total	33	48	81
Performance measures (95% CI)			
Sensitivity, %	54.55 (36.35–71.89)	Positive LR	1.64 (0.99–2.72)
Specificity, %	66.67 (51.59–79.60)	Negative LR	0.68 (0.45–1.04)
PPV, %	52.94 (40.39–65.13)	Diagnostic Accuracy	61.73 (50.26–72.31)
NPV, %	68.09 (58.27–76.52)		

CI, confidence interval; PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

the confidence interval crossed the 50% threshold. This suggests that for this population, OSTA is not a good enough diagnostic tool for detecting osteoporosis.

Since sensitivity and specificity are both affected by population and prevalence, positive predictive values (PPV) and negative predictive values (NPV) were calculated. The PPV or the probability of patients of having osteoporosis given a positive OSTA result with 0.71 as cut-off is 52.94%. The NPV or the probability of patients with no osteoporosis given a negative OSTA result with a 0.71 cut-off is 68.09%.

The positive likelihood ratio (LR+) was 1.64 (95% CI 0.99–2.72). This value denotes that OSTA is 64% more likely to give a positive test among truly osteoporotic patients as compared to patients with no osteoporosis, but this was not significant (95% CI 0.99–2.72). As a rule, the higher the computed positive LR from 1 as a reference point, the stronger the evidence for predicting the presence of the disease. The negative likelihood ratio (LR-) was 0.68 (0.45–1.04). This implies that OSTA is 32% and less likely to give a negative test among truly osteoporotic patients as compared to patients with no osteoporosis, but this was not significant (95% CI 0.45–1.04).

Finally, the overall diagnostic accuracy of OSTA was 61.73% (95% CI 50.26%–72.31%). This means that the model was able to correctly classify 61.73% of the true osteoporotic and non-osteoporotic patients.

Table 5 below shows the optimal cut off point generated was > 0.962 which can bring the highest combined sensitivity and specificity. The sensitivity of PIO was 57.58% (95% CI 39.22%–74.52%) while the specificity was 58.33% (95% CI 43.21%–72.39%).

The PPV or the probability of patients of having osteoporosis given a PIO result with 0.962 as cut-off is 48.72% (95% CI 37.85%–59.71%). The NPV or the probability of patients with no osteoporosis given a PIO result with a 0.962 cut-off is 66.67% (95% CI 55.71%–76.08%).

The positive likelihood ratio (LR+) was 1.38 (95% CI 0.89–2.16). This value denotes that PIO is 38% more likely to give a positive test among truly osteoporotic patients as compared to patients with no osteoporosis, but this was not significant (95% CI 0.89–2.16). The negative likelihood ratio (LR-) was 0.73 (95% CI 0.46–1.16). This implies that PIO is 27% and less likely to give a negative test among truly osteoporotic patients as compared to patients with no osteoporosis, but this was not significant (95% CI 0.46–1.16).

The overall diagnostic accuracy of PIO was 58.02% (95% CI 46.54%–68.91%). This means that the model was able to correctly classify 58.02% of the true osteoporotic and non-osteoporotic patients.

Fig. 3 compares the ROC curves of OSTA and PIO. The area under the curve of OSTA is 0.712 while the AUC of PIO is 0.686.

Table 6 compares the sensitivity and specificity of OSTA and PIO. The resulting P-value of 0.2728 denotes that the AUC's of the 2 tools are not significantly different. Both the sensitivity and specificity of OSTA and PIO were not significantly different from each other.

We have performed subgroup analysis with both sexes. There was no significant difference both OSTA and PIO between men and women.

4. Discussion

Osteoporosis has been increasingly recognized as a major global health problem over the last decade. Its incidence is noted to be

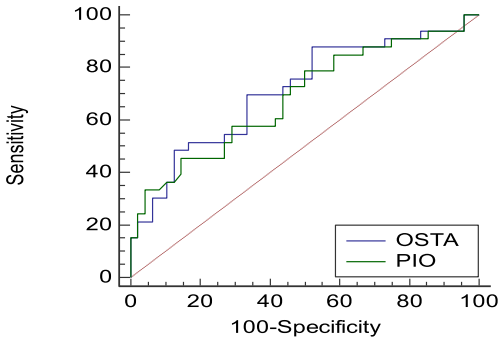

Fig. 3. Comparing the receiver operating characteristic curves of Predictive Index for Osteoporosis and Osteoporosis Self-assessment Tool for Asians.
OSTA, Osteoporosis Self-assessment Tool for Asians; PIO, Predictive Index for Osteoporosis.

Table 5
Performance measures of Predictive Index for Osteoporosis for predicting osteoporosis.

