Published in final edited form as:

J Clin Densitom. 2014 ; 17(4): 522–527. doi:10.1016/j.jocd.2013.02.010.

RELIABILITY OF LATERAL DISTAL FEMUR DUAL ENERGY X-RAY ABSORPTIOMETRY MEASURES

Nicole M. Mueske, M.S.¹, Linda S. Chan, Ph.D.², and Tishya A. L. Wren, Ph.D.^{1,3,4}

Study conducted at Children's Hospital Los Angeles, Los Angeles, California, U.S.A

Abstract

Dual-energy x-ray absorptiometry (DXA) of the lateral distal femur (LDF) has been suggested for patients with metal implants or joint contractures preventing DXA scanning at conventional anatomical sites. This study assessed variability in LDF DXA measures due to repeat scanning using data from 5 healthy young adults who had 3 unilateral scans with repositioning between scans. Variability due to image analysis was evaluated in 10 children who underwent bilateral LDF scans with each scan being analyzed 3 times by 2 raters. Regions of interest (ROIs) were defined in the anterior distal metaphysis (R1), metadiaphysis (R2), and diaphysis (R3) as described previously. An additional region (R4) was defined in the metaphysis similar to R1 but centered in the medullary canal. Variability was consistently lower for bone mineral density (BMD) than for bone mineral content (BMC) and bone area; R4 was more repeatable than R1; and variability due to repeat scanning was negligible. These results suggest that DXA measures of the lateral distal femur are reliable and may be useful when standard DXA measures cannot be obtained, but it is recommended that a central, rather than anterior, ROI be used in the metaphysis.

Keywords

DXA; Lateral DXA; bone mineral density; reliability

INTRODUCTION

Low bone mass may lead to an increased risk of fractures and may be a precursor to osteopenia and osteoporosis, even in pediatric populations. Dual-energy x-ray absorptiometry (DXA) is commonly used to assess bone mass through measurements of bone mineral content (BMC) and density (BMD). DXA has been preferred over other bone

© 2013 International Society for Clinical Densitometry. Published by Elsevier Inc. All rights reserved.

Corresponding Author: Nicole M. Mueske, M.S. Address: Children's Orthopaedic Center, Children's Hospital Los Angeles, 4650 Sunset Blvd., M/S 69, Los Angeles, CA 90027, Phone: (323) 361-4120, Fax: (323) 361-1310, nmueske@chla.usc.edu.

¹Children's Orthopaedic Center, Children's Hospital Los Angeles, Los Angeles, CA

²Department of Pediatrics, Keck School of Medicine, University of Southern California, Los Angeles, CA

³Departments of Orthopaedic Surgery and Radiology, Keck School of Medicine, University of Southern California, Los Angeles, CA

⁴Department of Biomedical Engineering, Viterbi School of Engineering, University of Southern California, Los Angeles, CA

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

assessments, particularly in clinical settings, because of its low cost, low radiation exposure, ease of use, and demonstrated relationship to fracture risk in adults (1, 2).

DXA protocols typically examine the whole body, lumbar spine, and/or hip (proximal femur) because these are the most common fracture sites in the elderly. However, in some pediatric populations such as children with cerebral palsy or spina bifida, accurate data often cannot be obtained from these sites due to contractures, metal implants, and positioning problems. Furthermore, because correlations between different sites decline as density decreases, it is important to measure BMD at sites that are prone to fracture due to low bone density (3). For these reasons, the lateral distal femur (LDF) scan has been suggested as an alternative technique for performing DXA measurements in pediatric patients (4, 5).

The LDF scan has been successfully used in healthy children (5, 6), children with cerebral palsy (4, 7), children with muscular dystrophy (7), children with spina bifida (8), and children undergoing chemotherapy (9). Although LDF reliability has been reported within individual studies (4, 5), reliability of the LDF scan acquisition and analysis has yet to be systematically investigated. Obtaining accurate and reliable bone mass measurements is important for both research and clinical applications. Therefore, the purpose of this study was to examine the reliability of lateral distal femur DXA scans by assessing intra- and inter-rater reliability of image analysis and variability associated with repeat scanning.

