Bone Reports 15 (2021) 101107

Contents lists available at ScienceDirect

Bone Reports

journal homepage: www.elsevier.com/locate/bonr

Normative data for peripheral quantitative computed tomography (pQCT) bone parameters in Australian men

Kara B. Anderson [a,*], Monica C. Tembo [a], Sophia X. Sui [a], Natalie K. Hyde [a], Pamela G. Rufus [a], Julie A. Pasco [a,b,c,d], Mark A. Kotowicz [a,b,c], Kara L. Holloway-Kew [a]

[a] Deakin University, IMPACT (Institute for Mental and Physical Health and Clinical Translation), Geelong, VIC, Australia
[b] Barwon Health, Geelong, VIC, Australia
[c] Department of Medicine – Western Health, The University of Melbourne, St Albans, VIC, Australia
[d] Department of Epidemiology and Preventive Medicine, Monash University, Prahran, VIC, Australia

ARTICLE INFO

Keywords:
Peripheral quantitative computed tomography (pQCT)
Normative data
Men
Reference values

ABSTRACT

Background: Peripheral quantitative computed tomography (pQCT) can provide information complementary to dual x-ray absorptiometry (DXA), however, there is sparse normative data to enable meaningful clinical interpretation and comparison. This study aimed to develop age-stratified normative data for pQCT-derived bone parameters in Australian men.

Methods: Participants were men ($n = 508$, age 33-96 yr) from the Geelong Osteoporosis Study. Bone parameters at 4% ($n = 469$) and 66% ($n = 436$) of radial length, and 4% ($n = 449$) and 66% ($n = 438$) of tibial length were acquired using pQCT (XCT 2000, Stratec Medizintechnik, Pforzheim, Germany). Best models of age, height and weight for each parameter were developed and where parameters exhibited variation with age, age decade mean (±SD) values were determined. Scatterplots were used to visualise the relationships between each of the parameters and age, height and weight.

Results: Thirteen parameters at tibial and radial sites were correlated with age, height and weight, allowing for their inclusion in multiple linear regression models. A positive association with age was found for total area of the tibia or radius (as appropriate) (mm^2) at all sites, trabecular bone area (mm^2) at 4% sites, and total bone area (both long bones) (mm^2) at 66% sites. A negative association with age was found for cortical density (mg/cm^3) and cortical thickness (mm) at both radial and tibial 66% sites, but total density (mg/cm^3) at the 66% radial site and total cortical density of both long bones (mg/cm^3) at the 66% tibial site only.

Conclusion: This study presents normative data for pQCT-derived bone parameters and describes age related associations in a number of these variables. Broadly, parameters of bone area were positively associated with age, whereas parameters associated with bone density and structure were negatively associated with age. These data have the potential to be used in clinical settings when assessing age-related decline in bone health.

Mini abstract: Normative data for pQCT parameters in Australian men are presented, adjusted for age, height and weight.

1. Introduction

Osteoporosis is a common condition of ageing defined by low bone mass and deterioration of bone microarchitecture (Czerwinski et al., 2007). These factors result in an increase in bone fragility and subsequent fracture risk. Currently, the bone mineral density (BMD) criteria for osteoporosis is based on measurements using dual X-ray absorptiometry (DXA), usually at the proximal femur and/or lumbar spine (World Health Organisation, 2007). Previous studies, however, have indicated that although individuals with a low BMD are at a high personal risk for fracture, the population burden of fracture arises from those who do not meet the bone density criteria for osteoporosis, that is, those with osteopenia (low BMD) or normal BMD (Pasco et al., 2006; Pasco et al., 2014). This therefore suggests that there are factors not captured by DXA-derived BMD, or physical limitations to DXA-derived BMD, such as dependence on soft tissue composition (Bolotin et al.,

* Corresponding author at: Epi-Centre for Healthy Ageing (ECHA), IMPACT Institute, Deakin University, PO Box 281 (Barwon Health), Geelong, VIC 3220, Australia.
E-mail address: kbanders@deakin.edu.au (K.B. Anderson).

https://doi.org/10.1016/j.bonr.2021.101107
Received 16 June 2021; Accepted 6 July 2021
Available online 8 July 2021

Table 1
List of peripheral quantitative computed tomography (pQCT) variables utilised in this study.

