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Studies on the cuticle and musculature of freshwater mite, *Unionicola aegyptiaca*

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Abstract

Background: The aquatic Acari are known as water mites and occupy a wide range of habitats. The freshwater mites, *Unionicola aegyptiaca*, were collected from the freshwater mussel, *Caelatura aegyptiaca*, River Nile, Sohag, Egypt. The present paper focuses on the structure of the cuticle and musculature of freshwater mite, *U. aegyptiaca*.

Results: Histologically, the cuticle consists of two main layers: epicuticle and procuticle. The latter divided into two sublayers, exocuticle (exo) and endocuticle (en). The musculature of the present species, *U. aegyptiaca*, is divided into three regions: gnathosoma, idiosoma, and legs. The muscles of the body are classified according to their position and function.

Conclusion: Details of muscles of gnathosoma, coxal epimerae, genital field, and legs were all described and discussed. The cuticle and musculature of *U. aegyptiaca* were studied by using the light microscope, and the drawings were down with the help of a camera Lucida. It is likely to note that the cuticle and musculature of freshwater mite, *U. aegyptiaca*, were described and discussed for the first time in Egypt.

Keywords: Water mites, *Unionicola*, Cuticle, Musculature

Background

The structure of the cuticular layers of mites has been studied by several authors (Grandjean, 1951; Woodring and Cook, 1962; Sannasi and Oliver, 1971; Tarba and Semenova, 1976; Pugh et al., 1987; Smrž, 1989; Iordansky and Stein-Margolina, 1993; Smrž, 2005). The cuticle of mites consists of two layers: epicuticle and procuticle, which is divided into exocuticle and endocuticle (Sannasi and Oliver, 1971; Bereiter-Hahn et al., 1984; Lindquist et al., 1996; Smrž, 2005). The cuticle of mites has to be sufficiently permeable to allow gas exchange but impermeable enough to prevent water loss (Haldane, 1927 cited in Colloff, 2009). Also, it varies in thickness, hardness, composition, and elasticity regarding different parts of the body and different species, in order to provide both mechanical protection and sufficient flexibility for locomotion (Haldane, 1927 cited in Colloff, 2009). Pritchard et al. (2015) reported that the sclerotized cuticle of mites can be identified by a brown/yellowish area which often covers the whole of the outer adult body.

During the nineteenth and twentieth centuries, musculature of invertebrates has been traditionally studied using light and electron microscopy (Chetverikov, 2014). The musculature of Acari is striated, and a complex skeletal musculature is involved regarding the movements of the various appendages. Both external and internal types of muscles are found in mites (Dhooria, 2016). Mitchell (1955, 1962) studied the musculature of aquatic mites, *Unionicola fossulata*, *Najadicola ingens*, and *Blankaartia ascoscuteellaris*. Mitchell (1955) reported that the musculature of water mites is separated according to its function into three groups: dorsoventral muscles, supportive muscles, and coxal muscles. Also, Treat (1965) and Chetverikov (2014) studied the genital musculature of the female mites, *Dicrocheles phalaenodectes*, *Loboquintus subsquamatus*, and *Trisetacus cf bagdasariani*.

The present work aims to study the anatomical structures of the cuticle and musculature of freshwater mite, *U. aegyptiaca*, by using a light microscope.

Materials and methods

In the present paper, the freshwater mussels, *Caelatura aegyptiaca*, were collected from a small stream like a bay

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branched from the Nile River about 1 km east of Girga city (26° 21' N and 31° 53' E), Sohag Governorate. The specimens of freshwater mites, *Unionicola aegyptiaca*, were collected from the freshwater mussels.

A: for the cuticle study

About 25 individuals of adult female freshwater mites, *Unionicola aegyptiaca*, were fixed with Carnoy's fluid, dehydrated in a graded series of alcohols, embedded in paraffin wax, sectioned at 3–5 µm, and stained with hematoxylin and eosin.

B: for the musculature study

About 30 individual adult females of the present species were preserved in clove oil about 30 min for clearing and then mounted in a droplet of Hoyer's medium. The mounted specimens were heated, until the appearance of air bubbles, to stretch safely the specimen under the weight of the slip cover.

