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ORIGINAL RESEARCH

Incidence of Hip Fracture in Barranquilla, Colombia, and the Development of a Colombian FRAX Model

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Abstract A FRAX model for Colombia was released June 30, 2010. This article describes the data used to develop the Colombian FRAX model and illustrates its features compared to other countries. Hip fracture cases aged 50 years or more who were referred to all hospitals serving the city of Barranquilla were identified prospectively over a 3-year period (2004–2006). Age- and sex-stratified hip fracture incidence rates were computed using the 2005 census. Present and future numbers of hip fracture cases in Colombia were calculated from the age- and sex-specific incidence and the national population demography. Mortality rates for 1999 were extracted from nationwide databases and used to estimate hip fracture probabilities. For other major fractures (clinical vertebral, forearm, and humerus), incidence rates were imputed, using Swedish ratios for hip to other major osteoporotic fracture, and used to construct the FRAX model. Incidence of hip fracture increased with age, more markedly in women than in men. Over all ages, the female to male ratio was 1.7. By extrapolation, there were estimated to be 7,902 new hip fracture cases (2,673 men, 5,229 women) in Colombia in 2010, which was predicted to increase to 22,720 cases (7,568 men, 15,152 women) in 2035. The 10-year probability of hip or major fracture was increased in patients with a clinical risk factor, lower BMI, female gender, a higher age, and a decreased BMD *T* score. The remaining lifetime probability of hip fracture at the age of 50 years was 2.5 and 4.7 % in men and women, respectively, which were lower than rates in a Mexican population (3.8 and 8.5 %, respectively) and comparable with estimates for Venezuela (2.4 and 7.5 %, respectively). The FRAX tool is the first country-specific fracture-prediction model available in Colombia. It is based on the original FRAX methodology, which has been externally validated in several independent cohorts. Despite some limitations, the strengths make the Colombian FRAX tool a good candidate for implementation into clinical practice.

Keywords FRAX · 10-year fracture probability · Hip fracture · Osteoporotic fracture · Osteoporosis

The authors have stated that they have no conflict of interest.

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Introduction

Osteoporosis is a skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue with a resulting increase in bone fragility and susceptibility to fracture. Osteoporosis is an important public health issue because the consequent fractures are a major cause of morbidity, mortality, and health expenditure worldwide. In white populations, about 50 % of women and 20 % of men older than 50 years will have a fragility fracture in their remaining lifetime [1]. Fractures of the hip, vertebral body, proximal humerus, and distal forearm (commonly termed "major osteoporosis fractures") have long been recognized as typical of osteoporosis, though fractures at many other sites are characteristic of osteoporosis [2, 3]. Because of this huge burden, assessment of an individual's risk of fracture is important so that intervention can be effectively targeted.

Of the risk-assessment tools available, the most widely used is FRAX®. FRAX is a computer-based algorithm (http://www.shef.ac.uk/FRAX) developed by the World Health Organization (WHO) Collaborating Centre for Metabolic Bone Diseases at Sheffield and first released in 2008. The algorithm, intended for primary care, calculates fracture probability from easily obtained clinical risk factors (CRFs) in men and women [4, 5]. The output of FRAX is the 10-year probability of a major fracture (hip, clinical spine, humerus, or wrist) and the 10-year probability of hip fracture. Probability is calculated from age, body mass index (BMI), and dichotomized risk factors comprising prior fragility fracture, parental history of hip fracture, current tobacco smoking, long-term oral glucocorticoid use, rheumatoid arthritis, other causes of secondary osteoporosis, and excessive alcohol consumption. Femoral neck bone mineral density (BMD) can be optionally input to enhance fracture risk prediction [6].

The risk of hip fracture and probably of other osteoporotic fractures varies markedly around the world [7]. The difference in incidence between countries is much greater than the differences in incidence between sexes within a country. Indeed, a greater than 10-fold difference in hip fracture incidence has been reported in different countries, which is much larger than the errors arising in such studies [7, 8]: variations of this magnitude are reported from prospective studies in Europe using a common methodology [9]. In addition, the risk of death differs between countries. This variation also contributes to the heterogeneity in fracture probability [4]. For this reason, FRAX models are calibrated to those countries where the epidemiology of fracture and death is known. Models are currently available for 49 countries.