Radial parameters	Tibial parameters
4% bone mass (g/cm)	4% bone mass (g/cm)
4% bone total area (mm^2)	4% bone total area (mm^2)
4% bone total density (mg/cm^3)	4% bone total density (mg/cm^3)
4% trabecular density (mg/cm^3)	4% trabecular density (mg/cm^3)
66% bone mass (g/cm)	66% bone mass (g/cm)
66% bone total area (mm^2)	66% bone total area (mm^2)
66% bone total density (mg/cm^3)	66% bone total density (mg/cm^3)
66% cortical area (mm^2)	66% cortical area (mm^2)
66% cortical density (mg/cm^3)	66% cortical density (mg/cm^3)
66% cortical thickness (mm)	66% cortical thickness (mm)
66% radius and ulna total area (mm^2)	66% tibia and fibula total area (mm^2)
66% radius and ulna cortical density (mg/cm^3)	66% tibia and fibula cortical density (mg/cm^3)
Polar stress strain index (mm^3)	Polar stress strain index (mm^3)

Table 2
Participant characteristics, given as mean ± SD or n (%) as appropriate.

Variable	Value
Age (yr)	62.6 ± 13.8
Height (cm)	174.8 ± 7.2
Weight (kg)	85.0 ± 13.9
Femoral neck BMD T-score	−1.074 ± 0.85
Alcohol consumption	103 (20.3)
Smoking status	38 (7.5)
Low mobility	122 (24.1)
Bisphosphonate use	3 (0.6)
Glucocorticoid use	11 (2.2)
Type 2 Diabetes	51 (10.0)
Diseases affecting bone metabolism (Type 1 diabetes, rheumatoid arthritis, secondary osteoporosis)	12 (2.4)
Primary osteoporosis	11 (2.2)

Note: Alcohol consumption defined as >2 standard drinks per day. Smoking status defined as current smoker. Low mobility measured on a dichotomised 7-point scale with "sedentary", "limited", "inactive", "chair or bedridden" and "bedfast" because categorised as low mobility. Primary osteoporosis defined as femoral neck T-score < −2.5.

2003), that are contributing to fracture risk. A range of technologies have been developed to attempt to bridge this diagnostic gap. One such technology is peripheral quantitative computed tomography (pQCT) (Hoiberg et al., 2016).

Utilising well established technologies, pQCT is performed similarly to conventional computed tomography (CT), except exclusively at peripheral sites, specifically the radius and tibia (Blew et al., 2014). Although a number of acquisition techniques are possible, standard protocols involve scan slices taken at 4% and 66% of the bone length. The slices produce a volumetric cross section of the leg or arm which can be used to calculate a broad array of three-dimensional parameters, unlike DXA, which is limited to two dimensions. Information can be obtained not only about the amount of bone present at the site but also how it is arranged, and the software has the capacity to differentiate between cortical and trabecular bone compartments.

At the current stage in its development, pQCT has primarily been used in paediatric settings and in rare conditions where a more detailed exploration of bone parameters is useful (Xafaki et al., 2018; Aeberli et al., 2020; Stagi et al., 2016; Gabel et al., 2018; Fonseca et al., 2013). Few studies have assessed pQCT parameters in older adults, and reference data in older adults or across the lifespan more broadly are limited. One study assessed muscle and bone parameters in a group of osteoporotic older adults (Drey et al., 2018). A cohort study assessed pQCT variables across the lifespan in healthy Japanese women (Gorai et al., 2001), while two other cohort studies focused exclusively on participants aged over 65 years (Sheu et al., 2011; Dennison et al., 2014). These studies of older adults had a focus on fracture risk but were limited in their capacity to see broader changes in parameters with age. To the best of our knowledge, no other studies have explored age related differences in pQCT parameters, and in particular, no studies have explored this in a wide age range of men.

The aim of the current study was to develop normative reference data for pQCT-derived bone variables in Australian men, which may be used to calculate age- and sex- matched z-scores.

