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# The muscles of the athletes to learn surface anatomy - The Influence of classical statues on anatomy teaching

Veronica Papa[1], Francesco Maria Galassi[2,3], Eugenio Polito[7], Giovanni Capelli[7], Angelo Rodio[7], Mauro Vaccarezza[4], Domenico Tafuri[1], Elena Varotto[2,5,6]

[1] Department of Motor Sciences and Wellness, University of Naples «Parthenope», 80132 Naples, NA, Italy
[2] Archaeology - College of Humanities, Arts and Social Sciences, Flinders University, Adelaide 5001, SA, Australia
[3] School of Medical History, Medical and Dental Association of the Province of Rimini, Via Flaminia, 185/B, 47923 Rimini, RN, Italy
[4] School of Pharmacy and Biomedical Sciences, Faculty of Health Sciences, Curtin University, Bentley, Perth, WA, 6102 Australia
[5] Department of Humanities (DISUM), University of Catania, Piazza Dante 32, 95124, Catania, Italy
[6] Casa di Cura «Santa Lucia» - Centro Polidiagnostico, Via Lombardia 1, 96100, Siracusa, Italy
[7] Department of Human, Social and Health Sciences, University of Cassino, 03043 Cassino (FR), Italy

## Abstract

Gross anatomy classes are still regarded as an integral part of human biomedical education worldwide. The first documentary evidence of the practice of anatomical dissection for teaching purposes dates back to the 13th century AD, although this practice seems to have originated in Ancient Greece, if not in earlier times. Dissection of the human body is practiced in most anatomy institutions worldwide despite increasing pressure to reduce material and staff costs, regardless the ongoing debate concerning the suitability of body donors for medical education. Moreover, anatomical teaching skills are also evolving and need to be tailored for the different areas of anatomical expertise students have to acquire: therefore, anatomic dissection goes probably beyond the scope of anatomy teaching in some classes such as sports sciences. However, there is no doubt that a practical approach to the study and teaching of anatomy is surely preferable to basic *ex cathedra* anatomy lectures. Here, we propose a new teaching method for sports sciences and fine arts students by training their surface anatomy skills through the study of ancient statues.

## Keywords

Anatomy teaching, dissection, muscular hypermorphism, surface anatomy, human anatomy education.

## Introduction

Physicians and health practitioners have been inherently and historically captivated by human anatomy whenever they seek for answers that can help unravel our bodies's most hidden secrets.

This journey towards self-discovery generally begins systematically in medical school, where the study of human anatomy was once considered a cornerstone of medical education. The subject has been, to some degree, de-emphasized over the years in order to save time for other priorities in a fast-packed, modern curriculum

* Corresponding author. E-mail: veronica.papa@uniparthenope.it


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(Drake, 2009; Meral Savran et al., 2015; McMenamin et al., 2016; Losco et al., 2017; Wilson et al., 2018.)

The ways in which medical educators teach the subject is also evolving: traditional anatomy education, based on topographical structural anatomy taught in lectures and gross dissection classes, has been replaced by a multiple range of study modules, including problem-based learning, plastic models or computer-assisted learning and curricula integration (Louw et al., 2009; Papa and Vaccarezza, 2013; Yammine, 2014; Chan and Pawlina, 2015; Moro et al., 2017; Periya, 2017).

In 1235 AD, when the first medical school opened in Salerno, Italy, anatomy rose to a prominent position in the medical curriculum and human dissection was performed as a sacramental procedure that illustrated the dissertations of revered ancient authors.

Recently, the idea that the Middle Ages were a time of obscurantism and decadence has been revised: the middle-to-late Middle Ages were indeed marked by many scientific accomplishments (Mavrodi and Paraskevas, 2014; Papa et al., 2019). The late 11th century and 12th century saw the establishment of a number of universities across Europe, including the University of Bologna.

