

[Supplementary material]

Understanding early horse transport in eastern Eurasia through analysis of equine dentition

William T.T. Taylor^{1,*}, Jinping Cao², Wenquan Fan³, Xiaolin Ma⁴, Yanfeng Hou³, Juan Wang⁵, Yue Li⁶, Chengrui Zhang⁷, Helena Miton⁸, Igor Chechushkov⁹, Jamsranjav Bayarsaikhan¹⁰, Robert Cook¹¹, Emily L. Jones¹², Enkhbayar Mijiddorj¹³, Tserendorj Odbaatar¹⁴, Chinbold Bayandelger¹⁴, Barbara Morrison¹⁵ & Bryan Miller¹⁶

¹ University of Colorado Boulder Museum of Natural History, USA

² Center for the Study of Ancient Civilization, Henan University, P.R. China

³ Henan Provincial Institute of Cultural Heritage and Archaeology, P.R. China

⁴ Henan Museum, P.R. China

⁵ Department for the History of Science and Scientific Archaeology, University of Science and Technology of China, P.R. China

⁶ School of Cultural Heritage & Ministry of Education Key Laboratory of Cultural Heritage Studies and Conservation, Northwest University, P.R. China

⁷ Department of Anthropology, Harvard University, USA

⁸ Santa Fe Institute, USA

⁹ South Ural State University (National Research University), Chelyabinsk, Russia

¹⁰ National Museum of Mongolia, Ulaanbaatar, Mongolia

¹¹ Tufts University, USA

¹² Department of Anthropology, University of New Mexico, USA

¹³ Ulaanbaatar University, Mongolia

¹⁴ National Museum of Mongolia, Ulaanbaatar, Mongolia

¹⁵ Morrison Designs, Missoula, USA

¹⁶ History of Art Department & Museum of Anthropological Archaeology, University of Michigan, USA

* Author for correspondence ✉ william.taylor@colorado.edu

OSM 1: horse bits in early China and bit damage

Horse bits at Xinzheng

Based on ancient literature and unearthed archaeological artefacts, before the Western Zhou period (e.g. Shang Dynasty), the horse bits were made of leather, which was replaced by bronze or other metal from the Western

Zhou period (Guo 1998). We can find this trace from a bronze bit, which copies the shape of a leather bit (see Figure S1: left) (Guo 1998). The shape altered in the end of the Western Zhou period and stabilized during the Eastern Zhou period (for a typical form, see Figure S1: centre) (Guo 1998).

In China, rare evidence of organic bits have been discovered at the Yanghai cemetery near the Turfan oasis, western China (see background in Beck *et al.* (2014)). Several bits made of wood and antler were found (see Figure S1: right) (Niyaz 2012). One of the wooden bit comes from Tomb 12, which has been scientifically dated to c. 3000 years ago (Beck *et al.* 2014).

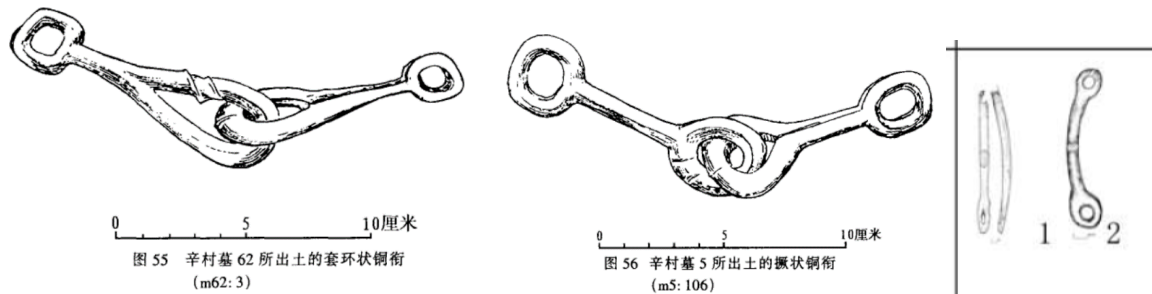


Figure S1. Left) bronze bit from tomb 62, Xincun site (Guo 1998: 61); centre) bronze bit from tomb 5, Xincun site (Guo 1998: 62); right) horse bits made of wood and antler from Yanghai cemetery (Niyaz 2012: 78).

Xinzheng horse data

All the horse skeletons were excavated from the famous Zheng-Han ancient city (Zheng-Han Gucheng, 郑韩故城), the ruins of ancient capital city of the Zheng and Han States in Xinzheng, Henan Province. See details at: http://www.kaogu.cn/en/Special_Events/Top_10_Archaeological_Discoveries_in_China_2017/2018/0418/61718.html.

All horse skeletons mentioned here are dated to the Eastern Zhou period (770–256 BC), which is divided into the Spring and Autumn period (when the city belonged to the Zheng state) and the Warring States period (when the city belonged to the Han state). The dating is based on forms and artifacts of related tombs. Generally speaking, horse artefacts like bronze bits were not buried with horse and chariots in their pits, but within the tombs around the horse (and chariot) pits. All horses buried in pits Zheng-Han Ancient City are male if the sex identification is available.