Information about the epidemiology of fractures in Colombia is sparse [10, 11] since there are no centralized health-care statistics available. Some information is available on the prevalence of radiographic vertebral fracture but no data on incidence [10]. The aim of the present study was to estimate hip fracture rates in Barranquilla, Colombia, for incorporation into a FRAX model and to determine the current and future national burdens of hip fracture.

Methods

Barranquilla is a Caribbean Colombian city, located at the north of the country, with tropical weather and a temperature mean of 27.4 °C. It is considered the fourth Colombian city, after Bogota, Medellin, and Cali. The population is estimated at 2,370,753.

Cases of hip fracture were identified prospectively over a 3-year period (2004–2006) in men and women aged 50 years or more who were admitted to any of the six hospitals that deal with hip fracture cases from rural and urban areas of Barranquilla (Hospital de Barranquilla, Hospital Universitario, Hospital Seguro Social, Clinica General del Norte, Clinica Bautista, Clinica de Fracturas). In Colombia, all patients with hip fracture are treated in hospital and the vast majority (90 %) are treated surgically [12]. Admissions were reported on a weekly basis to a data collection and coordinating center (Rheumatology and Orthopedics Center). The patients' history was obtained by patient or family interview at the time of admission and (for purposes other than this report) followed up throughout the hospital stay and for at least 1 year thereafter. Hip fractures were verified from review of the radiology reports. Repeat admissions for the same fracture were excluded from analysis.

Pathological fractures due to neoplasia were excluded as were high-energy fractures resulting from road traffic accidents. No account was taken of the residential address of each case. A total of 676 hip fractures were identified, 218 men and 458 women.

Incidence was computed by age and sex in 5-year age intervals using the population demography from Barranquilla, supplied from the 2005 census [13]. Since this source only gave the population in 5-year age intervals up to the age of 80 years and the population aged 80+ years, we estimated the population in the age intervals of 80–84, 85–89, 90–94, and 95–99 years using the ratio between the population of the whole country and Barranquilla for the age interval of 75–79 and 80+ years. Since FRAX estimates fracture risk from the age of 40 years, hip fracture rates between the ages of 40 and 50 years were computed by extrapolation after log transformation.

To compute the number of hip fractures, incidence rates were applied to the population of Colombia for 2010 [14] and, for hip fracture projections, to the expected (medium variant) population up to the year 2035. The lifetime probability of having a hip fracture in women and men from the age of 50 years was computed from the hazard functions of hip fracture and death using the method of Kanis and colleagues [8]. The mortality rate for 1999 was supplied by the WHO.

The incidence of other major osteoporotic fractures was not determined, and for the purposes of the FRAX model, it was assumed that the age- and gender-specific ratios of forearm, clinical spine, and humeral fracture incidence to hip fracture incidence in Sweden were comparable to those in Colombia. This assumption has also been used for many of the FRAX models with incomplete epidemiological information. Available information suggests that the age- and gender-stratified pattern of fracture is very similar in the Western world and Australia [15]. The construct of the FRAX model for Colombia used the beta coefficients of the risk factors in the original FRAX model and the incidence rates of hip fracture and mortality rates for Colombia.

In order to compare Colombian hip fracture probabilities with those of other regions of the world, the remaining lifetime probability of hip fracture from the age of 50 years was calculated for men and women, as described by Kanis et al. [5] using updated hip fracture incidence [7] and mortality [14] estimates. In the present analysis, values for the Colombia were compared with other estimates from the region (Argentina, Brazil, Chile, Ecuador, Mexico, and Venezuela) and those of China, Canada, Denmark, Finland, France, Hungary, Poland, Portugal, Spain, Sweden, the United Kingdom, and the United States.