MATERIALS & METHODS

LDF scans were performed on 3 groups of participants: 5 typically developing children (TD group), 5 ambulatory children with myelomeningocele (Myelo group), and 5 healthy adults (Adult group). Subjects in the TD and Myelo groups were randomly selected from a previous research study; subjects in the Adult group were volunteers for quality assurance testing. The study was approved by the Committee on Clinical Investigations at Children's Hospital Los Angeles.

A single certified radiology technologist performed all DXA acquisitions using a standard clinical densitometer (Delphi W, Hologic Inc., Bedford, MA, USA). The LDF scan was performed using the forearm protocol with the subject lying on the side being measured. Regions of interest (ROIs) were defined in the anterior distal metaphysis (R1), metadiaphysis (R2), and diaphysis (R3) as described by Henderson et al (5). To better represent cancellous bone, an additional region (R4) was defined in the metaphysis similar to R1, but centered in the medullary canal (Figure 1). To define the height of the ROIs, the width of the femur was measured in the diaphysis where the width was fairly consistent. All ROIs had a height of 2 times the width of the femoral shaft. The ROIs were placed end to end starting with R1 and R4, which originated just proximal to the distal growth plate. The width of R2 and R3 encompassed the entire width of the diaphysis. R1 had a width equal to half the width of the growth plate and was positioned extending posteriorly from the anterosuperior edge of the distal growth plate. R4 had a width equal to half the width of the femoral shaft and was positioned in the center of the medullary canal. If the femur was angled, R1 and R4 were angled to encompass the appropriate region. This was done first by angling R4 to form a parallelogram that followed the angle of the cortical bone at the distal

end of the femur where R1 and R4 are placed; to ensure that the area remained the same, the left and right corners were moved the same distance. R1 was adjusted to the same angle as R4. Bone mineral content (BMC), projected bone area (Area), and areal bone mineral density (BMD) were measured for each ROI.

Two main sources of variability were investigated: 1) variability due to image acquisition and 2) variability due to image analysis.

Variability due to image acquisition was examined using data from the adult subjects. These subjects underwent unilateral DXA scanning 3 times with repositioning between scans; each scan was analyzed once by a single rater. Coefficients of variation (CV) were derived for each measure for each subject. Differences between each pair of measurements were tested for significance from zero using the Student's paired t test.

Variability due to image analysis was examined using data from the pediatric subjects. Each subject underwent bilateral DXA scanning once; each scan was analyzed 3 times by 2 different raters. Coefficients of variation were derived for each measure for each subject. Two-factor analysis of variance (ANOVA) with two repeated measures was used to assess the differences of each DXA measure between subject groups, sides, raters, and readings. The last two factors were the repeated measures. We also tested the significance of the differences from zero between each pair of measurements using the Student's paired t test. The BMDP Statistical Software was used for the variability analyses (BMDP Statistical Software, Inc. Release 8.1, 2000, Statistical Solutions, Saugus, MA, USA).

In order to associate the ROIs with bone strength, 3% slices in the proximal and distal metaphyses were analyzed from peripheral quantitative computed tomography (pQCT) scans of the tibia (106 TD and 39 myelos) which were available from another study. Density weighted minimum principle moments of inertia (DWImin) and section moduli were measured using QCT Pro (Mindways, Austin, TX, USA). BMC and BMD were correlated with DWImins and section moduli using Stata statistical software (StataCorp LP, College Station, TX, USA).

RESULTS

The Adult group consisted of 2 men and 3 women with a mean $\pm$ standard deviation (SD) age of 29.2 ± 9.5 years (range 22–47). The TD group consisted of 3 boys and 2 girls with a mean $\pm$ SD age of 9.3 ± 1.9 years (range 7–12). The Myelo group consisted of 1 boy and 4 girls with a mean $\pm$ SD age of 9.7 ± 2.2 years (range 6–11). The functional neurosegmental levels of the children in the Myelo group according to the International Myelodysplasia Study Group criteria (10) were 3 children with sacral level and 2 children with mid lumbar level myelomeningocele.

