

Sexual differences on body condition in litter-dwelling scorpion *Tityus pusillus* Pocock, 1893 (Scorpiones: Buthidae)

Diferencias sexuales en la condición corporal del escorpión de hojarasca *Tityus pusillus* Pocock, 1893 (Scorpiones: Buthidae)

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Abstract. Body condition may be an important additional tool for ecological studies. However, this information is still lacking for many arachnids such as scorpions. In addition, sex can be considered as a determining factor in the body condition of individuals since it can present differences in life-history traits. Thus, we evaluated the body condition of the litter-dwelling scorpion *Tityus pusillus* Pocock, 1893. For this, 88 individuals (44 by sex) were used, where the following body condition parameters were measured: body size, fresh, dry, lipid and muscle mass. Our results showed that females have a significantly higher values than males in all parameters of body condition measured. Differences in life-history traits between sexes, such as foraging activity and reproductive investment may be directly related to these findings. Finally, our results suggest that females possess a higher environmental requirement to maintain body condition.

Key words: Ecophysiology; life history; Neotropical scorpion.

Resumen. La condición corporal puede ser una herramienta adicional importante para estudios ecológicos. Sin embargo, esta información aún falta para muchos arácnidos como los escorpiones. Además, el sexo puede considerarse como un factor determinante en la condición corporal de los individuos, ya que este puede presentar diferencias en los rasgos de historia de vida. Así, se evaluó la condición corporal del escorpión de hojarasca *Tityus pusillus* Pocock, 1893. Para ello, se utilizaron 88 individuos (44 por sexo), donde se midieron los siguientes parámetros de condición corporal: tamaño corporal, masa fresca, masa seca, masa lipídica y masa muscular. Los resultados mostraron que las hembras tienen valores significativamente más altos que los machos en todos los parámetros de condición corporal medidos. Las diferencias en los rasgos de historia de vida entre los sexos, como la actividad de forrajeo y la inversión reproductiva, pueden estar directamente relacionadas con estos hallazgos. Finalmente, los resultados obtenidos sugieren que las hembras tienen un mayor requisito ambiental para mantener la condición corporal.

Palabras clave: Ecofisiología; escorpión neotropical; historia de vida.

Evaluation of animal health through the body condition is a useful tool for ecological studies (e.g., Aubry *et al.* 2013; Battles *et al.* 2013; Iglesias-Carrasco *et al.* 2017). The body condition may be expressed in terms of nutrient storage comprising the amount of energy reserves and can be directly measured through the lipid mass (e.g., González-Tokman *et al.* 2011; Knapp & Knappová 2013; França *et al.* 2016). The size of the energy reserves of an animal possesses important implications for its ability to survive, grow and reproduce. For example, individuals with better body condition have higher fecundity (Moya-Laraño 2002; Barone & Frank 2003), and higher mating success (Cotton *et al.* 2006; Olivero *et al.* 2019). To obtain a more complete picture of body condition is necessary to investigate other traits than lipid mass. In this way, body condition may be used as a general surrogate for fitness (not only for energy reserves), and the fitness of an animal does not have to be connected exclusively to energy reserves (Kumano *et al.* 2010). For example, muscle mass is related to individual fitness in many arthropods groups while dry mass is considered as a proxy of biomass (Angelo & Slansky jr 1984; Hausmann *et al.* 2022). Thus, to obtain a more complete picture of body condition is necessary to investigate other traits than lipid mass.

Sex constitutes an important life-history trait that potentially affects the body condition of organisms (e.g., Dubois *et al.* 2010; Aisenberg & Peretti 2011; Lease & Wolf 2011). For example, in many arthropod classes, females possess more lipid mass than males because they use lipids to reproduce (Lease & Wolf 2011). However, this is not a universal rule, males may possess more lipid than females, especially in species with male-male contests (Crnokrak & Roff 1995). Males may also present more muscle mass than females. According to Aisenberg & Peretti (2011) males of *Allocosa brasiliensis* (Petrunkevitch, 1910) wolf-spiders showed higher values of muscle mass than females. These authors suggest that differences in life history between the sexes could be factors driving the body condition. In addition, the body condition may show a sex-related difference to environmental stressors. For example, urbanization negatively affected body mass and lipid content in males, but not females of the dung beetle *Dichotomius guaribensis* Valois, Vaz-de-Mello & Silva, 2017 (Salomão *et al.* 2020).

