Estimating regional bone mineral density-based T-scores using clinical information; tools validated for postmenopausal women in Sri Lanka

Hewa Walpola Amila Sewwandi Subasinghe a,⁎, Sarath Lekamwasam b, Patrick Ball c, Hana Morrissey c, Eisha Waidyaratne b

a Department of Pharmacy, Faculty of Allied Health Sciences, University of Ruhuna, Sri Lanka
b Faculty of Medicine, University of Ruhuna, Sri Lanka
c School of Pharmacy, University of Wolverhampton, United Kingdom

ARTICLE INFO

Article history:
Received 31 March 2020
Received in revised form
23 August 2020
Accepted 29 August 2020
Available online 16 September 2020

Keywords:
Osteoporosis
Postmenopausal women
Bone mineral density
Screening
Sri Lanka

ABSTRACT

Objectives: This study aims to develop and validate a country specific osteoporosis risk assessing tool for Sri Lankan postmenopausal women.

Methods: Community-dwelling postmenopausal women were enrolled to development (n = 602) and validation (n = 339) samples. Clinical risk factors (CRFs) of osteoporosis were assessed. Bone mineral densities (BMD) of femoral neck, total hip and lumbar spine were assessed by dual energy X-ray absorptiometry (DXA) scan. Radial ultrasound (US) bone scan was done. Linear regression analysis was performed in development sample considering regional BMDs as dependent and CRFs as independent variables. Regression equations were developed to estimate regional BMDs using best predictive CRFs. Sensitivity, specificity, positive and negative predictive values (PPV and NPV) were assessed to validate the new tools.

Results: Age, body weight and US T-scores showed positive correlations with BMDs of all 3 sites. Two osteoporosis risk assessing tools (OPRATs) were developed as OPRAT-1 and OPRAT-2. Prevalence of osteoporosis, in the validation sample was 74.3%. Sensitivity were high in both tools (OPRAT-1 and OPRAT-2; 83.2% and 82.5%) while specificity were moderate (44.8% for both). PPV of OPRAT-1 and OPRAT-2 were 79.5% and 81.2%. Both tools showed moderate NPV (OPRAT-1 and OPRAT-2; 51% and 47%).

Conclusions: Both OPRAT-1 and OPRAT-2 have high performance in screening postmenopausal women in Sri Lanka for risk of osteoporosis. OPRAT-2 is more convenient and can be used in any healthcare setting with limited resources to identify women who will be benefited by DXA. OPRAT-1 can be used if the radial US facility is available.

© 2020 The Korean Society of Osteoporosis. Publishing services by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Osteoporosis is an emerging public health concern all over the world mainly affecting the aging population. The current global prevalence of osteoporosis is over 200 million [1,2]. In Sri Lanka approximately 45% of women over 50 years are likely to have osteoporosis [3]. Fragility fracture is the clinical outcome of osteoporosis and hip fracture, the most sinister complication of the disease, is linked with increased mortality, morbidity, and health care cost [4–6].

Although the diagnosis of osteoporosis is based on bone mineral density (BMD), the restricted availability of the technology limits its use as a screening tool, especially in resource limited countries. Osteoporosis risk assessing tools which are based on clinical information are being used as an alternative to screen patients for osteoporosis or high fracture risk.

Risk calculators such as Osteoporosis Self-Assessment Tool for Asians (OSTA), Osteoporosis Risk Assessment Instrument (ORAI), and Simple Calculated Osteoporosis Risk Estimation (SCORE) are simple devices validated for local populations [7–12]. They are
Based on a combination of clinical risk factors (CRF), each given a weighting according to the importance. These tools vary with regards to the sensitivity and specificity in identifying high risk patients and performance [9,10,13–15].

Osteoporosis risk assessment tools need to be country specific since the associations between CRFs and osteoporosis or fracture risk have geographical variation. Many countries have developed their own models using either own data or data from surrogate populations. The Korean Osteoporosis Risk-Assessment Model (KORAM) has been developed specifically for Korean postmenopausal women and it has 84.8% sensitivity and 51.6% specificity in identifying high risk postmenopausal women [11]. Furthermore, Osteoporosis Pre-screening Model for Iranian Postmenopausal women (OPMIP) demonstrates sensitivity and specificity of 73.2% and 61%, respectively, in detecting high risk postmenopausal women [16].

In Sri Lanka, DXA facility is restricted to a few major cities covering only a small proportion of country’s population. Furthermore, no validated methods are available to detect osteoporosis or high fracture risk. In this study, we aim to fill this lacuna by developing and validating a country specific osteoporosis risk assessing tool for Sri Lankan postmenopausal women.