Based on observations on lower P2 of relatively well preserved horse skulls from the No. 1 horse and chariot pit

at Cuiyuanxiaoqu (翠园小区) site (24 horses, Spring and Autumn period, Zheng state), No. 1 horse pit at Houduanwanminzhai (后端湾民宅) site (three specimens, Spring and Autumn period, Zheng state), and No. 1 horse pit at Hongyuanshengwu (宏源生物) site (14 horses, Warring States period, Hanstate), we found a majority of the lower P2 show exposed enamel anteriorly (where the cementum has worn away), but the most of them do not display apparent abrasions (see Figure S2). Only a few P2's anterior parts show severe abrasions as well as depressions (see Figure S3). Obvious V-shaped wear of upper and lower P2 occurs, but rarely. See an example in Figure S4, 08ZHCY1-6 (left side).



Figure S2. Lower P2 showing anterior enamel exposure, but without obvious abrasions: 1) 08ZHCY1-8 (horse No 8. from horse and chariot pit 1 at Cuiyuanxiaoqu site, excavated 2008, age ≤ 9 , left side); 2) 08ZHCY1-11 (horse No 11. from horse and chariot pit 1 at Cuiyuanxiaoqu site, excavated at 2008, age ~ 8 , left side); 3) 2010ZHHM1-4 (horse No 4. from horse pit 1 at Houduanwan site, excavated 2010, age ~ 10 , left side); 4) 2012ZHYY1-14 (horse No. 14 from horse pit 1 at Hongyuanshengwu site, excavated 2012, age 5–6, left side) (photographs by J. Cao).



Figure S3. Lower P2 showing anterior enamel exposure with obvious abrasions: 1–2) 08ZHCY1-1 (horse No. 1 from Pit 1 at Cuiyuanxiaoqu site, excavated 2008, age ~12, right side); 3) 2012ZHYY1-1 (horse No. 1 from horse pit 1 at Hongyuanshengwu site, excavated 2012, age 9–10, right side); 4) 08ZHCY1-14 (horse No. 14 from horse and chariot pit 1 at Cuiyuanxiaoqu site, excavated 2008, age 3.5, right side) (photographs by J. Cao).



Figure S4. V-shaped wear to upper and lower premolars of horse 08ZHCY1-6 (horse No. 6 from horse and chariot pit 1 at Cuiyuanxiaoqu site, excavated 2008, age 8, left side) (photograph by J. Cao).

Table S1. Bit wear damage from chariot and riding horses from ancient China, ancient Mongolia, and modern Mongolia. Scoring system: 0: no traces; 1: light abrasion on anterior cementum, but no exposure of enamel; 2: exposure of anterior enamel; 3: obvious anterior erosion; 4: occlusal bevel; –: observation unavailable. For full dataset, see Tables S2–3.



Category	Horse use	Number of individuals		Upper P2	Lower P2	
All chariots		42	Limited impact	0	52%	43%
				1	2%	5%
				2	33%	33%
			High impact	3	0%	7%
				4	5%	12%
				–	0%	0%
East Asian riding		23	Limited impact	0	22%	4.3%
				1	17.4%	0%
				2	26.1%	4.3%
			High impact	3	0%	21.7%
				4	17.4%	39.1%
				–	17.4%	30.4%
Deer Stone-Khirigsuur Complex	?	19	Limited impact	0	16%	16%
				1	16%	26%
				2	21%	26%
			High impact	3	0%	5%
				4	42%	0%
				–	5%	26%






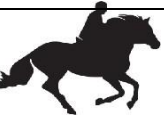
Table S2. Bit wear data from Xinzheng sites.

Site	Historical period	State	Individual No.	Sex (based on canine and pevis)	Age (based on incisors, limbs, and vertebrae)	Score of P2*			
						Upper P2 (L)	Upper P2 (R)	Lower P2 (L)	Lower P2 (R)
Cuiyuanxiaoqu (翠园小区)	Spring and Autumn period (771–476 BC)	Zheng (郑)	08ZHCY1-1	Male	~12	2	2	3	3
			08ZHCY1-2	?	~8	0	0	0	0
			08ZHCY1-3	Male	~7	4	–	4	–
			08ZHCY1-4	Male	~5–7	0	0	2	0
			08ZHCY1-5	Male	~9	2	2	2	2
			08ZHCY1-6	Male	~8	4	4	4	4
			08ZHCY1-7	?	3.5+	0	0	0	0
			08ZHCY1-8	Male	~9	2	2	2	2
			08ZHCY1-9	?	5+	0	0	0	0
			08ZHCY1-10	Male	~7	0	0	1	0
			08ZHCY1-11	Male	~8	2	2	2	2
			08ZHCY1-12	Male	5+	0	0	0	0
			08ZHCY1-13	Male	~7	0	2	4	2
			08ZHCY1-14	Male	~3.5	2	2	3	3
			08ZHCY1-15	Male	~11	0	0	2	2
			08ZHCY1-16	Male	8+	0	0	0	0
			08ZHCY1-17	Male	~8	0	0	0	0

			08ZHCY1-18	Male	8+	–	–	–	–
			08ZHCY1-19	Male	~8	0	0	–	–
			08ZHCY1-20	Male	5-6	0	0	0	0
			08ZHCY1-21	Male	7–8	0	0	0	0
			08ZHCY1-22	Male	~8	0	0	0	0
			08ZHCY1-23	Male	~8	0	0	0	0
			08ZHCY1-24	Male	~8	0	0	0	0
Hongyuanshengwu (宏源生物)	Warring States period (475–221 BC)	Han (韩)	2012ZH HY1-1	Male	9–10	–	–	0	3
			2012ZH HY1-2	Male	~8	0	0	0	0
			2012ZH HY1-3	Male	~9	0	–	4	4
			2012ZH HY1-4	Male	~12	2	2	2	2
			2012ZH HY1-5	Male	~9	2	2	2	2
			2012ZH HY1-6	Male	8–9	–	–	–	–
			2012ZH HY1-7	Male	~9	2	2	2	4
			2012ZH HY1-8	Male	~8	0	0	0	2
			2012ZH HY1-9	Male	15+	2	2	2	2
			2012ZH HY1-10	Male	~7	0	0	2	2
			2012ZH HY1-11	?	5-7	2	0	2	2
			2012ZH HY1-12	Male	5–7	–	–	–	–

