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INHALT

The UWGB Linothorax Project: Reconstructing and Testing Ancient Linen Body Armor

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Alicia Aldrete

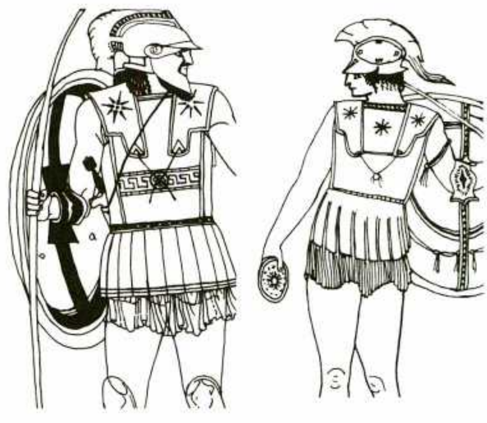

Fig. 1 : Left: Attic Red-figure stamnos. Achilles Painter. CVA Great Britain 4, British Museum 3 (III.I.c), Pl. 22.31. Right: Attic Red-figure hydria. c.440 B.C. CVA Greece 9, Athens, Benaki Museum 1, Pl. 3.2.

At least 32 ancient textual citations testify that one of the most common types of body armor employed by Greeks and numerous other ancient Mediterranean peoples from Archaic through Hellenistic times was composed of linen. In addition, we have identified over 750 images in ancient art ranging from vase paintings to sculptural reliefs, which offer further clues as to the appearance and construction of this armor (Fig. 1). The people and armies attested as having worn such linen corselets (sometimes called a linothorax) include the Egyptians, Assyrians, Persians, Phoenicians, Chalybes, Macedonians, Greeks, Carthaginians, Romans, Etruscans, Samnites, Lucanians, and Lusitanians. Despite its important role in ancient warfare, however, this armor has received scant attention in modern academic studies, and many aspects of its form and function remain mysterious (On ancient armor, see Hagemann 1919. Anderson 1970. Jarva 1995. Snodgrass 1999. Schwartz 2009). The main reason for this comparative scholarly neglect is the compelling one that, due to the inherently perishable nature of its component materials, no extant examples have survived. There also often seems to be skepticism that any armor made primarily out of fabric could have offered credible protection.

The University of Wisconsin-Green Bay Linothorax Project has been a six-year long exercise in reconstructive archaeology involving university faculty and students as well as community members, which has dispelled some of the mystery and obscurity surrounding this type of ancient armor. Backwards-engineering from available literary and visual sources, we have reconstructed several complete sets of armor in order to assess their wearability, fabrication, and expense. Next, we made a series of test patches using only the methods and materials that would have been available to people in the ancient world, and then subjected these patches to scientifically valid, controlled penetration testing by arrows to determine whether or not this type of armor would have provided viable protection to its wearer. The results of our research and testing suggest that the linothorax's long reign on ancient battlefields may have been due to the fact that not only was it surprisingly effective in safeguarding its wearer, but it also enjoyed a number of practical advantages over comparable metal body armor, including lightness of weight, coolness, flexibility, ease of construction and maintenance, and lower cost.