Repeat Scans

There were no significant differences between scans for any of the DXA measures. Most coefficients of variation for the repeat scans were within 5%, with a maximum of 8%, for all

measures in all regions except R1 (Table 1). R1 had maximum CVs of 12% for Area, 16% for BMC, and 7% for BMD.

Repeat Analyses

Based on the ANOVA, there was a significant difference in the DXA measures between Raters, and there was a significant interaction between Rater and Group. Rater 1 tended to obtain lower measurements for Area and BMC in the TD group, but higher measurements in the Myelo group (Table 2). The two raters obtained similar BMD measurements. The mean difference between raters was generally small. Overall, the differences were within 1.7% for Area, 3.1% for BMC, and 1.1% for BMD (Table 3). In the TD group, the differences were all within 1.5%, except for R1 Area and BMC which had differences of 8.3% and 9.8%, respectively. In the Myelo group, the differences were slightly higher for Area and BMC compared with the TD group, but remained less than 1.5% for BMD (Table 3).

The maximum coefficient of variation was 3% for BMD and 7% for BMC and Area for all regions except R1 (Table 4). For R1, CVs ranged up to 15% for Area and 16% for BMC. CVs for R1 BMD were within 3% in the TD group, but as high as 9% in the Myelo group.

R1 vs. R4

Comparing R1 versus R4, it appears that R4 produces more repeatable measurements. R4 had lower CVs than R1 for both repeat scans (Table 1) and repeat analyses (Table 4). The difference between raters was also lower for R4 compared with R1 (Table 3).

ROIs and Bone Strength

BMC and BMD from all ROIs were highly correlated with the moments of inertia and section moduli ($r = 0.75$, $p < 0.0001$) (Table 5).

DISCUSSION

The distal femur has been suggested as an alternative site for DXA measurements because it is usually free from metal implants and is a common site for fractures in children with lower extremity impairments. The LDF scan can usually be performed even in patients with hip or knee contractures. In fact, Szalay et al. found that 15% of children referred for DXA examinations at a pediatric bone center could only be imaged using the LDF scan due to contractures or inability to lie supine. In addition, 20% had indwelling hardware that interfered with standard DXA scanning (11). LDF scans have been used in studies of various pediatric populations including cerebral palsy, muscular dystrophy, and spina bifida (4, 7, 8). The technique has also been used for clinical assessment of children with a broad range of diagnoses including osteogenesis imperfecta, juvenile arthritis, chronic renal failure, multiple fractures, and non-specific osteoporosis or osteopenia in addition to the conditions mentioned previously (11).

Reproducibility of DXA measurements at conventional sites has been examined in adults and children. Same day scans in adult women were shown to have CVs for BMD of 0.9–2.6% in the lumbar spine and 0.9–2.5% in the proximal femur (12). In one study, the

precision of duplicate scans in healthy children averaged less than 2% for both the lumbar spine and femur but ranged up to 6.7% (13). Two studies have reported on the reliability of DXA measurements at the lateral distal femur, although the ROIs differ slightly. Henderson et al. reported mean differences of less than 3% in BMD of regions R1 (2.9%), R2 (2.3%), and R3 (1.2%) based on duplicate scans in 5 healthy children (5). Harke et al. reported CVs of 0.7%, 0.8%, 1.5%, and 2.0% for R1–R4 respectively for intra-rater variability and 1.5%, 2.5%, 4.7%, and 4.2% for inter-rater variability in LDF measurements in children with cerebral palsy (4). Our results are comparable with the results reported in these previous studies. In the current study, the CVs for lateral DXA BMD ranged from 0–9%, with the highest values being seen in R1. Excluding R1, the CVs had a much smaller range of 0–3% which is comparable to other DXA techniques and similar to what has been found in past studies. The higher CVs for R1 seen in the current study compared to Henderson et al. may be due to the differences in subject populations; the current study incorporated healthy adults while the latter study used children (5). The size of R1 is based on a measurement of the growth plate which is typically more difficult to see as the growth plate closes. Whereas the differences compared to Harcke et al. are most likely due to differences in ROI definitions. Harcke et al. used two ROIs (R1 and R2) to represent primarily cancellous bone and 2 ROIs to represent primarily cortical bone (R3 and R4). Therefore, Harcke et al.'s R1 is more similar to the current study's R4 (4).

