Biomechanics of an Alligator

Animals over the lifespan of the Earth have been adapting to their environments in order to survive. However, unlike the horse, *Equus* has changed greatly over the last five thousand years, which is in sharp contrast to the alligator, who has remained fairly unchanged. This shows how well adapted this reptile is, by producing the most effective and efficient strategy to catch its prey. Being a carnivorous predator, the alligator must be able to act quickly to snare their prey using its large jaws.

From observing this animal, it can be said that endurance isn’t one of its strengths. Instead, it saves its energy for short bursts of intense activity. Anatomically this can be proven by the observation of the large quantity of fast twitch type IIb muscle fibres. These fibres are especially useful when the alligator launches themselves into a jump to catch their prey. For an alligator to be able to perform this movement (the contraction and relaxation of the skeletal muscles) a motor neurone that is attached to a skeletal muscle, has an action potential run through the neuromuscular junction. Acetylcholine vesicles are released there and the acetylcholine is able to bind to the sarcolemma receptor. An action potential in the tissue is created by the influx of sodium ions in the muscle fibre. Calcium channels are opened when the action potential travels through the T-tubules to release the calcium into the cytoplasm. Actin-myosin binding sites and cross-bridges between the actin and the myosin heads are activated by the calcium ions. Energy is provided by the hydrolyzing adenosine triphosphate (ATP) for the myosin heads flexion. The sarcomere becomes shorter in length, as the actin filaments flexed to the middle of the sarcoma to cause a contraction. ATP is also needed for relaxation, as it is used to move/pump the calcium ions back inside the sarcoplasmic reticulum (Boundless, n.d.). Depending on the different fibres would depend on how the quick the contract and relaxation process occurred.

Within the muscle, there are three types of fibres; two fast twitch (Type IIa and Type IIb) and one slow (Type I) that vary in colour and function. Both Type I and IIa are red in colour due to intracellular myoglobin levels being high and dense capillary networks especially in Type I. This results in Type IIb being white in colour due to sparse capillary networks and the capacity for oxidative phosphorylation (OP) to produce ATP is lower. Capillary networks along with a “high capacity for ATP production via OP” allows aerobic cellular respiration finished off with OP. However, Type I has a low myosin hydrolysis of ATP into adenosine diphosphate from the use of ATPase compared to Type IIa and Type IIb. Anaerobic glycolysis is used by Type IIb which results in a high fatigue rate due to the build-up of lactic acid caused by incomplete glucose breakdown (Types
of Skeletal Muscle Fibres, n.d.). An asset of Type IIb fibres for alligators is that they spend a large quantity of time in aquatic environments, therefore may have limited access to oxygen when they perform acts such as the death roll. Alligators have ensured that this doesn’t affect their performance or the ability to maintain their specific gaits.

There is two main gaits terrestrial used by alligators, which are the belly crawl and high walk. However, it’s most commonly used locomotion is swimming, as its body structure is more highly adapted towards this (Crocodilian Locomotion - General, 2016).

Gait cycles are calculated each time the same extremity reaches the same position it was previously in, using the exact same point each time. For example, the hind foot in alligators could be used when the limb makes the first contact with the ground. As this occurs the functional length of the limb compresses, because part of the joint begins to flex to supports its body weight. Ankle flexion commits the highest amount of flexion; consequently “the shortening of functional hind limb length” while the limb-loading phase occurs, allows the knee to briefly flex once the foot is placed down. Once this phase has neared the end, all the stance phase muscles (caudofemoralis) are fully operational, which controls the ankle, knee and hip adduction angles, to keep within its small margin of the angle sizes. During this process, the femur is retracted and rotated. Therefore, “the limb motions that elicit propulsive ground reaction force by the end of the limb-loading phase relate primarily to femoral retraction and rotation” (Reilly et al., 2005). The range of Motion (RoM) of the hind limb can vary greatly across the different gaits or animal. For example, a weaker alligator in an aquatic environment may have a smaller range of motion that on land due to the increased resistance.

