Throwing the Ancient Greek *Dory*: How Effective is the Attached *Ankyle* at Increasing the Distance of the Throw?*

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THE major weapon of the ancient Greeks was the combat spear, or *dory* (δόρυ). It primarily was used for thrusting in hand-to-hand combat, but it could be thrown as a missile weapon as well. To prepare the spear to be thrown, the ancient Greeks would use a leather thong, called an *ankyle*, which they attached to the spear's shaft roughly around its center of mass. The ankyle would be fashioned where a small loop was formed where the warrior could insert his first two fingers, while still holding the spear with his other fingers and thumb and resting the spear in his palm. The purpose of the ankyle was to add more thrust to the spear, theoretically adding distance to the throw; however, the actual effect of the use of the ankyle on the dory's throw is unknown. We found that modern throwers threw facsimiles of the dory a mean of 15.94 ± 2.85 meters with the dory alone, but when using the ankyle, the mean distance thrown was 24.00 ± 4.86 meters. We show that using the ankyle improves the distance that the dory could be thrown by 50.5 percent. High-speed-video analysis reveals that the ankyle increases the launch velocity of the dory from 2.95 meters per second to 4.98 meters per second. Our results show that the ankyle is an effective device for increasing the distance that the dory could be thrown.

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Introduction

The spear, or dory (δόρυ), was the main weapon of the ancient Greek warrior. The conquering of a foe and the taking of booty was expressed by the ancient Greeks as 'won by the spear' rather than the more familiar adage of 'won by the sword'.[1] The spear is known primarily as a thrusting weapon, used to stab and to slice an adversary so that an advantage could be gained in combat and that victory could be won. However, we are told by Ammonios that the dory was used for more than a thrusting weapon, and it could sometimes be thrown like the athletic javelin (*akontion* or *akon*): '*Akontion* is different from *dory*. The *akontion* is smaller than the *dory*, while the *dory* is the largest missile that is thrown by hand'.[2]

Missile weapons have long been known to be a part of the ancient Greek warrior's arsenal. The poet Tyrtaeus tells us of 'light-armed' warriors, under the cover of a shield, pelting the enemy with rocks and spears.[3] These warriors are believed to have been an integral part of the phalanx, and not just supporting characters to the more heavily armored hoplite.[4] The differentiation of the hoplite from the 'light-armed' warrior during the Archaic period was not 'always sharp',[5] and a perfect example of this is pictured on a kylix found in the Athenian Agora (see Figure 1). The painting on the interior of the drinking cup depicts a Greek warrior carrying two spears and a shield while running at full stride. His shield and greaves make him look like a hoplite, but he is absent a bronze helmet and is fitted, instead, with a leather cap, and possibly being a similar example of one of Tyrtaeus's 'light-armed' warriors. He holds a shield, and thus it could provide him the cover to which Tyrtaeus refers. The pictured warrior carries not one but two spears, of slightly unequal sizes. The top one is shorter in length and has a smaller spearhead; the shorter length of the top spear coupled with its smaller spearhead suggests that it could be used effectively for throwing. But Snodgrass[6] warns us that '[s]mall size is not the only criterion for distinguishing a throwing-spear. A spearhead with an extremely slender blade will be suitable for throwing if it is light enough...' The spears of this warrior seem to be made with thin shafts of roughly the same length, or slightly shorter, than the warrior's height, respectively, and the spearheads look fairly sleek, probably making them light enough to be thrown effectively. Interestingly, neither spear has a clear depiction of the well-

1 J. K. Anderson, 'Hoplite Weapons and Offensive Arms', in V. D. Hanson (ed.), *Hoplites: The Classical Greek Battle Experience,* London 1991, 25.

2 Ammonios, *On Similar and Different Words* 23, from the translation of S. G. Miller, *Arete: Greek Sports from Ancient Sources,* Berkeley 2004, 48.

3 Tyrtaeus, 8.28; 11-13; 35-38

4 H. van Wees 'The Development of the Hoplite Phalanx: Iconography and Reality in the 7th Century', in H. van Wees, (ed.), *War and Violence in Classical Greece,* London 2000, 146-156.