2. Methods

2.1. Study design and participants

This analysis involved 508 men aged 33-96 yr, who provided valid pQCT scans at the radius and/or tibia as part of the 15-year men's follow up of the Geelong Osteoporosis Study (GOS), undertaken from 2016 to 2019. The GOS is an ongoing cohort study located in south-eastern Australia, featuring age-stratification and random selection sampling from the Australian electoral roll. It is compulsory for Australian citizens aged over 18 years to be enrolled on the electoral roll, resulting in a near comprehensive sampling frame. The full protocol for the GOS has been published elsewhere (Pasco et al., 2012). The 15-year men's follow up phase is the first in which pQCT scans were routinely undertaken. All participants provided written, informed consent. The study was approved by the Barwon Health Human Research Ethics Committee.

2.2. Peripheral QCT measures

Measurements were made of the non-dominant limb using a soft, non-elastic tape measure. Radial length was measured from the humero-radial joint cleft to the styloid process with the elbow bent at ~90 degrees; tibial length was measured from the medial joint cleft to the distal end of the medial malleolus while seated with the knee bent at ~90 degrees. The reference marker was placed along the flattest surface of the plateau of the tibial or radial endplate respectively. Standard transverse sections were performed at 4% and 66% of non-dominant radial and tibial length using peripheral quantitative computed tomography (pQCT; XCT 2000, Stratec Medizintechnik, Pforzheim, Germany) and software standard protocol (BonAlyse Oy, Jyvaskyla, Finland) was used to determine a variety of bone and other parameters. At the 4% site, the periosteal surface of the bone epiphysis was determined by contour algorithmic thresholds at 180 mg/cm^3 for both tibia and radius as per the software standard protocol, with Peel mode 1 and trabecular compartment detection set to 45% of bone area. At the 66% site, the surface was determined by a 280 mg/cm^3 threshold (Peel mode 1, 100% of bone area). Cortical bone was selected by a 711 mg/cm^3 threshold. These thresholds were also provided by the software manufacturer. The parameters included in these analyses are outlined in Table 1. Of 607 men who participated in the 15-year follow up, 521 underwent at least one pQCT scan.

2.3. Dual x-ray absorptiometry

Dual x-ray absorptiometry was measured at this follow-up using the Lunar Prodigy device and T-scores calculated using reference data for Australian men as reported by Henry et al. (2010). Femoral neck T-scores were used to classify participants as osteoporotic (T-score less

Table 3
Multiple linear regression modelling for radial pQCT parameters. Significant *p*-values are indicated in bold.

Parameters	Model adjusted R^2 (%)	Age β-coefficient	Age SE	Age *p*-value	Height β-coefficient	Height SE	Height *p*-value	Weight β-coefficient	Weight SE	Weight *p*-value	Constant
4% mass (g/cm)	16.91	–	–	0.541	0.009	0.002	<**0.001**	0.005	0.001	<**0.001**	−0.241
4% total area (mm^2)	20.53	1.428	0.234	<**0.001**	3.956	0.492	**0.008**	0.639	0.239	<**0.001**	−326.942
4% total density (mg/cm^3)	7.21	−1.008	0.175	<**0.001**	−1.008	0.367	**0.006**	0.524	0.178	**0.003**	522.474
4% trabecular density (mg/cm^3)	4.56	−0.619	0.143	<**0.001**	−1.051	0.299	<**0.001**	0.392	0.145	**0.007**	404.855
66% mass (g/cm)	16.27	–	–	0.070	0.007	0.001	<**0.001**	0.003	0.001	<**0.001**	−0.015
66% total area (mm^2)	21.04	0.672	0.085	<**0.001**	1.107	0.180	<**0.001**	0.306	0.085	<**0.001**	−84.838
66% total density (mg/cm^3)[#]	11.73	−19.337	7.264	**0.008**	−6.485	2.607	**0.013**	–	–	0.540	2081.292
66% cortical area (mm^2)	16.92	–	–	0.248	0.539	0.105	<**0.001**	0.260	0.053	<**0.001**	−9.358
66% cortical density (mg/cm^3)	11.77	−0.955	0.124	<**0.001**	–	–	0.750	–	–	0.283	1201.269
66% cortical thickness (mm)[Φ]	11.08	−0.081	0.033	**0.014**	−0.020	0.012	**0.087**	0.004	0.001	**0.003**	6.366
66% radius and ulna total area (mm^2)	24.43	1.517	0.170	<**0.001**	2.009	0.362	<**0.001**	0.833	0.171	<**0.001**	−134.178
66% radius and ulna cortical density (mg/cm^3)	8.33	−0.685	0.110	<**0.001**	–	–	**0.834**	−0.219	0.105	**0.038**	1211.27
Polar stress strain index (mm^3)	12.31	1.312	0.305	<**0.001**	3.448	0.650	<**0.001**	0.819	0.306	**0.008**	−337.079