			2012ZHHY1-13	Male	~8	–	–	–	–
			2012ZHHY1-14	Male	5-6	2	2	2	2
Houduanwan (后 端湾)	Spring and Autumn period (771–476 BC)	Zheng (郑)	2010ZHBM1-1	?	?	0	0	0	2
			2010ZHBM1-2	Male	~12–15	2	2	2	0
			2010ZHBM1-3	Male	~9	1	1	1	0
			2010ZHBM1-4	Male	~10	2	0	2	0

Table S3. Bit wear damage from chariot and riding horses from ancient China, ancient Mongolia, and modern Mongolia. Scoring system: 0: no traces; 1: light abrasion on anterior cementum, but no exposure of enamel; 2: exposure of anterior enamel; 3: obvious anterior erosion; 4: occlusal bevel; -: observation unavailable.

Site	Period	Horse use	# (N)	Score	Upper P2	Lower P2
Cuiyuanxiaoqu (翠园小区), Zheng state (郑)	Spring and Autumn period (771–476 BC)		24	0	16	13
				1	0	1
				2	6	5
				3	0	2
				4	2	3
				–	0	0
Houduanwan (后端湾), Zheng state (郑)	Spring and Autumn period (771–476 BC)		4	0	2	3
				1	1	1
				2	2	2
				3	0	0
				4	0	0
–	0	0				
Hongyuanshengwu (宏源生物), Han state (韩)	Warring States period (475–221 BC)		14	0	4	3
				1	0	0
				2	6	7
				3	0	1
				4	0	2
				–	4	1
Mongolia, various localities	Modern		13	0	5	0
				1	3	2
				2	0	2
				3	1	4
				4	2	0
				–	1	5
Mongolia, various localities	Early Iron Age (Pazyryk, Xiongnu) and		7	0	3	0
				1	0	0
				2	0	0
				3	0	1

	Early Middle Ages (Turkic)		4	2	4
			–	3	2
			0	0	0
			1	0	0
Shirezigou and Xigou, Xinjiang, China	Early Iron Age, <i>c.</i> 340–220 BC	6	2	3	1
			3	0	1
			4	2	4
			–	1	0

OSM2: bit wear data from Mongolia.

Table S4. Bridle and bit damage to the cranium and dentition of adult DSKC horses (>5 years) with sufficient level of preservation for assessment.

Specimen	Context	Age	Sex (DNA/canines)	Nasal remodelling?	Max LP2 bevel	LP2 anterior wear?/ indicative of biting?	Upper premolar bevel?	Diastema score	Intercuspid wear of LP2	Mandibular deformation	Other
NMM 001	Khuvsgul, Tsagaan Uul sum, Khushuutin GoldS Feature 2	16+ (incisors)	Indet.	—	1.1	YES/NO	YES	1		X	Concavity on LLP2 anterior, Chipped LP2 margin
NMM 002	Khuvsgul, Tsagaan Uul sum, Bor Hujiriin Gol 1 Feature 2	~14–15 (crown height)	Female	—	0	—	YES	—			
NMM 003	Khuvsgul, Tsagaan Uul sum, Khushuutin GoldS Feature 3	16+ (incisors)	Indet.	YES	0	NO	NO	—	X	X	
NMM 008	Bayan Ulgii, Tsengel sum, On Khad KS	~6–7 (incisors)	Male	—	2.27	YES/NO	NO	0	X	X	
NMM 009	Khuvsgul, Renchinkhumb e Sum, Tsatstain Khushuu Feature 2	20+ (crown height)	Male	NO	—	—	—	—	—	X	
NMM 016	Zavkhan, Shiluustei sum, Daagan Del DS	16+ (incisors)	Female	—	—	—	YES	1	X	X	Chipped LP2 margin
NMM 017	Khuvsgul, Alag-Erdene sum, Ulaan Tolgoi DS 4 feature 6	~11–18 (crown height)	Indet.	—	0	—	YES	—			
NMM 028	Khuvsgul, Renchinkhumb e sum, Zeerdegchingii n Khushuu KS F1 (2006)	~11–12 (crown height)	Male	—	2.22	YES/NO	Possible	—			Chipped LP2 margin