Diagnostic Level	Osteoporosis	Normal or Osteopenia	Total
> 0.962	19	20	39
≤ 0.962	14	28	42
Total	33	48	81
Performance measures (95% CI)			
Sensitivity, %	57.58 (39.22–74.52)	Positive LR	1.38 (0.89–2.16)
Specificity, %	58.33 (43.21%-72.39)	Negative LR	0.73 (0.46–1.16)
PPV, %	48.72 (37.85%-59.71)	Diagnostic Accuracy	58.02 (46.54–68.91)
NPV, %	66.67 (55.71%-76.08)		

CI, confidence interval; PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

Table 6
Comparison of Osteoporosis Self-assessment Tool for Asians and Predictive Index for Osteoporosis based on sensitivity and specificity.

Variable	AUC (95% CI)	SE	Difference	P-value	Sensitivity	P-value	Specificity	P-value
OSTA	0.712 (0.60–0.81)	0.0599	0.0265	0.2728	54.55	0.8056	66.67	0.484
PIO	0.686 (0.58–0.78)	0.0618			57.58		58.33	

OSTA, Osteoporosis Self-assessment Tool for Asians; PIO, Predictive Index for Osteoporosis; AUC, area under the curve; CI, confidence interval; SE, standard error.

rising and is projected to reach 65 000 by the year 2020 and almost 17 000 by the year 2050 [1]. In this current study, the disease prevalence was noted to be 40.7% as diagnosed by DXA.

In terms of the demographic and clinical variables of the study; age, gender, smoking history, alcohol consumption, and physical activity, were not associated with osteoporosis relative to the study population. However, patients diagnosed with osteoporosis on DXA was found to have a significantly lower BMI less than 21 compared to those with normal BMD or osteopenia. This was similar to a meta-analysis conducted by De Laet et al in 2005 which concluded that a low BMI of less than 20 kg/m^2 was an independent risk factor [15].

Contrary to a study done in Japan, however, it was reported that smoking status is associated with decreased BMD and it was the increased number of smoking years that was more significantly associated with decreased BMD among current and former smokers [15]. This is further supported by a meta-analysis done by Ward et al who reported that smoking was an independent risk factor negatively affecting bone mineral density [6]. The mechanism for this has not been fully elucidated but they speculated that one possible reason was that smoking negatively affects a person's body weight and thus, also negatively affect bone mineral density [6]. Smokers were found to weigh less than nonsmokers and thus less conversion of androgens to estrogens in adipose tissue, and less mechanical load on weight bearing bones resulting to lesser bone formation [6]. Smoking was also found to negatively affect reproductive hormone function in women, with smokers found to have earlier menopause by 1–2 years [6]. According to a study conducted by Yen et al smoking causes vascular endothelial damage resulting in impaired blood circulation and impaired wound healing [16].

As the trend of osteoporosis rises worldwide, screening tools were developed to identify patients at risk of osteoporosis. In the recent Summary of the Consensus Statements on Osteoporosis Prevention, Diagnosis, and Treatment in the Philippines, they recommended the OSTA to stratify the risk of an individual of having osteoporosis when DXA is not available [5]. It is an inexpensive, simple tool based on age and body weight originally developed for the use in post-menopausal Asian women [5]. On the other hand, the PIO which included current smoking as a risk factor in the formula was developed to identify the risk of osteoporosis among Korean men and to identify male candidates who benefit from taking the BMD screening [7].

In this current study, the predictive value of OSTA and PIO were compared. The mean OSTA index was 1.8 ± 2.5 in the normal or osteopenia group and −0.1 ± 0.72 in the osteoporosis group, which was found to be significantly different with a lower score for those with osteoporosis. The mean PIO index was 0.9 ± 0.2 in the normal or osteopenia group and 1.1 ± 0.0.3 in the osteoporosis group, which was found to be significantly different with a higher score for those in the osteoporosis group. In the study conducted by Moon et al they reported their mean OSTA index to be 1.77 ± 0.02 in the normal or osteopenia group and 1.54 ± 0.07 in the osteoporosis group which was significantly different. The mean PIO between the 2 groups, 0.95 ± 0.00 in the normal or osteopenia group and 1.03 ± 0.01 in the osteoporosis group, was also found to be significantly different [19].

