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TEACHING SYMMETRY AND ASYMMETRY IN HAND AND FOOT MUSCLE ANATOMY

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Abstract. *This study presents a pedagogical approach for teaching the anatomy of hand and foot muscles, emphasizing a three-vector symmetry in the superficial layer formed by the opponens, flexor, and abductor muscles of the thenar and hypothenar groups in the hand, and analogous medial plantar and lateral plantar groups in the foot. By leveraging symmetry (bilateral and functional), asymmetry (chirality and structural variations), and concepts like equality, identity, metamerism, and the spiral theory of the human body, this method enhances students' understanding of anatomical organization and evolutionary significance. Comparative dissections at the Department of Anatomy, Medical Faculty, Trakia University, reveal structural similarities in muscle fiber arrangement and innervation patterns. Anatomical variations, such as the less frequent presence of opponens digiti minimi and the rare opponens hallucis in the human foot, are contrasted with their higher prevalence in certain primates, such as chimpanzees and gorillas. This symmetry-based teaching strategy improves comprehension of functional adaptation, biomechanical coordination, and evolutionary patterns, offering a robust framework for anatomical education.*

Keywords: *symmetry, functional analogy, pedagogical approach, muscle anatomy*

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ПРЕПОДАВАНИЕ СИММЕТРИИ И АСИММЕТРИИ В АНАТОМИИ МЫШЦ КИСТИ И СТОПЫ

Аннотация. *Исследование представляет педагогический подход к обучению анатомии мышц кисти и стопы, акцентируя внимание на трехвекторной симметрии поверхностного слоя, сформированного мышцами оппоненс, флексор и абдуктор тенарной и гипотенарной групп кисти, а также аналогичных медиальной и латеральной плантарных групп стопы. Использование принципов симметрии (двусторонней и функциональной), асимметрии (хиральности и структурных вариаций), а также концепций равенства, идентичности, метамерии и спиральной теории человеческого тела способствует углублению понимания студентами анатомической организации и эволюционного значения. Сравнительные диссекции, проведенные на кафедре анатомии Медицинского факультета Университета Тракии, выявили структурные сходства в расположении мышечных волокон и иннервации. Анатомические вариации, такие как менее частое присутствие opponens digiti minimi и редкое наличие opponens hallucis в стопе человека, контрастируют с их высокой распространенностью у некоторых приматов, таких как шимпанзе и гориллы. Данный подход, основанный на симметрии, улучшает понимание функциональной адаптации, биомеханической координации и эволюционных закономерностей, предоставляя надежную основу для анатомического образования.*

Ключевые слова: *симметрия, функциональная аналогия, педагогический подход, анатомия мышц*

Definitions of Symmetry and Related Concepts. Symmetry refers to the balanced arrangement of structures around a central axis or plane, such as the

bilateral symmetry of the human body, where left and right halves mirror each other, ensuring balance and coordination (Palmer & Strobeck, 1986). Equality implies equivalence in measurable properties, such as muscle size or fiber arrangement, between corresponding structures in the thenar and hypothenar groups of the hand or medial and lateral plantar groups of the foot. Identity denotes the shared structural or functional essence of muscles, such as the analogous roles of opponens pollicis (hand) and opponens digiti minimi (hand/foot) in facilitating opposition. Metamerism describes the segmented, repeating organization of anatomical structures, evident in the layered arrangement of hand and foot muscles across superficial, intermediate, and deep layers. The spiral theory of the human body unifies these concepts by proposing that human anatomy is organized along dynamic, helical patterns that integrate symmetry, equality, and metamerism, reflecting evolutionary adaptations in muscle and skeletal arrangements [5]. This theory frames the hand and foot muscle groups as part of a broader spiral continuum, connecting upper and lower limb structures through functional and structural analogies.

Introduction. The muscles of the hand (thenar, hypothenar, central) and foot (medial plantar, lateral plantar, central) are critical for precise movements, grip, and locomotion. A three-vector symmetry in the superficial layer, formed by the opponens, flexor, and abductor muscles of the thenar (opponens pollicis, flexor pollicis brevis, abductor pollicis brevis) and hypothenar (opponens digiti minimi, flexor digiti minimi brevis, abductor digiti minimi) groups in the hand, and the medial plantar (abductor hallucis, flexor hallucis brevis, adductor hallucis) and lateral plantar (abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi) groups in the foot, highlights their structural and functional correspondence.

Aim.This study proposes a pedagogical approach using symmetry, asymmetry, equality, identity, metamerism, and spiral theory to teach hand and foot muscle anatomy, simplifying complex relationships and enhancing learning. Anatomical variations, such as the less frequent opponens digiti minimi and rare opponens hallucis in the human foot, are contrasted with their prevalence in primates like chimpanzees and gorillas. This approach aids students in understanding anatomical, clinical, and evolutionary significance.

