Ottoman bows – an assessment of draw weight, performance and tactical use

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Research

The Ottoman fighting bow emerged in Europe from a long eastern tradition of using high velocity projectiles to hunt and fight on horseback. The author compares its performance (favourably) with the longbow and explains how the tactics employed with this singular artefact accounted for Ottoman success in battle.

Keywords: Ottoman, arrow, bow, equestrians, fighting, hunting

Introduction

Bows of composite construction, made of wood, horn and sinew, have been known in Asia for thousands of years. Among many other types, the Ottoman Turkish bow has attracted the most attention in the western world. According to Turkish sources (Yücel 1997), Tozkoparan Iskender and Bursali Şuca in the early 1500s used this bow to achieve a range of 930 yards (1yd = 0.91m). In 1798, a record shot by Sultan Selim was recorded to a distance of 972yd (Klopsteg 2005). The Ottoman bows were the most important weapon of war, particularly for Turkish horse archers and remained the preferred weapon long after the introduction of firearms (Çelebi 1991).

Little information exists, however, about the effectiveness of Turkish bows in combat. Hansard wrote about the penetration of a metal helmet, made to withstand pistol shots, with two holes and the head (Hansard 1841). Shots through 2 inches (1in = 2.54cm) of metal, as well as through a 0.5in plank at 100yd, have been recorded (Klopsteg 2005). A wooden mannequin clad in chain mail was completely penetrated (Özveri pers. comm.). Data about the mechanical efficiency and performance of the bows have been published elsewhere (Karpowicz 2005). The purpose of this article is to assess the effectiveness of the weapon, through a consideration of the actual draw weight, i.e. the force required to pull the bowstring to the full length of an arrow. The results will allow a realistic assessment of the effective striking distance, together with the arrow's penetration. This in turn will help us to better understand the battle tactics of the Ottomans in conquering other countries during their period of expansion. The research on Turkish archery is also relevant to the use of bows in other areas of the world, either on a horse or on foot, and will help to shed light on the bow's effectiveness in warfare.

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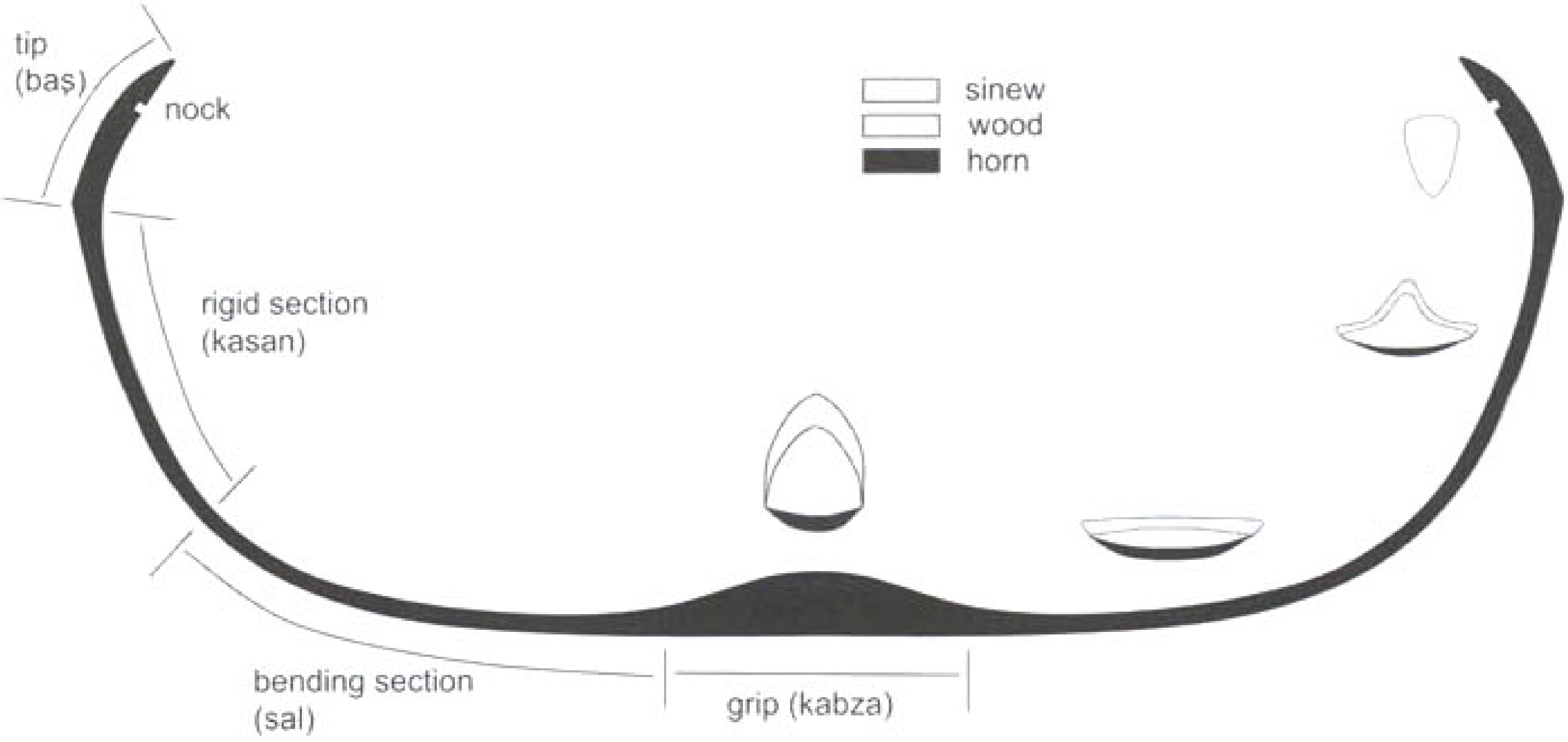