5 P. Krentz, 'Fighting by the Rules: The Invention of the Hoplite Agon', *Hesperia* 71 (2002), 29.

6 A. Snodgrass, *Early Greek Armour and Weapons: From the End of the Bronze Age to 600 B.C.,* Edinburgh 1964, 137.

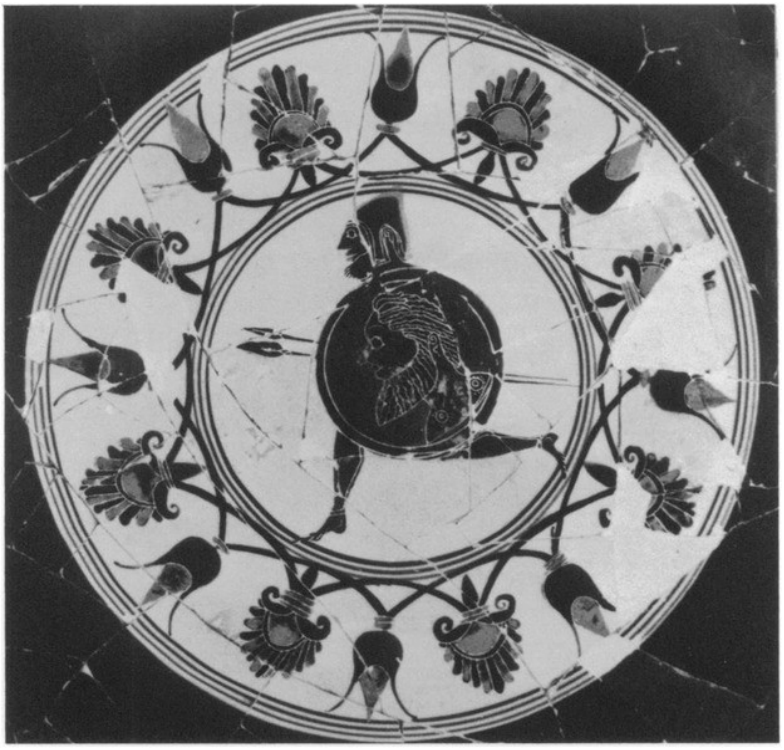

Figure 1. Detail of the interior of a black-figure Siana cup found in the Athenian Agora, ca. sixth century B.C.E., depicting a Greek warrior, running at full stride, carrying two spears of unequal length and a shield. See M. B. Moore and M. Z. Philippides. *The Athenian Agora, Volume XXIII: Attic Back-Figured Pottery,* Princeton, 1986, 299-300, no. 1678. The photograph is the courtesy of The American School of Classical Studies.

known butt-spike (*sauroter*) that is said to have been the counter-weight of the dory's spearhead and used to store the spear upright by impaling the butt-spike into the ground.[7] The absence of the butt-spike is consistent with the archaeological record, however. The sauroter 'disappears' at the end of the Bronze Age in southern Greece and only possibly 'reappears' during the seventh century B.C.E.,[8] and is 'a rarity' at best in the time leading up to the sixth century B.C.E.[9] Thus the warrior's spears could be used effectively for throwing, we think, especially because they are not weighed down in the aft by butt-spikes. A sauroter

7 See Hom. *Il.* 10.153 for the initial reference to the term *sauroter* and how it was used to support spears standing upright. See also Anderson, 'Hoplite Weapons and Offensive Arms', 24.

8 Anderson, 'Hoplite Weapons and Offensive Arms', 25.

9 Snodgrass, *Early Greek Armour and Weapons*, 133, writes, '...the spear-butt seems to have been a rarity before the sixth century, when examples begin to be dated by inscriptions...'

would be a detriment to a throwing spear because it would force the spear to fly awkwardly, with its tail down, and to land on its tail, decreasing both the velocity and the effectiveness of the spear tremendously. That said, the sauroter was most definitely necessary as a secondary weapon on a thrusting spear, especially if the spearhead were broken off during hand-to-hand combat. The sauroter, or 'lizard killer', earned its moniker honestly, and it would be an excellent tool for stabbing an adversary, but it was even better for delivering the *coup de grâce* to a downed, but not yet deceased, foe.