BMD measurements were more reliable than measurements of BMC and bone area. Small differences in specification of the ROIs directly affect BMC and area, which increase with the size of the ROI. The effect on BMD, however, is reduced because differences in BMC are normalized by differences in projected area. Thus, reliable BMD measurements are easier to obtain than reliable BMC measures. Fortunately, BMD is the measure of greatest clinical interest for comparing bone between subjects and assessing fracture risk.

For the metaphysis, R4 had better reliability than R1. R4 is similar to the distal region originally proposed by Harke et al. (4) which was replaced by the anteriorly positioned R1 in the subsequent paper by Henderson et al. (5). R4 is centered in the medullary canal, which we believe represents cancellous bone better than R1, which encompasses the anterior cortex. Inclusion of the anterior cortex makes R1 sensitive to placement of the ROI and rotation of the limb. Harke et al. found that ROIs representing cortical bone had higher variability than ROIs representing primarily trabecular bone (4). R4 still includes the lateral cortices which are in line with the x-ray beams, but avoids variability due to the significant BMC contributed by cortical bone in the anterior cortex. Because of its definition, variability in R1 may also be increased due to difficulty defining the width of the growth plate.

The largest source of variability resulted from having different raters perform the image analysis. This corroborates Harke et al.'s finding that inter-rater variation was greater in all measurements compared to intra-rater variation (4). There were no significant differences between readings performed by the same individual or due to re-positioning and re-scanning the subjects. We therefore recommend that processing of the DXA images be performed by a single individual whenever possible to avoid inter-rater variability. Nevertheless, the magnitude of difference between raters was small, and the CVs accounting for both intra- and inter-rater variability combined for BMD were less than 3% for R2–R4.

Zemel et al. showed that BMC and BMD for R1–R3 were highly correlated with measures of bone strength from pQCT (6). The current study's data supports these previous findings with R4 also being highly correlated with bone strength. This highlights the ability of LDF DXA to provide accurate insight into bone strength.

In summary, we found the lateral distal femur scan to be a reliable alternative for DXA measurements, especially for measurements of BMD. Because R4 is more reliable than R1, however, we suggest that the commonly used methodology be modified to include a central, rather than anterior, distal metaphysis region. Placement of ROIs should be performed by a single individual whenever possible, or care should be taken to maximize consistency between those performing the image analysis. The LDF scan has similar reliability to other DXA measures and should be considered for patients with orthopaedic or neuromuscular conditions.

Acknowledgments

The authors would like to thank Cassie Nguyen for her assistance with data analysis. Support for this study was provided by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) of the National Institutes of Health (NIH) under Award Number R01HD059826.