The mounted slides were kept in trays in an oven at 35 °C for 48 h for drying. The slides were photographed using a Canon digital camera attached to a light microscope. The musculature of three regions, gnathosoma (mouth parts), idiosoma, and legs, were drawn out from whole mounted specimens using a camera Lucida.

Identification

It is likely to note that the present species, *Unionicola aegyptiaca*, was identified and described as a new species by Ramadan et al. (2015). The mussel, *Caelatura aegyptiaca*, was described by Van Damme (1984) and Ibrahim et al. (1999).

The terminology and abbreviations of the cuticular layers and muscle groups of the present species are developed by Mitchell (1955), Alberti et al. (1981), and Alberti and Coons (1999).

Results

The cuticle

The cuticle of the present freshwater mite *Unionicola aegyptiaca* lacks any markings or structural modifications. No cell walls or other histological structure is demonstrable in the cuticular layers. The cuticle of the present species consists of two main layers: epicuticle and procuticle. Histologically, the epicuticle layer has a conspicuous yellowish green color while differential basophilia was recorded among the procuticle layer (Pl. 1a). The procuticle is characterized by fine striation and divided into two sublayers exocuticle (exo) and endocuticle (en) (Pl. 1a, d, e). Generally, each exocuticle and endocuticle sublayers are divided into two regions (exo1 and exo2, and en1 and en2, respectively). The examination of the histological sections through the cuticle revealed that the thickness and number of cuticular

layers vary according to the body region of the present species (Pl. 1a–g). Histologically, the epidermis appears as cuboidal cells with densely stained nuclei.

The musculature

The body of freshwater mite, *Unionicola aegyptiaca*, consists of five segments of palps (p1–p5), chelicerae (main shaft and two movable digits), two groups of coxal epimerae (I–IV), genital field (a pair of dorsoventral plate and a pair of ventral plates) and legs (Fig. 1a).

The musculature of the present species, *Unionicola aegyptiaca*, is divided into three regions: gnathosoma (mouth parts), idiosoma, and legs. Moreover, these muscles can be classified according to their position to the body and their function. According to their position of the body, the gnathosomal region includes the muscles of gnathosomal base (capitulum), chelicerae, palpi, and hypostome. The idiosomal region includes muscles of the coxal epimerae and genital field. According to the function of muscles, the gnathosomal region includes elevators, depressors, flexors, and hypostomal muscles. The idiosomal region includes dorsoventral, supportive, coxal (elevators and depressors), and genital muscles, while the leg segments include protractor, retractor, flexors, and elevator muscles. As a result of bilateral symmetry, the present work will describe the musculature of the right side of the body.

Muscles of gnathosomal region

The origin and insertion of the muscles in the gnathosomal region are illustrated in Table 1. The gnathosomal base and cheliceral shaft regions are supported by seven (4 elevators and 3 depressors) and six (3 elevators and 3 depressors) muscles, respectively (Fig. 1b). The palpal segments are supported by four flexor (fl2–fl5) muscles. The flexor muscles consist of several number of bands ranging from 3 to 8 bands (Fig. 1c). The hypostomal muscles are originated from the cheliceral muscles and inserted into the anterodorsal margin of coxal epimerae III (Fig. 2a).

The muscles of the idiosomal region

The origin and insertion of the dorsoventral muscles are connected with the body wall. The supportive muscles are originated from different areas (the body wall, coxae, and genital field) and inserted into the transverse coxal ligament (Table 2), while the coxal muscles are originated from the coxal epimerae and inserted into the first segment of the legs (Table 2). The genital field contains three pairs of genital plate muscles: dorsoventral, ventral, and valval muscles. The origin and insertion of genital muscles are illustrated in (Table 2). The drawings of the idiosomal muscles are shown in (Fig. 2a, b).