Possessing two spears, one small and one large, seems a reasonable battle tactic in that the small spear could be thrown effectively and easily, while the larger spear could be kept and be used for thrusting attacks in close-quarter combat.[10] Probably the three best examples of hoplites being armed with two spears of unequal length would be the images on the following artifacts: a Protocorinthian oil-container (*aryballos*), dated from the early seventh century B.C.E. (see Figure 2), an alabastron from Corinth, ca. second half of the seventh century (see Figure 3), and a Protocorinthian olpe, now known as the Chigi vase, also from Corinth, ca. 640 B.C.E. (see Figure 4).

The aryballos, being the earliest, also has the least specific detail concerning the spears pictured. One warrior is shown to the left, carrying two spears, one in his right hand, about waist high, with his arm bent—seemingly preparing for an underhand thrust—and the other is behind his left wrist, wedged between his arm and his shield. His four opponents facing him, two of whom carry two spears as well, similarly to him with the exception that the spears in their right hands are held overhead, and another combatant, in the rear, is poised to throw a spear while another is unsheathing a sword. An archer and a combatant are pictured behind the hoplite, but it is uncertain if they are his friends or foes, as the archer seems to be preparing to fire an arrow either into his back or to his right, but it is all for naught, as a sword-wielding combatant stabs the archer before he releases his arrow. If this scene is truly representative of battlefield tactics, then it mimics Tyrtaeus's description,[11] but we learn little about the details of the spears because of the imprecise style of the artist. An alabastron from Corinth and the Chigi vase, however, show us great detail with respect to the spears, assuming the dimensions displayed are accurate.

10 Snodgrass, *Early Greek Armour and Weapons*, 137. See also where Anderson, 'Hoplite Weapons and Offensive Arms', 16, states, 'But the two spears of the epic hero are used indifferently for throwing or for thrusting; it is the use of the first spear for throwing that renders a second spear necessary for thrusting at close quarters'. See also where H. van Wees, 'The Development of the Hoplite Phalanx', 148, writes, '...hoplite equipment regularly included two spears, at least one of which was normally thrown before the solider engaged in closer combat'.

11 Anderson, 'Hoplite Weapons and Offensive Arms', 17, writes, '...it seems to portray the state of affairs already deduced from Tyrtaeus—the intermingling of armored and unarmored men and the use of missile weapons, including the bows and arrow, which Tyrtaeus does not mention. The hoplite's spear may be for throwing...'

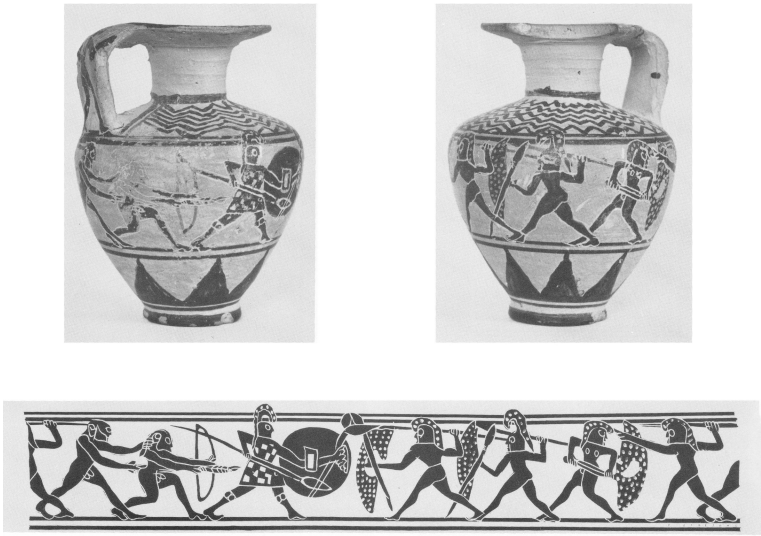

Figure 2. Protocorinthian Aryballos, c. 690-680 B.C.E., from Lechaion (Corinth Museum CP-2096); see Snodgrass, *Early Greek Armour and Weapons: From the End of the Bronze Age to 600 B.C.* Edinburgh 1964, pl. 15. The images are the courtesy of the University of California Press.