Known as the "Restorer of Anatomy" (Crivellato and Ribatti, 2006; Rengachary et al., 2009), Mondino de' Liuzzi (1275-1326) is considered the first to have performed a dissection after Herophilus (c. 335-c. 280 BC) and Erasistratus (fl. 250 BC) were active in Alexandria (Ptolemaic Egypt). Dissection took place in 1315 on an executed criminal, most likely a woman, and was observed by medical students and the public with the purpose to indicate the exact position of the anatomical elements described by Galen. According to the custom of that time, Mondino did not perform the dissection himself. Because of his distinguished status, the professor sat on a large, elevated chair above the dissection table, reading aloud from Galen's book of anatomy and commenting commenting on it for the benefit of the audience. While he was reading, a barber-surgeon performed the dissection following the professor's instructions (Di Matteo et al., 2017; Mavrodi and Paraskevas, 2014).

When a cadaver was made available, time became a capital issue, since there were no effective means of preserving it. This is why the abdominal cavity, which contained organs that putrefied most easily, was dissected first, followed by thorax, head, and extremities.

Mondino's book "Anothomia" was completed a round 1316 and for at least two centuries it remained a classical anatomical textbook used by all major European universities (Crivellato E., Ribatti D. 2006).

During the Renaissance, after the opening of the Anatomical Theatres in Padua (1490) and Bologna (1637), anatomy was considered an artistic and spiritual exploration of life, suffering, and death. These theatres were multifunctional: a place to understand human anatomy, to witness the exaltation of life through the analysis of death and to be captivated by science.

Anatomists began to dissect in order to investigate the structure of the body and produced texts illustrated with images based on their dissections (Porter, 2002; Richardson, 2000; Hunter, 2001).

In the 16th century Vesalius changed the face of anatomical studies and teaching with his observational studies on dissected human tissues and the consequent publication of *De Humani Corporis Fabrica*. Vesalius's work put the exquisite detail and three-dimensional form of the human body onto paper. His work and publications captivated, engaged and educated scholars and students and set the standard for subsequent generations of anatomical publications, research and training (Kemp, 2010; Riva et al., 2010; Eisma et al., 2013).

The text and iconography of Vesalius' *Fabrica* had a tremendous influence on medical thinking since its publication in 1543. The reasons were manifold: the visualization of natural and realistic human anatomy rather than anatomy that was theologically-inspired, the magnificent Renaissance depiction of the human body in different poses and in various stages of dissection, the unprecedented use of anatomical terminology, the classification into seven organ systems, and the reaction against the millennium-old theories of Galen (Van Hee et al., 2014).

One of the greatest challenges in anatomical studies is gaining appreciation of the three-dimensional nature of anatomical structures and their positional relationships. Achieving this from books and two-dimensional imaging is difficult and is, therefore, supplemented with the study of cadaveric specimen or plastic models. In the 17th century, as anatomical studies became more scientifically based, the first attempts to use injection to preserve anatomical preparations of the human body from deterioration were carried out by the Italian physician Marcello Malpighi (1628–1694). The Dutch naturalist Jan Swammerdam (1632–1680), too, used both colourless or coloured preserving chemical fluids composed of alcohol, mercury, different metals (including lead, tin, bismuth) and wax. The results of these trials were reasonable, although preparations were not durable and subsequently deteriorated.

Towards the end of the 17th century a collaboration between Gaetano Giulio Zumbo (1656-1701), a Sicilian wax artist, and the French surgeon Guillaume Desnoues (ca. 1650-1735) resulted in the creation of the first realistic anatomical models made from coloured wax, representing a valid alternative to dissected human specimens. Wax gradually took its place as a material capable of allowing the creation of extremely realistic (as to form and colour) and long-lasting artefacts (Ballestriero, 2010).

In 1977 von Hagens et al. introduced plastination, a new technique of tissue preservation: in this process water and lipids in biological tissues are replaced by polymers able to determine the mechanical and optical properties of the specimens. The resulting material is odorless and durable and retains structural and morphological details down to the histological level.