[#] Model includes interaction term age*height (**β-coefficient = 0.097**, **SE = 0.042**, ***p* = 0.020**).
[Φ] Model includes interaction term age*height (**β-coefficient = 0.000 SE = 0.000**, ***p* = 0.022**).

Table 4
Mean and standard deviation values for radial parameters at the 4% site by age decade.

Total area (mm^2)		
Age (yr)	n	Mean ± SD
30–39	27	489.593 ± 58.063
40–49	68	503.427 ± 77.640
50–59	107	504.930 ± 68.059
60–69	125	501.630 ± 73.192
70–79	94	519.285 ± 74.553
80+	48	526.932 ± 67.051

than −2.5).

2.4. Anthropometry and self-report measures

Height was measured without shoes using a wall-mounted Harpenden stadiometer to the nearest 0.1 cm; weight was measured in a hospital gown or minimal clothing on electronic scales to the nearest 0.1 kg. Smoking status was defined as either current smoker or non-smoker, based upon self-report of any current smoking of cigarettes or other tobacco products. Physical activity was measured using a 7-point mobility scale, dichotomised into "physically inactive" (sedentary, limited, inactive, bed/chair ridden, bedfast) and "physically active" (active, very active). Alcohol consumption was documented using the Cancer Council Food Frequency Questionnaire (FFQ) (Giles et al., 1996). Low alcohol consumption was defined as 0–2 standard drinks per day, in accordance with National Health and Medical Research Council recommendations (National Health Medical Research Council, 2009). Presence of Type 2 diabetes was determined by fasting plasma glucose (FPG) ≥7.0 mmol/L, self report and/or antihyperglyceamic medication use, with two participants being identified as having Type 1 diabetes and classified separately. Other diseases effecting bone metabolism including osteogenesis imperfecta, hyperthyroidism, malabsorption, chronic liver disease and rheumatoid arthritis were self-reported, with rheumatoid arthritis being confirmed by review of medical records, as many participants self-report osteoarthritis as rheumatoid arthritis. Bisphosphonate and glucocorticoid use were self-reported with participants advised to bring in any current medication to their visit.

2.5. Statistical analysis

All variables were tested for normality prior to analysis. Linear regression modelling was used to develop best models of age, height and weight for each of the parameters. Residuals were tested for model fit and potential polynomial modelling. Interaction terms were tested for variables in the final models and adjusted R^2 values were used to assess the validity of each of the models. Age-related differences were further described using decade mean values across the age range for variables associated with age. All analyses undertaken in this study were conducted using StataSE 15 (StataCorp. 2017. *Stata Statistical Software*: *Release 15*. College Station, TX: StataCorp LLC).

3. Results

3.1. Participant characteristics

Of the 521 men who underwent a pQCT scan at the 15-year follow up, 20 did not provide tibial scans, and three did not provide radial scans as they were unable to assume the correct position. Twenty-six radial and 39 tibial scans were removed due to measurement error, and according to a valid protocol (Blew et al., 2014), three radial scans were

Table 5
Mean and standard deviation values for radial parameters at the 66% site by age decade.