References

1. Blake GM, Fogelman I. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. *Postgrad Med J*. 2007; 83:509–517. [PubMed: 17675543]
2. El Maghraoui A, Roux C. DXA scanning in clinical practice. *QJM*. 2008; 101:605–617. [PubMed: 18334497]
3. Henderson RC. The correlation between dual-energy X-ray absorptiometry measures of bone density in the proximal femur and lumbar spine of children. *Skeletal Radiol*. 1997; 26:544–547. [PubMed: 9342815]
4. Harcke HT, Taylor A, Bachrach S, Miller F, Henderson RC. Lateral femoral scan: an alternative method for assessing bone mineral density in children with cerebral palsy. *Pediatr Radiol*. 1998; 28:241–246. [PubMed: 9545479]
5. Henderson RC, Lark RK, Newman JE, et al. Pediatric reference data for dual X-ray absorptiometric measures of normal bone density in the distal femur. *AJR Am J Roentgenol*. 2002; 178:439–443. [PubMed: 11804914]
6. Zemel BS, Stallings VA, Leonard MB, et al. Revised pediatric reference data for the lateral distal femur measured by Hologic Discovery/Delphi dual-energy X-ray absorptiometry. *J Clin Densitom*. 2009; 12:207–218. [PubMed: 19321369]
7. Henderson RC, Berglund LM, May R, et al. The relationship between fractures and DXA measures of BMD in the distal femur of children and adolescents with cerebral palsy or muscular dystrophy. *J Bone Miner Res*. 2010; 25:520–526. [PubMed: 19821773]
8. Szalay EA, Cheema A. Children with spina bifida are at risk for low bone density. *Clin Orthop Relat Res*. 2011; 469:1253–1257. [PubMed: 21042897]
9. Tryon E, Szalay EA. The lateral distal femoral DEXA scan in children: a chronology of growing bone? *Orthopedics*. 2008; 31:1093. [PubMed: 19226092]
10. Wright, JG. Neurosegmental level and functional status. In: Sarwark, JF.; Lubicky, JP., editors. *Caring for the Child with Spina Bifida*. American Academy of Orthopaedic Surgeons; Rosemont, IL: 2001. p. 71
11. Szalay EA, Harriman D. Adapting pediatric DXA scanning to clinical orthopaedics. *J Pediatr Orthop*. 2006; 26:686–690. [PubMed: 16932112]

12. Fuleihan GE, Testa MA, Angell JE, Porrino N, Leboff MS. Reproducibility of DXA absorptiometry: a model for bone loss estimates. *J Bone Miner Res.* 1995; 10:1004–1014. [PubMed: 7484275]
13. Henderson RC. Assessment of bone mineral content in children. *J Pediatr Orthop.* 1991; 11:314–317. [PubMed: 2056078]

Figure 1. Regions of interest for the LDF scan. R1, R2, and R3 are defined as described by Henderson et al. (5). R4 is similar to R1, but is centered in the medullary canal instead of encompassing the anterior cortex.

Table 1

Coefficient of variation (CV) for repeat scans (3 scans in each of 5 subjects).

Subject	N	R1			R2			R3			R4		
		Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD
1	3	0.08	0.06	0.03	0.01	0.01	0.003	0.01	0.03	0.02	0.00	0.02	0.02
2	3	0.08	0.10*	0.005*	0.02	0.02	0.003	0.06	0.04	0.08	0.03	0.04*	0.01*
3	3	0.12	0.16	0.04	0.03	0.05	0.02	0.03	0.05	0.03	0.03	0.05	0.01
4	3	0.02	0.02	0.03	0.03	0.04	0.01	0.03	0.04	0.01	0.06	0.05	0.003
5	3	0.03	0.06	0.07	0.03	0.02	0.01	0.03	0.01	0.03	0.03	0.06	0.03
Min	15	0.02	0.02	0.005	0.01	0.01	0.003	0.01	0.01	0.01	0.00	0.02	0.003
Max	15	0.12	0.16	0.07	0.03	0.05	0.02	0.06	0.05	0.08	0.06	0.06	0.03

* N=2

Note: None of the paired differences between readings are statistically different from zero.

Table 2

Mean of measurements on 5 subjects per group by group, side, rater, and reading.