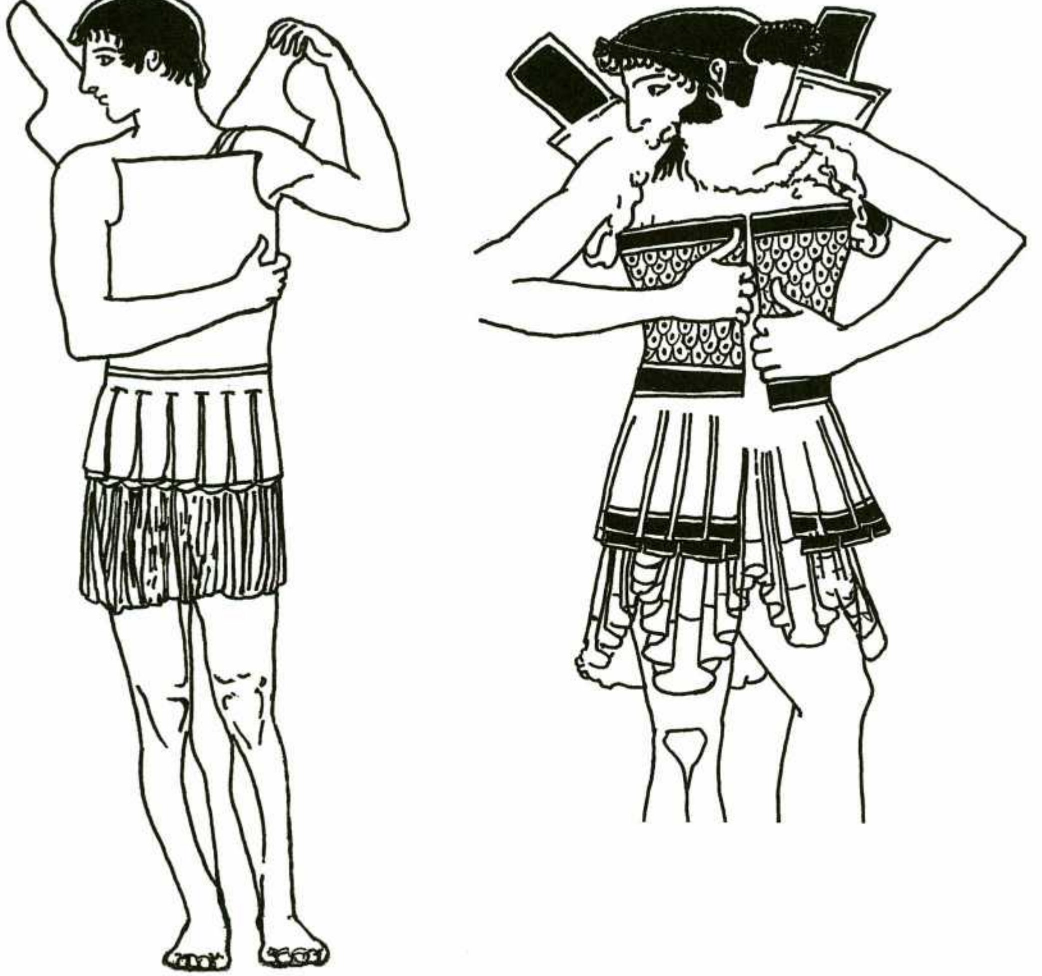

Fig. 2: Left: Red-figure kylix. CVA Italia 5, Bologna 1 (III.I.c), Pl. 16.1. Right: Red-figure kylix. Douris. c. 500 B.C. ARV 427, 3.

Ancient linen body armor is a subset of what has been labeled Type IV armor by scholars (JARVA 1995). Type IV armor has a distinctive appearance in ancient visual images consisting of a rectangular piece that was wrapped around the wearer's torso to form a tube, and a second U-shaped piece that was joined to the first section across the base of the U in the region of the wearer's upper back. This left the two arms of the U projecting upwards behind the wearer's shoulders. Each of these arms was then bent forward across the shoulders, one on each side of the head, and then tied down on the chest or stomach. The fact that ancient images of warriors arming for battle clearly show such features as the arms standing stiffly upright before being tied down and the two components being bent around their bodies and shoulders, demonstrates that Type IV armor had to have been made of a substance that was both fairly rigid, yet also quite flexible (Fig. 2). This unusual combination of qualities indicates that these corselets could not have been made

Fig. 3: Laminating layers of fabric together.

of metal, and accordingly must have been another substance, most likely cloth or leather. When such images are combined with the numerous literary descriptions of linen armor, it seems certain that many if not most of these images therefore depict linen body armor.

The first step in the reconstruction process was to develop a basic pattern for the two main components. To end up with armor whose shape was identical to the ancient images involved considerable trial and error, employing mock-ups made first out of heavy paper and then cardboard. Eventually we settled on a satisfactory design that became the model for our reconstructions. Next, we had to obtain construction materials which would be as close as possible to those which would have been available in the ancient Mediterranean world. Finding a source of historically authentic linen proved to be a particular challenge, but ultimately we were able to identify a group of local weavers who grew their own flax plants, harvested and processed them by traditional methods, then spun the flax fibers by hand into thread, and finally wove the thread into linen using historically accurate looms. We decided to use adhesives that would have been both cheap and widely available throughout the ancient Mediterranean, so we worked primarily with two glues: one made from flax seeds, and the other from the skins of rabbits.

The two main components of the armor were built up by cutting pieces of linen into the appropriate shape and then gluing the pieces together. In general, we found that the finished product was strongest when enough glue was used to saturate both layers. The laminated layers were allowed to dry, which usually took 8-10 hours, and

Fig. 4: G. Aldrete wearing our first reconstructed linothorax.

then the process was repeated until the requisite number of layers was attained (Fig. 3). Trial and error revealed that the maximum thickness that we could make a slab of laminated linen which would still retain full and repeated flexibility was around 12 mm. Once the two main pieces reached the desired thickness, they were attached together, and, as shown in the images, a double row of flaps known as pteruges were added around the bottom to provide some protection to the groin and upper thighs. A few metal fittings, and some decorative painting completed the construction process. Constructing a 17-layer linothorax of 12 mm thickness required a bolt of linen 16 meters long and 1 meter wide, and the lamination process consumed roughly 7.5 liters of glue (Fig. 4). It should be noted, however, that this was a rather generously-sized linothorax fitting individuals with up to a 122 cm chest circumference; considerably smaller amounts of materials would have been needed to fit the estimated average-sized Greek hoplite (On typical size of hoplites, see SCHWARTZ 2009, 98-101).

