**Kinematics of males *Eupalaestrus weijenberghi* (Araneae, Theraphosidae) locomotion on different substrates and inclines**

Valentina Silva-Pereyra1, C. Gabriel Fábrica1, Carlo M. Biancardi2, Fernando Pérez-Miles3

 1 Unidad en Biomecánica de la Locomoción Humana, Departamento de Biofísica, Facultad de Medicina, Universidad de la República, Montevideo, Uruguay.

2 Laboratorio de Biomecánica y Análisis del Movimiento, Departamento de Ciencias Biológicas, CenUR L.N., Universidad de la República, Paysandú, Uruguay.

3 Sección Entomología, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay.

Corresponding author: Valentina Silva-Pereyra

E-mail: valentinasilva@fmed.edu.uy

**Supplementary document 1**

**Muti-segment body models of the spider**

Let $x\_{f}(t)$, $y\_{f}(t$), $z\_{f}(t)$ be the  spatial coordinates of marker over the fovea $C\_{f}$ in time, and $x'\_{f}(t)$, $y'\_{f}(t$) the derivatives of $x\_{f}(t)$ and $y\_{f}(t$) respectively. The movement direction of $C\_{f}$ in the plane restrained by $X$-axis and $Y$-axis, is defined by an angle $α$ formed by the speed vector ($x'\_{f}(t)$,$y'\_{f}(t$)) and the $X$-axis (Figure 1), it was defined as $α(t)=tan^{-1}({y'\_{f}(t)}/{x'\_{f}(t)})$. It was assumed that the longitudinal mean line of the cephalothorax was parallel to the speed vector.

For$ i$ between 1 and 4, $d\_{i }$ is the distance between the fovea and the pair of legs $i$ on the longitudinal midline of the cephalothorax and $l\_{i }$ is the distance between the coxa$ij$and the longitudinal midline of the cephalothorax. $j$ takes the value 1 for the right legs and 2 for the left legs. Let $C\_{ij}$ be the virtual marker corresponding to the leg $ij$, its vector of spatial coordinates is:

**Figure 1.** Speed direction of the marker over the fovea ($C\_{f}$), and the measurement ($d\_{i }$and $l\_{i }$) used to obtain each coxa position ($C\_{ij}$).

$C\_{ij}(t)=\left(x\_{f}(t) +d\_{i}. cos α\_{i}(t) +l\_{i }. cos β\_{ij}(t), y\_{f}(t) +d\_{i }. sen α\_{i}(t) +l\_{i }. sen β\_{ij}(t), z\_{f}(t)\right)$ ;

with $α\_{i}=α $, $β\_{i1}=α\_{i}-\frac{Π}{2}$ and $β\_{i2}=α\_{i}+\frac{Π}{2}$for$ i=1, 2$ ;

and $α\_{i}=α+Π $, $β\_{i1}=α\_{i}+\frac{Π}{2}$ and $β\_{i2}=α\_{i}-\frac{Π}{2}$for $i=3, 4$ .

For $k$ between 1 and 3, take the value 1 for the most distal segment, 2 for the middle segment and 3 for the proximal segment. Let $C\_{p,ijk}(t)$ be the coordinates vector of the proximal marker of the segment $k$ of the leg $ij$ in each instant of the cycle, $C\_{d,ijk}(t)$ the coordinates vector of the distal marker and $m\_{ik}$ the mean mass of the segment $k$ of the pair of leg $i$, the special coordinate of segments centre of mass of each leg is:

$cm\_{ijk}(t)=(Pm\_{ik}.(C\_{p,ijk}(t)-C\_{d,ijk}(t))+C\_{p,ijk}(t)).m\_{ik}$ .

The mean mass of the cephalothorax-abdomen-coxae-trochanters is $m\_{f}$, the centre of mass of whole body was calculated as a function of time:

$bCOM\left(t\right)=C\_{f}\left(t\right). m\_{f}+\sum\_{}^{}cm\_{ijk}\left(t\right)$,

their spatial coordinates are $X\_{bCOM}(t)$, $Y\_{bCOM}(t)$, $Z\_{bCOM}(t)$.

The trajectories of $bCOM$ were used to calculate work and energy according to Willems et al. (1995). The vertical energy was considered as the sum of potential energy and vertical kinetic energy. The forward energy as the sum of forward and lateral kinetic energy. From the sum of increments of vertical and forward energy, the minimum external positive work was obtained $W\_{ext}^{+}$. The vertical work $W\_{v}^{+}$ and the forward work $W\_{f}^{+}$ were calculated from the sum of vertical and forward increases respectively; all were normalized with $M$ and the distance traveled. Also we quantify the recovery $R$, the exchange of energy by pendular mechanism at the centre of mass.