Figure 1. Schematic drawing of bow with cross-sections of different parts of limb.

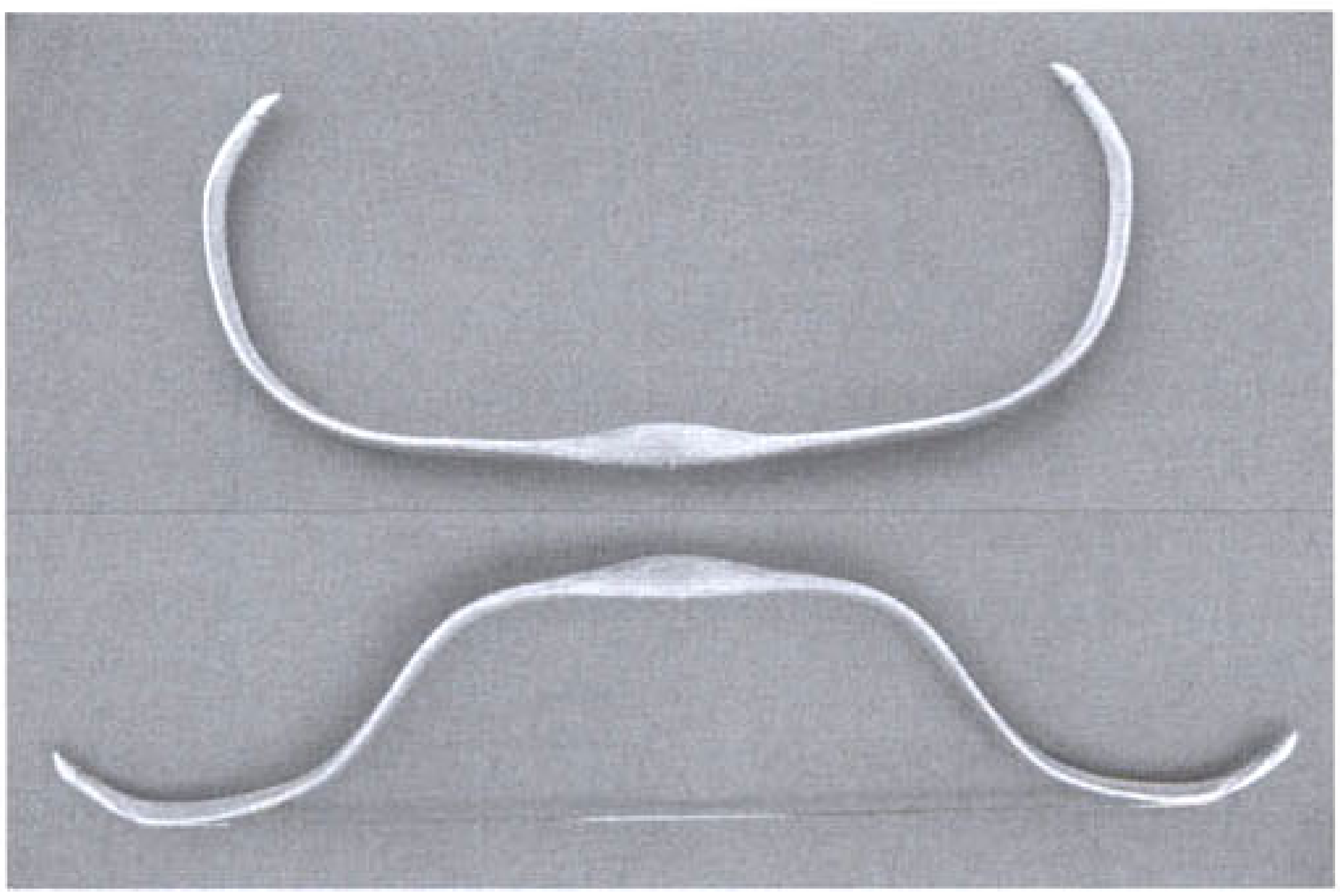

Figure 2. Typical bow unstrung (top) and strung (bottom).