Lastly, a new method of embalming bodies named Thiel method is worth mentioning (Thiel, 1992). This technique, developed by Walter Thiel at the University of Graz (Austria), is still not widely known and needs careful procedures and dedicated structures (Benkhadra et al., 2011; Eisma et al., 2011, 2013), but it looks promising to study the skeletal and the muscular systems in a more physiological and dynamic way and it is reported to be one of the best training tools in the field of anatomical surgery (Hammer et al., 2015).

Unfortunately, muscle protein fragmentation is relevant and thought to cause the flexibility of the Thiel embalmed bodies. Therefore, Thiel fixed specimens are not suitable for histological analysis nor biomechanical testing (Fessel et al., 2011; Hammer et al., 2014).

Mazzotti et al. (2010) clearly demonstrated the proper use of an anatomical model for teaching and diagnostic purposes: they studied *Venerina*, a wax removable model by Clemente Susini representing an accurate copy of the original anatomical preparation of a pregnant young woman. The model is about 145 cm tall and the pelvis shows an opened pregnant uterus with fetus and placenta; the fetus is about 15 cm crown-rump length, from which it has been estimated that the woman was in the fifth month of her pregnancy.

Observation of the body confirms that the organs are normal, except for the heart and great vessels: the walls of both ventricles are of equal thickness and the ventricles themselves of approximately equal size. The arch of the aorta and the enlarged pulmonary trunk are connected by a short duct about 3.5 mm in diameter originated at the level of the division of the pulmonary artery, reaching the aortic arch at the beginning of the descending part and corresponding to the normal insertion of the arterial duct that, in the fetus, connects the two great vessels; after birth it closes and becomes the arterial ligament. If the young woman really died from this congenital disease, her cause of death was surprisingly diagnosed from a wax model of her body after more than two centuries.

Furthermore, Galassi et al. (2015), examining the whole Bologna collection, stressed the importance of anatomical waxes and suggested a reintroduction of these models in the medical curriculum.

The effectiveness of arts-based approaches in medical education has been discussed for over 50 years. The assumption underlying the use of the arts in medical education appears to be that the arts can assist in the development of the student as a communicative doctor through two main theoretical mechanisms. Firstly, study of the arts can directly provide students with a 'simulation' of the wider experience of life necessary for mature interaction with other human beings, which might otherwise be unavailable to them. Secondly, direct participation in the artistic process may help students to explore their own feelings, question them, and develop new ways of thinking. Exposure to the arts has also been used to improve technical skills such as diagnostic observation skills (Perry et al., 2011).

Surface anatomy is an essential component of the study of the human body (Leonard, 1996; Standring, 2012). It is not just about knowing what lies under the skin and which structures are perceptible to touch in a living body, it is also about enabling learners to improve their skills in clinical examinations, interventional procedures, and interpretation of diagnosing images. Studying surface anatomy enables students to elaborate on their knowledge of the cadaver's static anatomy by enabling the visualization of how structures, especially those of the musculoskeletal system, move and function in a living human being (Barrows et al., 1968; Bergman et al., 2013).

Surface anatomy was not introduced into anatomy education until well into the 1940s (McLachlan and Patten, 2006). The first studies of the use of live models in anatomy education were published more than 40 years later (Barrows et al., 1968; Stillman et al., 1978). Nowadays, surface anatomy is promoted as one of the most important modalities contributing to an optimal learning content of anatomy education (Sugand et al., 2010). Studying surface anatomy provides an elaboration on the static anatomy of the cadaver by enabling students to see phenotypical structures, particularly those of the musculoskeletal system, move and function in a living human being. Furthermore, surface anatomy sessions enable students to familiarize themselves with important surface landmarks and to observe, examine, and interact with a living person. In some institutions, surface anatomy is therefore thought to be of vital importance for education, sometimes even more important than teaching anatomy with cadavers (Monkhouse, 1992).

A recent development within surface anatomy education is body painting. The concept of painting on a live model was described by Cody (1995), but Op Den Akker et al. (2002) were the first to introduce body painting as a teaching tool. In body painting sessions, hypo-allergenic, water-based body paint is used by students to paint anatomical structures and/or concepts (e.g. dermatomes) on their peers under supervision by anatomy staff (McMenamin, 2008; Azer, 2013).