To calculate the segments kinetic energy of each leg we considered each segment as a solid cylinder with its axis of rotation on the proximal end, its radius of gyration was:

$$I\_{ijk}=(\frac{1}{4}r\_{k}^{2}+\frac{1}{12}ls\_{ijk}^{2})^{0.5}$$

with $ls$ is the length of segments and $r$ their radius.

The internal work $W\_{int}$, was obtained assuming energy transfer among the segment of each leg, from the sum of the increments of the curves in time of kinetic energy of each leg. Also was standardized on $M$ and the distance travelled. The mechanical work was calculated as the algebraic sum of internal and external work.

Finally, the mean height of the centre of mass ($H\_{COM}$) was defined as the mean of the $Z\_{bCOM}$ vector. The step length ($Lp$) of a locomotion cycle was calculated as:

$Lp=(X\_{bCOM}^{2}(t\_{f})+Y\_{bCOM}^{2}(t\_{f}))^{0,5}-(X\_{bCOM}^{2}(t\_{i})+Y\_{bCOM}^{2}(t\_{i}))^{0.5}$ .

And the relative step length by dividing the step length over $H\_{COM}$.

Table 1. Measures of cephalothorax and abdomen (n = 12, mean±s.d.)

|  |
| --- |
| Measures of cephalothorax |
| Distance fovea (mm) | 10.29±0.45 |
| Distance I (mm) | 1.58±0.37 |
| Distance II (mm) | 5.79±0.58 |
| Distance III (mm) | 11.57±0.88 |
| Distance IV (mm) | 15.65±1.20 |
| Width I (mm) | 11.32±1.73 |
| Width II (mm) | 13.99±0.94 |
| Width II (mm) | 13.04±1.38 |
| Width IV (mm) | 9.60±1.40 |
| Mass (10-2 g)  | 219±23 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Segment** | **Leg** | **Diameter (mm)** | **Length (mm)** | **Mass (10-2g)** | **Center of mass (%)** | **Radius of gyration (mm)** | **Moment of inertia** |
| **Femur** | I | 2.35±0.37 | 14.12±0.70 | 71±16 | 43.8±15.9 | 4.11 | 1.20 |
| II | 12.91±0.61 | 58±12 | 51.3±15.7 | 3.77 | 0.82 |
| III | 11.48±0.63 | 68±17 | 53.6±8.8 | 3.36 | 0.77 |
| IV | 14.13±0.71 | 67±28 | 55.3±12.7 | 3.76 | 1.14 |
| **Patella-tibia** | I | 2.40±0.272.25±0.44 | 16.87±0.73 | 65±12 | 39.4±5.6 | 4.90 | 1.56 |
| II | 15.11±0.56 | 45±13 | 29.6±8.2 | 4.40 | 0.87 |
| III | 13.59±0.49 | 43±15 | 33.0±6.4 | 3.80 | 0.68 |
| IV | 18.52±0.59 | 70±19 | 38,7±16,2 | 5.26 | 2.02 |
| **Metatarsus** | I | 1.41±0.16 | 10.11±0.58 | 16±0.4 | 55.2±16.9 | 2.93 | 0.22 |
| II | 9.95±0.54 | 14±0.5 | 53.4±12.1 | 2.40 | 0.18 |
| III | 11.18±0.32 | 17±0.6 | 48.2±17.2 | 3.25 | 0.26 |
| IV | 16.96±0.60 | 36±23 | 47.4±21.9 | 4.68 | 1.11 |
| **Tarsus** | I |  |  | 10±0.3 |  |  |  |
| II |  | 0.8±0.3 |  |  |  |
| III |  | 0.8±0.4 |  |  |  |
| IV |  | 10±0.2 |  |  |  |

Table 2. Measures and inertial parameter of segments leg (n = 12, mean ± S.D.).

**Original measurements**

The average values of the cephalothorax measures used to build our multi-articulated mechanical models of tarantula body are presented in the table 1. The distance fovea and the distances I to IV were taken from the insertion of the leg to the clypeus over longitudinal midline of the cephalothorax, so each $d\_{i }$was the distance fovea less the distance for the leg $i$. The width I to IV correspond to the double of each $l\_{i}.$ The mass reporter here correspond to the cephalothorax plus the abdomen.

The table 2 show the average values of the limb segments measures.

**References**

Willems PA, Cavagna GA, Heglund NC. 1995 External, internal and total work in human locomotion. *J. Exp. Biol.* 198, 379–393.