Age (yr)	n	Mean ± SD
Total area (mm^2)		
30–39	26	160.894 ± 18.112
40–49	67	170.377 ± 26.495
50–59	99	174.126 ± 23.759
60–69	120	178.829 ± 25.963
70–79	83	181.497 ± 26.054
80+	41	185.732 ± 19.195
Total density (mg/cm^3)		
30–39	26	855.965 ± 74.497
40–49	67	816.937 ± 88.449
50–59	99	825.732 ± 76.326
60–69	120	790.913 ± 92.503
70–79	83	776.593 ± 95.987
80+	41	729.988 ± 94.374
Cortical density (mg/cm^3)		
30–39	26	1171.506 ± 23.125
40–49	67	1150.097 ± 31.270
50–59	99	1152.341 ± 26.487
60–69	120	1138.159 ± 40.918
70–79	83	1134.888 ± 38.820
80+	41	1114.608 ± 43.348
Cortical thickness (mm)		
30–39	26	2.939 ± 0.295
40–49	67	2.879 ± 0.380
50–59	99	2.960 ± 0.387
60–69	120	2.823 ± 0.402
70–79	83	2.763 ± 0.426
80+	41	2.541 ± 0.480
Radius and ulna total area (mm^2)		
30–39	26	350.240 ± 35.012
40–49	67	367.496 ± 53.684
50–59	99	375.051 ± 43.381
60–69	120	386.904 ± 56.724
70–79	83	395.121 ± 53.992
80+	41	405.372 ± 37.617
Polar stress strain index (mm^3)		
30–39	26	383.286 ± 60.437
40–49	67	399.951 ± 96.524
50–59	99	422.506 ± 86.599
60–69	120	426.901 ± 89.350
70–79	83	430.092 ± 84.139
80+	41	405.877 ± 67.802

excluded due to excessive movement. Ultimately, 508 men provided 474 radial images and 457 tibial images that were included in this analysis, with 469 radial and 449 tibial images included at the distal (4%) site, and 436 radial and 438 tibial images included at the proximal (66%) site.

Descriptive characteristics of participants are described in Table 2. On average, participants were aged 62.6 yrs. (SD = 13.8), with approximately 24% exhibiting low mobility. High alcohol consumption was observed in 20% of the participants, whereas only approximately 8% reported being current smokers. Approximately 2% of participants were taking a glucocorticoid or suffering from a disease affecting bone metabolism, and 10% suffered from Type 2 diabetes mellitus. Similarly, around 2% of participants would be classified as having osteoporosis by femoral neck T-score, with the average T-score being −1.074 (SD = 0.85). Interestingly, less than 1% of participants reported taking a bisphosphonate at this visit.

3.2. Modelling

The results of linear regression modelling for radial parameters are detailed in Table 3. Parameters of bone area at the radius show increasing values with increasing age, whereas parameters of bone density at the radius decrease across the age span. Models for proximal total radial density (mg/cm^3) and radial cortical thickness (mm) showed interaction between age and height which was included in multivariable regression modelling. Testing of residuals did not indicate a need for polynomial modelling. Tables 4 and 5 provide age-decade mean values by acquisition region (distal and proximal radius respectively). These tables may be used for the calculation of T- and *Z*-scores.

The results of linear regression modelling at the tibia are detailed in Table 6. As at the radius, parameters of bone area at the tibia increased with increasing age, whereas parameters of bone density at the tibia decreased. Models for proximal tibia total area (mm^2) and tibia and fibula total area (mm^2) included interaction terms of age and weight that are detailed in the multivariable regression modelling in Table 6. As at the radius, analysis of the residuals found no need for polynomial modelling of these parameters. Similar to results for the radius, Tables 7 and 8 provide age-decade mean values for parameters by acquisition region (distal and proximal tibia respectively), which may be used for the calculation of T- and *Z*-scores.

4. Discussion

A number of pQCT-derived parameters showed correlation with age, height and/or weight. Regarding relationships with age, bone area parameters showed a tendency for higher values in older aged individuals, whereas bone density and structural parameters tended to be lower in older individuals compared to their younger counterparts. Lower bone density at higher ages is expected in alignment with decreasing DXA values with age (Henry et al., 2004), and the observed increase in area across age groups in this study may relate to increased endosteal bone loss and compensatory periosteal apposition under stable bone mass as a result of ageing (Popp et al., 2014; Martin and Seeman, 2008).

Drey et al. examined radial pQCT bone and muscle parameters in older adults aged over 65 and their association with fracture (Drey et al., 2018), and found mean cortical density (not described in text, but likely 66% Cortical Density) to be 1077.2 (SD = 58.0) mg/cm^3. Other parameters are not described in text, and further, the sample is 86.3% female and limited to those older in age. Cortical density was higher across the entire age range in the current study, with the oldest age group (aged 80+) having a mean value of 1114.6 (SD = 43.3) mg/cm^3. This may be due to expected density being higher in men than women, even in older adults. Alternatively, a thicker cortical area in men may lead to an edge effect in the analysis of cortical density (Rittweger et al., 2004). Other studies such as Dennison et al. have explored pQCT parameters and fracture in a similar way, but have not provided mean pQCT values for comparison to the current study (Dennison et al., 2014).