Group	Side	Rater	Reading	R1			R2			R3			R4		
				Area	BMD	BMC	Area	BMD	BMC	Area	BMD	BMC	Area	BMD	BMC
TD	Left	1	1	8.40	6.33	0.72	11.71	10.52	0.86	11.32	10.56	0.90	5.84	4.28	0.71
		2	2	8.31	6.26	0.72	11.81	10.57	0.86	11.38	10.62	0.89	5.87	4.38	0.73
		3	3	8.20	6.17	0.72	11.82	10.59	0.86	11.41	10.63	0.89	5.93	4.37	0.72
		2	1	8.86	6.80	0.73	11.90	10.71	0.86	11.53	10.77	0.90	6.03	4.47	0.72
		2	2	8.80	6.72	0.72	11.71	10.51	0.86	11.30	10.58	0.90	5.83	4.24	0.71
		3	3	8.81	6.79	0.72	11.97	10.76	0.86	11.57	10.83	0.90	6.07	4.79	0.72
	Right	1	1	7.78	5.65	0.70	11.74	10.65	0.88	11.55	10.79	0.91	5.84	4.23	0.71
		2	2	7.67	5.62	0.71	11.82	10.71	0.87	11.62	10.84	0.90	5.93	4.39	0.73
		3	3	7.50	5.53	0.71	11.79	10.69	0.87	11.61	10.85	0.90	5.92	4.39	0.73
Myelo	Left	1	1	8.11	5.93	0.71	11.79	10.72	0.88	11.60	10.84	0.90	5.89	4.23	0.71
		2	2	8.77	6.48	0.71	11.81	10.72	0.88	11.60	10.85	0.90	5.95	4.27	0.70
		3	3	8.67	6.49	0.71	11.87	10.79	0.88	11.67	10.91	0.90	5.96	4.29	0.70
		2	1	7.34	4.82	0.65	10.05	8.63	0.86	10.04	9.23	0.92	5.08	3.26	0.64
		2	2	7.49	4.90	0.65	10.22	8.73	0.85	10.23	9.33	0.91	5.14	3.28	0.64
		3	3	7.53	4.98	0.65	10.28	8.79	0.85	10.19	9.35	0.92	5.21	3.34	0.64
	Right	1	1	6.95	4.66	0.68	9.61	8.31	0.87	9.70	8.95	0.92	4.77	3.01	0.63
		2	2	7.00	4.57	0.65	9.89	8.52	0.86	9.96	9.15	0.92	4.98	3.18	0.63
		3	3	7.10	4.60	0.65	9.70	8.30	0.86	9.58	8.89	0.93	4.75	3.01	0.63
Myelo	Left	1	1	7.25	4.74	0.65	10.02	8.48	0.85	9.92	9.08	0.92	5.01	3.22	0.63
		2	2	7.63	4.99	0.65	10.10	8.55	0.85	10.06	9.17	0.92	5.03	3.24	0.64
		3	3	7.62	4.95	0.65	10.12	8.59	0.85	10.07	9.22	0.92	5.11	3.28	0.64
	Right	1	1	7.03	4.57	0.65	9.88	8.41	0.86	9.77	8.98	0.93	4.98	3.17	0.63
		2	2	6.97	4.52	0.65	9.85	8.35	0.85	9.83	8.97	0.92	4.84	3.07	0.63
		3	3	7.18	4.83	0.68	9.89	8.42	0.86	9.82	9.03	0.93	4.94	3.15	0.64

Table 3

Mean difference between raters (Rater1-Rater2) in 5 subjects per group, with 2 sides per subject and 3 readings per side for each rater.

Group	N	R1			R2			R3			R4			
		Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD	
TD	60	Mean	8.32	6.23	0.713	11.81	10.66	0.868	11.51	10.76	0.900	5.92	4.34	0.659
	30	Abs. diff.	-0.69	-0.61	-0.006	-0.06	-0.08	-0.001	-0.06	-0.08	-0.001	-0.07	0.01	0.010
	30	% diff.	-8.3%	-9.8%	-0.8%	-0.5%	-0.8%	-0.1%	-0.5%	-0.7%	-0.1%	-1.2%	0.2%	1.5%
Myelo	60	Mean	7.26	4.76	0.656	9.97	8.51	0.855	9.93	9.11	0.920	4.99	3.18	0.635
	30	Abs. diff.	0.44	0.27	-0.008	0.33	0.24	-0.006	0.31	0.24	-0.006	0.22	0.17	0.004
	30	% diff.	6.1%	5.7%	-1.2%	3.3%	2.8%	-0.7%	3.1%	2.6%	-0.7%	4.4%	5.3%	0.6%
Total	120	Mean	7.79	5.50	0.684	10.89	9.58	0.861	10.72	9.93	0.910	5.45	3.76	0.647
	60	Abs. diff.	-0.13	-0.17	-0.007	0.13	0.08	-0.003	0.12	0.08	-0.004	0.08	0.09	0.007
	60	% diff.	-1.7%	-3.1%	-1.0%	1.2%	0.8%	-0.3%	1.1%	0.8%	-0.4%	1.5%	2.4%	1.1%

Bold indicates p<0.05

Table 4

Coefficient of variation (CV) for repeat analyses. There were 6 readings (2 raters with 3 analyses each) for each side in 10 subjects.