NMM 030	Arkhangai, Undoor Ulaan sum, Urt Bulagyn KS KYRI 21	~11-16 (crown height)	Male	-	8.52	-	YES	0			Impacted UL M1, broken URM1,
NMM 034	Khuvsgul, Tumurbulag sum, Zunii Gol A1F3	~11-14 (crown height)	Female	-	1.37	NO	YES	1	X	X	Chipped LP2 margin
NMM 040	Khuvsgul, Tumurbulag sum, Zunii Gol K3	~10-14 (crown height)	Male	-	3.73	YES/NO	YES	-			
NMM 041	Khuvsgul, Tumurbulag sum, Zunii Gol DS 4	~9-14 (crown height)	Female	-	1.64	YES/NO	YES	0			Chipped LP2 margin
NMM 045	Bayankhongor, Erdenetsogt sum, Bor Shoroonii Am HM1	~14-17 (crown height)	Male	-	0.83	YES/NO	Possible	1			Tooth fragment between URM1 and M2, Concavity on LLP2 anterior
NMM 047	Khuvsgul, Renchinlkhumb e sum, Zeerdegchingii n Khushuu FA	~10-15 (crown height)	Male	-	0	YES/NO	NO	1			Chipped LP2 margin
NMM 050	Uvs, Zuunkhangai sum, ZK 257-3	~14-17 (crown height)	Indet.	-	0	YES/NO	YES	0			
NMM 051	Uvs, Zuunkhangai sum, ZK 1-3	20+ (crown height)	Indet.	-	0	NO	-	1	X	X	Bone remodeling around LR mandible
NMM 056	Bayankhongor, Erdenetsogt sum, Shatar Chuluu DS 1	~13-14 (crown height)	Male	Possible	2.64	-	Possible	1			Impacted ULM3
NMM 057	Bayankhongor, Erdenetsogt sum, Shatar Chuluu KS 1	~8-9 (incisors)	Male	-	1.98	YES/NO	YES	0			
NMM 095	Bayankhongor, Morin Mort	16+ (incisors)	Female	-	2.26	NO	YES	0	X		Chipped LP2 margin, tooth row bowed outwards



Figure S5. 3D image of mandible from juvenile horse, ~2–2.5 years of age, from the site of Uguumur (NMM 014), which also exhibits evidence for veterinary dentistry on the upper incisors. Arrow shows intercuspid wear to the deciduous second premolar (photograph by W.T.T. Taylor).

Table S5. Bridle and bit damage to the cranium and dentition of modern and ancient riding horses (>4 years) with sufficient level of preservation for assessment.

Specimen	Historical period	Age	Sex	Nasal remodelling?	Max LP2 bevel	LP2 anterior wear?/ indicative of biting?	Upper premolar wear?	Diastema score	Other
CMH 02	Modern	~16+ (incisors)	Male	Yes	3.43	NO	NO	1	Concavity to lower LP2 anterior margin, Chip fracture
CMH 04	Modern	~16+ (incisors)	Male	No	3.13	YES/YES	NO	0	Concavity to lower LP2 anterior margin, chip fracture
CMH 05	Modern	(~4.5 eruption)	Male	No	–	–	NO	–	
CMH 06	Modern	(5+ eruption)	Male	No	–	–	NO	–	
CMH 07	Modern	~13–16 (incisors)	Male	YES	–	–	NO	–	
CMH 08	Modern	~11–12 (incisors)	Male	No	–	–	NO	–	
CMH 09	Modern	~16+ (incisors)	Female	No	0	YES/YES	NO	1	
CMH 10	Modern	5+ (eruption)	Female	YES	–	–	NO	–	
CMH 11	Modern	~7 (incisors)	Female	–	0	YES/NO	–	1	
CMH 12	Modern	~4 (eruption)	Male	YES	0	YES/NO	NO	1	
CMH 13	Modern	5+ (eruption)	Male	No	–	–	NO	–	Impacted teeth (upper left M2,M3)
CMH 14	Modern	5+ (eruption)	Male	–	2.59	YES/YES	–	0	
CMH 15	Modern	~8–9 (incisors)	Male	Possible	–	–	NO	–	
NMM 013	Pazyryk (sixth to fourth centuries BC)	~14–15 (crown height)	Male	–	6.39	YES/YES	YES	0	
NMM 071	Xiongnu (second century BC to second century AD)	~9–10 (incisors)	Male	Possible	6.58	YES/YES	YES	2	
NMM 080	Xiongnu (second century BC to second century AD)	~16+ (incisors)	Female	Possible	0	YES/YES	NO	1	

	AD)								
NMM 094	Xiongnu (second century BC to second century AD)	~10–12 (crown height)	Indeterminate	No	–	–	NO	–	
NMM 011	Turkic (fifth to eighth centuries AD)	~8–9 (incisors)	Male	Yes	9.81	YES/YES	YES	0	
NMM 081	Turkic (fifth to eighth centuries AD)	~8–13 (incisors)	Male	–	7.21	NO	–	0	
NMM 082	Turkic (fifth to eighth centuries AD)	~4–5 (eruption)	Male	NO	1.68	YES/YES	NO	3	Bone formation at lower left P2 margin
NMM 087	Turkic (fifth to eighth centuries AD)	~4–4.5 (eruption)	YES	–	–	–	–	–	

OSM3: rein angle measurements.