2. Methods

2.1. Participants

Community dwelling post-menopausal women (n = 605) were selected from Galle district, Sri Lanka by a stratified random sampling method. After initial screening, 602 postmenopausal women were included in the study sample that was used to develop the tool. Women who were cognitively impaired, failed to give consent, had diseases that can affect bone health (malabsorption, hyperparathyroidism, hypothyroidism, hypogonadism) or were on medications that could affect bone metabolism (thyrroxin, thiazide) were excluded.

The tools developed were validated on a separate sample of postmenopausal women selected from the same locality using the same inclusion criteria 6 months after the initial study. Among 364 women, 25 were excluded (cognitively impaired or failed to give consent) and the final validation sample included 339 postmenopausal women.

The study was approved by the Ethical Review Committee, Faculty of Medicine, University of Ruhuna, Sri Lanka (Ref No. March 09, 2016:3.3) and followed the Declaration of Helsinki. All patients agreed to participate in the study and provided written informed consent.

2.2. Measurements

A survey of CRFs was conducted using a pre-designed and content validated data sheet. This survey included details about demographic and anthropometric data, reproductive history, medical history and co-morbid conditions, personal and family history of osteoporotic fractures, behavioral factors such as smoking, alcohol consumption, and glucocorticoids use.

Weight and height were measured adhering to standard protocols. BMDs of the lumbar spine (L1-L4), femoral neck (FN), and total hip (Hip) were measured with DXA scan (Hologic Discovery W, Hologic Inc, Bedford, MA, USA). Women were categorized as osteoporosis, osteopenia or normal, based on the BMD T-scores, adhering to the World Health Organization (WHO) criteria [17,18]. Quantitative ultrasound (QUS) (Sunlight Mini Omni, Israel) of the radius of the non-dominant side was performed in randomly selected 260 participants of tool development sample and 207 participants of tool validation sample. QUS measures the quality of bones as speed of sound (SOS, m/s) penetration. SOS data and SOS associated T-scores were gathered from patients who underwent QUS scans. All DXA and QUS scans were done by 2 trained technicians adhering to the manufacturers’ protocols. The machines were calibrated on each day prior to scanning.

2.3. Statistical analysis

A woman was considered to have osteoporosis if the T-score of the lumbar spine (L1-L4), femoral neck or total hip region was \( \leq -2.5 \). Descriptive statistics; means (SD) and medians (IQR) were calculated for continuous numerical variables. Frequency distributions and percentages were used for categorical variables.

In the tool development process Pearson’s correlation was used to identify clinical risk factors associated with T-scores. These factors were used in multilinear regression models (MLR) as independent variables and T-scores as dependent variables to assess the osteoporosis predicting ability. It was aimed to predict regional T-scores than BMD since absolute BMD is not used in the detection of osteoporosis. Separate regression analyses were conducted with and without QUS T-scores. Regression equation to predict regional T-scores was developed by multiplying each predictor variable with its relevant unstandardized coefficient (B) and adding them to the constant of the model. The best model to predict regional T-scores was selected based on \( R^2 \) (coefficient of determinations) which assessed the predictive ability of the model.

In the validation of the tools, T-scores of hip, FN, and spine were estimated for all participants in the validation sample using the osteoporosis risk assessing tools developed above. Actual T-scores of the spine, hip, and FN were compared with the respective estimated values using the paired t-test. Bland-Altman plots were constructed to assess the systematic difference between estimated and actual T-scores. Adhering to the WHO recommendations, the diagnosis of osteoporosis was made when the T-score was less or equal \(-2.5\) in the total spine, total hip or femoral neck. The sensitivity, specificity, PPV and NPV of new osteoporosis risk assessment tools with regards to their ability to discriminate women with and without osteoporosis were calculated.

The OSTA index was calculated for all study participants in the validation sample. They were categorized in to high (< -4), intermediate (-4 to –1), and low risk (>-1) groups [7]. The new tools were compared with the OSTA index.

3. Results

3.1. Characteristics of the development and validation samples

The development and validation samples contained 602 and 339 community dwelling postmenopausal women, respectively. Table 1 shows the descriptive characteristics of these samples.

The prevalence of osteoporosis in the development sample was 65.3% and another 28.5% had osteopenia. Further, 74.3% women in the validation sample had osteoporosis while another 21.5% had osteopenia.