That the Greeks possessed and used the basic technology of laminating together layers of linen is attested by archaeological evidence. A small fragment of laminated linen containing 14 layers has been found in a grave among a cache of arms and armor at Mycenae (STUDNICZKA 1887). It is thought that this may well be a piece of an actual linothorax, although admittedly it could have come from any type of laminated armor, perhaps cloth greaves. Similarly, a fragment of layered linen found at Tarquinia was identified by the excavator as having originally been part of a linen corselet (HELBIG 1874). Also, currently ongoing research has revealed that the masks worn by actors in Greek plays were made out of laminated layers of linen (COHEN 2009). Thus there is evidence that the Greeks used such lamination technology for various applications. It is possible, however, that some of the visual images may depict armor in which layers of linen were simply sewn together rather than laminated.

Our reconstructions established that it was possible to use laminated linen to make armor consistent in appearance with Type IV armor. Additionally, we now had a good sense of the shape and some of the characteristics of this armor. The next challenge was to address the criticism sometimes leveled against such armor – that it could not have offered effective protection to its wearer. To investigate this, we made a number of experimental test patches employing various types of fabrics, glues, and weaves, and then subjected

Fig. 5: Measuring penetration of arrow into test patch.

them to penetration tests by shooting them with arrows under controlled conditions. For these experiments, dozens of test patches, which were roughly .5 by .5 meter square, were created using historically authentic fabric and glues. We focused on arrow penetration because, not only would this have been one of the most common battlefield hazards, but it was also a type of attack that we could precisely regulate and measure, and thus producing scientifically valid experimental data. We tested for a number of different variables. These fell into two basic categories: differences in the construction of the test patches themselves, and differences in how we shot them. The fabric variables included different thicknesses of fabric, different fabrics, different numbers of layers (mostly10, 15, and 20 layers), and different arrangements of the cloth layers to alternate the direction of the weave. We also experimented with laminated versus sewn test patches, and even some patches that consisted of quilted layers of linen stuffed with wool.

The patches were hung on a dense foam block simulating a human torso, which was strapped securely to a heavy wooden stand. Our arrows were hand-made wooden ones with natural feather fletching (Fig. 5). We used arrowheads of a number of different shapes and weights. Most of these were hand-cast iron and bronze arrowheads that were sharpened by hand and which had shapes and weights similar to those of attested examples of ancient Greek, Macedonian, and Persian examples (On ancient arrows and arrowheads, see Erdmann 1973 and Blyth 1977, 31-41).

Fig. 6: Bartell wearing final reconstructed linothorax shortly after being shot with arrow.

Although we wanted to use authentic replica arrows that would emulate the flight characteristics of ancient arrows, when it came to a choice of bow, we selected modern compound bows which employ a system of cables and pulleys to obtain a specific hold weight at maximum draw. This modern equipment was essential in order to maintain consistency from shot to shot in terms of the power applied to the arrow. Had we chosen replica wooden or composite bows, then each shot would have varied in power due to small differences in draw length, different archers having different pull lengths, and atmospheric conditions such as humidity affecting the resistance of the wood or other natural bow materials. We had the hold weight at maximum draw of the modern compound bows tested, and this gave us a precise figure which would not vary from shot to shot. We used several different bows, calibrated with hold weights of 25, 50, and 65 pounds. We took test shots from 7.5, 15, and 30 meters, as well as longer-range, lofted shots fired at an upward angle which then descended toward the target.

The arrow tests revealed that the linothorax would have provided excellent protection to its wearer. For example, when a 12 mm laminated test patch was shot from 15 meters with a 50 pound pull bow, the arrowhead failed to fully penetrate the test patch. To give a further idea of the degree of protection afforded by the linothorax, when an arrow was shot at the foam target block without any test patch affixed to it from a very weak 25 pound bow at a range of 7.5 meters, the arrow still had enough power to penetrate an impressive 230 mm deep into the foam target block. But when the same arrow was shot under the same conditions at the foam block with the 20 layer laminated test patch attached, however, it penetrated a mere 5 mm into the test patch, going barely half-way through the armor and leaving the foam block (or hypothetical person) completely unscathed.