Materials and Methods. The study was conducted at the Department of Anatomy, Medical Faculty, Trakia University. Comparative dissections of the hand’s thenar (abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, adductor pollicis), hypothenar (abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi), and central (lumbricales, dorsal and palmar interossei) muscle groups, and the foot’s medial plantar (abductor hallucis, flexor hallucis brevis, adductor hallucis), lateral plantar (abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi), and central (lumbricales, dorsal and plantar interossei) muscle groups were performed to analyze muscle fiber arrangement,

origins, insertions, and innervation. A teaching strategy emphasizing the three-vector symmetry in the superficial layer (opponens, flexor, abductor) and integrating symmetry, equality, identity, metamerism, and spiral theory was implemented in anatomy courses. Student performance and feedback were evaluated to assess the approach's effectiveness.

Results. Dissections of 4 male and 3 female bodies confirmed a three-vector symmetry in the superficial layer of the hand's thenar and hypothenar groups and the foot's medial and lateral plantar groups, where opponens, flexor, and abductor muscles share origins from carpal/tarsal bones and flexor retinaculum/plantar ligaments, with analogous insertions on metacarpals/metatarsals. In the hand, thenar muscles are primarily innervated by the median nerve, and hypothenar muscles by the ulnar nerve, exhibiting structural equality in fiber arrangement and identity in opposition-related functions. In the foot, medial plantar muscles (innervated by the medial plantar nerve) and lateral plantar muscles (innervated by the lateral plantar nerve) show similar symmetry, though the opponens digiti minimi is less consistently present and opponens hallucis is rarely distinct in humans. The central groups in both hand and foot show metameric organization across layers, with dual innervation (median/ulnar in hand, medial/lateral plantar in foot). The pedagogical approach improved students' understanding of muscle coordination and evolutionary adaptations, with the symmetry clarifying functional and reciprocity. Students showed better retention of anatomical details and biomechanical concepts.

Anatomical Variations and Primate Comparisons. Anatomical variations in the hand's hypothenar muscles are relatively common, particularly in the abductor digiti minimi (21% absence or fusion) and flexor digiti minimi brevis (21% absence or dual bellies), while opponens digiti minimi is more stable. In the foot, the opponens digiti minimi is less frequently distinct, often represented by deep fibers of the flexor digiti minimi brevis, inserting on the fifth metatarsal's distal half. The opponens hallucis is even rarer in humans, typically absent or fused with flexor hallucis brevis, reflecting reduced need for hallux opposition in bipedal locomotion. In contrast, primates like chimpanzees, gorillas, and baboons frequently exhibit distinct opponens digiti minimi and opponens hallucis muscles, supporting arboreal grasping and climbing (Diogo & Wood, 2012). Evolutionary studies indicate that these muscles develop from conserved embryonic templates, linking their structure to primate ancestry. These muscles are more developed in these species due to their functional role in prehensile foot movements, highlighting evolutionary divergence in human bipedalism. The pedagogical approach used these variations to illustrate evolutionary adaptations, enhancing student understanding of comparative anatomy.

Discussion.The three-vector symmetry in the superficial layer of the hand's thenar and hypothenar groups and the foot's medial and lateral plantar groups, rooted in shared origins and innervation patterns, reflects bilateral symmetry and metamerism. Their functional asymmetry—thumb/toe precision versus

palmar/plantar deepening—illustrates chirality, where hands and feet are mirror images but non-superimposable [2]. The spiral theory unifies these observations, suggesting that hand and foot muscles follow helical patterns, connecting upper and lower limb structures through evolutionary adaptations [4]. This pedagogical approach simplifies learning by presenting muscle groups as symmetrically organized yet functionally distinct. Clinically, understanding innervation is critical for diagnosing conditions like carpal tunnel syndrome (hand) or tarsal tunnel syndrome (foot), where nerve compression impairs muscle function [3]. The approach enhances memorization and deepens understanding of evolutionary, clinical, and comparative contexts.

Conclusion. The hand's thenar, hypothenar, and central muscle groups, and the foot's medial plantar, lateral plantar, and central muscle groups demonstrate a three-vector symmetry in their superficial layer (opponens, flexor, abductor), alongside functional asymmetry and anatomical variations. The opponens digiti minimi and opponens hallucis are less frequent in human feet but common in primates like chimpanzees and gorillas. By integrating symmetry, equality, identity, metamerism, and spiral theory, this pedagogical framework enhances students' understanding of anatomical organization, functional coordination, and evolutionary significance, providing a model for effective anatomical education.

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