Considerations for Restoring Center of Rotation in the Portuguese Water Dog Total Hip Arthroplasty in the Context of the Canine as a Translational Model

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INTRODUCTION: Restoring biomechanical function of the hip joint is critical to the success of total hip arthroplasty (THA). Many geometric measurements must be considered for achieving adequate joint restoration, while avoiding leg-length discrepancy. These include cervico-diaphyseal (CD) angle, anteversion (AV) angle, lateral femoral head offset (Lho), and length proportions from the center of rotation (center of femoral head) to the medullary isthmus and lesser trochanter (**Fig. 1**) [1-3]. Canines are often used as translational models for studying femoral implants to be used in humans. If species-related variations significantly influence the restoration of biomechanical function in translational studies, this could impact results and interpretations. Using our large sample of Portuguese Water Dogs (PWDs), a medium to large breed, we sought to understand the age-, sex-, and arthritis-related effects on proximal femoral geometric morphologies that are important for restoring the center of rotation in THA in this important animal model. The geometric measurements made in the present study are shown in **Figure 1**.

ABREVIATIONS: Greater trochanter (GT), center of lesser trochanter (CLT), center of femoral head (CFH), top of femoral head (TFH) **Figure 1A**: lateral femoral head offset (Lho), cervico-diaphyseal (CD) angle, total femoral length (Ltot), **Figure 1B:** Lateral distance from CFH to GT (Lht), Neck Length (Lhd), **Figure 1C**: anteversion (AV) angle, **Figure 1D** distance from TFH to CLT (1), axial distance from CFH to GT (2), neck depth to TFH (3), axial distance from GT to TFH (4), distance from TFH to isthmus (5).

METHODS AND MATERIALS: PWD carcasses were autopsied for various organ pathologies in prior studies that were part of a large research effort known as "The Georgie Project" [4,5]. The right femora were examined (total sample= 415, males= 145, females= 207, unknown sex= 63) from the remaining skeletally mature animals that had been donated for these studies. Age range: 2-16 years old. Various measurements were collected directly on the bones using digital calipers (Mitutoyo) and a goniometer. The AV angle was measured on digital pictures using ImageJ (https://imagej.nih.gov/ij/). The magnitude of femoral head osteoarthritis (OA) was scored using the descriptions of Dennis [6] with a slight modification in methods because we quantified OA directly on the bone and not from radiographs. Severe arthritis was determined to be a score of 4-5 according to the descriptions described by Dennis [6]. Statistical analyses were conducted using NCSS (2020). As a means for potentially controlling confounding effects of animal size, we conducted multiple regression analyses to elucidate the effect of age, sex, and OA on the measured parameters. To test for male vs. female differences, unpaired t-tests were conducted and percentile differences were calculated.

RESULTS: The parameter averages ( ), medians (M), and standard deviations (SD) are reported in **Table 1**. Significant differences between males and females were shown in all parameters except the CD and AV angles, and measurements 2 and 4. However, when specimen body size was controlled using multivariate analyses, only two parameters showed a significant male-female difference (Lht and measurement 1). **Table 2** shows the results of the multivariable regression analyses: the cells highlighted (left column) indicate where model explained >20% of the variation. The unhighlighted cells indicate the model was a poor fit and offered little insight into the variation of the response variable. Regression coefficients are reported and statistical significance is indicated with asterisks (*** p< 0.05, ** p< 0.01, *** p<0.001**). There were no significant interactions in any model, and age was not significant and was excluded from the models.

DISCUSSION: The results of measurement 1 (**Fig. 1D**) mirror human data reported by Noble et al. [3] where male femoral heads have longer axial distances from the center of the lesser trochanter. The PWD's center of the femoral head is on average below the apex of the greater trochanter (-11.0 mm), which is notably different from humans. Our sample of PWDs showed fewer sex-related differences of the proximal femur than what has been reported in humans, suggesting less concern for sex-related differences for THA in PWDs than in humans. Our results also indicate that age was not significant in explaining variations in geometric parameters of the PWD proximal femur. Age has also been reported in humans to have minor effect on many geometric parameters of the proximal femur [3]. Majority of the variations in the proximal femoral geometries in our PWD sample can be explained by the length of the femur (hence body size) and severe arthritis of the femoral head. Our sample showed that severe arthritis significantly reduced the CD angle by 12˚ on average. CD angle has significant implications for establishing leg length and transferring hip reaction forces throughout the femur [7]. Canines suffer from secondary OA with the most common causes of hip OA being attributed to trauma or dysplasia though some studies have suggested that a predisposition for arthritis can be inherited [5,8]. We showed that PWD males had a significantly larger Lho than females, however the multiple regression analysis indicated that femur length explained most of the variation in Lho, therefore the male-female difference is mostly attributed to males being larger than females in our sample. Both Lht and measurement 1 showed that when specimen body size was controlled for that females were significantly smaller.