Limb	N	R1			R2			R3			R4		
		Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD	Area	BMC	BMD
Left 1	6	0.04	0.04	0.01	0.02	0.02	0.003	0.02	0.02	0.000	0.03	0.05	0.02
Left 2	6	0.08	0.08	0.004	0.02	0.02	0.01	0.02	0.02	0.000	0.04	0.05	0.01
Left 3	6	0.04	0.03	0.03	0.02	0.02	0.001	0.02	0.03	0.01	0.04	0.04	0.01
Left 4	6	0.06	0.07	0.01	0.01	0.02	0.002	0.02	0.02	0.001	0.03	0.03	0.01
Left 5	6	0.06	0.07	0.01	0.01	0.01	0.001	0.01	0.01	0.001	0.03	0.03	0.01
Right 1	6	0.04	0.05	0.003	0.01	0.01	0.000	0.01	0.01	0.000	0.01	0.02	0.02
Right 2	6	0.09	0.09	0.003	0.02	0.02	0.001	0.01	0.02	0.001	0.03	0.04	0.01
Right 3	6	0.06	0.05	0.01	0.02	0.02	0.000	0.02	0.03	0.01	0.04	0.05	0.02
Right 4	6	0.09	0.10	0.01	0.01	0.01	0.002	0.01	0.01	0.001	0.02	0.03	0.02
Right 5	6	0.10	0.11	0.01	0.02	0.02	0.000	0.01	0.02	0.002	0.03	0.04	0.02
Left 6	6	0.04	0.04	0.004	0.03	0.03	0.004	0.03	0.03	0.003	0.06	0.06	0.01
Left 7	6	0.09	0.04	0.08	0.01	0.02	0.004	0.01	0.02	0.004	0.04	0.03	0.01
Left 8	6	0.15	0.16	0.01	0.06	0.05	0.01	0.06	0.04	0.02	0.06	0.07	0.01
Left 9	6	0.06	0.06	0.002	0.01	0.01	0.003	0.01	0.01	0.002	0.03	0.04	0.01
Left 10	6	0.04	0.05	0.01	0.06	0.04	0.02	0.05	0.04	0.02	0.06	0.07	0.01
Right 6	6	0.02	0.02	0.002	0.02	0.02	0.003	0.02	0.02	0.005	0.04	0.04	0.01
Right 7	6	0.09	0.04	0.09	0.02	0.02	0.006	0.02	0.03	0.01	0.04	0.05	0.02
Right 8	6	0.13	0.15	0.03	0.03	0.02	0.01	0.05	0.03	0.03	0.03	0.03	0.01
Right 9	6	0.12	0.14	0.02	0.01	0.01	0.003	0.01	0.01	0.000	0.02	0.02	0.02
Right 10	6	0.06	0.07	0.01	0.04	0.03	0.01	0.03	0.02	0.003	0.05	0.05	0.01
Min	20	0.02	0.02	0.002	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.02	0.01
Max	20	0.15	0.16	0.09	0.06	0.05	0.02	0.06	0.04	0.03	0.06	0.07	0.02

Note: 1–5 are TD, 6–10 are Myelo.

Table 5

Correlations for ROIs and measures of bone strength.

	R1		R2		R3		R4	
	BMC	BMD	BMC	BMD	BMC	BMD	BMC	BMD
Proximal DWImin[*]	0.78	0.76	0.77	0.8	0.77	0.79	0.78	0.75
Proximal Section Modulus	0.78	0.79	0.76	0.81	0.75	0.8	0.77	0.78
Distal DWImin[*]	0.85	0.82	0.86	0.86	0.82	0.84	0.86	0.79
Distal Section Modulus	0.82	0.82	0.85	0.85	0.8	0.84	0.84	0.8

All correlations are significant $p < 0.0001$

* DWImin: density weighted minimum principle moment of inertia