In the mechanical theory of the aquatic locomotion of the mediolateral flexion, joint stiffness has degenerated for modern alligators. It is believed that Metriorhynchus (see figure 1) had a smaller osteological RoM, as they required more truck support from the osteoderms. A smaller/stiffer RoM could be the result of other tissues that affect the joint; such as skin that increases the thickness around the joint disallowing the limb, for example, to go back as far (Molnar et al., 2015).
Kinematics has shown that during swimming, alligators require their tail to propel them forward using lateral undulations, but it commences in the pelvic region. While their dorsal part of the head is carried above the water surface: their body’s midpoint is submerged under the water with “a mean depth of 1.6 ± 0.1 times the body depth”. As a result, an incline is created from the head to the submerged body producing “a mean angle of 8.6° ± 2.09°”. Adduction of the legs occurs against the body to allow movement and stability; while “the plantar surfaces of the feet [are] directed medially” (Fish, 1984).

From observations made from an alligator’s gait: the use of its tail can be seen to be very important in both its kinematics and kinetics. An alligator’s centre of mass naturally is very low and to the centre of their body due to their very large heavy head and tail. Without a tail, their centre of mass becomes cranially-displaced from the distal tail which causes drag, as a result of the imbalances of typical forces. Its tail enables a walk that has longer and quicker strides, which is orthopedically correct; as it stops exaggerated lateral undulations of the pelvic girdle (Georgi et al., 2015).

Gaits within the same species tend to have the same basic phases, however anatomically there are variations. For example, Crocodylidae moves rapidly using a gallop, however unlike the Alligatoridae they use a bounding asymmetric gait. Longer muscle fascicles than Alligatoridae in the pectoral limb allows Crocodylidae to establish an enlarged working range. Alligatoridae, on the other hand, has an enlarged force-exerting capability due to their greater muscle physiological cross-sectional areas. An asymmetrical gait is performed by Crocodylidae as a result of these factors, which allows them to complete a quicker cycle, increasing flexibility allowing more reach to engage in a gallop (Allen et al., 2014).
Salamanders, *Dicamptodon tenebrous* are also known to share alligators’ axial and pelvic movements, as they both have “a double node standing wave” which is situated near the girdles. Nodes within alligators are established further forward than salamanders, as their nodes appear nearer the mid-truck. However, alligators’ total pelvic rotation is known to be 26° considerably smaller than 40° of the salamander, but both these “peak pelvic rotation to the foot-down side” occurred ahead of foot up. An example is when the limb is protracted because pelvic rotation has occurred to the opposite side (Reilly and Elias, 1998).

Information on an alligator’s biomechanics allows a greater understanding of how the animal is able to produce movement in order to survive. For example, without limb adductions, the movement wouldn’t be possible and there would be a high emphasis on truck support off the osteoderms. On the other hand, information is taken with caution in order to be aware of bias, reliability and reproducibility. Journal articles are said to be more reliable than websites, as they have to declare their points of interest and are verified before they are published. Websites don’t have this process, therefore it’s more difficult to trust the information unless it’s known to be written by a credible source. Hence why more journal articles were used, but a selection of the studies could have been more recent. Older papers may be less reliable due to the improvement of technology and information available to the researcher. For example, Fish’s (1984) study used a camera with 65 frames/second (FPS), where the study’s accuracy could be improved with a higher FPS camera. At present phone cameras, such as the iPhone 7 has a higher amount of FPS (240 FPS) (iPhone 7 - Technical Specifications, n.d.) than the camera used in the study. If the same study was to be repeated now, the study would be cheaper as cameras are more readily available and more accurate, as the film could be slowed down further. However, newer studies such as Georgi *et al* (2015) would have required much more expense technology to keep producing tails throughout the alligator’s lifetime. This information may also not be representative since only one alligator was used. However, it would be difficult to find other alligators with the exact condition. A problem that had been highlighted across the majority of these articles: as alligators aren’t easy to manipulate to perform in a study due to their carnivorous outlook. Overall, the information that had been gathered did correspond greatly; with many of the authors completing a range of studies. Older articles were also referenced in newer ones backing up the trustworthiness of the authors and studies.
References

Journals


Websites


Films