Construction and use

The Ottoman bow has several distinct sections: a centrally located grip of bulbous shape (*kabza*), two bending sections (*sal*) attached to the grip, two non-bending sections (*kasan*) with a ridge along the centre and two tip sections (*baş*) with notches for the bowstring (nocks). The bows represent the typical composite construction (Figure 1). A wooden core lamination runs through the entire bow. Horn strips are attached to the side of the bow facing the archer with the exception of the tips. A layer of sinew is attached to the opposite side up to the transition between the tips and the rigid sections. The horn-faced side is made round, the sinew-faced side is usually flat in the *sal* sections. Without the bowstring, the limbs have a pronounced reflex curvature. In a strung bow, only the bending sections are flexed. The rigid *kasan* sections retain their curvature, giving the bow the familiar 'Cupid' shape (Figures 2 and 3).

The archery collection of the Topkapı Palace Museum in Istanbul contains several hundred Turkish bows, dated from the fourteenth to the nineteenth centuries, as well

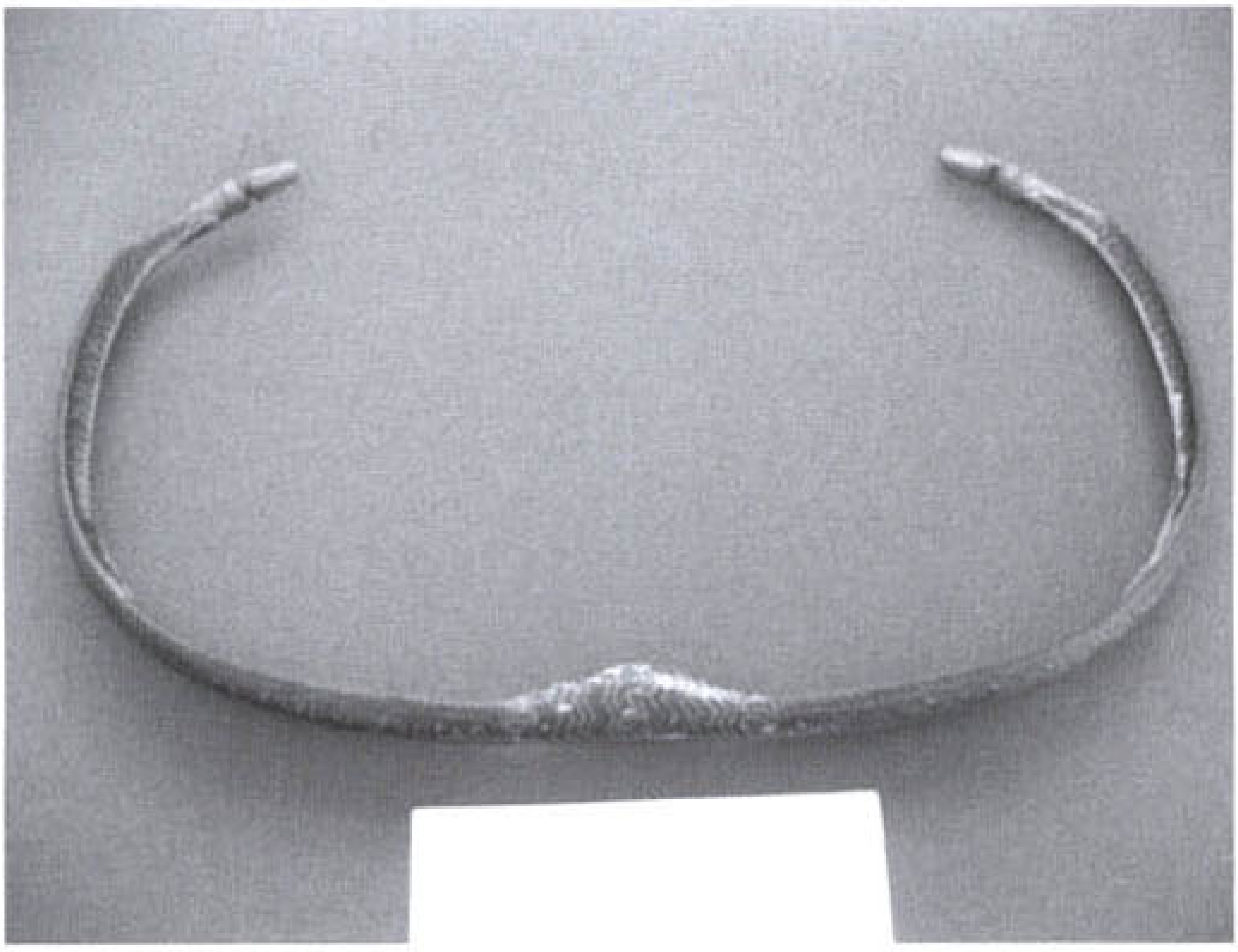

Figure 3. Ottoman bow (Topkapı Palace collection, cat. no. 1/8848).

as many bows of Persian, Crimean-Tartar and Arab origin. It is without doubt the largest collection of Ottoman archery equipment in the world (Yücel 1998). All the bows are very similar in appearance, with a maximum difference in length of about 25cm. Bows used by infantry were longer, other types, including war bows used on horseback (*tirkeş)*, target (*puta*) and flight bows (*menzil*) were of similar length (Yücel 1998). Generally, the length of bow was selected individually, depending on the archer's length of draw. Nevertheless, the war arrows' length varied from 25 to 29in, excluding the arrow point (Yücel 1998). The draw length of 28in was typical in archery shooting for distance, where a shorter, 24.5in arrow was drawn within a groove (*siper*) attached to the archers hand for an additional 3in. The 28in draw was chosen here as the most common length of draw.

Draw weight