The Corinthian alabastron[12] depicts the battlefield equipment of a hoplite: sword, breastplate, helmet, and best of all, two spears, one longer, with a larger spearhead and thicker shaft than the other, but the shorter and thinner one is fitted with a throwing loop, the tell-tale sign that it is indeed a missile weapon. The throwing loop,[13] or ankyle (Greek: ἀγκύλη, Latin: *amentum*), was used by the Greeks to enhance the power transferred to the spear while throwing it, theoretically making the spear travel farther and with more force. Recent scholarship has shown that the use of an ankyle increases the distance of the ancient Greek javelin (*akon* or *akonition*) throw by fifty-eight percent, indicating that the ankyle, indeed, did increase the distance of the throws.[14]

12 See Snodgrass, *Early Greek Armour and Weapons*, 208, plate 33.

13 For specific details regarding the ankyle, see H-G Buchholz *et al. und Fischfang: Archaeologica Homerica Band I Kapitel J Gottingen*, 1973, J83-J96.

14 S. R. Murray *et al.* 'Efficacy of the Ankyle in Increasing the Distance of the Ancient Greek Javelin Throw', *Nikephoros* 23, forthcoming. See also in an abstract from a conference presentation at the American College of Sports Medicine 2011 Annual Meeting, S. R. Murray *et al.* 'Efficacy of the Ankyle in Increasing the Distance of the Ancient Greek Javelin Throw'. *Medicine & Science in Sports & Exercise*, 43(5Supplement), (2011), S598.

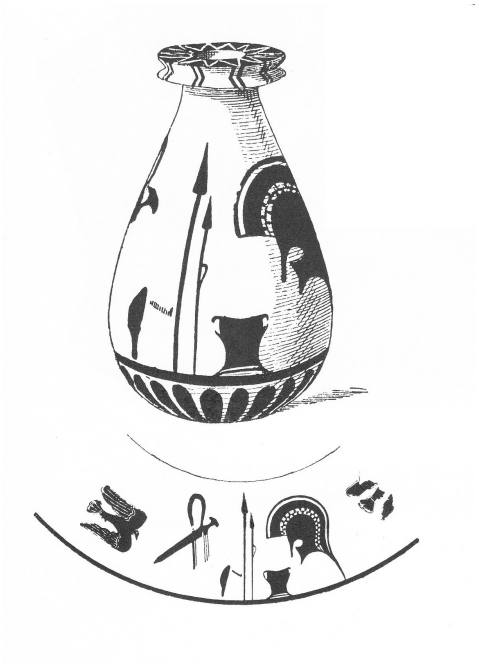

Figure 3. An alabastron from Corinth, c. 625 B.C.E. (Berlin 3148), depicting hoplite equipment, especially two spears, with one being shorter and having an attached throwing loop, or *ankyle* (Greek: ἀγκῦλη, Latin: *amentum*).

Unlike the athletic javelin, which used a 'free' ankyle—meaning that the leather thong was wrapped around the javelin back on itself to secure it to the javelin and that no knot was used,[15] the military spear had the ankyle firmly attached because immediate action was required during warfare.[16] We are told this indirectly by Plutarch, when he describes where Philopoemen was struck in the thigh by a spear, in battle, and that it could not be removed immediately because of the thong's fastening on the weapon.[17] Obviously the ankyle had to be solidly attached to the spear if it were still connected to the weapon after a throw and after piercing the thigh of Philopoemen. Further, Livy tells us that Antiochus's troops had their thongs softened by rain before the Battle of Magnesia in 190 B.C.E.[18] If the thongs were detached easily, then no seasoned warrior would allow

15 S. G Miller, *Arete*, 69, states, '...erroneous modern reconstructions notwithstanding, it is clear that the ankyle was not tied to the shaft of the akon: it would fall off after unwinding completely. Indeed, the vase paintings clearly show that no knot was used on the ankyle'.

16 H. A. Harris, 'Greek Javelin Throwing', *Greece & Rome, Second Series* 10 (1963), 29, writes, 'The thong of the military javelin must obviously have been permanently attached to the shaft; warfare requires instant action'.

17 Plut. *Vit. Phil.* 6.4-5

18 Livy 37.41

them to get wet, and to soften and to stretch, to the point where they would be less effective. Lastly, the pictorial evidence leaves no doubt that the military spears used fixed ankylai. The attached ankyle is shown clearly on the shorter spear pictured on the Corinthian alabastron. Likewise, spears on the Chigi vase were fitted with attached, throwing loops. The historical evidence is clear that spears were thrown in hoplite battle. Snodgrass summarized this conclusion most eloquently thus: '...[I]t seems an inescapable conclusion that the early hoplite often, though not invariably, went into battle carrying two or more spears; and it is very probable that one at least of these was habitually thrown.'[19]

Figure 4. Protocorinthina olpe, now known as the Chigi vase, ca. 640 B.C.E., depicting Greek warriors outfitted with spears and shields; note that each spear on the left of the image is fitted with a throwing loop, or ankyle (Greek: ἀγκῦλη, Latin: *amentum*). The photograph is the courtesy of Dr. Jeffrey M. Hurwit of the Department of Classics and the Department of Art History at the University of Oregon.