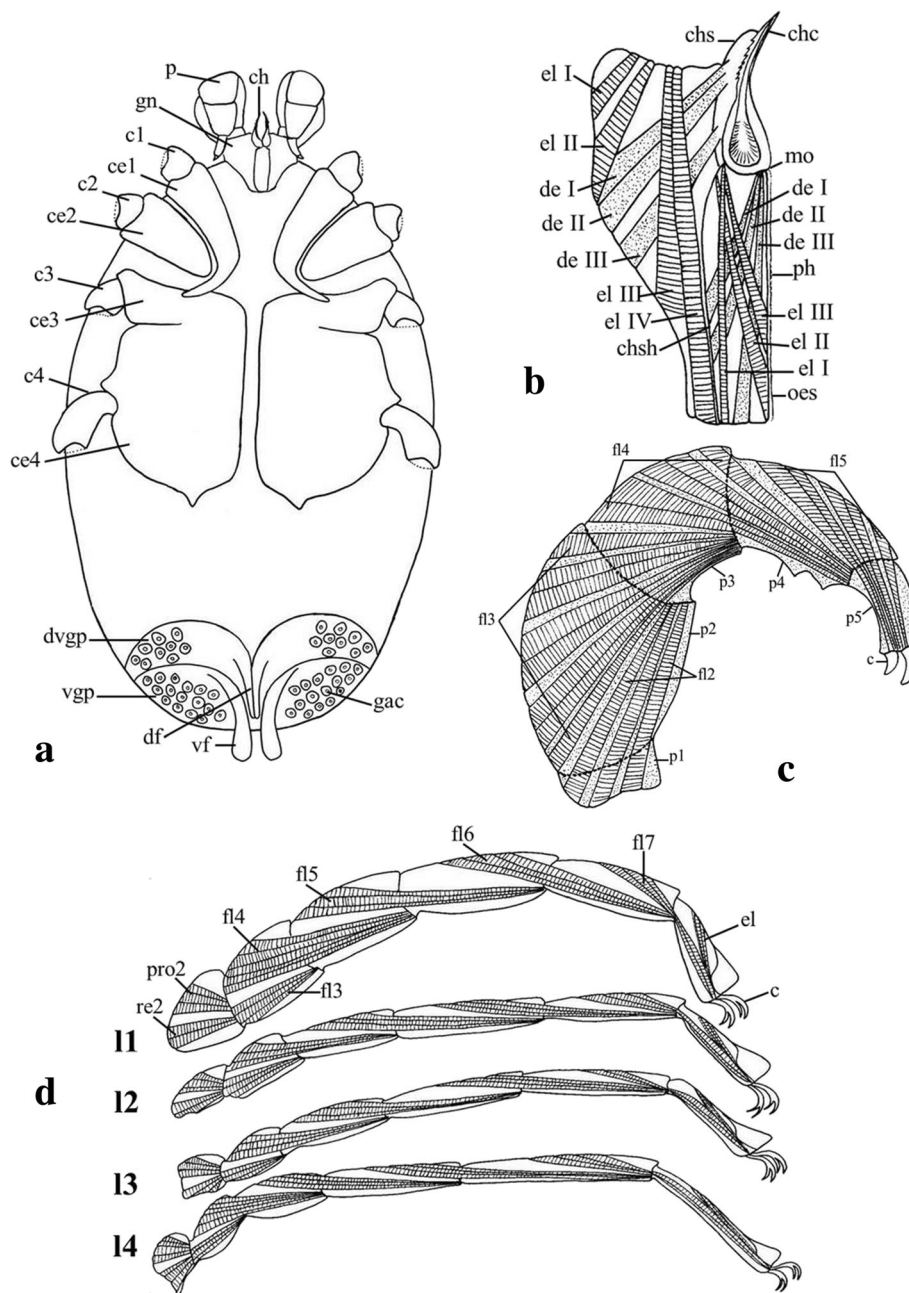


Fig. 1 Diagrammatic drawings of the adult female *Unionicola aegyptiaca* showing **a** structure of the ventral body, **b** gnathosomal base and cheliceral muscles, **c** palpal muscles, and **d** leg muscles

Leg muscles

The segments of legs (11–14) of the freshwater mite, *Unionicola aegyptiaca*, are supported by protractor (pr2), retractor (re2), five flexor (fl3–fl7), and elevator (el) striated muscles (Fig. 1d). The tarsus of each leg is supported by elevators muscles which are responsible for the claw elevation (Table 3). The previous muscles include several number of bands ranged from 2 to 5 in all legs (Pl. 1h).