The assessment of draw weight is based on the thickness and width of the bending sections and on the length of bows. The greater the cross-sectional dimensions of limbs, the more force is required to pull the bowstring. A longer bow, at the same limb cross-section, requires less force to draw, since the leverage afforded by the limbs is greater. The estimates of draw weight cannot be based on only one or even several specimens, as such results will have little statistical value. This research was based on 39 bows selected randomly from the Topkapı collection and seven bows from the Military Museum in Istanbul (Dönmez) (Table 1). Later sporting bows, where identified, were not included, since such bows underwent special treatment, consisting of drying with heat prior to shooting to enhance performance. The length, as measured along the curvature of the bow between the string nocks, is given, together with the width and thickness of the bending sections of limbs. The measured section represents the area where the limbs are the thinnest, close to the transition with the rigid sections. The thickness of protective covering, leather or tree bark,

Table 1. Dimensions and draw weight estimates for Ottoman bows.

Reference number	Bow length nock-to-nock		Limb width	Min. limb thicknes	Estimated draw weight @ 28in (71cm)	
	cm	in	mm	mm	lb	kg
Topkapi Palace Museum bows:						
1/1046	115	45.3	38	12.3	120	55
1/1044	107	42.1	30	11.5	90	40
1/1095	106	41.7	32.2	12.8	140	65
1/1048	128	50.4	43.4	13.9	130	60
1/8885	98	38.6	34	7.9	40	20
1/9541	104.5	41.1	28.4	12.6	120	55
1/9344	107	42.1	31.2	12.1	110	50
1/1111	110.5	43.5	32.6	14.1	200	90
1/1146	103.5	40.7	31	11.9	120	55
1/1073	97	38.2	30.8	11.3	120	55
1/1110	103.5	40.7	28.2	12	110	50
1/9305	108.5	42.7	31	13.4	140	60
1/9166	106	41.7	32.3	12.5	120	55
1/1093	107.5	42.3	31.9	12.3	120	55
1/1085	104	40.9	27.8	11.9	100	45
1/1077	106	41.7	28.6	12	100	45
1/1134	118	46.5	35.9	11.6	90	40
1/1133	120	47.2	36.8	11.8	80	40
1/1079	114	44.9	33.4	13	140	60
1/1094	106.5	41.9	30	11.3	90	40
1/1082	108	42.5	35.2	13.1	160	75
1/8848	108.5	42.7	32.2	10.5	70	30
1/9125	106	41.7	28.5	9.7	50	25
1/9062	105	41.3	32.3	15.1	240	110
1/9123	102.5	40.4	29.4	13.2	150	70
1/9088	99	39.0	27.6	14.7	220	100
1/9016	104	40.9	29.8	12	110	50
1/8844	107	42.1	31.2	14.5	190	85
1/8965	108.5	42.7	32.9	11	80	40
1/8996	106.5	41.9	27.9	12.7	120	55
1/8969	104.5	41.1	30	13.2	150	70
1/8931	111	43.7	33.4	12.1	130	60
1/8998	123	48.4	34.9	12.9	100	45
1/8928	108.5	42.7	31.8	15.6	230	100
1/9021	101	39.8	29.1	11	90	40
1/8883	103.5	40.7	26.6	10.6	70	30

Table 1. (Contd.)