19 Snodgrass, *Early Greek Armour and Weapons*, 138.

The throwing of the spear in hoplite battle is well established, but how far could the spear be thrown? What effect did the ankyle have on the throwing process? To our knowledge, no study has examined the distance that the dory could be thrown nor the effect that the attached ankyle would have on the dory's throw. We know that the ancient Greeks used a throwing loop for the javelin throw in their athletic festivals, and recent scholarship has shown that the use of the ankyle improved the throw by fifty-eight percent.[20] However, the athletic javelin was extremely light, approximately 450 grams, and the ankyle was 'free,' meaning it was not permanently attached, so we cannot be sure that the same effect would occur with the dory. So, we undertook to study the distance that the dory could be thrown from a standing position, and what, if any, effect the ankyle would have on the dory's throw.

Methods

Construction of the Spears

Using the images on an alabastron from Corinth and the Chigi vase (see Figures 3 and 4) as our guide, we constructed spears from 1.8-meter long, 2.54-cm diameter wooden dowels and fitted them with spearheads cast in bronze (see Figures 5, 6, and 7). The spearheads weighed approximately 600 grams each and were approximately 28 centimeters in length, including the socket (see Figure 5). The sockets of the spearheads were tapered from a 2.54-centimeter diameter at their openings down to a 1-centimeter diameter at their ends, and this occurred over a distance of 10 centimeters. The wooden dowels had their tips sanded in a tapered fashion that would match the sockets of the spearheads so that a solid union could be formed. The spearheads were fitted to the wooden dowels by gently hammering them in place. We initially installed small wood screws through some pre-drilled holes in the bases of the spearheads, firmly securing the spearheads to the wooden dowels, mimicking the rivets that the ancients used. But after repeated throws in our preliminary testing, we found that, depending on how the spears landed, the wood screws could lead to the shafts splintering. Each spear would have to survive well over fifty throws during our testing. If the spears were thrown incorrectly, landing on their tails first, the force from the throw would make the spearheads slam into the ground, placing a lateral force on the spearheads and occasionally causing the wooden shafts to splinter. To combat this, we simply hammered the spearheads onto the wooden dowels and wrapped some adhesive tape around the base of the spearheads and continued down the wooden shafts another fifteen centimeters. The weight of the tape was minimal and would not affect the throwing of the spears at all, but it kept the spear shafts from splintering during our testing. The overall weight of each spear, including the bronze spearhead, was 1.2 kilograms.

20 Murray *et al.*, 'Efficacy of the Ankyle in Increasing the Distance of the Javelin Throw'.

Figure 5. Pictured are spears constructed from 1.8-meter long, 2.54-cm diameter wooden dowels fitted with bronze spearheads. The total weight of each spear is 1.2 kg. Note the spear on the left is fitted with a throwing loop called an *ankyle* (Greek: *ἀγκῴλη,* Latin: *amentum*), and both spears are painted with alternating black or white, 10-cm sections for high-speed-video analysis. The photograph is the courtesy of the authors.

Figure 6. The spearheads were cast in bronze, weighed approximately 600 grams each, and were approximately 28 cm in length, including the socket. The socket of the spearhead was tapered from a 2.54-cm diameter at its opening down to a 1-cm diameter at the end, and this occurred over a distance of 10 cm. The photograph is the courtesy of the authors.