Results

Hip Fracture Incidence

A total of 676 cases of hip fractures were registered in 2004–2006, 218 in men and 458 in women, aged between 50 and 99 years. In both sexes, annual incidence per 100,000 persons increased with age (Table 1). Incidence was lower in men than in women for all ages. Hip fracture rates in both sexes increased in an exponential manner with age. The incidence standardized to the world population was 78 and 127/100,000 in men and women, respectively.

Current Burden

When hip fracture rates were applied to the Colombian population, it is estimated that more than 7,900 hip fractures occurred annually in men and women aged 50 years or more in 2010. Of these, 66 % occurred in women (Table 2). The majority of hip fractures in women occurred after the age of 75 years.

Hip Fracture Projections

In the year 2010, the estimated total population of Colombia was 46.3 million. In 2035, the population is expected to increase by about 25 % to 58.7 million. However, the increase in the total population will not be uniform. The greatest increase will be in the elderly. The number of men and women aged 50 years or more is expected to double from 8.1 million to 17.5 million. The number of individuals aged 85 years or more will increase in men and women more than threefold. Since hip fracture risk increases exponentially with age, there will be a large increase in the number of hip fractures from 2,673 in 2010 to 7,568 in men in 2035 and from 5,229 to 15,152 over the same interval in women (see Table 2).

Fracture Probability Without BMD

The lifetime probability of sustaining a hip fracture at the age of 50 years was 4.5 % in women and 2.5 % in men. The 10-year probability of sustaining a hip fracture at the age of 50 years was 0.1 % in men and 0.1 % in women in the absence of CRFs and a BMI of 25 kg/m^2. The 10-year

Table 1 Hip fracture cases (2004–2006), population at risk, and annual hip fracture rates by age and sex in Barranquilla, Colombia

Age range (years)	Men			Women		
	Hip fractures	Population	Yearly incidence / 100,000	Hip fractures	Population	Yearly incidence / 100,000
50–54	8	25,129	10.6	9	27,942	10.7
55–59	16	19,077	28.0	23	21,565	35.6
60–64	22	13,489	54.4	34	15,888	71.3
65–69	21	10,965	63.8	43	14,335	100
70–74	26	8,117	107	73	11,140	218
75–79	52	6,289	276	94	8,979	349
80–84	34	3,756	301	89	5,751	516
85–89	21	1,580	443	47	2,702	581
90–94	12	491	815	36	1,004	1,195
95–99	6	105	1,905	10	270	1,222
Totals	218	88,998	81.6	458	109,576	139

Table 2 Estimated number of hip fractures in 2010 and in 2035 in Colombia by age and sex

Age (years)	Men		Women	
	2010	2035	2010	2035
50–54	114	182	128	198
55–59	243	433	351	608
60–64	347	710	527	1,062
65–69	275	768	519	1,421
70–74	320	1,010	830	2,549
75–79	551	1,767	942	2,949
80–84	352	1,149	888	2,856
85+	471	1,549	1,044	3,509
50+	2,673	7,568	5,229	15,152

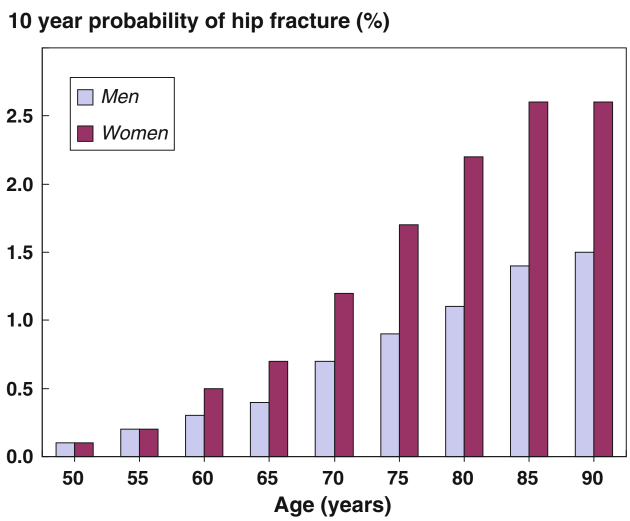

Fig. 1 Ten-year probability of hip fracture for men and women with no clinical risk factors and a BMI of 25 kg/m^2

probability of hip fracture increased with age in men and women. For women the probability was stable after the age of 85 years due to the competing effect of mortality on the fracture hazard. The hip fracture probability for men and women with no CRFs is shown in Fig. 1.