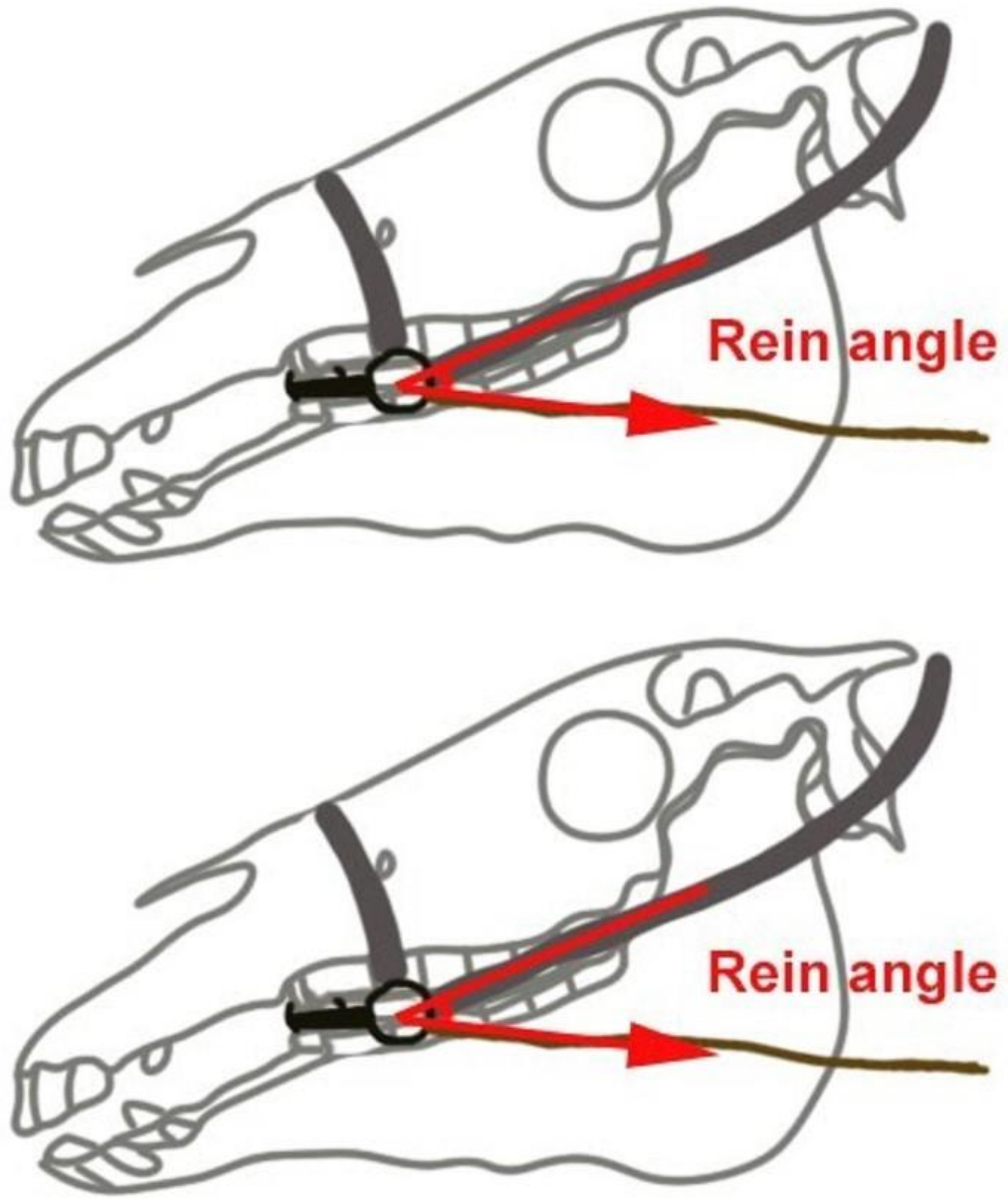


Figure S6. Measurement of rein angle formed by the projected intersection of the reins with the bridle cheek strap (figure by W.T.T. Taylor).

Table S6. Rein angle measurements used in the analysis.

Unique identifier	Subset / Category	Gait	Angle	Source
English_riding1	Riding - English	NA	74.86	Google Images
English_riding2	Riding - English	Trot	82.44	Google Images
English_riding3	Riding - English	Trot	88.48	Google Images
English_riding4	Riding - English	Trot	77.74	Google Images
English_riding5	Riding - English	Trot	58.6	Google Images
English_riding6	Riding - English	Canter	83.39	Google Images
English_riding7	Riding - English	Trot	75.24	Google Images
English_riding8	Riding - English	Trot	92.31	Google Images
English_riding9	Riding - English	Trot	88.94	Google Images
English_riding10	Riding - English	Trot	95.51	Google Images
English_riding11	Riding - English	Walk	58.93	Google Images
English_riding12	Riding - English	NA	79.93	Google Images
English_riding13	Riding - English	NA	72.74	Google Images
English_riding14	Riding - English	Trot	85.38	Google Images
English_riding15	Riding - English	Walk	55.37	Google Images
English_riding16	Riding - English	Trot	86.12	Google Images
English_riding17	Riding - English	Canter	74.53	Google Images

English_riding18	Riding - English	NA	82.93	Google Images
English_riding19	Riding - English	Canter	76.91	Google Images
English_riding20	Riding - English	Walk	66.08	Google Images
English_riding21	Riding - English	Walk	64.61	Google Images
Mongolian_riding_1	Riding - Mongolian	Gallop	19.98	Google Images
Mongolian_riding_2	Riding - Mongolian	Gallop	27.21	Google Images
Mongolian_riding_3	Riding - Mongolian	Gallop	21.78	Google Images
Mongolian_riding_4	Riding - Mongolian	Gallop	43.36	Google Images
Mongolian_riding_5	Riding - Mongolian	Gallop	26.66	Google Images
Mongolian_riding_6	Riding - Mongolian	Gallop	14.24	Google Images
Mongolian_riding_7	Riding - Mongolian	Gallop	21.11	Google Images
Mongolian_riding_8	Riding - Mongolian	Gallop	10.18	Google Images
Mongolian_riding_9	Riding - Mongolian	Gallop	25.38	Google Images
Mongolian_riding_10	Riding - Mongolian	Gallop	24.94	Google Images
Mongolian_riding_11	Riding - Mongolian	Gallop	22.16	Google Images