Two spears were fitted with ankylai made from seventy-centimeter long, leather straps, cut approximately one centimeter wide and two-and-one-half millimeters thick. A loop was tied in one end with a bowline knot, and the ankyle was tied to the shaft of the spear with a simple hitch knot; the remainder of the leather strap was wound tightly around the shaft and secured by a small piece of adhesive tape (see Figure 8). The ankylai were tied to the spears where the forward tip of the loop would be at a point roughly sixty percent of the length of the spears, copying the ankylai pictured on the alabastron from Corinth and the Chigi vase. This allowed the hand of the thrower, once the index and middle

fingers were inserted into the loop of the ankyle, to be roughly over the point of balance of the spear. Interestingly, current javelin throwers have, by rule, their grip cords placed over the point of balance of the javelin,[21] ensuring that the thrower's hand is in close proximity to the javelin's balance point. With respect to our spears, the balance point was well ahead of the actual mid-point of the spear because of the weight of the spearheads. The placement of the ankyle at a point that was roughly sixty percent of the length of the spear allowed our throwers' hands to be placed relatively close to the spear's point of balance, depending on the size of the throwers' hands, and thus mimicking the set-up of a modern-day javelin thrower. This was purely by happenstance, as we were just copying where the throwing loops were fitted to the spears in the alabastron from Corinth and the Chigi vase, but it is extremely interesting to note, and it provides circumstantial evidence that the artists' renderings are accurate, at least from their physicality based on the physics of throwing.

Our spears were not fitted with a butt-spike (sauroter), and this is consistent with the archaeological record. If we had placed a butt-spike on our spears, the balance would have been completely off, that is, too far toward the aft, and achieving a parabolic flight path would have been all but impossible, especially with the placement of the ankylai at approximately the sixty-percent, length-point of the spear, as is pictured in on the alabastron from Corinth and the Chigi vase.

Testing Procedures

The methodology of our study was approved by our university's Institutional Review Board for the protection of human subjects. Sixteen men (age = 22.94 ± 5.58 years, range = 23 years; height = 179.4 ± 5.98 centimeters, range = 20 centimeters; mass = 99.5 ± 25.4 kilograms, range = 86 kilograms) volunteered to throw our facsimiles of an ancient Greek combat spear, with and without an ankyle. These distributions are skewed positively because of a small number of large athletes and a pair of older participants; this is noted in the range values accompanying the means and standard deviations.

Each subject reported for an orientation session, where informed consent was secured, and then, each subject was instructed on how to throw a spear with and without an ankyle. The subjects warmed up through various calisthenics and practiced throwing the spear, both with and without the ankyle, until each subject reached a modest level of mastery defined by being able to throw the spear, with it having a parabolic flight path and landing flat or on point. Each subject was randomly placed in one of two groups that either threw the spear for five trials without the ankyle first (Group 1; n = 8) or for five trials with the ankyle first

21 *USA Track & Field 2010 Competition Rules.* <http://www.usatf.org/about/rules/2010/2010rules.pdf>, accessed 22 March 2011. Rule 193 Throwing the Javelin, number 6, reads as follows: 'The grip, which shall cover the center of gravity...'

(Group 2; n = 8). Within the next week, each subject reported back for data collection, warmed up through modest calisthenics, and then threw the spear for a minimum of ten trials (five trials for each condition, i.e., with the ankyle or without the ankyle). The spear had to have a parabolic flight path and land on point or flat to be considered a valid throw. If not, the subject repeated the throw until five valid throws were recorded for each condition. The subjects were allowed to take only one step forward, while remaining behind a throwing line, and they were allowed as much time as they needed between throws to be considered fully recovered from the previous throw, generally about one minute. The throws were measured by a retractable measuring tape, recorded to the nearest inch, and converted to meters.

High-speed-video Analyses

We used high-speed (500 frames per second; Photron Fastcam™ with Photron Fastcam Viewer version 3.1.4.0 software) video to capture the image of one subject throwing the spear with and without the ankyle. We painted two spears with alternating, black or white, 10-centimeter sections, to provide an accurate point of reference to measure the speed of the spears during the throws (see Figures 5 and 7). Velocity was obtained by using a known distance referenced in the plane of motion and finite differentiation of positional data.

Statistical Analyses

Descriptive statistics were obtained on the height, mass, age, and each of five trials with the two types of throws, with the ankyle and without the ankyle. Tests of normality were conducted using the Kolmogorov-Smirnov test. Reliability analyses were conducted via Cronbach's alpha statistic, oneway ANOVAs testing for statistical differences and trends across trials. A Pearson product-moment, zero order correlation coefficient was calculated to determine the level of covariation between the two conditions. Means and standard deviations were calculated for the distance thrown for the trials with and without the ankyle. The means of the trend free trials[22] in each condition were compared using a matched-pairs t-test. Statistical significance was set at $p \leq 0.05$, and confident intervals are presented. Effect sizes were calculated as Cohen's d.[23] Statistical analyses were conducted on PASW, Version 18.0.2, Chicago, IL, USA.