3.2. Development of the tools

In bivariate analysis, anthropometric variables and QUS measures were associated (\( P < 0.001 \)) with BMD and BMD based T-scores of hip, femoral neck, and spine (Table 2). Number of participants with parental history of hip fractures, long-term glucocorticoid use, previous history of fractures (after 45 years age), smoking or consumption of alcohol were very low and did not show significant associations with BMD or regional T-scores.
The MLR analysis revealed that the 2 clinical risk factors; age and body weight, either with or without QUS T score have a greater ability to predict regional T-scores in postmenopausal women (Table 3). The best model with the highest R² value was selected to predict the respective regional T-score.

Two osteoporosis risk assessment tools were devised (with and without QUS T score have a greater ability to predict regional T-scores in postmenopausal women). The best model with the highest R² value was selected to predict the respective regional T-score. The MLR analysis revealed that the 2 clinical risk factors; age and body weight, either with or without QUS T score have a greater ability to predict regional T-scores in postmenopausal women (Table 3). The best model with the highest R² value was selected to predict the respective regional T-score. Two osteoporosis risk assessment tools were devised (with and without QUS T score) based on the outcome of MLR analysis. Formulae with E1 contained QUS data and formulae with E2 does not contain QUS data. The best model with the highest R² value was selected to predict the respective regional T-score. If at least one of these estimated T-score was ≤ −2.5, then the patient was considered to have osteoporosis.

2. Osteoporosis Risk Assessment Tool 2 (OPRAT-2) - Estimated regional T-scores are denoted as T.Hip.E2, T.Spine.E2 and T.FN.E2 were calculated using below regression formulae.

If at least one of these estimated T-score was ≤ −2.5, then the patient was considered to have osteoporosis.

### Table 1
Descriptive characteristics of development and validation samples.

| Variable                  | Development sample | Validation sample |
|---------------------------|--------------------|-------------------|
|                          | Mean (SD)/N [%]    | Mean (SD)/N [%]   |
| **Age, yr**               | Age (yr)           | Age (yr)          |
|                          | 67.3 (8.3)         | 63.8 (9.3)        |
| **Body weight, kg**       | Body weight (kg)   | Body weight (kg)  |
|                          | 53.8 (10.1)        | 51.8 (10.4)       |
| **Height, cm**            | Height (cm)        | Height (cm)       |
|                          | 148.5 (6.3)        | 147.8 (5.6)       |
| **BMI, kg/m²**            | BMI (kg/m²)        | BMI (kg/m²)       |
|                          | 24.4 (4.2)         | 23.6 (4.4)        |
| **Waist, cm**             | Waist (cm)         | Waist (cm)        |
|                          | 80.3 (9.9)         | 77.9 (9.8)        |
| **Hip, cm**               | Hip (cm)           | Hip (cm)          |
|                          | 94.8 (9.6)         | 92.3 (9.1)        |
| **Blood glucose use**     | Blood glucose use  | Blood glucose use |
|                          | Glucocorticoid use | Glucocorticoid use|
|                          | 32 (5.3)           | 76 (22.4%)        |
| **Parent fractured hip**  | Parent fractured hip| Parent fractured hip|
|                          | 11 (2%)            | 14 (4.1%)         |
| **Previous fractures**    | Previous fractures | Previous fractures|
|                          | 86 (14.3%)         | 53 (15.6%)        |
| **Current smoking**       | Current smoking    | Current smoking   |
|                          | 0                 | 0                 |
| **Body weight, kg**       | Body weight (kg)   | Body weight (kg)  |
|                          | 53.8 (10.1)        | 51.8 (10.4)       |
| **Hip, cm**               | Hip (cm)           | Hip (cm)          |
|                          | 94.8 (9.6)         | 92.3 (9.1)        |
| **Waist, cm**             | Waist (cm)         | Waist (cm)        |
|                          | 80.3 (9.9)         | 77.9 (9.8)        |
| **BMI, kg/m²**            | BMI (kg/m²)        | BMI (kg/m²)       |
|                          | 24.4 (4.2)         | 23.6 (4.4)        |
| **Height, cm**            | Height (cm)        | Height (cm)       |
|                          | 148.5 (6.3)        | 147.8 (5.6)       |
| **Body weight, kg**       | Body weight (kg)   | Body weight (kg)  |
|                          | 53.8 (10.1)        | 51.8 (10.4)       |
| **Hip, cm**               | Hip (cm)           | Hip (cm)          |
|                          | 94.8 (9.6)         | 92.3 (9.1)        |
| **Waist, cm**             | Waist (cm)         | Waist (cm)        |
|                          | 80.3 (9.9)         | 77.9 (9.8)        |
| **BMI, kg/m²**            | BMI (kg/m²)        | BMI (kg/m²)       |
|                          | 24.4 (4.2)         | 23.6 (4.4)        |
| **Height, cm**            | Height (cm)        | Height (cm)       |
|                          | 148.5 (6.3)        | 147.8 (5.6)       |

SD, standard deviation; BMI, body mass index.