Reference number	Bow length nock-to-nock		Limb width	Min. limb thicknes	Estimated draw weight 28in (71cm)	
	cm	in	mm	mm	lb	kg
1/9105	108	42.5	36.2	11.8	120	55
1/9064	104.5	41.1	27.2	12.2	110	50
1/9087	111	43.7	32.4	13.8	180	80
Military Museum bows:						
1	100.5	39.6	27	10	70	30
2	101	39.8	26	12	110	50
3	105	41.2	27	10	60	25
4	101	39.8	28	12.5	130	60
5	108	42.6	31	13	130	60
6	101	39.8	27	10.5	70	30
7	103	40.5	26	12	100	45
average:	**107**	**42**	**31.0**	**12.2**	**120**	**55**
new bows:						
1	106.0	41.7	29.3	11.7	97	44
2	120.5	47.4	32.7	13.8	116	53
3	112.5	44.3	33	12	116	53
4	115.5	45.5	32.7	13.8	140	64

was subtracted from the measurements. If the measurements could not be taken directly, the covering thickness was estimated at 1mm.

Since the direct measurement of draw weight on an ancient bow was not an option, the collected measurements of old bows were compared with measurements taken from five new bows of identical construction made by the author. The draw weight of new bows, drawn to 28in, was measured with a digital scale (Tri-Coastal model 264A).

In comparing the bows to assess the weight, a simplified formula was devised, taking advantage of the relation between the length, the limb cross-section and the draw weight (Betteridge 1997; Kooi pers. comm.).

$$F = F_o * (L_o/L)^3 * (W/W_o) * (T/T_o)^3$$

(Where F is the draw weight, L is the length, W is the width and T is the thickness of the old bow. F_o, L_o, W_o and T_o represent the measurements of the new bow).

The draw weight of each old bow was calculated by taking F_o, L_o, W_o and T_o of a new bow with the length dimension as close as possible to the old bow. A 1 per cent error in thickness measurement will give about 3 per cent error in draw weight. A 1 per cent error in width gives a 1 per cent error in weight and a 1 per cent error in length leads to 2 per cent error in weight. There are other sources of error, however. According to the author's