Discussion

The cuticle

The present results showed that the cuticle of freshwater mite, *Unionicola aegyptiaca*, consists of two main layers: epicuticle and procuticle. Also, the procuticle layer is divided into two sublayers: exocuticle and endocuticle. Each of the previous sublayer divided into two regions (exo1 and exo2, and en1 and en2, respectively). Similar results were recorded by Sannasi and Oliver (1971) and

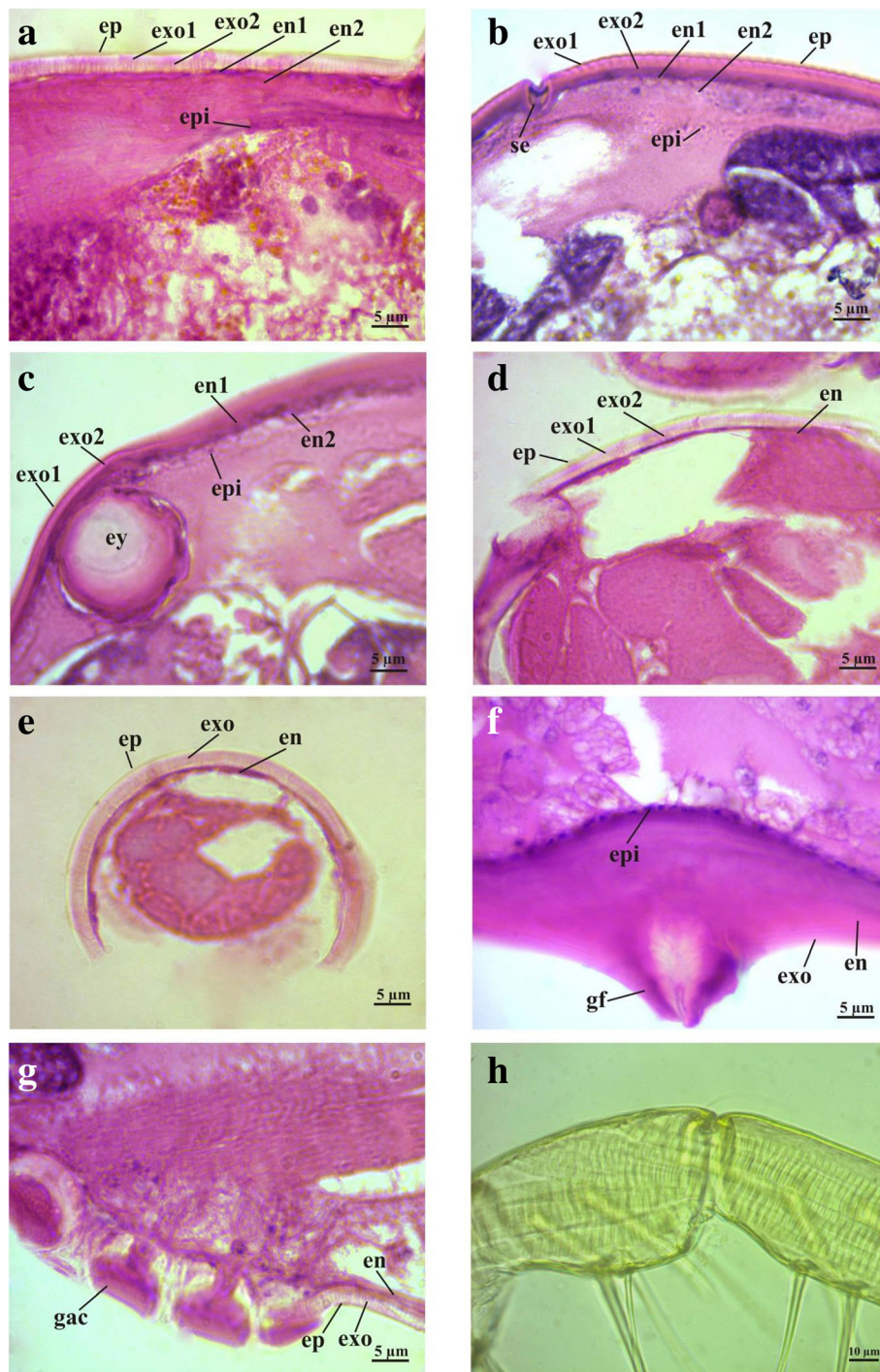


Plate 1 a–g Photomicrographs of histological sections of adult female *Unionicola aegyptiaca* showing the cuticular layers of **a** body wall, **b** around the seta, **c** around the eyes, **d** palpal segments, **e** leg, **f** around genital flaps, and **g** between genital acetabulae. **h** Photograph of leg muscles of adult female *Unionicola aegyptiaca*