However, to the best of our knowledge, no studies other than body painting papers concerning the arts-based approach to train surface anatomy have been published nowadays.

The use of wax models and reproduction of human bodies (such as sculptures) could help teaching anatomy according to the different skills students have to acquire. It is also worth mentioning that the teaching of anatomy should be arranged according to the different skills students need to use in their future practice: anatomical dissection is therefore beyond the scope of anatomy teaching in some classes such as sports sciences.

According to Lambertini (1936): "*often missing in the teaching of anatomy is the in vivo topography of the muscle so that the student does not appreciate the value of the muscle in a dynamic and aesthetic way and therefore s/he is unable to catch its functional value properly*". Moreover, "*the main topic in fine art is the human figure represented by the means of plans, lines and color and therefore body structure, bones and joints, muscles and tendons and all that is by nature in motion reduced to the stiffness of the drawing* " (Della Seta, 1930).

Keeping these assumptions in mind, it could be a smart move to practice surface anatomy on wax reproductions and sculptures: studying statues' surface anatomy overcomes anatomy of the cadaver by enabling students to analyse musculoskeletal system structures; moreover surface anatomy sessions enable students to familiarize themselves with important surface landmarks and the statue itself can be considered as a 3D moving model of a human being.

## Materials and Methods

In July 2013, an important ancient statue from the National Archaeological Museum of Naples (MANN) moved to Cassino during the National University Championships, supported and sponsored by University of Cassino and Southern Lazio.

The statue itself is a sculpture of unknown identity, found in 1936 in the Roman theatre of Cassino (Lazio) and became part of the National Museum of Naples collection (Zanker, 2010).

It was originally known as "General of Cassino" was later renamed "Athlete of Cassino" because of its defined athletic *physique*.

The statue dates back to the mid first century BC and portrays a mature man, clean-shaved, with a mane of short hair adhering to the head and accentuated receding hairline; wrinkles on the forehead and eyebrows raised help to provide the impression of concentration and awareness (see figs. 1-3). Quite in contrast to the head and the face, the naked body appears in resting position with one leg raised

**Table 1.** Length of statue body segments (cm). Statue scale 1:120 (human male 1,75-1,80 m tall)

| | |
|---|---|
| Styloid process-Olecranon of the ulna | 37 cm |
| Olecranon-Acromion | 50 cm |
| Trochanter-Meniscus | 61 cm |
| Meniscus-Lateral Malleolus | 49 cm |

with the foot on a rock, the arms crossed and a cloak to cover what remains of the hilt of a sword, ready to be drawn.

The representation into sharp relief of the *serratus magnus* muscle, typical of classical sculpture, requires a deep knowledge of human anatomy, giving support to the hypothesis that dissection was practiced by classical sculptors, possibilities generally denied or ignored by scholars due to repulsion and prejudice rather than to the lack of sources.

The sculpture belongs to the type of statues depicting an athletic body combined with a portrait representing the real face of the purchaser and thus reflecting the aesthetic concept which aimed to give heroic aura to eminent Romans through athletic nudity.

We cannot interpret this statue simply as the physical embodiment of personal inspiration to power but it implies inspiration from the Hellenic model and becomes far more impressive than that of traditional togate statues (Zanker, 2010). These properties make this sculpture apt for analysis of the use the statue dynamics and its 3D posture to teach and train surface anatomy.

Anatomy courses are often delivered to sport sciences undergraduates as basic classes during the first and the second year. Unfortunately, in undergraduate courses such as sports sciences (especially in non-English speaking countries such as Italy) practical sessions are less and less implemented, meaning that presentation notes, textbooks, atlas or 3D devices are the only learning tools available for students.

In this reassessment, we therefore propose to teach surface anatomy to sport and fine art students through the evaluation of ancient statues (where available).