### Table 2
Pearson correlations (r) between anthropometric measures, bone mineral density/speed of sound and T-scores.

| Variable                  | Hip T-score | FN T-score | Spine T-score |
|---------------------------|-------------|------------|---------------|
| Age                       | 0.47        | 0.46       | 0.41          |
| Body weight               | 0.68        | 0.58       | 0.58          |
| Height                    | 0.25        | 0.21       | 0.30          |
| BMI                       | 0.21        | 0.21       | 0.30          |
| SOS                       | 0.45        | 0.45       | 0.40          |

Hip, total hip; FN, femoral neck; Spine, L1-L4; BMD, bone mineral density; BMI, body mass index; SOS, speed of sound. P-values of all the associations were <0.001.

### Table 3
Outcome of the multilinear regression analysis.

| Dependent variable | Independent variables considered in the model | Predictor variables | R² |
|--------------------|-----------------------------------------------|---------------------|----|
| T-FN               | Constant + Body weight                        | 0.38                |
| 1                  | Constant + Body weight + US T-score           | 0.40                |
| 2                  | Constant + Body weight + US T-score + age     | 0.44                |
| 3                  | Constant + Body weight                        | 0.33                |
| T-Hip              | Constant + Body weight + US T-score           | 0.41                |
| 1                  | Constant + Body weight + US T-score + age     | 0.45                |
| 2                  | Constant + Body weight                        | 0.22                |
| 3                  | Constant + Body weight + US T-score           | 0.29                |
| 4                  | Constant + Body weight + US T-score + age     | 0.31                |
| T-Spine            | Constant + Body weight                        | 0.31                |
| 1                  | Constant + Body weight + US T-score           | 0.38                |
| 2                  | Constant + Body weight + US T-score + age     | 0.39                |
| 3                  | Constant + Body weight + US T-score + age     | 0.22                |
| QUS-T-score was not considered as a predictor variable in below analyses. | Constant + Body weight + US T-score + age | 0.25                |

QUS, quantitative ultrasound; FN, femoral neck. *Indicate the models with best predictive ability.
Regional T-scores were estimated for all participants in the validation sample using the formulae in OPRAT-1 and OPRAT-2. Table 4 depicts mean comparisons between the actual and estimated regional T-scores. Standard error of mean (SEM) of actual and estimated T-scores are comparable in OPRAT-1 and OPRAT-2.

Bland-Altman plots were constructed to assess the agreement between the estimated (by OPRAT-1 or OPRAT-2) and actual T-scores of the validation sample (Figs. 1 and 2). In all plots, > 95% of values were within the limits of agreement (mean of difference ±1.96 SD).

The prevalence of osteoporosis in the validation sample, estimated based on the DXA derived T-score was 74.3%. This figure was not statistically different (P < 0.001) from the estimations made by the OPRAT-1 (75.4%) and OPRAT-2 (75.5%). The OSTA index revealed 32.4% were at high risk of osteoporosis while 34.5% were at intermediate risk. The remaining study participants were at low risk of osteoporosis.

The sensitivity of OPRAT-1 and OPRAT-2 were 83.2% and 82.5%, respectively, while specificity remained at 44.8% in both tools. Further, PPV and NPV of OPRAT-1 was 79.5% and 51%, respectively, while the corresponding values were 81.2% and 47% in OPRAT-2, respectively. The OSTA showed 76.2% sensitivity and 59.8% specificity. The PPV and NPV of OSTA were 84.6% and 46.4%, respectively.

The similar standard error of estimate (SEE) and R² values of OPRAT-1 and OPRAT-2 depict their comparable predicting ability of regional T-scores (Table 5).