Smrž (2005) on some mite species such as *Dinotrombium giganteum*, *Rhysotritia duplicata*, *Steganacarus striculus*, *Steganacarus magnus*, *Phthiracarus* sp., and *Tropacarus carinatus*. Also, Smrž (2005) reported the same structure of the cuticle on the nymphal stages of

some mite species such as *Hermannia gibba*, *Tectocephus velatus*, *Scutovertex minutus*, *Achipteria coleoptrata*, and *Eupelops occultus*.

In the present data, the epidermis appears as cuboidal cells with densely stained nuclei. Similar data were found

Table 1 The origin and insertion of the gnathosomal muscles of adult female *Unionicola aegyptiaca*

Muscle	Gnathosomal base muscles	
	Origin	Insertion
Elevators I, II	First segment of palp	Body wall
Elevators III, IV	First segment of palp	Hypostomal muscles
Depressors I, II, III	Cheliceral sheath	Body wall and coxal epimerae
	Cheliceral muscles	
	Origin	Insertion
Elevator I	Ventral wall of cheliceral shaft	Dorsally, base of the claw
Elevators II, III	Lateral wall of cheliceral shaft	Dorsally, base of the claw
Depressor I, II	Lateral wall of cheliceral shaft	Ventrally, base of the claw
Depressor III	Ventral wall of cheliceral shaft	Ventrally, base of the claw
	Palpal muscles	
	Origin	Insertion
Flexor 2	Segment 1 (3 bands)	Segment 2
Flexor 3	Segment 2 (8 bands)	Segment 3
Flexor 4	Segment 3 (5 bands)	Segment 4
Flexor 5	Segment 4 (5 bands)	Segment 5
	Hypostomal muscles	
	Origin	Insertion
	Cheliceral muscles	Coxal epimerae III

in the freshwater mite, *Unionicola fossulata* (Mitchell, 1955). Sannasi and Oliver (1971) suggested that the epidermal cells of the cuticle of mite, *Dinothrombium giganteum*, form a syncytium in the normal mite.

The musculature

The present investigation revealed that the musculature of the freshwater mite, *Unionicola aegyptiaca*, is divided into three regions: gnathosoma (mouth parts), idiosoma, and legs. Similar data were mentioned by Mitchell (1955, 1962) for other species of unionicolid mites, *Unionicola fossulata* and *Najadicola ingens*, and trombiculid mite, *Blankaartia ascocutellaris*. Whitmoyer et al. (1972) and Lindquist et al. (1996) distinguished the musculature in eriophyoid mites into three groups: skeletal, peripheral, and visceral muscles. They said that the skeletal muscles include gnathosomal, dorsoventral, genital and anal regions, and legs.

