Muscle Organization in Running Crabs

Fiddler crab, *Uca pugilator*

Ghost crab, *Ocypode quadrata*

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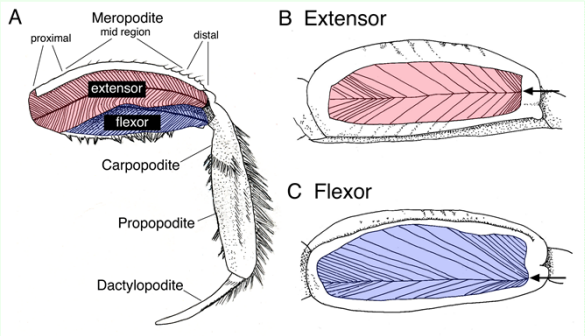
Abstract:

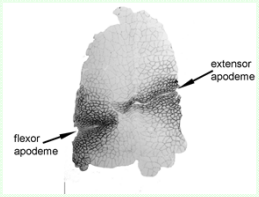
We compared the muscle composition of ghost crabs (*Ocypode quadrata*) and their closest living relatives, the fiddler crabs (*Uca pugilator*). The ghost crab is capable of running at very high speeds (1 meter /s), but relatively less is known about the running abilities of the fiddler crabs. I was interested comparing the running capabilities of these two species and finding out how the muscles that power running compares in both animals. We have been able to identify two major fiber types: large, fast glycolytic fibers, and smaller fast fatiguing-resistant fibers. These are defined by different isoforms of the muscle proteins: myosin heavy chain, troponin T, and troponin I. Ghost crabs are faster runners than the fiddler crabs, in part because they have larger leg muscles.



Leg Muscle Organization

Figure 1A (Top Left). Crab muscles have 3 segments in their legs: meropodite, propodite, and dactylopodite. The main segment that was studied here was the meropodite , taken from the 2nd and 3rd walking legs because these are the legs that power locomotion. Within each segment are three different regions, the proximal, mid and distal regions. In order to move, the flexor and extensor must alternatively flex and extend the carpopodite. The extensor apodeme is centered along the mid-line while the flexor apodeme is shifted towards the inferior margin of the leg. (Figure 1 B and C arrows). (From Perry et al. 2008)

Figure 2 (Right). Cross section of muscles of the meropodite showing extensor and flexor muscles. Muscles are stained with a reaction to reveal mitochondrial enzymes (dark). Muscles close to their insertion points on the apodeme are aerobic, while the larger muscle masses of the muscle mid-regions are not.



Anatomical Comparisons

The ghost crabs that were studied range in size from 1-70.3g. The fiddler crabs had a much smaller size range, from 0.87-5.23g. However, by standardizing muscle cross-sectional areas to animal mass, we could compare the relative amount of leg muscle in the two species. On a mass-specific basis, we found that ghost crabs have muscles with about 2X the cross sectional area of that found in fiddler crabs. This greater muscle mass probably explains some of the differences in running performance between the two species.

Running Speeds

Ghost crabs are able to run at very high speeds. As their body mass increases, their running speed also increases but their stride frequency decreases (not shown). The same pattern was found in the fiddler crabs, but at much lower speeds and frequencies, as was expected.

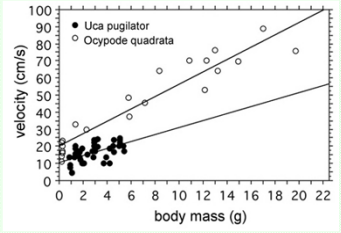


Figure 3. The ghost crabs run at a higher velocity than fiddler crabs.

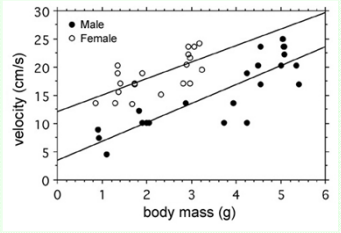


Figure 4. Female fiddler crabs run faster than male fiddler crabs with corresponding body mass.