4. Discussion

This study developed 2 osteoporosis risk assessing tools i.e, OPRAT-1 and OPRAT-2 which could predict regional T-scores of hip, spine and FN of Sri Lankan postmenopausal women. Each tool consisted of 3 formulae to estimate spine, hip and FN T-scores. OPRAT-1 uses age, body weight and radial QUS T-score data to estimate regional T-scores. OPRAT-2 is a simpler tool and needs only age and body weight to estimate T-scores. Therefore OPRAT-2 can be easily used as a screening tool of high osteoporosis risk in postmenopausal women. Numerous osteoporosis screening tools have been developed and validated in other countries, regions or ethnicities such as OSTA, ORAI, ORACLE and OSIRIS [7,9–12]. None of them has been validated for Sri Lankan population previously.

OPRAT-1 and OPRAT-2 were developed using multilinear regression analyses based on the hypothesis that clinical risk factors of osteoporosis could predict regional T-scores. In contrast, most of currently available osteoporosis risk prediction tools have been developed as scoring systems assigning a weight for the clinical risk factors used in the tool [7,9,16]. Age and body weight were clinical risk factors considered as potential predictors of BMD T-scores and thus used in the final regression analyses to develop the new tools. Advanced age and low body weight are well known determinants of osteoporosis and fragility fractures [22–26]. Age and body weight, together, contribute to bone mass greater than other risk factors [23,25,26]. Therefore, these 2 factors have been used in many osteoporosis risk prediction models either alone or in combination with other clinical risk factors such as oestrogen use, race, presence of rheumatoid arthritis, non-traumatic fractures, current hormone replacement therapy, smoking, regular exercises, and others [7,20]. OSTA uses only age and body weight to calculate the osteoporosis risk [7]. Tools such as ORAI, SCORE, OSIRIS, and Sao Paulo Osteoporosis Risk Index (SAPORI) are using clinical risk factors other than age and body weight [9,19,20,27]. However, this study did not reveal significant associations between parental history of hip fractures, long-term glucocorticoid use, previous history of fractures (after 45 years age), smoking or consumption of alcohol, and regional T-scores.

Bone QUS is used to assess osteoporosis, although limitations exist [28–31]. OPRAT-1 was developed on the assumption that QUS data, when combined with other CRFs, would be a better predictor of BMD based T-scores. We were unable to find previously developed osteoporosis risk prediction tools using QUS inputs.

The validation study proves that both OPRAT-1 and OPRAT-2 perform well as screening tools of osteoporosis. Both tools had high and similar osteoporosis predicting ability. Further, both OPRAT-1 and OPRAT-2 have comparable sensitivity performance with OSTA. Sensitivity, specificity, PPV and NPV statistics of our study are concordant with previously developed osteoporosis risk assessment indices such as OST, ORAI, SCORE, KORAM, and OSIRIS [7,9–12].

We used the T-score cut-off value of −2.5 in any of the skeletal sites (femoral neck, hip, spine) described in the WHO guidelines to diagnose osteoporosis in this study. Different cut-off values were used in various osteoporosis risk assessing tools. The OST originally used only the FN BMD T-Score < −2.5 to identify osteoporosis [7] but, Saravi later considered T-score < −2.0 in FN, spine or total hip in Argentinian postmenopausal women, and achieved a higher sensitivity (83.7%) [32]. Similar to our analysis, the WHO criteria have been used Su et al in Taiwan [8] and Regginster et al in France [19] to diagnose osteoporosis.

We used 2 independent study samples, selected using the same criteria for the development and validation of OPRAT-1 and OPRAT-2. A study sample drawn from all 9 provinces of the country would be more rational in developing country specific risk assessment tools. But this could be a daunting task due to logistics and cost considerations. The OST was built using 860 postmenopausal women from 8 Asian countries [7], but contribution from an individual country was lower than our study. Further, we used community-dwelling women in this study to avoid selection bias, though some studies did not include community samples. OSIRIS was built on data from 1303 postmenopausal women selected from

| Tool     | Variable | Actual T-scores Mean (SD) | Estimated T-scores Mean (SD) | Mean (SD) of difference | SEM   | P-value |
|----------|----------|---------------------------|------------------------------|-------------------------|-------|---------|
| OPRAT-1  | T - Spine - T.Spine.E1 | −3.10 (1.35) | −2.92 (0.75) | 0.18 (1.12) | 0.08  | 0.021   |
|          | T - Hip - T.Hip.E1     | −1.48 (1.18) | −1.59 (0.77) | 0.11 (0.91) | 0.06  | 0.086   |
|          | T - FN - T.FN.E1      | −1.95 (1.18) | −1.71 (0.76) | −0.24 (0.94) | 0.06  | <0.001  |
| OPRAT-2  | T - Spine - T.Spine.E2 | −3.14 (1.38) | −2.88 (0.64) | −0.26 (1.17) | 0.06  | <0.001  |
|          | T - Hip - T.Hip.E2     | −1.46 (1.20) | −1.59 (0.70) | 0.12 (0.93) | 0.05  | 0.014   |
|          | T - FN - T.FN.E2      | −1.93 (1.16) | −1.69 (0.70) | 0.23 (0.92) | 0.05  | <0.001  |