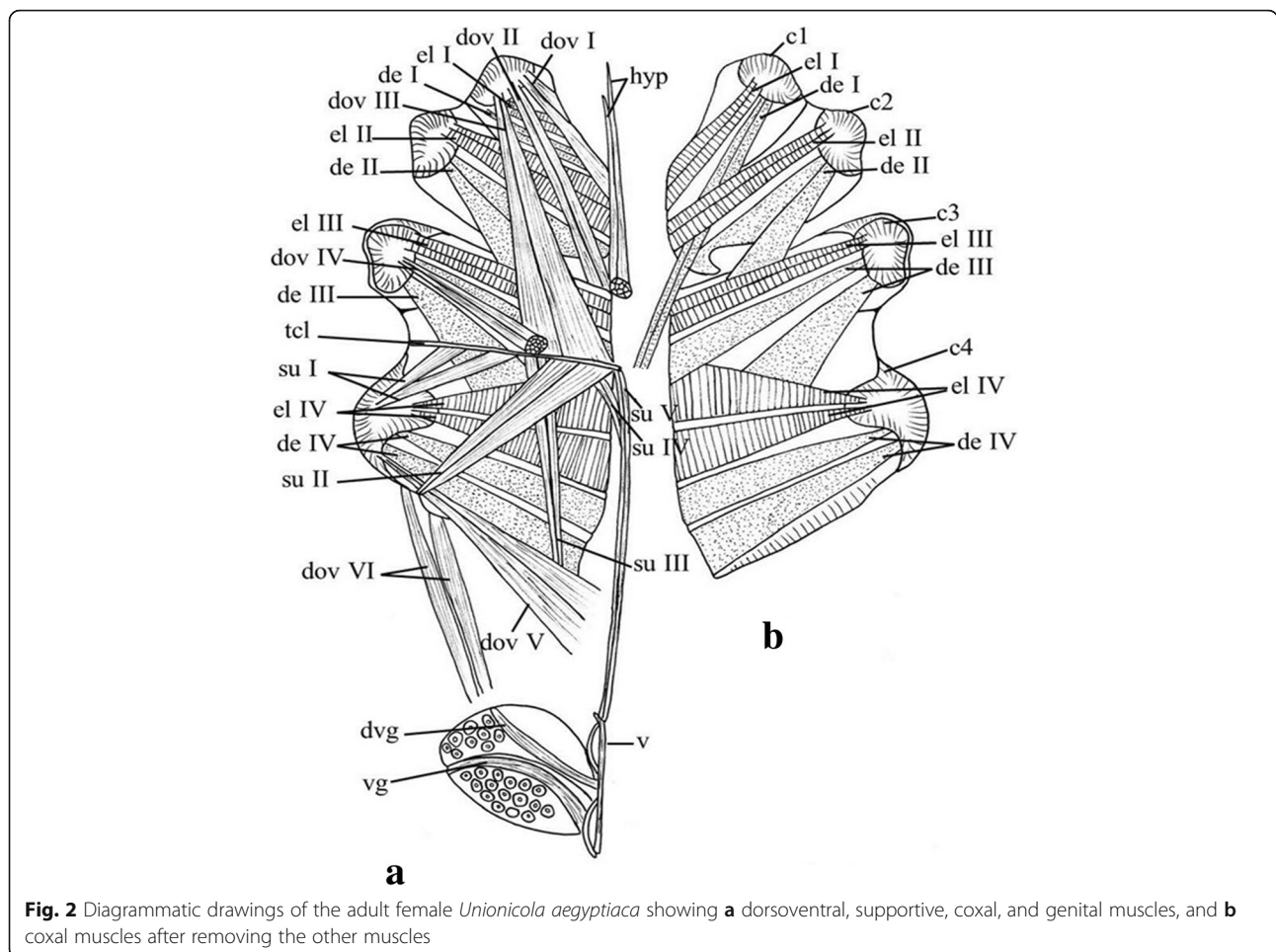
In each side of the body, the gnathosomal base and cheliceral shaft regions of the present species, *U. aegyptiaca*, are supported by seven (4 elevators and 3 depressors) and six (3 elevators and 3 depressors) muscles, respectively. The present author suggested that the contraction of the cheliceral muscles is responsible for the elevation and depression of the cheliceral claw. Similar data was reported by Mitchell (1955) for the freshwater mites, *Unionicola fossulata* and *Najadicola ingens*. The cheliceral shaft of *Blankaartia ascocutellaris* consists of

three elevators, two depressors, and two protractor muscles (Mitchell, 1962).

The palpal segments of the present species *U. aegyptiaca* are supported by four flexor muscles which contain 3 to 8 bands. The palpal segments of *Unionicola fossulata* and *Najadicola ingens* are supported by three flexors which include two muscles and two bands (Mitchell, 1955). The palpal segments of *Blankaartia ascocutellaris* consist of three elevators, two depressors, three flexors, and three adductors muscles (Mitchell, 1962).

Also, the origin and insertion of the cheliceral and palpal muscles of *U. aegyptiaca* are similar to those of *Unionicola fossulata* and *Najadicola ingens* (Mitchell, 1955). Chetverikov (2014) showed that the gnathosomal muscles (cheliceral muscles and extrinsic muscles of palps) and opisthosomal muscles of *Loboquintus* mites are attached to the three posterior depressions near the prodorsal shield margin.