Studies assessing body condition have been widely performed with arthropods, especially insects (e.g., Baines *et al.* 2015; Zanchi *et al.* 2019; Stahlschmidt & Chang 2021). However, studies assessing body condition in arachnids, especially scorpions are scarce (Olivero *et al.* 2019; Oviedo-Diego *et al.* 2024). This is particularly surprising considering that these animals have been proven to be good ecological bioindicators (Gerlach *et al.* 2013; Lira *et al.* 2021a; Olivero *et al.* 2021). Thus, in order to provide an additional tool for future ecological studies, the present work proposes to analyse the body condition of males and females of the *Tityus pusillus* Pocock, 1893 scorpion. This is a small litter dwelling scorpion widely found in the Atlantic Forest from the Brazilian northeastern region (Lira *et al.* 2018a, 2020). As other scorpion species, *T. pusillus* sexes show different history trait histories, males are more vagrant while females are usually found in more cryptic microhabitats (Lira *et al.* 2018b). In addition, *T. pusillus* females not males are sensitivity to habitat changes, individuals that inhabit sites with less litterfall exhibiting smaller size (Lira *et al.* 2021b). Therefore, in this study, we tested the prediction that *T. pusillus* male and female will show differences in body condition related to their history of life.

At total of 88 adult individuals of *T. pusillus* (44 males and 44 females) were used. These individuals were collected during nocturnal period (19:00-22:00 h) from Tapacurá Ecological Station (8°2'28"S, 35°11'46"W), an Atlantic Forest fragment with approximately 400 ha, located in the municipality of São Lourenço da Mata, Pernambuco, Brazil. No gravid females were used to avoid biases due to embryos. In the laboratory, measurements of the prosoma length of the animals were performed with a digital caliper (0.01 mm). Then, the animals were weighed (fresh weight) on a semi-analytical scale with a precision of 0.001 gr. After that, dry, muscle and lipid masses were measured, according to Contreras-Garduño

et al. (2008) and González-Tokman *et al.* (2011). To obtain the dry weight, the scorpions were placed in an oven at 60 °C for 48 h and then weighed on the semi-analytical scale. After that, the animals were kept individually for 24 h in Eppendorf containing 2 mL of chloroform (CHCl₃), then they were dried in the oven again and weighed. The difference between the first and second weighing was considered as the lipid mass. To obtain muscle mass, scorpions were kept in Eppendorf containing 0.8 M potassium hydroxide (KOH) for 48 h, then dried and weighed again. The difference between the anterior and new weight was considered as muscle mass.

To assess sexual differences in *T. pusillus* body condition, models were created using the following dependent variables: prosoma length, fresh mass, dry mass, lipid mass and muscle mass with sex as a fixed effect. The normality, homoscedasticity and overdispersion of the variables were evaluated graphically and using the 'fitdistrplus' package (Delignette-Muller & Dutang 2015). If the assumptions were not met, the variables were modeled according to their best distribution. For normally distributed data, the 'lm' function was used and for gamma and binomial distributions, the 'glm' function from the stats package (R Core Team 2018). Variables with negative binomial distribution were modeled with the 'glm.nb' function of the MASS package (Ripley *et al.* 2013) and the statistical significance of the GLMs was calculated with the 'ANOVA' function of the 'car' package (Fox *et al.* 2013).

Our results showed that *T. pusillus* possess sex-related differences in size and masses analysed in our study. Females were significantly larger than males (Chi = 44.260, df = 1, $p < 0.005$; Fig. 1A) exhibiting mean prosoma length 3.72 ± 0.27 mm while males possess 3.26 ± 0.34 mm. *Tityus pusillus* females were also approximately 20% heavier in terms of fresh mass (F = 35.636, df = 1, $p < 0.005$; Fig. 1B), muscle mass (Chi = 7.697, df = 1, $p = 0.006$; Fig. 1D) and lipid mass (F = 22.615, df = 1, $p < 0.005$; Fig. 1E). In dry mass, the differences were even more pronounced, with females on average 40% heavier than males (Chi = 54.216, df = 1, $p < 0.005$; Fig. 1C).

The body condition in *T. pusillus* males and female's scorpions was assessed based on body size and fresh, dry, lipid and muscle masses. In general, females had higher values in all body parameters analysed than males. These results may be associated with different life history-traits between sexes. Similar to other scorpion species (Polis 1990), *T. pusillus* females are sedentary, usually staying in more cryptic shelters than males (Lira *et al.* 2018b). In addition, previous studies pointed that this scorpion species is a sit-and-wait hunter (Lira *et al.* 2013; Dionisio-da-Silva *et al.* 2020). Therefore, females may have reduced foraging opportunities compared to males, thus need to be efficient during prey capture. This may be reflected in the greater muscle and dry masses presented by females. One hand, a greater muscle mass may indicate a better performance in capturing prey while dry mass indicates the individual's ability to convert food into biomass (*e.g.*, Copus & Gibb 2013; Hausmann *et al.* 2022). On the other hand, greater muscle mass may mean greater energy expenditure for muscle maintenance. In addition, scorpion females have higher energy expenditure with reproduction (*e.g.*, litter production and parental care) than males (Polis & Sissom 1990). For example, *T. pusillus* females are able to produce until three broods in a year (Albuquerque & Lira 2016). In addition, Silva-Júnior *et al.* (2022) found that *T. pusillus* females with a limited food resource produce litters weaker than females with more food resources. These factors reinforce necessity to keep higher energy reserves (*e.g.*, lipid mass) in *T. pusillus* females.