Doubling the thickness of the test patch roughly doubled its resistance to penetration. The most important variables turned out to be the thickness of the test patch, the strength of the bow, and the distance from the target. The number of layers, density of weave, and type of glue proved to have relatively minor effect. Laminated test patches possessed about 15 % more resistance to penetration than sewn ones, while quilted patches were ineffective. We calculated that the force required to penetrate a 12 mm laminated test patch was approximately 70 Joules, roughly equivalent to the same amount of force needed for the same arrow to penetrate bronze armor nearly 2 mm thick. We also shot arrows at a replica linothorax while one of us was wearing it, and the reconstructed armor held up to this "real life" test very satisfactorily (Fig. 6).

In conclusion, laminated linen armor appears to have been an extremely viable form of protection, and one that even offered a number of significant advantages over metal armor. First, it is a far more practical material to wear in a hot climate, and would have enabled the soldier wearing it to have much greater endurance, both in battle and on the march. Metal armor heats up quickly, and under the glare of a hot sun can quite literally bake its wearer, whereas linen armor stays cool and comfortable.

Second, the weight of the linothorax is considerably less than metal forms of body armor. Our reconstruction linothorax weighs about 4 kg. A bronze cuirass providing an equivalent degree of protection would have weighed around 10 kg.

Third, when linen gets wet, the tensile strength of its fibers actually increases by about 33 % percent, so that the linothorax would have functioned well in humid or wet environments. This raises the issue of having to use waterproof glues or else applying a waterproof coating to the finished linothorax. We found that a test patch coated with beeswax successfully resisted penetration by water even after a 6 hour simulated rain followed by 1 hour of total immersion in water.

Fourth, the linothorax used materials that would have been widely available even to relatively poor inhabitants of the ancient world, and the technical skills needed to make a linothorax, weaving and gluing, were common ones familiar to almost all peoples of the ancient Mediterranean. Rather than requiring the specialized skills of a blacksmith to manufacture or repair it, quite literally almost any woman in the ancient world would have been able to construct or repair one.

Fifth, the ubiquity of the materials and skills needed to make a linothorax may have made them significantly cheaper to make than comparable metal armor. They could also have been mass-produced more readily since, unlike a bronze cuirass, a linothorax did not have to be constructed to fit a specific individual. Because of the ties at the side and top, a linothorax can be easily adjusted to achieve a perfect fit within a generous range of body sizes.

Sixth, in addition to being cooler and lighter than metal armor, the linothorax had another distinct advantage in wearability: its flexibility. Even when laminated with as many as 15-20 layers, the linothorax retains a certain flexibility, and we found that when we wore it for several hours, our body heat caused the glue to become somewhat soft, so that the linothorax would mold itself to a particular body shape, making it surprisingly comfortable to wear for extended periods.

Finally, the linothorax possesses all these advantages while still providing good protection to its wearer, especially from arrows. Literary and iconographic sources clearly testify that the linothorax was in use for a long time by many different cultures. Our experiments in reconstructing the linothorax demonstrate some of the reasons for this popularity and suggest that it may have been a surprisingly effective form of protection for ancient Mediterranean warriors. A detailed account of our reconstructions and experimental tests, including all relevant textual sources and the complete list of visual images, will be available in our forthcoming book, Unraveling the Linothorax Mystery: Reconstructing and Testing Ancient Linen Armor (Johns Hopkins University Press). In the meantime, for more information, please visit the Linothorax Project website.

Summary

A considerable body of both ancient textual and artistic evidence indicates that a common form of ancient Mediterranean body armor was made out of linen, however, the lack of extant examples and lingering doubts as to whether such armor would have been effective have combined to render even the most basic characteristics of this armor obscure and mysterious.

The UWGB Linothorax Project has been an exercise in reconstructive archaeology whose goal was to recreate historically plausible examples of linen body armor in order to assess aspects of its construction and function. The results indicate that it was a surprisingly effective form of protection.
Website: http://www.uwgb.edu/aldreteg/Linothorax.html

Zusammenfassung

Eine beachtliche Menge antiker Textnachweise und künstlerischer Belege deuten auf eine übliche Form des antiken mediterranen Körperpanzers aus Leinen hin. Allerdings haben das Fehlen erhaltener Schutzpanzer und die fortbestehenden Zweifel, ob ein solcher effektiv genug wäre, dazu geführt, dass selbst die grundlegendsten Charakteristika dieser Panzer unbekannt und geheimnisvoll blieben.
Das UWGB Linothorax Project war eine Übung zur rekonstruierenden Archäologie, deren Ziel es war, historisch plausible Beispiele der leinenen Schutzpanzer nachzubilden, um Aspekte ihrer Konstruktion und Funktion zu beurteilen. Die Ergebnisse zeigen, dass es sich um einen überraschend effektiven Schutz handelt.

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