Probabilities of a major fracture according to the presence of CRFs are given in Table 3. Each of the CRFs contributed independently to fracture probability (see Table 3). Smoking and alcohol were relatively weak risk factors as they increased the probability for a major fracture from 5.2 % to only 5.8 and 6.8 %, respectively, in women at the age of 80 years. A parental history of hip fracture was associated with the highest risk (10 % at 80 years). Intermediate increments in probability were associated with the long-term use of glucocorticoids, rheumatoid arthritis, and a prior fragility fracture (8.2, 7.7, and 8.7 %, respectively) at the age of 80 years.

Table 3 Ten-year probability of a major fracture (%) in men and women according to the presence of clinical risk factors (CRF) in the absence of BMD

CRF	Age (years)				
	50	60	70	80	90
Men					
None	1.0	1.9	2.1	2.3	2.6
Alcohol	1.2	2.4	2.7	3.1	3.5
Rheumatoid arthritis	1.3	2.7	3.0	3.5	4.0
Glucocorticoids	1.5	3.1	3.2	3.4	3.6
Smoking	1.0	2.0	2.2	2.5	2.7
Parental history	1.9	3.8	3.5	5.1	6.1
Prior fracture	2.1	4.0	4.0	3.9	4.3
BMI (20 kg/m^2)[a]	1.0	2.0	2.2	2.5	2.7
Women					
None	1.3	3.1	4.0	5.2	6.2
Alcohol	1.5	3.8	5.1	6.8	8.1
Rheumatoid arthritis	1.7	4.2	5.8	7.7	9.1
Glucocorticoids	2.1	5.0	6.7	8.2	8.4
Smoking	1.3	3.3	4.5	5.8	6.3
Parental history	2.5	5.9	6.6	10	12
Prior fracture	2.8	6.3	7.7	8.7	10
BMI (20 kg/m^2)[a]	1.3	3.3	4.7	6.0	6.1

BMI is set at 25 kg/m^2 except where indicated

[a] No other CRF

Fracture Probability with BMD

The 10-year probability of a major osteoporotic fracture for men and women without CRFs according to age and *T* score is shown in Fig. 2. At any given age, fracture probability in women increased with decreasing *T* score. By contrast, at any given *T* score, fracture probabilities rose with age up to the age of 70 or 80 years and thereafter decreased. The decreasing probability at older ages results from the competing effect of BMD on mortality.

At the extreme of *T* score (−4.0 SD), probabilities decreased progressively with age in men because of the more marked competing effect of the death risk on fracture risk. At younger ages (below 65 years), the fracture probability was similar in men and women. For example, at the age of 55 years with a *T* score of −2.5 SD, the probability of a major fracture was 5.2 % in men and 5.6 % in women. With advancing age probabilities in men were qualitatively similar to those in women, increasing to 70 years and thereafter decreasing with age.

The 10-year probability of hip fracture in women calculated with the Colombian FRAX model, for a *T* score at −2.5 SD and no other CRFs, was 0.8 % at the age of 50 years and rose with age to 2.0 % at the age of 80 years

Fig. 2 Ten-year probability of a major osteoporotic fracture for men (*left*) and women (*right*) with BMI 25 kg/m^2 according to age and BMD *T* score for femoral neck BMD