A study of Japanese women determined cut-points for vertebral fracture for pQCT parameters, but were limited to parameters of the distal radial slice, which were not comparable to the parameters obtained in the current study. It is noteworthy, however, that parameters of bone density in this group plateaued until approximately 40 years of age at which point they started decreasing with age. Density measures do not appear to plateau in the current sample in a similar fashion.

The Osteoporotic Fractures in Men (MrOS) study examined pQCT parameters in men in relation to nonvertebral fractures. Scans were performed at the 4% and 33% radial sites, and 4%, 33% and 66% tibial sites, resulting in three sites of overlap with the current study (4% radius

Table 6
Multiple linear regression modelling for tibial pQCT parameters.

Parameters	Model adjusted R^2 (%)	Age β-coefficient	Age SE	Age *p*-value	Height β-coefficient	Height SE	Height *p*-value	Weight β-coefficient	Weight SE	Weight *p*-value	Constant
4% mass (g/cm)	20.20	–	–	0.314	0.013	0.004	**0.002**	0.018	0.002	<**0.001**	0.436
4% total area (mm^2)	32.04	3.857	0.491	<**0.001**	10.631	1.063	<**0.001**	2.614	0.525	<**0.001**	−985.777
4% total density (mg/cm^3)	7.61	−0.758	0.159	<**0.001**	−1.466	0.343	<**0.001**	0.720	0.169	<**0.001**	564.328
4% trabecular density (mg/cm^3)	3.19	−0.314	0.141	**0.026**	−0.991	0.305	**0.001**	0.520	0.151	**0.001**	400.902
66% mass (g/cm)	25.97	–	–	0.782	0.029	0.004	<**0.001**	0.013	0.002	<**0.001**	−1.448
66% total area (mm^2)[#]	22.44	6.996	2.107	**0.001**	5.773	0.785	<**0.001**	4.938	1.563	**0.002**	−797.278
66% total density (mg/cm^3)	8.27	−1.773	0.279	<**0.001**	–	–	0.300	–	–	0.205	733.542
66% cortical area (mm^2)	25.59	–	–	0.068	2.399	0.349	<**0.001**	1.139	0.184	<**0.001**	−158.525
66% cortical density (mg/cm^3)	13.05	−0.954	0.117	<**0.001**	–	–	0.348	−0.259	0.123	**0.035**	1188.193
66% cortical thickness (mm)	13.37	−0.014	0.002	<**0.001**	–	–	0.141	0.012	0.002	<**0.001**	4.141
66% tibia and fibula total area (mm^2)[Φ]	27.52	7.966	2.254	<**0.001**	6.552	0.840	<**0.001**	5.873	1.672	<**0.001**	−923.929
66% tibia and fibula cortical density (mg/cm^3)	15.34	−1.010	0.113	<**0.001**	–	–	0.385	–	–	0.068	1168.65
Polar stress strain index (mm^3)	19.79	7.103	1.917	<**0.001**	35.212	4.193	<**0.001**	4.478	2.068	*0.031*	−3659.89

[#] Model includes interaction term age*weight (**β-coefficient = −0.057, SE = 0.025, *p* = 0.024**).
[Φ] Model includes interaction term age*weight (**β-coefficient = −0.062, SE = 0.027, *p* = 0.022**).

Table 7
Mean and standard deviation values for tibial parameters at the 4% site by age decade.

Total area (mm^2)		
Age (yr)	n	Mean ± SD
30–39	28	1306.759 ± 126.705
40–49	66	1302.273 ± 178.511
50–59	101	1304.916 ± 148.399
60–69	121	1337.320 ± 158.958
70–79	93	1359.414 ± 161.426
80+	40	1353.700 ± 164.467

and tibia, and 66% tibia) (Sheu et al., 2011). However, no variables selected for presentation of results in the study by Sheu et al. were comparable to the current study (Sheu et al., 2011).