The present data showed that the idiosomal region of the present species includes dorsoventral, supportive, coxal (elevators and depressors), and genital muscles. Similar results were mentioned by Mitchell (1955) for other species of freshwater mites such as *Unionicola fossulata* and *Najadicola ingens*. Mitchell (1962) reported that the different body regions of *Blankaartia ascocutellaris* include dorsal, dorsoventral, ventral, coxal (elevators and depressors), genital field, and excretory pore



muscles. Treat (1965) studied the female genital muscles of moth ear mite, *Dicrocheles phalaenodectes*, and divided them into five anatomical groups: dorsoventral, lateral, ventral, epigynial, and endostylar.

The present work revealed that the right side of the idiosomal region of freshwater mite, *U. aegyptiaca*, had six and five dorsoventral and supportive muscles, respectively.

Mitchell (1955) studied the musculature of freshwater mite, *Unionicola fossulata*, and described seven dorsoventral and four supportive muscles. Mitchell (1962) reported seventeen dorsoventral, six dorsal, and eight ventral muscles for trombiculid mite, *Blankaartia ascocutellaris*.

There are some similarities and differences in the number, origin, and insertion of the dorsoventral and supportive muscles between the present species, *U. aegyptiaca*, and the freshwater mite, *Unionicola fossulata* (Mitchell, 1955). In contrast to other Acari, the opisthosoma of eriophyoid mites is nearly free of dorsoventral muscles (Nuzzaci, 1976 and Shevchenko, 1983, 1986).

Shevchenko (1983, 1986) observed in *Cecidophyopsis ribis* a greater number of ventrolateral muscles in the first juvenile instar.

In the present work, the coxal muscles of *U. aegyptiaca* originated from the coxal epimerae and inserted into the first segment of the legs. These muscles are differentiated into four elevators and four depressors in all coxal epimerae. These results are in accordance with the coxal muscles of freshwater mites, *Unionicola fossulata* and *Najadicola ingens* (Mitchell, 1955), and trombiculid mites, *Blankaartia ascocutellaris* (Mitchell, 1962). It is likely to note that the number of bands of elevators and depressor muscles on the coxal epimera is different in the present species compared with the previously published mite species (Mitchell, 1955, 1962).

The genital field of the present species, *U. aegyptiaca*, is supported by three pairs of genital plate muscles: dorsoventral, ventral, and valval muscles. In contrast, Mitchell (1955) illustrated two pairs of genital plate muscles for freshwater mite, *U. fossulata*. Also, the genital field of *B. ascocutellaris* is associated with six pairs

Table 2 The origin and insertion of dorsoventral muscles, supportive muscles, ventral (coxal) muscles, and genital muscles of adult female *Unionicola aegyptiaca*

Muscle	Dorsoventral muscles	
	Origin	Insertion
I	Posterior margin of coxa I (2 bands)	Coxal epimerae I
II	Posterior margin of coxa I (2 bands)	Coxal epimerae III
III	Posterior margin of coxa I (2 bands)	Coxal epimerae IV
IV	Posterior margin of coxa III (2 bands)	Coxal epimerae IV
V, VI	Posterior margin of coxa IV (2 band)	Body wall posterior coxal epimerae IV
Muscle	Supportive muscles	
	Origin	Insertion
I, II	Posterior margin of coxa IV (2 bands)	Transverse coxal ligament
III	Posterior margin of coxal epimerae IV (2 band)	Transverse coxal ligament
IV	Body wall (2 band)	Transverse coxal ligament
V	Central genital field (2 band)	Transverse coxal ligament
Functional group	Ventral (coxal) muscles	
	Origin	Insertion
	Leg I	
Elevator I	Coxal epimerae I (2 band)	First segment of leg I (protractor)
Depressor I	Body wall between coxal epimerae IV (2 band)	First segment of leg I (retractor)
	Leg II	
	Coxal epimerae II (2 band)	First segment of leg II (protractor)
Depressor II	Coxal epimerae II (2 band)	First segment of leg II (retractor)
	Leg III	
	Coxal epimerae III (2 band)	First segment of leg III (protractor)
Depressor III	Coxal epimerae III (2 band)	First segment of leg III (retractor)
	Leg IV	
	Coxal epimerae IV (2 band)	First segment of leg IV (protractor)
Depressor IV	Coxal epimerae IV (2 band)	First segment of leg IV (retractor)
Functional group	Genital muscles	
	Origin	Insertion
Dorsoventral muscles	Dorsoventral plate	Dorsal flap
Ventral muscles	Ventral plate	Ventral flap
Valval muscles	Genital valve	Genital duct

