Morphometric analysis of acetabular rim shape among ancient Mongolian pastoralists

Jacqueline T. Eng[1], Andrew Baker[2], Pingbo Tang[3], Shannon Thompson[1], Jamie M. Gomez[1]
[1]Department of Anthropology, Western Michigan University; [2]Department of Anthropology, Purdue University; [3]School of Sustainable Engineering and the Built Environment, Arizona State University

Western Michigan University
College of Arts and Sciences

Introduction

The adoption of nomadic pastoralism may have marked new physiological stresses to the hip for the bipedally-adapted human rider. Relatively few studies have examined differences in acetabular shape resulting from long-term equestrianism [1, 2]. Steppe populations of Mongolia began a nomadic pastoral lifestyle during the Late Bronze Age, which has persisted to the present day, with whole communities of men, women, and children riding horses as part of their lifeway.

Materials and Methods

Three-dimensional laser scans captured morphometric data of os coxae of pastoral samples (n=34) from the National University of Mongolia. Samples date from four periods, spanning incipient pastoralism in the Bronze Age to the later Mongol Period (Table 1, Figure 1). To determine whether acetabular shape among pastoralists is distinct, these pastoral data are also compared to scans of 20th century "White" Euro-American samples from the Hamann-Todd human (HTH) osteological collection (n=20).

Table 1. Samples from Mongolia and the Hamann-Todd human (HTH) collection

Sample	Time	Subadult	Adult (20+yrs) Male	Adult (20+yrs) Female	Total Adult	Total Sample
Bronze	2800-500BC	1	4	3	7	8
Scythian	6th-3rd c. BC	0	3	1	4	4
Xiongnu	3rd c. BC - AD 2nd c.	Adol: 1M, 1F	4	5	9	11
Mongol	AD 13th-14th c.	Adol: 2M, 2F	3	4	7	11
Total Mongolian sample		**7**	**14**	**13**	**27**	**34**
Hamman-Todd (HTH)	20th c. AD	1M adol, 1F <12yrs	9	9	18	20

Figure 1. Map of Mongolia and sites from two periods

Scans were taken with a NextEngine Desktop 3D Scanner and ScanStudio™ software (v.1.3.2). Data were captured from the Mongolian samples as 360° scans with eight divisions in standard definition using wide mode (resolution of 0.015"), while bracket scans were taken for HTH samples due to time constraints and to focus scan data from the acetabulum vs. entire os coxa (Figure 2). Each scan was trimmed and compressed to eliminate overlapping data points, then saved as XYZ file format (coordinate data) that could be opened in other programs.

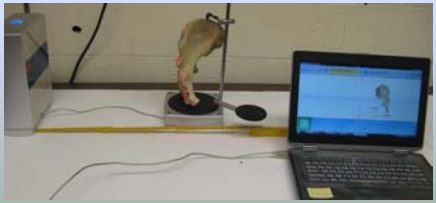


Figure 2. Scanning acetabulum with NextEngine 3D scanner

Scan Data Analysis

CloudCompare (v.2.3), an open source 3D point cloud processing software, was used to: 1) trim points—as close as possible within the same plane—to the acetabular rim (Figure 3); and 2) obtain radius distance of this rim. These data were analyzed for the shape of the acetabular rim relative to a best fitted cylinder.

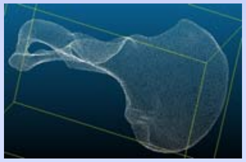
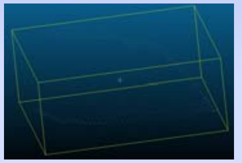


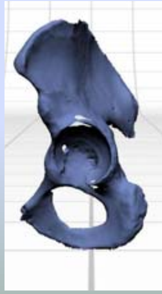
Figure 3. Os coxa before trim (left); after CloudCompare trim to acetabular rim (right)



A least-square algorithm using the Gaussian-Newton method fits a cylinder against the 3D data points along the rim. The Gaussian-Newton method estimates the parameters of a cylinder through minimizing the sum of squares of the Euclidean distances from input points to the cylinder surface. As these Euclidean distances are along the radius of the cylinder, they are known as "radical distances." The magnitude of these radical distances is an indicator of the deviation of the rim from a perfect cylinder.