Mongolian riding_12	Riding - Mongolian	Gallop	57.24	Google Images
Mongolian riding_13	Riding - Mongolian	Gallop	28.99	Google Images
Mongolian riding_14	Riding - Mongolian	Gallop	23.06	Google Images
Mongolian riding_15	Riding - Mongolian	Gallop	26.38	Google Images
Mongolian riding_16	Riding - Mongolian	Gallop	34.95	Google Images
Mongolian riding_17	Riding - Mongolian	NA	36.52	Google Images
Mongolian riding_18	Riding - Mongolian	Gallop	36.15	Google Images
Mongolian riding_19	Riding - Mongolian	NA	19.63	Google Images
Mongolian riding_20	Riding - Mongolian	Walk	32.36	Google Images
Mongolian riding_21	Riding - Mongolian	Standing	59.58	Google Images
Mongolian riding_22	Riding - Mongolian	Standing	42.46	Google Images
Mongolian riding_23	Riding - Mongolian	Walk	30.79	Google Images
Mongolian riding_24	Riding - Mongolian	Trot	34.19	Google Images

Mongolian riding_25	Riding - Mongolian	Trot	37.63	Google Images
Mongolian riding_26	Riding - Mongolian	Trot	28.54	Google Images
Mongolian riding_27	Riding - Mongolian	Walk	32.24	Google Images
Mongolian riding_28	Riding - Mongolian	Standing	27.55	Google Images
Mongolian riding_29	Riding - Mongolian	Walk	46.59	Google Images
Mongolian riding_30	Riding - Mongolian	Walk	31.61	Google Images
Mongolian riding_31	Riding - Mongolian	Standing	30.02	Google Images
Mongolian riding_32	Riding - Mongolian	Standing	40.18	Google Images
Mongolian riding_33	Riding - Mongolian	Walk	46.66	Google Images
Mongolian riding_34	Riding - Mongolian	Standing	42.36	Google Images
Mongolian riding_35	Riding - Mongolian	Trot	38.34	Google Images
Mongolian riding_36	Riding - Mongolian	Trot	37.59	Google Images
Mongolian riding_37	Riding - Mongolian	Standing	40.83	Google Images

Mongolian riding_38	Riding - Mongolian	Trot	33.35	Google Images
Mongolian riding_39	Riding - Mongolian	Trot	44.29	Google Images
Mongolian riding_40	Riding - Mongolian	Trot	35.53	Google Images
Mongolian riding_41	Riding - Mongolian	Walk	24.51	Google Images
Mongolian riding_42	Riding - Mongolian	Gallop	31.27	Google Images
Mongolian riding_43	Riding - Mongolian	Walk	39.31	Google Images
Mongolian riding_44	Riding - Mongolian	Walk	39.94	Google Images
Mongolian riding_45	Riding - Mongolian	Gallop	25.48	Google Images
Mongolian riding_46	Riding - Mongolian	Trot	25.47	Google Images
Mongolian riding_47	Riding - Mongolian	Gallop	30.27	Google Images
Mongolian riding_48	Riding - Mongolian	Trot	27.32	Google Images
Mongolian riding_49	Riding - Mongolian	Walk	30.48	Google Images
Mongolian riding_50	Riding - Mongolian	Walk	35.99	Google Images

Mongolian riding_51	Riding - Mongolian	Walk	23.11	Google Images
Mongolian riding_52	Riding - Mongolian	Walk	34.45	Google Images
Mongolian riding_53	Riding - Mongolian	Walk	30.83	Google Images
Mongolian riding_54	Riding - Mongolian	Trot	30.79	Google Images
Mongolian riding_55	Riding - Mongolian	Gallop	21.92	Google Images
Mongolian riding_56	Riding - Mongolian	Walk	46.67	Google Images
Mongolian riding_57	Riding - Mongolian	Gallop	21.93	Google Images
Mongolian riding_58	Riding - Mongolian	Walk	35.52	Google Images
Mongolian riding_59	Riding - Mongolian	Walk	38.7	Google Images
Mongolian riding_60	Riding - Mongolian	Trot	33.35	Google Images
Mongolian riding_61	Riding - Mongolian	Trot	12.15	Google Images
Mongolian riding_62	Riding - Mongolian	Braking	9.91	Google Images
Mongolian riding_63	Riding - Mongolian	Walk	47.16	Google Images

Mongolian riding_64	Riding - Mongolian	Walk	36.52	Google Images
Mongolian riding_65	Riding - Mongolian	Walk	38.5	Google Images
Mongolian riding_66	Riding - Mongolian	Trot	30.43	Google Images
Mongolian riding_67	Riding - Mongolian	Braking	33.03	Google Images
Mongolian riding_68	Riding - Mongolian	Standing	30.42	Google Images
Mongolian riding_69	Riding - Mongolian	Walk	36.74	Google Images
Mongolian riding_70	Riding - Mongolian	Walk	44.78	Google Images
Mongolian riding_71	Riding - Mongolian	Walk	24.08	Google Images
Mongolian riding_72	Riding - Mongolian	Gallop	22.71	Google Images
Mongolian riding_73	Riding - Mongolian	Trot	35.78	Google Images
Mongolian riding_74	Riding - Mongolian	Trot	28	Google Images
Mongolian riding_75	Riding - Mongolian	Trot	26.63	Google Images
Mongolian riding_76	Riding - Mongolian	Walk	32.03	Google Images