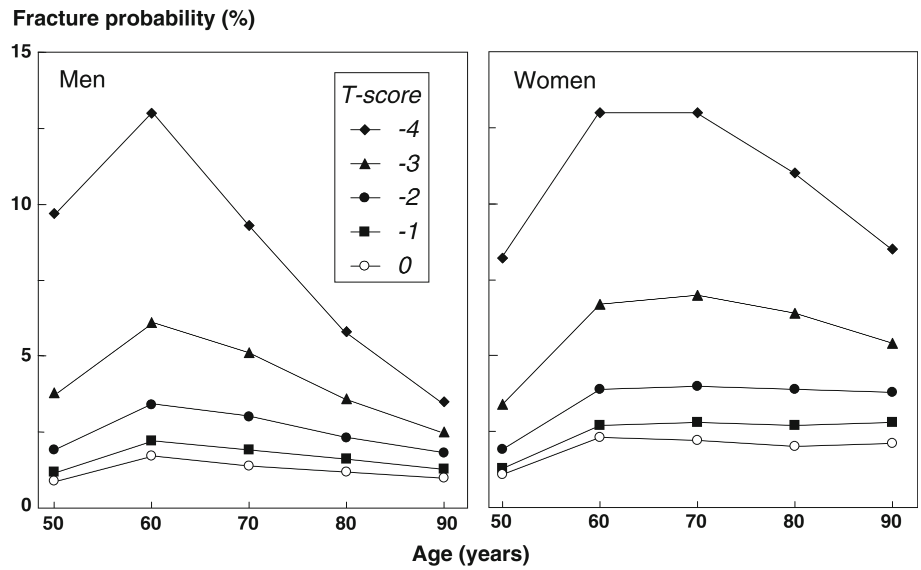

Table 4 Ten-year probabilities of a major fracture (hip, clinical spine, humerus, and forearm) and a hip fracture calculated with the Colombian FRAX model for women

	Age (years)								
	50	55	60	65	70	75	80	85	90
Major fracture									
No clinical risk factors	1.3	2.2	3.1	3.5	4.0	4.7	5.2	5.7	6.2
Previous fracture[a]	2.8	4.7	6.3	7.1	7.7	8.4	8.7	9.5	10
BMD *T* score −2.5 SD[a]	2.5	4.1	5.2	5.4	5.4	5.4	5.1	4.8	4.7
Previous fracture + BMD *T* score −2.5 SD	4.9	7.6	9.0	9.0	8.6	8.2	7.4	6.9	6.9
Hip fracture									
No clinical risk factors	0.1	0.2	0.5	0.7	1.2	1.7	2.2	2.6	2.6
Previous fracture[a]	0.4	0.8	1.3	1.8	2.5	3.1	3.4	4.0	4.0
BMD *T* score −2.5 SD[a]	0.8	1.3	1.5	1.7	1.9	2.0	2.0	1.9	1.6
Previous fracture + BMD *T* score −2.5 SD	1.8	2.5	2.8	2.9	3.0	2.9	2.6	2.5	2.1

The table shows results for women with BMI of 25 kg/m^2

[a] No other clinical risk factors

and decreased thereafter. At younger ages (below 65 years), the fracture probabilities were slightly higher in men than in women. For example, at the age of 55 years with a *T* score of −2.5 SD, the probability of hip fracture was 1.7 % in men and 1.3 % in women.

Intervention Thresholds

In Colombia the current threshold for the reimbursement of treatments is based on BMD measurements by dual-energy X-ray absorptiometry (DXA) with a treatment threshold set at −2.5 SD. In Table 4, the probabilities corresponding to this threshold are shown together with those equivalent for women with a previous fragility fracture and compared with women with no CRFs in the absence of BMD.

In women aged 50, 60, 70, and 80 years without CRFs and with a BMD *T* score of −2.5 SD, the 10-year probability of a major osteoporotic fracture was 2.5, 5.2, 5.4, and 5.1 %, respectively. In women with no CRFs and without DXA, the respective age-specific probabilities were 1.3, 3.1, 4.0, and 5.2 %. Thus, the BMD criterion for reimbursement using a fixed *T* score becomes less and less appropriate with advancing age. For example, at the age of 50 years, women with a *T* score of −2.5 SD had twice the risk of their counterparts with no CRFs. In contrast, at the age of 80 years and above, fracture probabilities were

Table 5 Lifetime probability of hip fracture in the Colombian population compared with selected countries