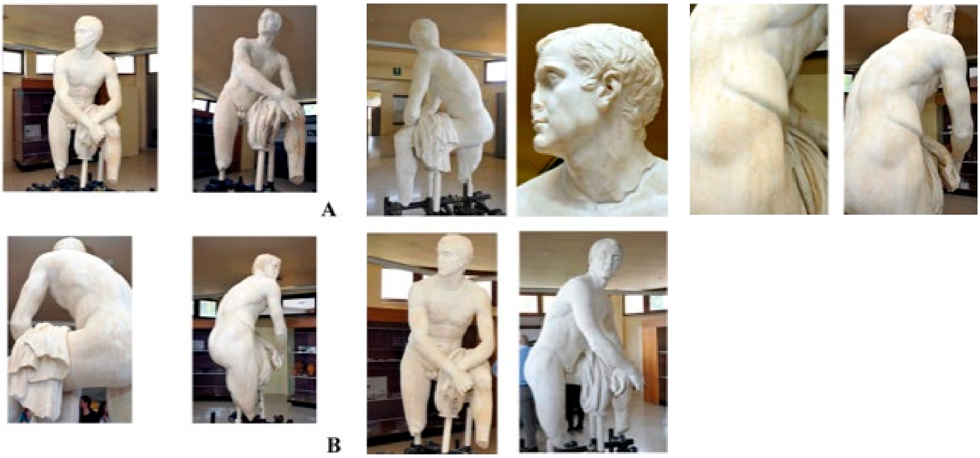
The preliminary assessment of the statue was performed by both sport sciences and art and literature undergraduate students of the University of Cassino and Southern Lazio under the supervision of some of the authors (VP; AR).

Anthropometric features were measured using a flat tape in order to study surface anatomy (Asad and Nasir, 2015). The results are shown in Table 1.

## Results and Discussion

As shown in figure 1, the athlete does not present hypertrophy of the deltoid, trapezius, biceps and triceps muscles, typical features of throwing sports, while it seems that lumbar sacral muscles are symmetrically developed, which is a specific feature of dexterity, agility and combat sports athletes (Holmberg, 2009; Zemková, 2014).

According to Lambertini (Lambertini, 1936) the muscular hypertrophy of specific muscle fascicles caused by an overactive, continuous and peculiar exercise of specific muscle groups in certain sports can be defined as muscle hyper-morphisms. Muscle




**Figures 1-3.** Unknown artist, "the Athlete of Cassino", 1st century BC, Naple's National Archaeological Museum (MANN), Naples, Italy; G. Carettoni Museum, Cassino, Italy. Photo credits: D. Marino, E. Polito. By concession of the Ministry of Cultural Goods and Activities and of Tourism - National Archaeological Museum of Naples.

hyper-morphisms therefore testify the practice of a particular and distinctive sport practice.

The idea that the practice of different sports could result in a preferential, not exclusive and characteristic muscle groups activation was indeed already deeply and firmly established in the 5th Century BC: in Polykleitos' Doryphoros, the *pectoralis major*, *serratus anterior*, *rectus abdominis* and the obliquus externus abdominis muscles show, in fact, the hyper-morphisms of momentum sports.

The here discussed athlete does not present, compared to others such as Polykleitos' Doryphoros, a slender physical appearance but a squat, short-limbed phenotype similar to Agasias' Fighting warrior. [Louvre Museum official site: http://cartelen.louvre.fr/cartelen/visite?srv=car_not_frame&idNotice=17178, accessed February 20, 2018.]

The Athlete of Cassino is in fact characterized by symmetrical appearance of hypertrophic muscles capable of strong, stocky and long lasting contractions even if muscles themselves are poorly sculpted and defined in shape. Moreover, a fair amount of adipose tissue remains under the skin as the morphology of the *rectus abdominis* seems to demonstrate.

Furthermore, according to the hyper-morphisms characterizing combat and fighting sports, he presents harmonic development and right proportions between the upper and lower part of the body.

The spine and back features of combat athletes typically include a significant increase in volume of all of the muscles responsible for extension of the spine (*latissimus dorsi* and the intrinsic spinal muscles) as well as the *gluteus maximus*, thigh hip extensor.