In summary, our results showed that body condition is different between males and females of the *T. pusillus* scorpion. Females had larger body size, fresh, dry, lipid and muscle masses than males. These results may be related to different life-history traits between sexes. Finally, knowing body condition may open up new opportunities for ecological studies with scorpions.

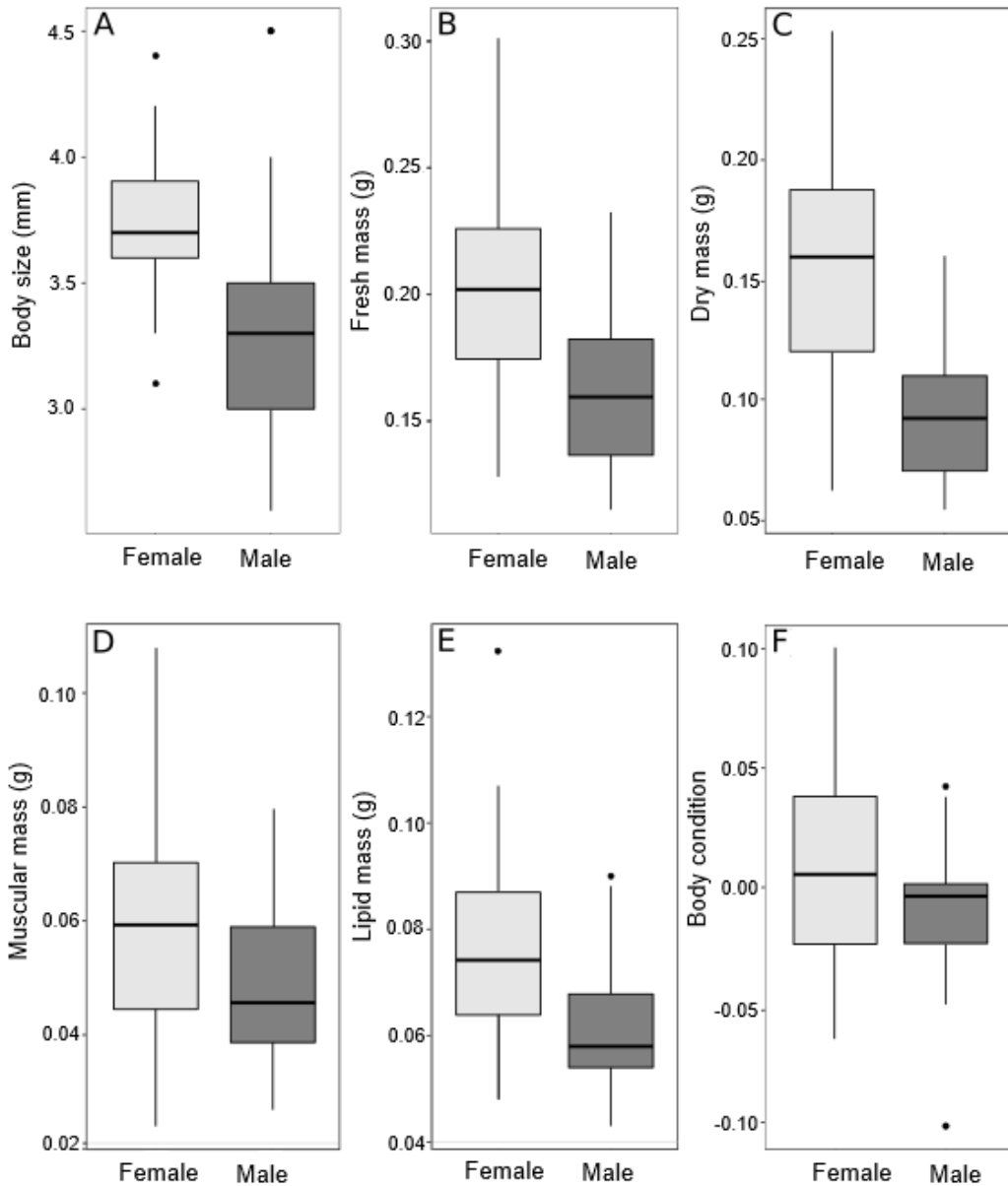


Figure 1. Corporal condition parameters in *Tityus pusillus* Pocock, 1893 females and males. **A)** Body size. **B)** Fresh mass. **C)** Dry mass. **D)** Muscular mass. **E)** Lipid mass. **F)** Body condition. / **Figura 1.** Parámetros de la condición corporal en *Tityus pusillus* Pocock, 1893 hembras y machos. **A)** Tamaño del cuerpo. **B)** Masa fresca. **C)** Masa seca. **D)** Masa muscular. **E)** Masa lipídica. **F)** Condición corporal.

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Author Contributions

MOMM: Investigation, data curation, resources, writing - original draft. **GJBM:** Resources, funding acquisition, writing - review & editing. **AFAL:** Conceptualization, supervision, methodology, investigation, visualization, writing - review & editing.

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