Country	Lifetime risk at 50 years (%)	
	Women	Men
Sweden	28.5	13.1
Denmark	16.5	5.8
Argentina	16.3	4.0
United States (Caucasian)	15.8	6
Canada	14	5.2
United Kingdom	13.7	4.8
Finland	12.7	5.5
France	12.7	3.6
Spain	12.0	4.2
Chile	11.4	3.8
Portugal	10.1	3.6
Turkey	8.9	3.5
China (Hong Kong)	8.8	4.1
Mexico	8.5	3.8
Brazil	8.5	3.0
Venezuela	7.5	2.4
Hungary	7.4	3.5
Colombia[a]	4.7	2.5
Poland	4.5	2.0
Ecuador	4.3	2.1
China	2.4	1.9

[a] This study

lower in women with osteoporosis than in their counterparts with no CRFs. A similar observation was made when looking at hip fracture probabilities. The explanation is that in the oldest old there is a decrease in the probability of fracture because of the competing death risk, particularly in individuals with low BMD, plus the decrease in *T* score with advancing age. Indeed, the average *T* score in women at the age of 85 years is lower than −2.5 SD.

In women with a previous fracture, probabilities were higher than in women at the threshold of osteoporosis and rose progressively with age to 80 years. This would suggest that a viable threshold for reimbursement could be the probability equivalent of a prior fracture, in the absence of BMD.

Comparison Across Countries

Table 5 gives a sample of the remaining lifetime probability of hip fracture from the age of 50 years in men and women. The country samples include those with very high probabilities (Sweden and Denmark) and those among the lowest. Lifetime probabilities for Colombia were among the lowest, comparable to those in Ecuador and Poland.

Discussion

This study characterizes for the first time the hip fracture incidence in a region of Colombia from the age of 50 years, based on regional data from Barranquilla. As expected, in both sexes incidences per 100,000 persons increased with age. At all ages, incidences were higher in women than in men. Based on age-standardized annual incidence of hip fracture for men and women combined, Colombia belongs to the low-risk countries for osteoporosis [7]. The majority of hip fractures occurred in men and women aged 75 years or more. Demographic projections given in this study indicate that the Colombian population aged 50 years and over will double between 2010 and 2035 and that the population aged 80 years or more will triple, so the burden of the disease will increase markedly with time. We estimate that the annual number of hip fractures will increase from about 7,900 in 2010 to nearly 23,000 in 2035. These estimates are relatively robust in that all individuals who will be aged 50 years or more in 2035 are currently adults. However, these estimates may be conservative since they assume that the age- and sex-specific risk of hip fracture remains unchanged over this period. If the age- and sex-specific incidence increases, as it has, for example, in Mexico [16], then the number of fractures may be more than doubled [17].

Notwithstanding the demographic shifts in the future, the hip fracture rates in Colombia are low. Colombia has one of the lowest age-standardized rates in the world (78 and 127/100,000 in men and women, respectively), somewhat lower than that of the Philippines (46 and 133/100,000 in men and women, respectively) [7]. Within Latin America, rates in the present study were higher than those reported for Ecuador but lower than those for other countries where hip fracture rates have been reported (Argentina, Brazil, Chile, Mexico, and Venezuela). The low incidence is reflected in the low 10-year and lifetime probabilities in the present report.

Reasons for the marked variation in hip fracture risk between countries (and in some cases within countries) are conjectural. The secular trends in incidence which are documented in many countries [18] strongly suggest environmental rather than genetic factors. Risk factors for hip fracture such as low BMI, low BMD, low calcium intake, reduced sunlight exposure, early menopause, smoking, alcohol consumption, and migration status may have important effects within communities but do not explain differences in risk between communities [9]. The factor which best predicts heterogeneity of risk is socioeconomic prosperity [19], which in turn may be related to low levels of physical activity or an increased probability of falling on hard surfaces. The determinants of a low fracture risk for Colombia, particularly modifiable risks, would be of great importance for devising strategies for the primary prevention of hip fracture worldwide.