22 F. M. Henry, *"Best' versus 'Average' Individual Scores', The Research Quarterly* 38 (1967), 317-20; F. M. Henry, 'The Loss of Precision from Discarding Discrepant Data', *The Research Quarterly* 21 (1950), 145-52; and W. Kroll, 'Reliability Theory and Research Decision in selection of a Criterion Score', *The Research Quarterly* 38 (1967), 412-19.

23 J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*, Hillsdale, NJ, 1988. E. G. Carmines and R. A. Zeller, *Reliability and Validity Assessment,* Thousand Oaks, CA 1979; D. George and P. Mallery, *SPSS for Windows Step by Step: A Simple Guide and Reference. 11.0 Update,* 4th ed., Boston 2003.

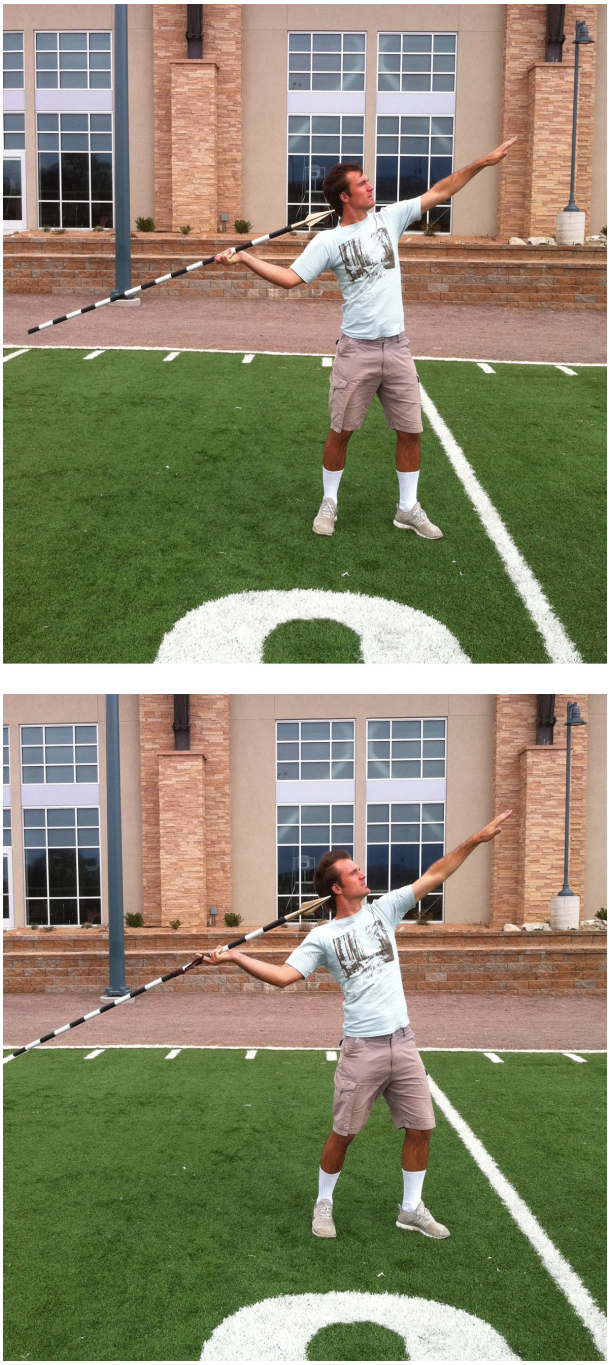

Figure 7. Pictured are the starting throwing positions without the ankyle (top) and with the ankyle (bottom); note the hand position of the grip is similar in both positions with respect to the balance point of the spears. The photographs are the courtesy of the authors.

Figure 8. When using the ankyle the grip was completed by inserting the first two fingers into the loop of the ankyle and then using the last two fingers and thumb to grasp the spear. The photograph is the courtesy of the authors.