FN, femoral neck; OPRAT, Osteoporosis Risk Assessment Tool; SD, standard deviation; SEM, standard error of mean. E1, estimated 1; E2, estimated 2. This table shows mean (SD) comparison of actual and estimated regional T-scores. Paired t-test was performed for the analysis and P < 0.05 was considered statistically significant.
an outpatient osteoporosis clinic [12]. Further, Reginster et al validated OSIRIS in 798 postmenopausal women referred by rheumatologists at visits to routine check-ups or follow-ups [19].

There are a few limitations in this study. These formulae contain only age and body weight, and the other clinical risk factors such as previous fracture and parental history of hip fracture were not considered due to low numbers. Both OPRAT-1 and 2 consist of 3 separate formulae to estimate T-scores of the hip, FN, and spine. Hence all 3 calculations should be done to make a clinical decision. This perhaps is time consuming and less user friendly. Furthermore, the study participants were limited to 1 province and this may limit the generalizability of the findings.

5. Conclusions

In conclusion, both OPRAT-1 and OPRAT-2 can be used as screening tools to identify postmenopausal women with high risk of osteoporosis. OPRAT-2 is more convenient and practical in any setting as it uses only data of age and body weight. The OPRAT-1 requires radial QUS data, which is a major limitation.

To the best of our knowledge, these are the first osteoporosis risk assessing tools developed for Sri Lankan postmenopausal women using country specific data. This study suggests that OPRAT-2 is a useful screening tool for osteoporosis to identify patients who need bone densitometry scanning. It can be used even in a primary care setting or in general use as a self-screening tool.

Further, this is an affordable and simple tool that can be used with basic resources. Therefore, it is a low-cost osteoporosis screening method and would be advantageous to use in rural healthcare centres of Sri Lanka where DXA facilities are not accessible. Finally, facilitation of osteoporosis early identification will enable to initiate preventive and therapeutic strategies aiming at reducing the health and socioeconomic burden while improving quality of life of postmenopausal women.

Conflicts of interest

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

CRediT author statement

Hewa Walpola Amila Sewwandi Subasinghe: Conceptualization, Methodology, Writing - review & editing, Funding acquisition. Sarath Lekamwasam: Conceptualization, Methodology, Writing - review & editing, Supervision. Patrick Ball: Conceptualization, Methodology, Resources, Funding acquisition, Supervision. Hana Morrissey: Methodology, Resources, Writing - review & editing, Funding acquisition, Supervision. Eisha Waidyaratne: Supervision, Writing - review & editing.
Acknowledgments

Authors are thankful to the Technicians at the DXA scan unit of the Teaching Hospital, Karapitiya, Galle, Sri Lanka. This study was funded by the University Grants Commission of Sri Lanka (grant number UGC/VC/DRIC/PG2016(I)/RUH/01) and the University of Wolverhampton, UK. ORCID Hewa Walpola Amila Sewwandi Subasinghe: 0000-0002-4275-6610. Sarath Lekamwasam: 0000-0002-3541-9982. Patrick Ball: 0000-0001-8918-2119. Hana Morrissey: 0000-0001-9752-537X. Eisha Waidyaratne: 0000-0001-5696-0228.

References

[1] Alquaiz AM, Kazi A, Tayel S, Shaikh SA, Al-Sharif A, Othman S, et al. Prevalence and factors associated with low bone mineral density in Saudi women: a community based survey. BMC Muscoskel Disord 2014;15:5.
[2] International osteoporosis foundation. Epidemiology. [Internet]. International Osteoporosis Foundation; 2017 [cited 2018 Dec 3]. Available from: http://www.iofbonehealth.org/epidemiology.
[3] Lekamwasam S, Wijayaratne L, Rodrigo M, Hewage U. Prevalence of osteoporosis among postmenopausal women in Sri Lanka: a cross-sectional community study. APLAR J Rheumatol 2007;10:234.
[4] Tuzun S, Eskiyurt N, Akarirmak U, Saridogan M, Senocak M, Johansson H, et al. Incidence of hip fracture and prevalence of osteoporosis in Turkey: the FRACTURK study. Osteoporos Int 2012;23:949.
[5] Ahlborg HG, Rosengren BE, Jarvinen TL, Rogmark C, Nilsson JK, Sernbo I, et al. Prevalence of osteoporosis and incidence of hip fracture in women - secular trends over 30 years. BMC Muscoskel Disord 2010;11:48.
[6] Watts J, Abimanyu-Ochom J, Sanders KM. Osteoporosis costing all Australian: a new burden of disease analysis - 2012 to 2022. Osteoporosis Australia; 2013. Available from: http://dro.deakin.edu.au/eserv/DU:30060270/watts-osteoporosiscoasting-2013.pdf.
[7] Koh HK, Sedrine WB, Torralba TP, Kung A, Fujwara S, Chan SP, et al. A simple tool to identify asian women at increased risk of osteoporosis. Osteoporos Int