This study benefits from being drawn from a randomly-selected, population-based sample, making it broadly representative of the Australian population. Furthermore, it provides valuable data for men across the entire age-range, which is lacking in the literature. Parameters were measured at tibial and radial sites, including at both distal and proximal locations, which aims to provide data about both cortical and trabecular rich bone in the peripheral skeleton. However, the data are limited by the cross-sectional nature of study, and exclusion criteria for movement in scans, as well as survivorship bias, may have resulted in bias towards healthier participants in the sample. Most (~98%) of the participants of this study were white, which may limit the applicability of the results to the other populations. Comparisons to other studies is also limited, due to heterogeneity in data collection methods for pQCT parameters, and selection of which parameters are included in published results. In the future, it would be useful to provide similarly collected population-based data for women, and continue data collection into the future to provide longitudinal information regarding pQCT in these individuals. Future data collection in the Geelong Osteoporosis Study will involve collecting data for newly recruited younger men (ages 20–40) which will be able to form the basis of a young adult mean suitable for the calculation of T-scores. Further, it would be useful to reach consensus about the optimal data collection methods for pQCT parameters, and which parameters should be reported in the literature.

5. Conclusion

This study presents normative data for pQCT-derived bone parameters across the adult age span. Broadly, parameters related to bone area increased with age, whereas parameters related to bone density declined with age. The data presented in this study have the potential to be used in a clinical setting as population-based reference data and can be used for comparison in future studies regarding pQCT bone parameters across the adult lifespan.

Transparency document

The Transparency document associated with this article can be found, in online version.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 8
Mean and standard deviation values for tibial parameters at the 66% site by age decade.

Age (yr)	n	Mean ± SD
Total area (mm^2)		
30–39	29	732.388 ± 75.221
40–49	66	755.496 ± 122.856
50–59	98	750.875 ± 115.699
60–69	119	765.036 ± 105.868
70–79	89	780.562 ± 105.260
80+	37	794.608 ± 89.043
Cortical density (mg/cm^3)		
30–39	29	1130.198 ± 22.446
40–49	66	1117.807 ± 21.644
50–59	98	1118.608 ± 31.147
60–69	119	1105.450 ± 37.679
70–79	89	1093.463 ± 38.363
80+	37	1084.028 ± 38.144
Cortical thickness (mm)		
30–39	29	4.554 ± 0.692
40–49	66	4.467 ± 0.656
50–59	98	4.497 ± 0.652
60–69	119	4.132 ± 0.669
70–79	89	4.133 ± 0.574
80+	37	3.709 ± 0.848
Tibia and fibula total area (mm^2)		
30–39	29	850.647 ± 83.836
40–49	66	870.898 ± 139.362
50–59	98	868.100 ± 125.908
60–69	119	888.275 ± 113.852
70–79	89	908.478 ± 118.515
80+	37	920.676 ± 98.275
Tibia and fibula cortical density (mg/cm^3)		
30–39	29	1130.892 ± 21.345
40–49	66	1117.485 ± 21.626
50–59	98	1118.082 ± 29.227
60–69	119	1104.439 ± 36.414
70–79	89	1091.174 ± 37.240
80+	37	1079.836 ± 38.097
Polar stress strain index (mm^3)		
30–39	29	3200.585 ± 370.483
40–49	66	3335.095 ± 708.199
50–59	98	3331.631 ± 602.140
60–69	119	3291.616 ± 533.556
70–79	89	3322.999 ± 525.660
80+	37	3274.483 ± 565.181

Acknowledgements

The Geelong Osteoporosis Study has received grants from the National Health and Medical Research Council (NHMRC) of Australia (299831, 628582) KBA is supported by an Australian Government Research Training Program Scholarship. MCT is supported by a by Deakin Postgraduate Scholarship. SXS is supported by an Executive Dean Health Research Fellowship. NKH is supported by a Dean's Research Postdoctoral Fellowship. KLH-K is supported by an Alfred Deakin Postdoctoral Research Fellowship. The authors thank Professor Graham Giles of the Cancer Epidemiology Centre of The Cancer Council Victoria, for permission to use the Dietary Questionnaire for Epidemiological Studies (Version 2), Melbourne: The Cancer Council Victoria 1996.

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