This study used the standard deviation of these radical distances for measuring the distortion of the rim from a cylinder. We divided each standard deviation result by its associated radius of the fitted cylinder to acquire a "normalized" standard deviation to account for individual size differences.

We used the function "lscylinder" in a MATLAB (programming language) function library, the Least Squares Geometric Elements library (LSGE), to complete the cylinder extraction and rim distortion analysis described above.



Statistical tests

Independent samples t-tests were conducted to compare samples by age (subadult-adult) and sex, within and between Mongolian and HTH samples. One-way ANOVA tests compared the different periods within the Mongol sample and to the HTH sample, with post-hoc LSD tests to determine which conditions were significantly different. All tests were run with SPSS v.18.

Results

Within the Mongolian sample there are no significant differences between subadults and adults in acetabular rim shape, nor between males and females (both adolescent and adult comparisons) (Table 2).

Sample		N	Mean	SD	t	df	p
Mongolian sample	Subadult	7	0.030	0.007	-0.715	32	0.480
	Adult	27	0.033	0.012			
	Male	14	0.033	0.004	-0.079	25	0.937
	Female	13	0.033	0.003			
	Adol. M	3	0.027	0.008	-1.497	4	0.209
	Adol. F	3	0.035	0.004			
HTH	Adult M	9	0.034	0.013	0.929	16	0.367
	Adult F	9	0.030	0.007			
Mongolia	Adults	27	0.033	0.012	-0.368	43	0.714
HTH	Adults	18	0.032	0.011			
Mongolia	Male	14	0.033	0.014	0.214	21	0.833
HTH	Male	9	0.034	0.013			
Mongolia	Female	13	0.033	0.01	-0.951	20	0.353
HTH	Female	9	0.030	0.007			
Mongolia	Subadult	7	0.030	0.007	0.226	1.107	0.856
HTH	Subadult	2	0.032	0.016			

Table 2. Results of t-tests comparing normalized radical distances STD (mm)

Table 3. Results of post-hoc LSD tests, with respect to the Scythian sample

Period		Mean Diff.	Std. Err.	Sig.
Scythian	Bronze	.00747	.00705	.296
	Xiongnu	.01471	.00676	.036*
	Mongol	.01405	.00705	.053*
	HTH	.01179	.00622	.065

Despite the differences in their form of subsistence-related movements, there are also no significant differences between the HTH sample with the Mongolian pastoral sample (comparison by age and sex). A one-way ANOVA test of Mongolian adult samples to those of HTH, while showing no significant difference between sites, suggests the Scythian sample is significantly different from Xiongnu and Mongol period samples, and close to the level of significance in difference with the HTH sample (Table 3).

Discussion and Conclusion

These results suggest the acetabular rim shape does not change significantly as a result of long-term horse riding. Within the Mongolian samples there are no significant differences among men, women, and subadults, but historical accounts note the young starting age of riding among Mongolians of both sexes [3, 4], which may explain these results. The Scythian sample may be distinct from the other periods (and HTH) since they were a western nomadic group that may have had a different riding style, and possibly different genetic heritage and associated hip morphology. What is surprising is the lack of distinct differences between the Mongolian samples and the 20th century HTH collection, which comprise different genetic and activity profiles.

Possible explanations: 1) (Mongolian style of) horse riding does not markedly alter hip shape, which must still conform to bipedal locomotion; 2) limitations of small sample sizes; and/or 3) analysis may need to account for shape metrics other than radical distance as a measure of distortion, e.g., total acetabular (concave) shape, not just rim. Future studies can address these questions.

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