As far as we are concerned about what is a general feature of a wrestler, the statue, due to its posture, does not present hypertrophy of the trapezius. In combat ath-

**Figure 4-5.** Polykleitos, "Doryphoros", II-I century BC., MANN, Naples, Italy. Photo credits: A. Panarello, V. Papa. By concession of the Ministry of Cultural Goods and Activities and of Tourism - National Archaeological Museum of Naples.

letes, in fact, the *trapezius* typically thickens widening its belly at the spinous processes of the thoracic vertebrae, origin of its transverse portion (figs. 1B and 2).

As would be expected, the full musculature of both anterior thorax and the abdominal region shows an impressive gain in volume and shape. Especially in contact sports, the thorax and abdomen muscles involved in respiration have to increase their activity because of the multiple "*bear hugs*", a rough, tight embrace typical of wrestling moves occurring in wrestling fights.

As also shown in fig 2, in fact, *sternocleidomastoid* and *infrahyoid muscles* typically gain in shape and volume since the wrestlers and the boxers look after their face and head, therefore covering themselves with their arms and flexing the head.

The clavicular head of the left *sternocleidomastoid* can be accurately identified whilst the right one is hidden between the skinfolds of the neck; at the same time both the upper edge of the left clavicle up to its acromial end and the jugular notch of the sternum, which is well designed in its three portions, are clearly visible. The epigastric arch is not clearly delineated while bordering with *latissimus dorsi*, *serratus magnus* is undoubtedly well defined (fig. 1).

Furthermore, deep longitudinal grooves, the *linea semilunaris* or *Spigelian line* are clearly visible lateral to *linea alba* separating the *rectum* from oblique muscles; the latter, on the right side, is particularly defined in shape and almost seems to protrude from the iliac crest (fig. 3) being in close continuity with the *gluteus maximus* and *tensor fasciae latae (*fig. 3).

Lastly a brief mention of the Polykleito's Doryphoros needs to be made, mostly in order to better understand the hyper-morphisms differences between the two artworks.

We analyzed the Doryphoros housed in the National Museum of Naples which is one of the best among the many ancient replicas (Della Seta, 1930).

Sporting activities such as discus, hammer or javelin throw, determine asymmetric hyper-morphisms which do not comply with bilateral symmetry: the muscles of the dominant body part are therefore more defined in shape than those in the non-dominant side.

The statue distributes its body weight on the right leg according to a pattern which is thought to have been introduced by Polykleitos himself; the left leg is slightly slid and carried back, the support is provided only by the front of the foot. The athlete holds the javelin (this being a modern recreation of the statue) into the left hand while the right leg distributing the body weight slightly leaps forward according to the idea the athlete was left handed and maybe getting ready for his skill (fig. 4).

Furthermore, the *serratus magnus* and the external oblique muscle of the abdomen which partially originates on the ribs are more defined in shape on the left side rather than on the right one; the latter protruding out of the iliac border. The *pectoralis major, serratus magnus, external oblique* and *rectus abdominis* muscles are also represented according to Lambertini's hyper-morphisms definition of asymmetric sports (fig. 5) (Della Seta 1930; Lambertini, 1936; Moon, 1995).

## Conclusion

Although we and others have previously suggested that dissection and prosection need to remain essential tools in anatomy teaching even in modern medical curricula and clinical training, it is also undoubtedly true that it is necessary to examine the curriculum, the mode of teaching, the quality of how it is delivered, and the infrastructure within which it is delivered for optimal and proficient tailoring of anatomy teaching and learning material. Considering the most recent trends in anatomy pedagogy where at least in a short term learning all the various anatomy learning tools seem to be equivalent (including dissection, Losco et al., 2017,; Wilson et al., 2018), we therefore strongly suggest that surface anatomy training on models such as ancient statues could be considered a valuable tool along with surface anatomy training in those classes in which dissection is independent from the purpose of the study course as sports sciences and fine arts. This additional tool, related to statue and models availability, should become a relevant part of the anatomy "armamentarium" for learning and teaching.

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affiliation, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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