Table 5
Regression analyses comparing actual and estimated T-scores in the validation sample.

| Tool   | Variable | r   | R²  | SEE | P-value |
|--------|----------|-----|-----|-----|---------|
| OPRAT-1 | T.Hip.E1 | 0.63 | 0.40 | 0.92 | <0.001  |
|        | T.Spine.E1 | 0.56 | 0.31 | 1.12 | <0.001  |
|        | T.FN.E1   | 0.61 | 0.38 | 0.94 | <0.001  |
| OPRAT-2 | T.Hip.E2 | 0.64 | 0.41 | 0.93 | <0.001  |
|        | T.Spine.E2 | 0.53 | 0.28 | 1.17 | <0.001  |
|        | T.FN.E2   | 0.61 | 0.37 | 0.92 | <0.001  |

R², coefficient of determination; r, correlation coefficient; SEE, standard error of the estimate; OPRAT, osteoporosis risk assessing tool; FN, femoral neck. This table shows the statistics of regression analysis that predicts the ability of new osteoporosis risk assessing tools to identify high risk patients.

Fig. 2. Bland-Altman plots of actual and OPRAT-2 estimated regional T-scores. 2a-actual T-spine and OPRAT-2 estimated T.spine.E2, 2b-actual T-Hip and OPRAT-2 estimated T.Hip.E2, 2c-actual T-FN and OPRAT-2 estimated T.FN.E2.

3541-9982. Patrick Ball: 0000-0001-8918-2119. Hana Morrissey: 0000-0001-9752-537X. Eisha Waidyaratne: 0000-0001-5696-0228.

Acknowledgments

Authors are thankful to the Technicians at the DXA scan unit of the Teaching Hospital, Karapitiya, Galle, Sri Lanka. This study was funded by the University Grants Commission of Sri Lanka (grant number UGC/VC/DRIC/PG2016(I)/RUH/01) and the University of Wolverhampton, UK. ORCID Hewa Walpola Amila Sewwandi Subasinghe: 0000-0002-4275-6610. Sarath Lekamwasam: 0000-0002-3541-9982. Patrick Ball: 0000-0001-8918-2119. Hana Morrissey: 0000-0001-9752-537X. Eisha Waidyaratne: 0000-0001-5696-0228.
Su FM, Liu DH, Chen JF, Yu SF, Chiu WC, Hsu CY, et al. Development and validation of an osteoporosis self-assessment tool for Taiwan (OSTA) postmenopausal women - a sub-study of the Taiwan Osteoporosis survey (TOPS). PloS One 2015;10:1–12.

Kadarette SM, Jaglal SB, Kreiger N, McIsaac WJ, Darlington GA, Tu JV. Development and validation of the Osteoporosis Risk Assessment Instrument to facilitate selection of women for bone densitometry. Can Med Assoc J 2000;162:1289–94.

Lydick E, Cook K, Turpin J, Melton M, Stine R, Byrnes C. Development and validation of a simple questionnaire to facilitate identification of women likely to have low bone density. Am J Manag Care 1998;4:37–48.

Oh SM, Nam BH, Moon SH, Kim DY, Kang DR, et al. Development and validation of osteoporosis risk-assessment model for Korean postmenopausal women. J Bone Miner Metabol 2013;31:423–32.

Sedrine W, Chevallier T, Zegels B, Kvasz A, Micheletti M, Gelas B, et al. Development and assessment of the Osteoporosis Index of Risk (OSIRIS) to facilitate selection of women for bone densitometry. Gynecol Endocrinol 2002;16:245–50.

Huang JY, Song WZ, Zeng HR, Huang M, Wen QF. Performance of the Osteoporosis Self-Assessment Tool for Asians (OSTA) in screening osteoporosis among middle-aged and old women in the Chengdu region of China. J Clin Densitom 2015;8:339–45.