Fiber Diameters

Ghost crabs have small cell diameters to facilitate efficient oxygen delivery to their cells during physical activity. To maximize diffusion of oxygen, they have infoldings that project from their outer cell membrane deep into the fiber. These infoldings provide a larger surface area with more mitochondria, helping to efficiently supply ATP to these cells. The proximal region supports sustained movement, thus it needs more mitochondria and oxygen, so the fibers here are small in diameter with extensive infoldings. The mid region supports short, anaerobic bursts of energy (sprints), so cells don't need as many mitochondria, thus their lack of infoldings. In fiddler crabs, individual fibers are significantly larger, with no infoldings.

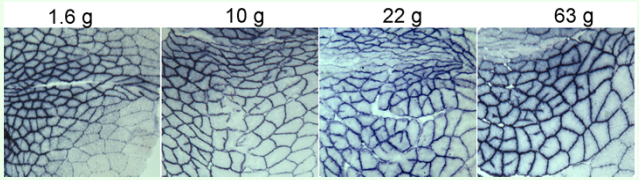
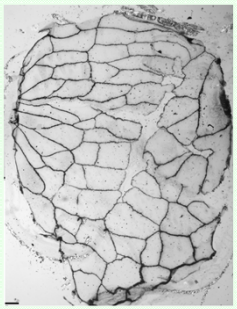
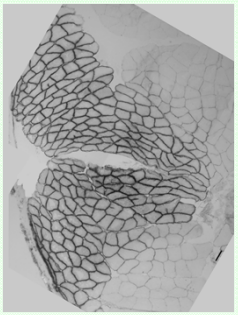


Figure 5 (Above). As ghost crabs get bigger, the concentration of infoldings in the proximal region gradually increases.
Figure 6A (Below Left). Fiddler crab cross section of mid-region fiber, cells are large, no infoldings. Figure 6B (Below Right) Ghost crab cross section proximal/mid-regions; smaller cell diameter, proximal cells have infoldings.





Molecular Differences

Whole muscles are composed of single fibers, consisting of different types of proteins. In crabs, differences in protein isoforms occur for troponin T (TnT), troponin I (TnI) and myosin heavy chain (MHC). Troponin T has three different isoforms, each of which appear in different concentrations depending on where in the muscle the fiber was taken, and the size of the crab. In other crustacean muscles, TnT isoform expression is used to define specific muscle fiber types. Here, we found that comparable fibers in ghost crabs and fiddler crabs express different TnT isoforms.

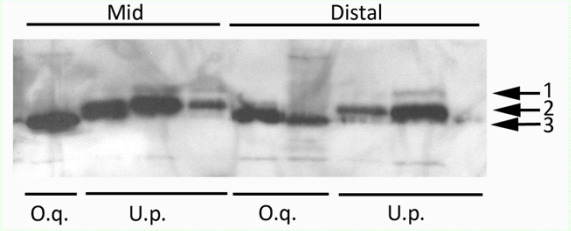


Figure 7. Western blot of TnT isoforms using a polyclonal anti-TnT antibody. TnT_3 is seen in ghost crabs (*O.q.*) in mid region and distal fibers. TnT_1 and TnT_2 are seen in fiddler crabs (*U.p.*) in mid region and distal fibers. All ghost crab fibers express TnT3,while the fiddler crab fibers express different combinations of TnT1 and T2.

Conclusions

Fiddler and ghost crabs, though closely related, have significant differences in muscle structure and function, including:

- Anatomical differences in muscle composition
- Muscle protein types differ between the two families.
- Ghost crab can run significantly faster than the fiddler crab.

These significant differences in muscle composition may help explain some of the difference in running capabilities.

Reference:

Perry et al., 2008. Skeletal Muscle Fiber types in the Ghost Crab, *Ocypode Quadrata*: Implications for Running Performance. The Journal of Experimental Biology. 673-683.