Results

All obtained variables did not violate normality assumptions with the exception of age ($p < 0.001$). The mean distance the spear was thrown for all subjects, without the ankyle, was 15.94 ± 2.85 meters. When the subjects threw the spear with the ankyle, the mean distance achieved was 24.00 ± 4.86 meters, an improvement of 50.5 percent of the mean throw without the ankyle. The Pearson correlation between the types of throws was $r = 0.76$, $p = 0.001$. Effect size as Cohen's d was 0.90, indicating a large treatment effect.[24] Cronbach's standardized α statistic showed excellent reliability with all α values > 0.98.[25] The matched pairs t-test was statistically significant ($t(2 \text{ tailed}) = 9.86$, $p < 0.001$, confidence interval of the difference between means = 6.32 to 9.81).

Using the ankyle to throw the dory increased the velocity at which a spear could be thrown. In a high-speed-video analysis of one of our best throwers, it was shown that the launch velocity for the dory during the throw without an ankyle was 2.95 meters per second, but when the ankyle was used, the launch velocity increased to 4.98 meters per second.

24 J. Cohen, 'Things I have learned (so far)', *American Psychologist* 35 (1990), 1304-12.

25 Carmines and Zeller, *Reliability and Validity Assessment* and George and Mallery, *SPSS for Windows Step by Step.*

Discussion

We found that using the ankyle increased, on average, the distance that the dory could be thrown by 50.5 percent of the mean throw without the ankyle. That is a substantial and significant result—both from a practical and a statistical standpoint—and it shows why the ancient Greeks would have used the ankyle in battle for their missile weapons. Increasing the distance that a combat spear could be thrown by 50.5 percent, without a doubt, would be advantageous in ancient warfare insofar as it would allow for a greater range with missile weapons while, potentially, preventing one's own warriors from being in harm's way. It would be akin, in a rudimentary way, to a modern military force achieving air dominance over an adversary. However, specific battle tactics and their effectiveness, while important and interesting in their own right, are beyond the scope of this study.

Our finding is similar to a recent investigation on the effect that the ankyle had on the ancient Greek athletic javelin, where a 58-percent improvement was reported, using a similar methodology.[26] The 7.5-percent difference in the reported improvements between the two studies, we believe, probably is related to three factors: one, the athletic javelin is much lighter, at 450 grams, than the dory, at 1.2 kilograms; two, the ankyle was 'free' and not attached on the athletic javelin, meaning that the aerodynamic drag of the attached ankyle for the dory during flight may account for the lesser improvement; and three, the athletic javelin is far more streamlined than the combat spear, so the aerodynamic drag of the dory, especially with its thicker shaft and broad-bladed spearhead is higher. Future studies could investigate the efficacy of the fixed versus the 'free' ankyle with respect to the athletic javelin as well as the military dory to see which would be the most effective for increasing the overall distance of the throws, but it would be for academic and not practical purposes because the military weapon most definitely used an attached ankyle because of the principle of military readiness.

Interestingly, learning to throw the dory was fairly easy for our subjects. Most of our subjects were athletic in that they were currently participating on a collegiate athletic team, that is, American football, or had participated on an athletic team, either scholastic or intramural, in the previous few years, with the exception of our two oldest subjects. Only one subject had formal training in throwing a javelin, and he was a former scholastic state champion in the javelin throw. Despite the majority of our subjects never having trained in throwing a spear, after being instructed on how to throw properly, our subjects reached a rudimentary level of mastery within ten to twenty minutes of practice. After the orientation session, each of our subjects could throw the dory to where it would fly in a parabolic path and pitch on point on a consistent basis.

The high-speed-video analysis revealed the true advantage that the ankyle provided. We videoed one of our best throwers to see precisely how the ankyle affected the launch velocity that he could produce. The ankyle allowed our

26 Murray *et al.,* 'Efficacy of the Ankyle in Increasing the Distance of the Javelin Throw'.

thrower to improve his launch velocity from 2.95 meters per second to 4.98 meters per second, and his best throws were in excess of 36 meters with the ankyle compared to 19 meters without it. The increased leverage that the ankyle provides the thrower is the key to the increased distance that the dory could be thrown.

Conclusion

The ancient Greeks used an attached ankyle to aid their throwing of the military spear, or dory. To our knowledge, no study has examined the effect that the ankyle has on the distance that the dory could be thrown. We have found that the ankyle improves the distance that the dory can be thrown significantly, increasing the distance the dory is thrown without an ankyle by 50.5 percent.

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