Mongolian riding_77	Riding - Mongolian	Gallop	21.87	Google Images
Mongolian riding_78	Riding - Mongolian	NA	31.85	Google Images
Mongolian riding_79	Riding - Mongolian	Stop	47.92	Google Images
Mongolian riding_80	Riding - Mongolian	Gallop	21.51	Google Images
Mongolian riding_81	Riding - Mongolian	Walk	30.95	Google Images
Mongolian riding_82	Riding - Mongolian	NA	35.55	Google Images
Mongolian riding_83	Riding - Mongolian	NA	16.03	Google Images
Mongolian riding_84	Riding - Mongolian	Stop	37.69	Google Images
Mongolian riding_85	Riding - Mongolian	Stop	40.56	Google Images
Mongolian riding_86	Riding - Mongolian	Walk	27.99	Google Images
Mongolian riding_87	Riding - Mongolian	Walk	16.88	Google Images
Mongolian riding_88	Riding - Mongolian	Walk	39.89	Google Images
Mongolian riding_89	Riding - Mongolian	Gallop	12.71	Google Images

Mongolian riding_90	Riding - Mongolian	Trot	48.09	Google Images
Mongolian riding_91	Riding - Mongolian	Gallop	16.74	Google Images
Mongolian riding_92	Riding - Mongolian	Trot	6.67	Google Images
Mongolian riding_93	Riding - Mongolian	Gallop	36.98	Google Images
Mongolian riding_94	Riding - Mongolian	Gallop	15.45	Google Images
Mongolian riding_95	Riding - Mongolian	Gallop	37.07	Google Images
Mongolian riding_96	Riding - Mongolian	Stop	31.24	Google Images
Horse_racing2	Riding - Race	Gallop	36.98	Google Images
Horse_racing3	Riding - Race	Gallop	37.01	Google Images
Horse_racing3	Riding - Race	Gallop	59.05	Google Images
Horse_racing4	Riding - Race	Gallop	58.23	Google Images
Horse_racing5	Riding - Race	Gallop	40.46	Google Images
Horse_racing5	Riding - Race	Gallop	45.42	Google Images
Horse_racing6	Riding - Race	Gallop	51.14	Google Images
Horse_racing6	Riding - Race	Gallop	77.56	Google Images
Horse_racing6	Riding - Race	Gallop	50.31	Google Images
Horse_racing6	Riding - Race	Gallop	54.95	Google Images

Horse_racing7	Riding - Race	Gallop	41.77	Google Images
Horse_racing8	Riding - Race	Gallop	68.35	Google Images
Horse_racing9	Riding - Race	Gallop	37.39	Google Images
Horse_racing10	Riding - Race	Gallop	57.85	Google Images
Horse_racing11	Riding - Race	Gallop	37.9	Google Images
Horse_racing12	Riding - Race	Gallop	46.05	Google Images
Horse_racing13	Riding - Race	Gallop	41.22	Google Images
Horse_racing13	Riding - Race	Gallop	45.58	Google Images
Horse_racing14	Riding - Race	Gallop	40.57	Google Images
Horse_racing15	Riding - Race	Gallop	84.45	Google Images
Horse_racing16	Riding - Race	Gallop	51.65	Google Images
Horse_racing17	Riding - Race	Gallop	31.7	Google Images
Horse_racing18	Riding - Race	Gallop	47.34	Google Images
Horse_racing18	Riding - Race	Gallop	55.14	Google Images
Horse_racing19	Riding - Race	Gallop	35.01	Google Images
Horse_racing20	Riding - Race	Gallop	24.85	Google Images
Horse_racing20	Riding - Race	Gallop	24.47	Google Images
Horse_racing21	Riding - Race	Gallop	26.57	Google Images
Horse_racing22	Riding - Race	Gallop	32.53	Google Images
Horse_racing22	Riding - Race	Gallop	29.74	Google Images

Plate 21.4	Traction - ancient chariot	Stop	57.09	Spruytte (1983)
Plate 14.6	Traction - ancient chariot	Trot	60.63	Spruytte (1983)
Plate 7.2	Traction - ancient chariot	NA	45.78	Spruytte (1983)
Plate 7.1	Traction - ancient chariot	Stop	40.22	Spruytte (1983)
Plate 22.8	Traction - ancient chariot	Walk	83.22	Spruytte (1983)
Plate 8.6	Traction - ancient chariot	Gallop	58.36	Spruytte (1983)
Plate 15.3	Traction - ancient chariot	Trot	37.65	Spruytte (1983)
Plate 7.3	Traction - ancient chariot	Gallop	48.43	Spruytte (1983)
Plate 29.7	Traction - ancient chariot	Trot	52.39	Spruytte (1983)
Plate 8.5	Traction - ancient chariot	Gallop	62.99	Spruytte (1983)
Plate 25.7	Traction - ancient chariot	Gallop	45.23	Spruytte (1983)
Plate 13.1	Traction - ancient chariot	Stop	58.14	Spruytte (1983)
Plate 15.2	Traction - ancient chariot	Walk	40.39	Spruytte (1983)