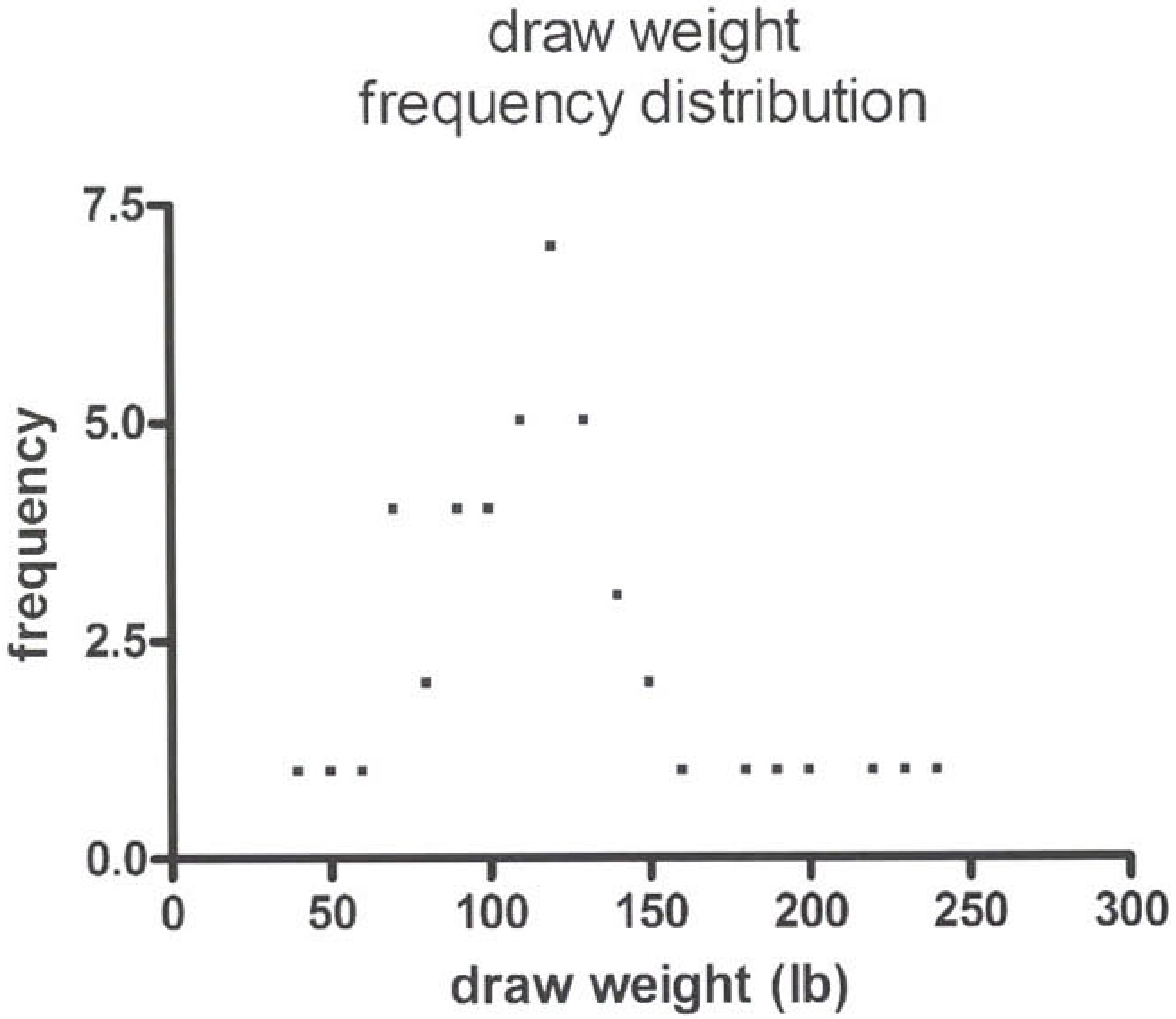

Figure 4. Histogram of draw weight data.

experiments, even two bows of nearly identical dimensions may have the draw weights differ by up to10lb (1lb = 0.45kg). It is because the construction of these bows is too complex to allow for such precision. There are inevitable differences in proportions of materials in the composite structure, small differences in material properties depending on the origin, possible variations in the length of bowstring and slight differences in bending resistance of various sections of bows. Therefore an accuracy greater than 5-10lb cannot be seriously claimed. To avoid confusion, the estimated draw weights of bows were rounded to the nearest 10lb and listed in Table 1. Figure 4 shows the numbers of bows with recorded draw weights, giving an approximate bell-curved distribution.

An experienced archer or a bow maker would have no difficulty in guessing the draw weight of bows by visual assessment alone. The calculated results are close to estimates by the author, made during the examination. The results are also similar to estimates by Payne-Gallwey, who measured the thickness in the middle of the bending section at 0.5-0.75in and estimated the weight of thicker-limbed bows at 150-60lb (Payne-Gallwey 1907).

Discussion

The draw weight of the 46 Ottoman bows varied between 40 and 240lb with a mean of 120lb and the standard deviation of 44lb (median 115lb). For a more realistic assessment, six low weight bows at and below 70lb can be eliminated, since it is unlikely that these bows, although suitable for hunting, would be acceptable for warfare by a trained soldier. Ten bows at and above 150lb can also be removed from the group, since only unusually strong individuals could make use of them. For example bows above 180lb were most likely used for show of strength by exceptional athletes (*pehlivan*), or for exercise rather than warfare. This leaves 30 bows, with a mean draw weight of 111lb and the standard deviation of 17lb. Therefore the realistic range of draw weights, to include the majority of Ottoman bows, would be from around 90lb to 130lb, possibly to 140lb for the shortest bows.

The listed draw weights represent a draw of 28in. If the bows are drawn further, to 29in, as would be the case with the longest war arrow, the force would rise by about 5-10lb. It will decrease by a similar amount with a shorter arrow of 27in. There can also be a steep increase of the drawing force towards the end of draw in the shortest bows, below 41in (104cm). Such increase can add another 10-15lb to the draw weights, and even 20lb for the shortest 39in (100cm) bows.

The draw weight changes with temperature and ambient humidity for all materials of natural origin, including horn, wood and sinew of the bows. Higher humidity or temperature softens the structure to lower the draw weight. The new bows' weight was measured at a relative humidity of between 35 and 55 per cent and a temperature of around 16°C. At high humidity in excess of 75 per cent and temperature above 25°C, the bows may lose around 10lb of force. The bows will also gain force in very dry conditions. Climatic conditions could thus prove to be a decisive factor in warfare. The bows, although well protected by a covering of leather or birch bark and varnished, would eventually lose their power in bad weather. In the author's estimate, one week of exposure to rain can ruin a bow, or at least cause serious damage, unless it is protected. Even then, in the 100 per cent humidity environment, a bow should not be kept strung for more than two weeks to avoid permanent loss of power. Periodic drying would be essential in such conditions. The bow strings were made of silk, rawhide, gut or sinew. All these materials weaken when exposed to moisture, and no doubt the archers carried several spares. In extremely dry, desert conditions, the materials of bows become brittle and may not withstand the strains of use. The Mongols, whose bows were of composite construction, kept their bows in meat stores to provide moisture.

