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The effects of locomotor movements and feeding on heart activity in the solifuge *Eremobates marathoni* Muma & Brookhart (Solifugae, Eremobatidae)

Fred Punzo
Department of Biology,
University of Tampa,
Tampa, Florida 33606,
USA

Summary

In the present study, I examined the heart activity (heart rate) in adult females of the solifuge *Eremobates marathoni*. Heart rates were monitored in stationary as well as active non-feeding animals using a non-invasive optical procedure. Solifuges were placed on a suspended styrofoam ball housed in a suspension system which allowed the ball to move freely in any direction in response to the weight of the animal. This caused the solifuge to move its legs, thereby stimulating ambulatory movements. The ball was locked in a fixed position for animals at rest. Another group of solifuges were recorded continuously at rest for 48 h in order to assess heart activity over a prolonged period. Arachnids in another group were forced to "walk" continuously in order to ascertain the amount of time required to reach exhaustion. I also monitored heart activity in another group of solifuges as they ingested prey. Mean resting heart rates ranged from 13–16 beats/min over a 5-min testing period, then increased to 41 beats/min after 2 min of locomotor activity. All locomotor activity ceased after 3.2–4 min for solifuges that were forced to "walk" for a continuous period. In the feeding experiments, solifuges exhibited a mean heart rate of 14.7 beats/min for 5 min before feeding. During feeding and ingestion of prey heart activity increased to 31.8 beats/min. These represent the first data available for heart activity in a solifuge.

Introduction

The role of the circulatory system in homeostasis as well as factors affecting heart rate have been rather extensively studied in insects and spiders (see reviews by Jones, 1964, 1974; Carrel, 1987). However, very little information is available on the dynamics of circulation and cardiac function in solifuges (Ruppert & Barnes, 1994). Although the general anatomy of the solifuge heart and circulatory system has been described for a few species (Bernard, 1896; Meglitsch, 1967), no one has analysed factors which may influence heart activity in this arachnid group. In fact, very few physiological analyses have been conducted on solifuges because they are difficult to maintain under laboratory conditions for long periods (Punzo, 1994a). In the present study I report on the effects of locomotor movements and feeding on heart activity in the solifuge *Eremobates marathoni* Muma & Brookhart.

Methods

All of the solifuges used in these experiments were adult females of *Eremobates marathoni* (mean body length 23.7 ± 2.8 mm (S.D.); mean body weight 6.48 ± 1.1 g, originally collected in Brewster County, Texas as previously described by Punzo (1994b). Solifuges were maintained in a Percival Model 80A environmental chamber (Boone, Iowa) at 21–22°C, 65–72% relative humidity (RH), under a photoperiod regime of 12L:12D. They were fed on a diet consisting of mealworms, crickets and cockroaches. The experiments were carried out at room temperature (20–22°C). Statistical procedures used in this study follow those described by Sokal & Rohlf (1981).

I used a modification of the non-invasive optical procedure described by Carrel & Heathcote (1976) to monitor heart activity (beats/min). To summarise, the abdomen was illuminated directly above the heart using a 5mW helium-neon laser with a beam width of 0.8 mm. This procedure is based on the fact that the amount of light absorbed by the heart changes during contraction and relaxation cycles. A photodiode, with a variable operational amplifier, was connected to a chart recorder and an oscilloscope (the light/photo-current response was linear). During all experiments, heart activity was recorded on a Sony CE video camera for subsequent analyses. Solifuges were deprived of food for 48 h before testing except for those animals whose heart activity was monitored while feeding. Each solifuge was tested only once for all heart activity determinations.

In order to record heart activity in stationary (resting) as well as active ("walking") non-feeding animals, I used a procedure identical to that described by Paul *et al.* (1989) for the theraphosid spider *Eurypelma californicum* Ausserer. To summarise, all test animals were attached to a metal bar (at the midpoint of the opisthosoma) with paraffin wax and positioned directly above a styrofoam ball. To monitor heart activity in active animals, each solifuge was lowered on to a ball housed in a suspension system allowing the ball to move freely in any direction. For stationary tests (no locomotor activity) ($n=10$), an aluminium lever was used to lock the ball in a fixed position. Animals were habituated to test conditions for a period of 1 h before experimentation. At the start of a trial, each animal ($n=10$) was placed on a ball locked in a fixed position and its resting heart rate monitored over a 5-min period. After 5 min, the lever was removed allowing the ball to rotate freely in response to the weight of the animal. This caused the solifuge to move its legs ("walk") in response to the movement of the ball, thereby stimulating locomotor activity. Animals placed on such a freely rotating ball exhibited a spontaneous, voluntary ambulatory pace. Solifuges were allowed to exhibit locomotor movements for 2 min (minutes 6 and 7). After 7 min, the ball was again locked into a fixed position and heart activity monitored for another 3 min (total time/trial = 10 min) (Fig. 1).

An additional group of 5 solifuges were recorded continuously under stationary conditions for 48 h in order to assess heart activity over a prolonged period. Animals in another group ($n=5$) were forced to "walk" continuously in order to ascertain the amount of time required to reach exhaustion and the subsequent cessation of locomotor activity.