SIGNIFICANCE: The size of the specimen and severity of arthritis account for most of the variation of the given parameters measured. In our sample, age had no effect, and sex had little influence in the proximal femoral geometry suggesting proximal femoral component designs can be asexual for PWDs.

REFERENCES: [1] De Fine et al. (2017) Orthop Traumatol-Surg 103: 349-; [2] Lum and Dorr (2018) J Orthop 15: 992-; [3] Noble et al. (1995) CORR 316: 31-; [4] Chase et al. (2002) PNAS USA 99: 9930-; [5] Chase et al. (2005) Am J Med Genet A. 135: 334-; [6] Dennis (2012) (BVA)In Practice 34:178-; [7] Sarierler et al. (2017) Turk J Vet Anim Sci 41: 85-; [8] Wessely et al. (2017) Vet Comp Orthop Traumatol 30:377-.

Figure 1

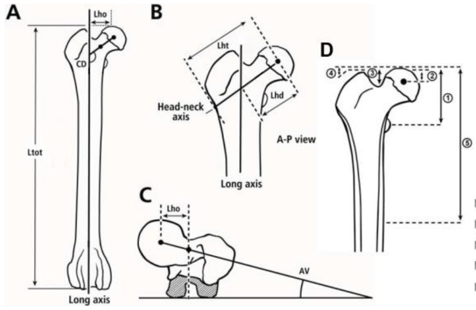

Table 1

	Male			Female				
	Mean	Median	SD	Mean	Median	SD	x̄ % Diff.	t-test
Lht (mm)	34.9	35.0	±3.1	32.5	32.3	±2.8	7.4%	**p< 0.001**
Lho (mm)	14.7	14.5	±2.4	14.1	14.0	±2.0	4.5%	**p< 0.01**
Lhd (mm)	18.9	18.0	±4.1	17.9	17.0	±3.7	5.2%	**p< 0.05**
CD Angle (deg)	127	127	±8	127	127	±8	0.1%	p> 0.5
AV Angle (deg)	13	13	±6	13	13	±5	1.1%	p> 0.5
Measurement 1 (mm)	27.6	27.6	±2.2	25.3	25.5	±2.0	7.9%	**p< 0.001**
Measurement 2 (mm)	-11.0	-10.8	±1.6	-10.6	-10.6	±1.6	33.8%	p= 0.05
Measurement 3 (mm)	6.5	6.4	±1.2	6.0	6.1	±1.0	9.7%	**p< 0.001**
Measurement 4 (mm)	-1.3	-1.1	±1.6	-1.4	-1.4	±1.3	9.4%	p= 0.4
Measurement 5 (mm)	107.1	106.4	±8.1	99.4	100.3	±7.3	7.2%	**p< 0.001**

Table 2

	Multiple Regression Analysis				
	Adj. R^2	Ltot	Weight	Sex	Severe OA
Lht (mm)	0.28	**0.13*** **	**0.03***	**-0.85***	**-1.05***
Lho (mm)	0.05	**0.04****	0.02	-0.08	0.72
Lhd (mm)	0.07	**0.11*****	0.02	0.39	-1.25
CD Angle (deg)	0.15	**0.19****	-0.07	1.6	**-12*****
AV Angle (deg)	0.007	0.03	-0.02	-0.21	**2.52***
Measurement 1 (mm)	0.39	**0.13*****	-0.007	**-0.57***	**-1.04****
Measurement 2 (mm)	0.16	-0.01	**-0.04*****	-0.21	**-1.89*****
Measurement 3 (mm)	0.39	**0.05*****	-0.01	-0.07	**-2.58*****
Measurement 4 (mm)	0.1	**-0.04*****	**0.02****	-0.14	**-1.27*****
Measurement 5 (mm)	0.48	**0.59*****	0.02	-0.67	-1.29