Another factor which affects the draw weight is the period of time a bow is strung and used. The attendant stress causes creep (viscoelastic or plastic flow) in natural materials. The decrease in weight depends on the length of time a bow is used, and can be around 5 per cent, if a bow is kept strung for a week. The weight drops quickly at first, but then stabilises over an extended period of time. A permanently strung bow, after six months of use in varying humidity and temperature conditions, still retained 85 per cent of the initial weight. Since old archery manuals (Faris & Elmer 1945; Latham & Paterson 1970) provide many detailed instructions on effective methods to string bows in field conditions, it is to be doubted that the bows were kept strung for more than several weeks at a time.

The draw weight, of 110-20lb, appears exceedingly high by today's standards. However, it should be borne in mind that the archers were professionals, accustomed to constant practice since childhood (De Busbecq 2001) and well used to physical exertion. The slave collection system of the Ottomans (*devşirme*) allowed for inclusion of only the strongest individuals, who would then join the ranks of Janissaries, after years of physical labour (Imber 2002). There are written accounts of exercises with bows of increased strength until even the heaviest could be drawn effortlessly (Rycaut 1995). Since the ability to use heavy bows is based not only on strength, but in a large part on skill, physically fit men who practice for many years are certainly capable of such effort.

The arrow velocities for various weights of arrow were published recently (Karpowicz 2005). Generally, war arrows were the heaviest, between 310 and 620 grains (20 and 40g) (Yücel 1998). The arrows were made of beech wood in the fourteenth century, of reed in the fifteenth century and pine in the sixteenth century (Aydin 1999). Heavier hardwoods, such as beech, were baked to stiffen them (Tekeli 1999). The arrows would leave a 110lb bow at a velocity, depending on the arrow mass, of between 225 and 300 feet per second (69m/s and 91m/s). This gives the kinetic energy of arrows from 60ftlb (81J) to 70ftlb (95J) and the efficiency between 55 and 70 per cent. An efficiency as high as this, with such a small weight of arrow, is due to the horn and sinew in the composite construction (Kooi & Bergman 1997). This level of performance can only be approached by selfbows with much heavier arrows or at a longer draw. The excellent toughness and resiliency of materials explains the superiority of the composite bows, but only if used to the best advantage in the short-limbed bows.

One can estimate a maximum striking distance for an arrow at an initial velocity of 250fps (76m/s) to be about 350yd and for 300fps (91m/s) about 500yd (Liston 1995). At such extreme distances no real damage can be expected, other than harassment and wounding. Low weight arrows, even as short and slim as the Turkish, loose their energy in flight to a greater degree than heavier arrows. This is partly due to the increased air drag, greater for high velocity arrows. Also, the effects of gravity during the latter part of flight, which can help to regain energy in case of heavy arrows (Soar 2006), are less for the arrows of low weight. However, at a shorter distance, the effects would be devastating. The 620 grain arrow (40g), shot from one of the heaviest Ottoman bows in this study at 180lb, will have the velocity of 280fps (85m/s) and the kinetic energy 109ftlb (147J). It is worth noting 40ftlb is considered sufficient for complete penetration of large animals, such as elk or moose, in hunting.

The flat trajectory of a fast arrow will also facilitate accuracy. The most likely minimum standard for Turkish archers was to strike a man-sized target from a distance of about 60m (Klopsteg 2005). Target archery was much practised for greater proficiency. There are reports of arrows shot in a circle around a coin, barely touching it, from a distance of 30ft and of aiming with such certainty that an eye of an enemy could be pierced in battle (De Busbecq 2001). The method of shooting employed the thumb, equipped with a ring, to hold the bowstring. There are numerous accounts of sharpshooters whose skill alone could change the course of battle (McEwen 1974).