Chaovisitsaree S, Namwongprom SAN, Morakote N, Sunthornlimsiri N, Piynamongkol W. Comparison of osteoporosis self-assessment tool for Asian (OSTA) and standard assessment in menopause clinic. Chiang Mai J Med Assoc Thail 2007;90:420–5.

Muslim DAJ, Mohd EF, Sallehudin AY, Tengku-Muzaffar TMS, Ezane AM. Performance of osteoporosis self-assessment tool for asian (osta) for primary osteoporosis in post-menopausal Malay women. Malaysian Orthop J 2012;6:35–9.

Matin N, Tabatabaie O, Keshkhar A, Yazdani K, Asadi M. Development and validation of osteoporosis prescreening model for Iranian postmenopausal women. J Diabetes Metab Disord 2015;14:1–9.

Kanis JA, McCloskey EV, Harvey NC, Johansson H, Leslie WD. Intervention thresholds and the diagnosis of osteoporosis. J Bone Miner Res 2015;30:1747–53.

Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ, Khaltava N. A reference standard for the description of osteoporosis. Bone 2008;42:467–75.

Reginster JY, Ben Sedrine W, Viethel P, Micheletti MC, Chevallier T, Audran M. Validation of OSTEIRIS®a, a prescreening tool for the identification of women with an increased risk of osteoporosis. Gynecol Endocrinol 2004;18:3–8.

Pinheiro MM, Reis Neto ET, MacHado FS, Oumara F, Szczepfild J, Szczepfild VL. Development and validation of a tool for identifying women with low bone mineral density and low-impact fractures: the Sao Paulo Osteoporosis Risk Index (SAPORI). Osteoporos Int 2012;23:1371–9.

Johansson H, Kanis J, Oden A, Johnell O, McCloskey E. BMD, clinical risk factors and their combination for hip fracture prevention. Osteoporos Int 2009;20:1675–82.

Mantila Roosa SM, Hurd AL, Xu H, Fuchs RK, Warden SJ. Age-related changes in proximal humerus bone health in healthy, white males. Osteoporos Int 2012;23:2775–83.

Pisani P, Renna MD, Conversano F, Casciaro E, Di Paola M, Quarta E, et al. Major osteoporotic fragility fractures: risk factor updates and societal impact. World J Orthoped 2016;7:171.

Salamat MR, Salamat AH, Abedi I, Janghorbani M. Relationship between weight, body mass index, and bone mineral density in men referred for Dual-Energy X-Ray Absorptiometry scan in Isfahan, Iran. J Osteoporos 2013;2013:205963.

Shapses SA, Riedt CS. Bone, body weight, and weight reduction: what are the concerns? J Nutr 2006;136:1453–6.

Shapses SA, Von Thun NL, Heymsfield SB, Ricci TA, Osipina M, Pierson RN, et al. Bone turnover and density in obese premenopausal women during moderate weight loss and calcium supplementation. J Bone Miner Res 2001;16:1329–36.

Ben sedrine W, Devogelaer JP, Kaufman JM, Goemaere S, Depreseux G, Zegels B, et al. Evaluation of the simple calculated osteoporosis risk estimation (SCORE) in a sample of white women from Belgium. Bone 2001;28:374–80.

Marín F, González-Macias J, Díez-Pérez A, Palma S, Delgado-Rodríguez M. Relationship between bone quantitative ultrasound and fractures: a meta-analysis. J Bone Miner Res 2006;21:1126–35.

McCloskey EV, Kanis JA, Oden A, Harvey NC, Bauer D, González-Macias J, et al. Predictive ability of heel quantitative ultrasound for incident fractures: an individual-level meta-analysis. Osteoporos Int 2015;26:1979–87.

Nayak S, Oikoon L, Liu H, Grabe M, Gould MK, Allen IE, et al. Meta-analysis: accuracy of quantitative ultrasound for identifying patients with osteoporosis. Ann Intern Med 2006;144:832–41.

Siribaddana SH, Kovas Y, Fernando DJS. Quantitative ultrasound of bone and calcium intake in suburban males in Sri Lanka. Int J Rheum Dis 2008;11:407–13.

Saravi FD. Osteoporosis Self-Assessment Tool performance in a large sample of postmenopausal women of Mendoza, Argentina. J Osteoporos 2013;2013:150154.

H.W.A.S. Subasinghe, S. Lekamwasam, P. Ball et al.