The optimal cutoff value for OSTA was 0.712 which turns out to be significant (P = 0.0004) with a sensitivity of 54.55% (95% CI 36.35–71.89) and a specificity of 66.67% (95% CI 51.59%–79.60%), respectively. This means that an OSTA score of < 0.712 is considered high risk for osteoporosis. Furthermore, the findings showed that 67% of patients without osteoporosis would have an OSTA score of ≥ 0.71. This specificity indicates its potential for screening of osteoporosis because of its ability to correctly identify those without the disease. However, only 55% of patients with osteoporosis would have OSTA score of < 0.71. Its low sensitivity requires confirmatory tests for definitive diagnosis. Meanwhile, its predictive values show that 53% of high risk patients (< 0.71) actually have osteoporosis while the low risk patients (≥ 0.71) have 53.85% chance of being osteoporosis free. Likelihood ratios however show that it alters probability to a small degree.

For the PIO, the optimal cut off value was noted to be 0.962, which is significant and implies that PIO can discriminate high risk and low risk patients for osteoporosis (P = 0.0027). Its sensitivity, specificity, positive predictive value, negative predicative value, positive and negative likelihood ratios of the PIO were as follows: 57.58%; 58.33%; 48.72%; 66.67%; 1.38; and 0.73, respectively.

Assessment of smoking status for the prediction of osteoporosis was supported by recent research results such as in the Framingham study wherein current smokers exhibited greater bone loss than former or never smokers [17]. Although in a similar study conducted by Moon et al, their results also showed that there was no statistically significant difference between the 2 ROC graphs of OSTA and PIO [19]. However, the sensitivity and specificity of OSTA, 71.9% and 64.0%, respectively, and the sensitivity and specificity of PIO, 67.6% and 72.7%, respectively, was higher than the results of our study. The difference in the results of our study may be because of the differences in the population characteristics since our study included both men and women, and the prevalence of osteoporosis in our study was found to be higher at 40.7% as compared to the above study which was at 4.9% [19].

Accordingly, the cut off values for OSTA and PIO from our study, 0.712 and 0.962, respectively, was relatively not far from the results of the study by Moon et al, whose cut off values were 0.5 for OSTA and 1.07 for PIO [19].

When compared using ROC curve analysis, the performance measures of OSTA and PIO did not vary significantly (P = 0.27). On closer examination of the diagnostic accuracy measures of both tests, the values are near 50% for most measures since the 95% CI of both tests both cross 50%. This suggests that OSTA and PIO are not good enough tools to correctly classify patients with osteoporosis and with no osteoporosis. This may imply a need for the use of a more sensitive and more specific diagnostic tool that will include other variables that are predictive of osteoporosis.

Our study has salient limitations. The subjects in our sample were recruited from the Center for Osteoporosis and Bone Health or from clinics, and they may have different characteristics from the general population. This explains why the prevalence of osteoporosis was high (59%), which may affect the prognostic accuracy of the tools (OSTA and PIO).

The PIO formula only considered the current smoking status of

the patient, but based on literature, length of time and pack years of smoking also significantly affect bone mineral density.

Though the more sensitive and specific clinical tools are those that incorporate many risk factors for osteoporosis, the simple, fast and easy tools to calculate PIO, which only uses age, weight, and smoking status, may still prove to be valuable for clinicians in the primary healthcare setting who may not always have easy access to other online clinical tools.

In our setting, either the OSTA or PIO may be used since their performance did not vary significantly in predicting the risk for osteoporosis.

5. Conclusions

BMI was associated with osteoporosis but not age, gender, smoking history, alcohol consumption, and physical activity relative to the study population. The optimal cut-off point of OSTA and PIO to discriminate high risk and low risk patients for osteoporosis were as follows: 0.712 and 0.686 respectively, based on ROC analysis.

The sensitivity of OSTA was 54.55% while its specificity was 66.67%. The PPV given a positive OSTA result with 0.71 as cut-off is 52.94%. The NPV given a negative OSTA result with a 0.71 cut-off is 68.09%. The sensitivity of PIO was 57.58% while the specificity was 58.33%. The PPV given a PIO result with 0.962 as cut-off is 48.72%. The NPV given a PIO result with a 0.962 cut-off is 66.67%.

The performance measures of OSTA and PIO did not vary significantly in predicting the risk for osteoporosis in Filipino men 50–69 years of age and Filipino women 50–65 years of age, and thus identify who of these patients should undergo DXA.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

CRediT author statement

Lyza Camille P. Gadong: Conceptualization, Methodology, Software, Validation, Verification, Formal analysis, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Monica Therese Cabral:** Conceptualization, Methodology, Resources, Supervision, Writing - review & editing. **Maria Leonora Capellan:** Conceptualization, Resources, Supervision, Writing - review & editing. **Nerissa Ang-Golangco:** Conceptualization, Resources, Supervision, Writing - review & editing.

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