The present study also describes the FRAX model for the assessment of fracture probability in men and women from Colombia. In the absence of BMD, probabilities of a major fracture were higher than hip fracture probabilities at all ages and both increased with age in men and in women up to 85 years. The 10-year absolute probability of any major osteoporotic and hip fracture in the presence of a single risk factor increased with advancing age in both sexes, being consistently higher in women than in men. Each of the CRFs contributed independently to fracture probability but with a different weight. Consistent with other country models, the Colombian model identified a parental history of hip fracture as the strongest risk factor: between a 50-year-old woman without risk factors and a 90-year-old woman with a parental history of hip fracture, the individual probability of a major osteoporotic fracture increased almost 10-fold (from 1.3 to 12 %). Long-term use of glucocorticoids, rheumatoid arthritis, and a prior fragility fracture were associated with moderate increments in probability.

Fracture probability depends upon the integration of death risks and fracture risks. The present study illustrates the importance of this with regard to BMD. Although fracture probability increases with decreasing *T* score, the relationship between probability and *T* score was not linear. Thus, at any given *T* score, fracture probabilities rose with age to the age of 60–70 years and thereafter remained stable or decreased. The decrease in fracture probability with age for a given *T* score was more marked in men (see Fig. 2). The declining fracture probability with age is partly mediated by the increased risk of death in the general population, an effect more marked in men than in women. A more important component of the effect is that low BMD is associated with an increased risk of death, which is captured in the FRAX algorithm [4, 5]. This explains why the declining fracture probability with age is much more marked at low *T* scores.

This effect has implications for practice guidelines. In Colombia, as in many countries, the threshold for the reimbursement of treatments is based on BMD measurements with DXA with a treatment threshold set at −2.5 SD. This study confirms that the BMD criterion for reimbursement using a fixed *T* score is associated with a greater than twofold difference in fracture probability, depending on age, and becomes less and less appropriate with advancing age (see Table 4). Over and above this effect, the assessment of BMD and age alone does not capture all determinants of fracture probability which are provided by the additional independent risk factors used in FRAX. For this reason, the use of BMD criteria alone for the reimbursement of treatment is problematic. This has been recognized in the development or the updating of practice guidelines which have taken more account of fracture probability and placed less reliance on the *T* score for BMD [20–27].

The present study has several strengths and limitations. A strength is that the data on hip fracture rates are prospective and based on several years of observation. We were able to minimize the overidentification of cases (double counting) and to exclude pathological fractures or high-energy fractures resulting from road traffic accidents. We were also able to assess the accuracy of data from self-report and from radiographic reports. A major weakness is that the hip fracture rates are based on a regional rather than a national estimate. The FRAX model assumes, therefore, that the hip fracture rates in Barranquilla (5.1 % of the Colombian population) represent the hip fracture rates for the whole of Colombia. In addition to large variations in fracture rates around the world, fracture rates may vary within countries. Up to twofold differences in hip fracture incidence have been reported using common methodology, with the higher rates often found in urban communities in Argentina, Turkey, Sweden, Norway, Switzerland, Croatia, and the United States [15]. Until national estimates are available for Colombia, clinicians should be aware of this possible variation in hip fracture rates and the estimates of fracture probability.

There are also important limitations in the construct of the FRAX model, which requires information on the risk of death and fracture. Hip fracture statistics were collected in 2004–2006, but mortality data were from 1999. If survival is increasing in Colombia (as it is in many countries), then 10-year fracture probability estimates may be underestimated. With regard to fracture, information is required on the incidence of major fractures (hip, spine, forearm, and humerus). In contrast to hip fractures, the incidence of other major fractures could not be determined. As undertaken for many countries with incomplete information, the incidence of these three types of osteoporotic fractures was imputed from the hip fracture incidence in Colombia and the relationship between hip fracture incidence and that of the other sites in Sweden (Malmö) [2]. This assumes that the ratio of hip fracture incidence to the incidence of other index fractures is similar in Colombia and in Sweden. This assumption, used in the development of some FRAX models, appears to hold true for the several countries where this has been tested [2, 15].

The FRAX tool is the first country-specific fracture-prediction model available in Colombia. It is based on the original FRAX methodology, which has been externally validated in several independent cohorts. Despite some limitations, the strengths make the Colombian FRAX tool a good candidate for implementation into clinical practice.

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