Turkish bowmen also employed the strategy of loosing a shower of arrows from a distance. In this respect, the heavy longbow arrows (normally between about 800 and 1500 grains, 52 to 97g) would be at an advantage, within, however, a rather substantial limitation of distance (up to 280yd for a 150lb longbow, Soar 2006). The draw weight of sixteenth century English longbows, as found with the Mary Rose ship, was similar to the Turkish bow, between 100lb and 172lb (according to Hardy 1992), or between 90lb and 130lb (Soar 2006). Bodkin-tipped arrows fired from English longbows could penetrate early plate armour (Bickerstaffe 2002; Soar 2006; Strickland & Hardy 2005). The penetration, however, was not sufficient to eliminate the opponent from a longer distance. The arrow effectiveness was again much greater from a closer distance, where, even if no penetration occurred, the impact alone could potentially cause death by shock (above 80J of energy; Soar 2006). The performance of Ottoman bows would be as good, or better, if heavier arrows were used. Until more research is done, it is difficult to estimate how effective were the Ottoman arrows on steel armour. Unlike the English arrows, at least 10mm in diameter, the Turkish war arrows of barreled shape were only 5-6mm in diameter at the point end. Since penetration of smaller diameter projectile would be greater, one can expect the Turkish arrows to be more effective on plate armour, and certainly so on chain mail. This may explain why the Ottomans did not see the need to employ heavy arrows.

The use of the bow had developed gradually to meet the demands of battle. It is said that the original tactics of horse archers in Central Asia derived from a hunting procedure, where mounted hunters enclosed large tracts of land in an ever tightening circle to kill all animals within it. This exercise must have indeed been useful in acquiring the legendary skills on horseback and agility with bows in battle. A common practice, known among all Turkic peoples, including the Ottomans (De Busbecq 2001), was shooting from a horse, while passing at a gallop under a target hung well above the ground, as training for the famous 'Parthian shot' - the well aimed arrow sent backwards to kill the pursuing enemy (Imber 2002). The Ottomans were fast riders whose main tactic was ambush, and a sudden, but disciplined retreat, together with the skilled exercise of the 'Parthian shot', followed by a return to close with the disorganised enemy. A second tactic was galloping alongside the enemy formations to pick out individual targets, men or horses, with deadly accuracy, until the coherence of a defence was broken up (de la Broquière 1988). The high velocity arrows require less lead distance in aiming, when both the target and the archer are mobile. On a galloping horse, they are a definite advantage, as opposed to slow moving projectiles, such as the heavy longbow arrows. The use of bow by mounted archers remained until the end of the seventeenth century, although the core of the army, the Janissaries fighting on foot, were the first to acquire firearms in the fifteenth century (Imber 2002).

Conclusion

The Ottoman bow was a weapon of great power, derived from high draw weight and high mechanical efficiency. The combination of high velocity light arrows and the powerful bow made it possible to cause great damage to the enemy in close combat, and to effect significant disruption at a distance. It also allowed for better accuracy from horseback. There is no doubt the bow contributed greatly to the success of the Ottoman army in conquering vast territories in Asia, the Middle East and Europe.

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Glossary

Air drag: force, caused by air resistance, acting on the arrow during flight and greater for arrows of high velocity. In Turkish arrows, however, air drag is minimised by the arrows' small diameter and small length.

Arrow point: forward extremity of arrow, usually of metal or other hard material. Arrow points had different shapes depending on use.

Barreled arrows: arrows tapering from the centre towards the ends. Turkish arrows were usually barreled which reduced air drag during flight.

Bending section of bow: limb sections close to grip, bent in a strung and drawn bow.

Bodkin: type of small arrow point, usually square or rhomboidal in cross-section with a pointed end, effective in penetrating chain mail and plate armour. European and Turkish bodkins were similar in shape, except the method of mounting on the wooden shaft of the arrow was different and the Turkish were smaller.

Bow limb: one half of the bow extending from the grip.
Bow nocks: notches in the tips of the bow where the bowstring is attached.
Bowstring: a string attached between the bow nocks in a strung bow.
Composite bow: a bow composed of horn, wood and sinew.
Draw length: maximum length of draw, equals the length of arrow less its point, usually expressed in inches (in).
Draw weight: force, usually expressed in pounds (lb), to pull the bowstring to the full extent of the arrow (the same as bow weight).
Efficiency of bow: ratio of kinetic energy of arrow to the energy stored in the bow during draw. Bows are less efficient with low mass arrows, even though the arrow velocity is greater.
Flight bow: bow designed for shooting to achieve maximum distance.
Longbow: type of selfbow, made of yew wood and usually no less than 6 feet in length, widely used in England.
Reflex: curvature of bow limbs, without the bowstring attached, in the direction opposite to that of stringing and drawing the bow.
Rigid section of bow: non-bending part of limb, between the tips and the bending section.
Selfbow: a bow made entirely of one piece of wood.
Thumb ring: a ring, made of horn, bone, stone, metal or leather, used to protect the archer's thumb from abrasion by the bowstring.