I also monitored heart activity in solifuges ($n=10$) that were in the act of feeding (food ingestion). All

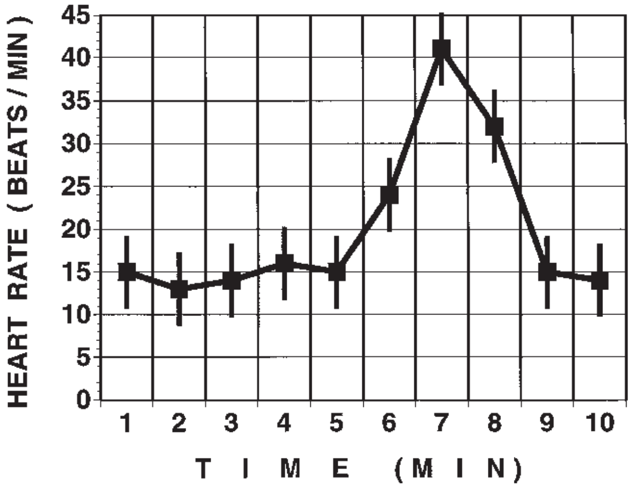

Fig. 1: Heart rate in *Eremobates marathoni* females during an initial 5-min period at rest followed by 2 min of locomotor activity and a 3-min recovery period. Values represent means for 10 solifuges. Vertical lines represent ± S.E. See text for details.

measurements were recorded from solifuges in a stationary position. The heart activity of each animal was monitored for a 5-min period before feeding. Following this, each animal was offered a cricket (*Acheta* sp.; mean body weight 2.4 ± 0.07 g, S.D.) and its heart activity was monitored over another 5-min period during which the solifuge began to grind the prey in its chelicerae and ingest the prey.

Results

Mean heart rates for the 10 solifuges at rest ranged from 13–16 beats/min over the initial 5-min test period (Fig. 1). This increased to 41 beats/min after the 2-min period of locomotor activity ($t=14.3$, $p<0.01$). Heart rate then decreased to 14 beats/min after the subsequent 3-min stationary period.

Four of the five solifuges which were monitored continuously over a 48 h period exhibited resting values between 13.7 and 16.2 beats/min. However, the heart activity for one of these solifuges increased quite suddenly from normal resting values to 21–24 beats/min at various intervals (32 min, 5 h, 14 h, 28 h) during the 48-h period of observation. This shows that heart rate can fluctuate even in undisturbed animals. At no time, however, did heart rates for stationary animals approach the values indicated above for "walking" animals (32–41 beats/min).

All locomotor activity ceased after 3.2–4.4 min for solifuges that were forced to "walk" for a continuous period without rest (mean 3.34 ± 0.21, S.D.). These animals appeared to be exhausted and did not exhibit subsequent locomotor activity until a 1.5–2 min rest period had elapsed.

In the feeding experiments, solifuges exhibited a mean heart rate of 14.7 beats/min (± 1.9, S.D.) for the 5-min period before feeding. Following cheliceral grinding and subsequent ingestion, mean heart rate increased to 31.8 beats/min (± 4.8, S.D.) ($t=21.8$, $p<0.001$) after a period of 10 min.

Discussion

The results of these experiments indicate that heart rates increase significantly as a result of exercise or feeding. This is in general agreement with the data available for spiders, although the difference between resting vs. active animals is not nearly as pronounced for *E. marathoni* as that reported for some spiders. For example, Bristowe (1932) reported a heart rate of 120 beats/min for a *Liphistius desultor* Schiödte spider that had been run to exhaustion; this declined to a resting heart rate of 27 beats/min after a 40-min period of inactivity. Sherman & Pax (1970) reported a resting heart rate of 48 beats/min for a lycosid spider which increased to 176 beats/min after 30 s of running. In a study reported by Anderson & Prestwich (1985), heart rate during the first 2 min increased from 18 to 44 beats/min for individuals of *Brachypelma smithi* (F. O. P.-Cambr.) forced to run on a treadmill, and increased more slowly to 58 beats/min after 10 min of running. This is similar to the values reported in this study for *E. marathoni*: resting heart rates of 13–16 beats/min increasing to 41 beats/min after 2 min of exercise. Post-exercise heart rate in the theraphosid spider *Eurypelma californicum* decreased from a mean of 53.4 to 21.7 beats/min after 30–60 min of rest (Paul *et al.*, 1989).

Heart rates for *E. marathoni* females during feeding and ingestion were significantly higher than pre-feeding rates, although the level of increase was not as high as in those solifuges forced to simulate walking movements. It appears that increased heart rate accompanies any generalised increase in bodily activity in this solifuge.

Previous studies have suggested that spiders, in general, are capable of sustaining locomotor activity for only short periods of time. Bristowe (1932) reported that the tropical spider *L. desultor* exhibits exhaustion within several s of dashing out of its burrow. Similar results have been reported for two species of amaurobiid spiders (Cloudsley-Thompson, 1957; Wilson & Bullock, 1973). However, Bromhall (1987) reported that 15 species of spiders comprising 11 families maintained forced running activity for at least 90 s, although running speeds decreased after an initial period of 20 s. Prestwich (1988) showed that running speeds in *Filistata hibernalis* Hentz, *Lycosa lenta* Hentz and *Phidippus audax* (Hentz) also decreased significantly after the first 20 s of activity and continued to decline over a 2-min testing period. In the present study, all locomotor activity ceased after 3.2–4.4 min for solifuges that were forced to "walk" for a continuous period without rest. A recovery period of 1.5–2 min was required before they resumed locomotor activity of any kind. This suggests that solifuges may reach exhaustion much more rapidly than araneomorphs. This is somewhat surprising in view of the fact that many species of solifuges wander over considerable distances in their search for prey (Bolwig, 1952; Muma, 1966; Wharton, 1987; Punzo, 1997). I have often observed solifuges moving rapidly over the surface of the ground at night while searching for prey (Punzo, 1994b) or mates (Punzo, 1997). When threatened, they immediately flee their antagonist with a rapid burst of speed (pers. obs.); however, I have no data on the maximal amount of time that these running episodes can be sustained. In any event, more information on heart rates for additional solifuge species is required in order to assess any variation that might exist within this arachnid group.

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