Plate 8.4	Traction - ancient chariot	Gallop	46.97	Spruytte (1983)
Plate 24.6	Traction - ancient chariot	Trot	49.08	Spruytte (1983)
Plate 13.2	Traction - ancient chariot	Gallop	58.34	Spruytte (1983)
Plate 13.2	Traction - ancient chariot	Gallop	67.03	Spruytte (1983)
Horse_carriage1	Traction - Carriage	Walk	51.35	Google Images
Horse_carriage2	Traction - Carriage	Canter	45.39	Google Images
Horse_carriage3	Traction - Carriage	Trot	53.98	Google Images
Horse_carriage4	Traction - Carriage	Walk	68.87	Google Images
Horse_carriage5	Traction - Carriage	Walk	54.6	Google Images
Horse_carriage6	Traction - Carriage	Trot	69.4	Google Images
Horse_carriage7	Traction - Carriage	Walk	66.29	Google Images
Horse_carriage8	Traction - Carriage	Trot	54.83	Google Images
Horse_carriage9	Traction - Carriage	Trot	52.98	Google Images
Horse_carriage9	Traction - Carriage	Trot	64.28	Google Images
Horse_carriage10	Traction - Carriage	Stop	60.16	Google Images
Horse_carriage11	Traction - Carriage	Walk	48.87	Google Images
Horse_carriage12	Traction - Carriage	Stop	59.58	Google Images
Horse_carriage13	Traction - Carriage	Trot	74.34	Google Images

Horse_carriage14	Traction - Carriage	Trot	75.13	Google Images
Horse_carriage15	Traction - Carriage	Walk	53.2	Google Images
Horse_carriage16	Traction - Carriage	Walk	45.98	Google Images
Horse_carriage17	Traction - Carriage	Trot	53.48	Google Images
Horse_carriage19	Traction - Carriage	Walk	45.66	Google Images
Horse_carriage20	Traction - Carriage	Trot	50.39	Google Images
Horse_carriage21	Traction - Carriage	Trot	63.43	Google Images
Horse_carriage22	Traction - Carriage	Walk	57.86	Google Images
Harness_racing1	Traction - Harness race	Trot	63.97	Google Images
Harness_racing2	Traction - Harness race	Trot	51.41	Google Images
Harness_racing2	Traction - Harness race	Trot	55.19	Google Images
Harness_racing2	Traction - Harness race	Trot	61.7	Google Images
Harness_racing3	Traction - Harness race	Trot	60.38	Google Images
Harness_racing4	Traction - Harness race	Trot	41.62	Google Images
Harness_racing5	Traction - Harness race	Trot	41.4	Google Images
Harness_racing6	Traction - Harness race	Trot	63.6	Google Images

Harness_racing7	Traction - Harness race	Trot	57.23	Google Images
Harness_racing8	Traction - Harness race	Trot	62.45	Google Images
Harness_racing9	Traction - Harness race	Trot	55.34	Google Images
Harness_racing10	Traction - Harness race	Trot	51.93	Google Images
Harness_racing11	Traction - Harness race	Walk	53.75	Google Images
Harness_racing12	Traction - Harness race	Trot	60.5	Google Images
Harness_racing13	Traction - Harness race	Trot	48.78	Google Images
Harness_racing14	Traction - Harness race	Trot	51.56	Google Images
Harness_racing15	Traction - Harness race	Trot	45.24	Google Images
Harness_racing16	Traction - Harness race	Trot	50.41	Google Images
Harness_racing16	Traction - Harness race	Trot	53.5	Google Images
Harness_racing17	Traction - Harness race	Trot	49.38	Google Images
Harness_racing18	Traction - Harness race	Trot	42.07	Google Images

Harness_racing19	Traction - Harness race	Trot	53.59	Google Images
Harness_racing19	Traction - Harness race	Trot	50.14	Google Images
Harness_racing20	Traction - Harness race	Trot	49.52	Google Images
Harness_racing21	Traction - Harness race	Trot	73.07	Google Images
Harness_racing22	Traction - Harness race	Trot	56.36	Google Images
Harness_racing23	Traction - Harness race	Trot	51.91	Google Images
Harness_racing24	Traction - Harness race	Trot	54.35	Google Images
Harness_racing25	Traction - Harness race	Trot	49.39	Google Images
Harness_racing26	Traction - Harness race	Trot	56.86	Google Images
Horse_Plough1	Traction - Plough	Walk	42.51	Google Images
Horse_Plough2	Traction - Plough	Stop	54.32	Google Images
Horse_Plough3	Traction - Plough	Walk	60.95	Google Images
Horse_Plough4	Traction - Plough	Stop	47.32	Google Images
Horse_Plough5	Traction - Plough	Walk	66.05	Google Images
Horse_Plough6	Traction - Plough	Walk	44.32	Google Images
Horse_Plough7	Traction - Plough	Walk	67.19	Google Images

Horse_Plough8	Traction - Plough	Walk	62.22	Google Images
Horse_Plough10	Traction - Plough	Walk	59.53	Google Images
Horse_Plough11	Traction - Plough	Walk	50.37	Google Images
Horse_Plough12	Traction - Plough	Walk	67.96	Google Images

References

- BECK, U. *et al.* 2014. The invention of trousers and its likely affiliation with horseback riding and mobility: a case study of late 2nd millennium BC finds from Turfan in eastern Central Asia. *Quaternary International* 348: 224–35. <https://doi.org/10.1016/j.quaint.2014.04.056>
- GUO, B. 1998. *Research on Shang and Zhou chariot equipment*. Beijing: Culture Relics (in Chinese)
- NIYAZ, E. 2012. On the horse gears unearthed in Yanghai Necropolis, Turpan, and related issues. *Journal of Xinjiang University (Philosophy, Humanities & Social Science)* 40: 76–79 (in Chinese).
- SPRUYTTE, J. 1983. *Early harness systems: experimental studies. A contribution to the history of the horse*. New York: Hyperion.