Comparability of HR-pQCT Bone Quality Measures Improved by Scanning Anatomically Standardized Regions

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Current HR-pQCT scan protocols do not account for limb length, despite the tremendous variation in bone density and geometry along the distal radius and tibia. Consequently, limb-length introduces considerable variability that confounds the interpretation of biological effects and increases the scatter in cross-sectional and normative datasets. In this study we measured the variability in bone quality parameters related to limb-length and propose a protocol for defining anatomically-standard scan regions based on measured limb-length.

HR-pQCT scans covering twice the typical scan length along the distal radius and tibia were acquired in adult men (n=15) and women (n=12). Percutanous limb length was measured using standard anthropometric protocols. Bone parameters were calculated for three subvolumes that corresponded to the normal scan length (110 slices) based on the following positioning scenarios: (1) the standard fixed distance from the jointline; (2) the average % location of the standard position based on limb-length in the present study population; (3) the average % location of the standard position estimated from height data in previous population HR-pQCT studies in the literature. The standard deviation of differences between fixed and relative positions was calculated. The percent difference for representative bone parameters (BMD, Tb.BMD, Ct.Th, Tb.N) was calculated from their measurement in subvolumes based on the default position, and either relative scan position.

The average anatomic position in the study population was 4.0±0.5% in the radius and 7.2±0.6% at the tibia, corresponding to a variance of ±1.1 and 2.2 mm in the scan position, respectively. The height-estimated anatomic position for optimal comparability to previous HR-pQCT population data was 4.1% and 7.4%. Differences in bone measurements between fixed and relative scan regions were minimal on average; however individual differences exhibited substantial variability (Table 1).

The large distribution of differences between bone parameters measured at a fixed distance from the joint and measured at an anatomically relative distance indicates limb length contributes significant variance to bone quality measurements. This strongly recommends the use of scan positioning that adjusts based on measured limb length, particularly for cross-sectional studies and normative database generation. The minimal average differences between fixed distance scanning and the literature-derived relative distance suggest that anatomically-standardized scan positioning can maintain a high degree of comparability to legacy population data.

Table 1: Summary of variability in HR-pQCT measures associated with limb length

	Relative position based on limb length measured in current study participants **[Radius: 4.0% | Tibia: 7.2%]**		Relative position estimated from height of existing HR-pQCT population data in the literature **[Radius: 4.1% | Tibia: 7.4%]**	
	Difference vs. Fixed: Population Averages	**Variance and Range of Differences**	**Difference vs. Fixed: Population Averages**	**Variance and Range of Differences**
Radius				
BMD	-0.6%	6.7% [-9.8, +20.8]	1.2%	6.6% [-10.2, +19.5]
Ct.BMD	0.4%	5.6% [-5.7, +20.2]	0.0%	5.4% [-6.2, +19.1]
Ct.Th	-0.9%	18.8% [-18.6, +66.7]	2.1%	18.6% [-19.8, +66.7]
Tb.BMD	0.5%	2.4% [-5.3, +5.1]	-0.5%	2.5% [-5.2, +5.6]
Tb.N	-0.6%	5.2% [-15.0, +3.4]	0.4%	5.2% [-14.6, +3.5]
Tibia				
BMD	-0.1%	3.1% [-6.0, +6.6]	-1.2%	3.2% [-7.4, +5.4]
Ct.BMD	0.1%	2.3% [-3.9, +5.4]	-0.7%	2.3% [-5.1, +5.0]
Ct.Th	-0.3%	11.8% [-24.1, +27.5]	-3.4%	11.5% [-28.6, +22.2]
Tb.BMD	0.2%	4.0% [-11.6, +7.4]	1.3%	4.3% [-10.9, +9.8]
Tb.N	-0.4%	5.0% [-20.4, +8.3]	0.6%	4.6% [-16.1, +10.4]