Table 3 The origin and insertion of leg muscles of adult female *Unionicola aegyptiaca*

Muscle	Origin	Insertion
Protractor 2	Anterolateral wall, segment 1	Base of segment 2
Retractor 2	Posterolateral wall, segment 1	Base of segment 2
Flexor 3	Segment 2	Base of segment 3
Flexor 4	Segment 2	Base of segment 4
Flexor 5	Segment 3	Base of segment 5
Flexor 6	Segment 4	Base of segment 6
Flexor 7	Segment 5	Base of claws
Elevator	Segment 6	Base of claws

of genital plate muscles (Mitchell, 1962). In addition, the excretory pore of *B. ascoscuteilaris* has five pairs of excretory muscles.

The leg segments (11–14) of the freshwater mite, *Unionicola aegyptiaca*, are supported by protractor (pr2), retractor (re2), five flexor (fl3–fl7), and elevator (el) muscles. Similar data are reported by Mitchell (1955, 1962) for the mites *U. fossulata* and *B. ascoscuteilaris*. The number of leg muscle bands in *U. aegyptiaca* ranged from 2 to 5 in all legs, while the leg bands of *U. fossulata* ranged from 2 to 4 (Mitchell, 1955) and from 1 to 3 for *B. ascoscuteilaris* (Mitchell, 1962). The origin and insertion of the leg muscles of *U. aegyptiaca* are

similar to those of *U. fossulata* and *B. ascoscuteilaris* (Mitchell, 1955, 1962, respectively). It is likely to note that the depressor muscles of leg tarsus were absent in *U. aegyptiaca* and *U. fossulata* (Mitchell, 1955) and present in *B. ascoscuteilaris* (Mitchell, 1962).

Conclusion

The study of cuticle and musculature of freshwater mite, *Unionicola aegyptiaca*, was carried out for the first time in Egypt. The present work depends on the examination of the histological sections by using light microscope, while the drawings were carried out with the help of a camera Lucida. The cuticle consists of two main layers: epicuticle and procuticle. The musculature of the present species is divided into three regions: gnathosoma, idiosoma, and legs. Finally, the studies on the cuticle and musculature of the freshwater mites are few. So, more studies on them are required in the future.

Abbreviations

c: Claw; c1–c4: Coxa I–IV; ce1–ce4: Coxal epimerae I–IV; ch: Chelicera; chc: Cheliceral claw; chs: Cheliceral sheath; chsh: Cheliceral shaft; de I–de IV: Depressors (I–IV); df: Dorsal flaps; dov I–dov IV: Dorsovenral muscles (I–IV); dvg: Dorsoventral genital muscles; dvgp: Dorsoventral genital plate; el: Elevator of leg tarsus; el I–el IV: Elevators (I–IV); en: Endocuticle; en1: First endocuticle; en2: Second endocuticle; ep: Epicuticle; epi: Epidermis; exo: Exocuticle; exo1: First exocuticle; exo2: Second exocuticle; ey: Eye; gac: Genital acetabulae; gf: Genital flaps; gn: Gnathosomal base; hyp: Hypostomal muscles; l1–l4: Legs I–IV; mo: Mouth opening; oes: Esophagus; p: Palp; p1: Palpal trochanter; p2: Palpal femur; p3: Palpal genu; p4: Palpal tibia; p5: Palpal tarsus; ph: Pharynx; fl2–fl7: Flexors (2–7); pro2: Protractor; re2: Retractor; se: Setal insertion; su I–su V: Supportive muscles (I–V); tcl: Transverse coxal ligament; v: Valval muscles; vf: Ventral flaps; vg: Ventral genital muscles; vgp: Ventral genital plate

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Authors' contributions

RSA was responsible for the points of research and writing and revision of the manuscript. TIG was responsible for writing and revision of the manuscript. MAN carried out the fieldwork as part of her doctorate research and wrote the first manuscript. All authors read and approved the final manuscript.

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Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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