CAN WATER STRIDERS ADJUST THEIR JUMPING PERFORMANCE TO THEIR BODY MASS THROUGH INDIVIDUAL EXPERIENCE?

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Introduction

In response to predators' attacks from under the water surface, water striders use sudden upward escape-jumps to escape danger. Water striders perform as if they "knew" how to move their legs for maximization of their speed but without breaking the water surface. In this study we focused on if the jumping behavior can be modified by water striders through individual experience or it is the fixed behavior. Also because water strider females, but not males, naturally experience an addition of extra mass during extended periods of mating, it could be assumed that females were more familiar to additional weight. Therefore we used female water striders to see the adjustments of leg movements to increased body mass.

Materials & Methods

1. Experimental design

Weight adding treatment and induced jumping treatment were performed on 29 individuals of *Gerris latiabdominis* (Fig1). During 3 days between first and second test the insects in the ***jumping induced*** group were poked manually 3~5 times per hour, for 5 hours each day to induce 15-25 jumps per day.

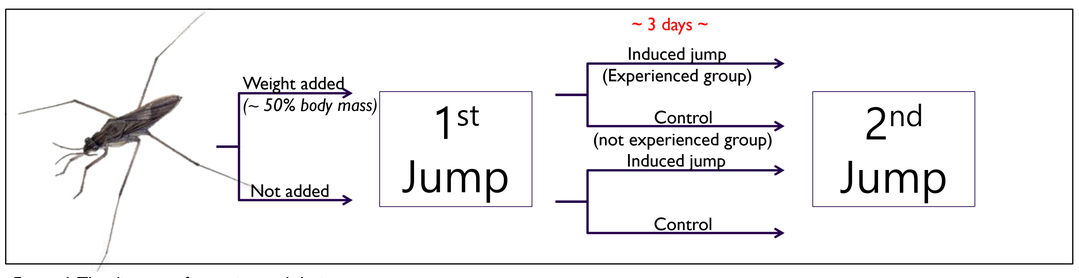

Figure 1. The diagram of experimental design

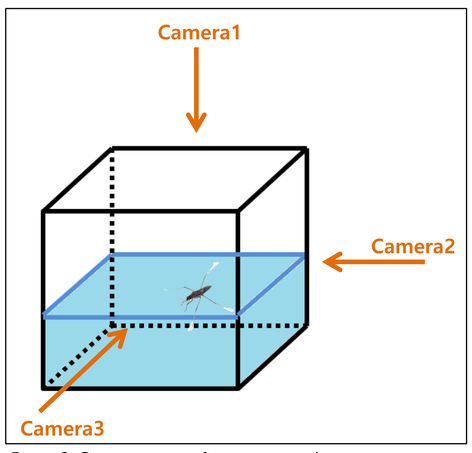

Figure 2. Camera settings for jump recording

The jumps were filmed in a water tank by 3 high speed cameras in orthogonal positions (to obtain 3D coordinates) (Fig2)

2. Video analysis

In each frame of recorded videos, body center, femur-tibia joint, and femur-body joint coordinates were extracted by Maxtraq program (Fig3). And 3 parameters were organized from these coordinates data.

1)Average leg speed : average of vertical femur-tibia joint speed based on body center coordinate system

2)Average angular speed : average of femur vertical angle speed

3) Body center speed : the speed of body center when water strider leaves water surface.

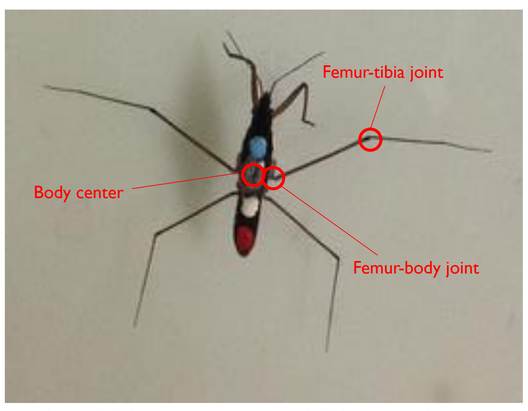

Figure 3. Points used for data analysis. This water strider posses small weight glued at "body center".

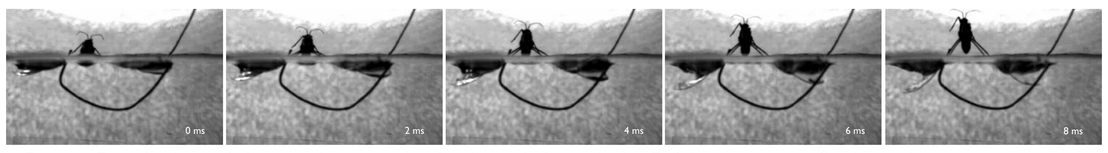

Figure 4. Example of recorded jump with water surface breaking in high speed video Each frame represents 2 miliseconds.

3. Statistical analysis

Analyses were performed using SAS Proc Mixed and Proc Reg. In mixed model, the fixed effects were *weight adding* treatment, *jump order* and the *interaction* of the two effects. The individual water striders were considered as random effect.

Model
Average leg speed
Average angular speed ~ *weight* + *order* + *weight* * *order* + *individual*
Body Center speed

Results

1. Leg movement speed is related to total body movement speed

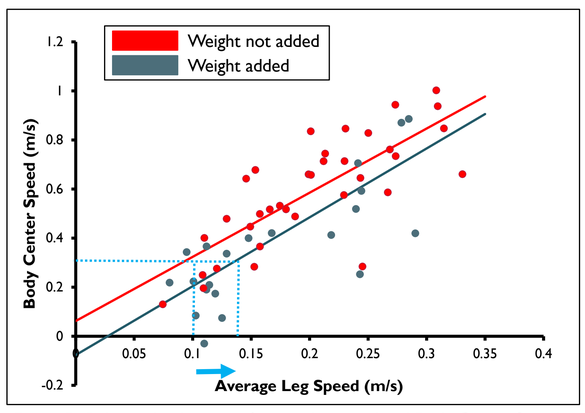

Figure 5. Relationship between Average leg speed and Body Center Speed. *Average angular speed also shows similar relations.*

Average Leg Speed is positively correlated with Body Center Speed ($p<0.001$)(Fig5).

The figure suggests that in order to maintain the body speed at the level similar to the speed before weight was added a weight-added individual should **increase leg speed** . `

However, increased leg speed, as well as increased weight, may both lead to breaking of water surface (Yang et al. 2016), which is not good for efficient jumping. In order to decrease chances of surface breaking weight-added individuals should **decrease leg speed**

WHAT DO WATER STRIDERS DO?

2. Water striders react differently to treatment by changing their leg movement speed

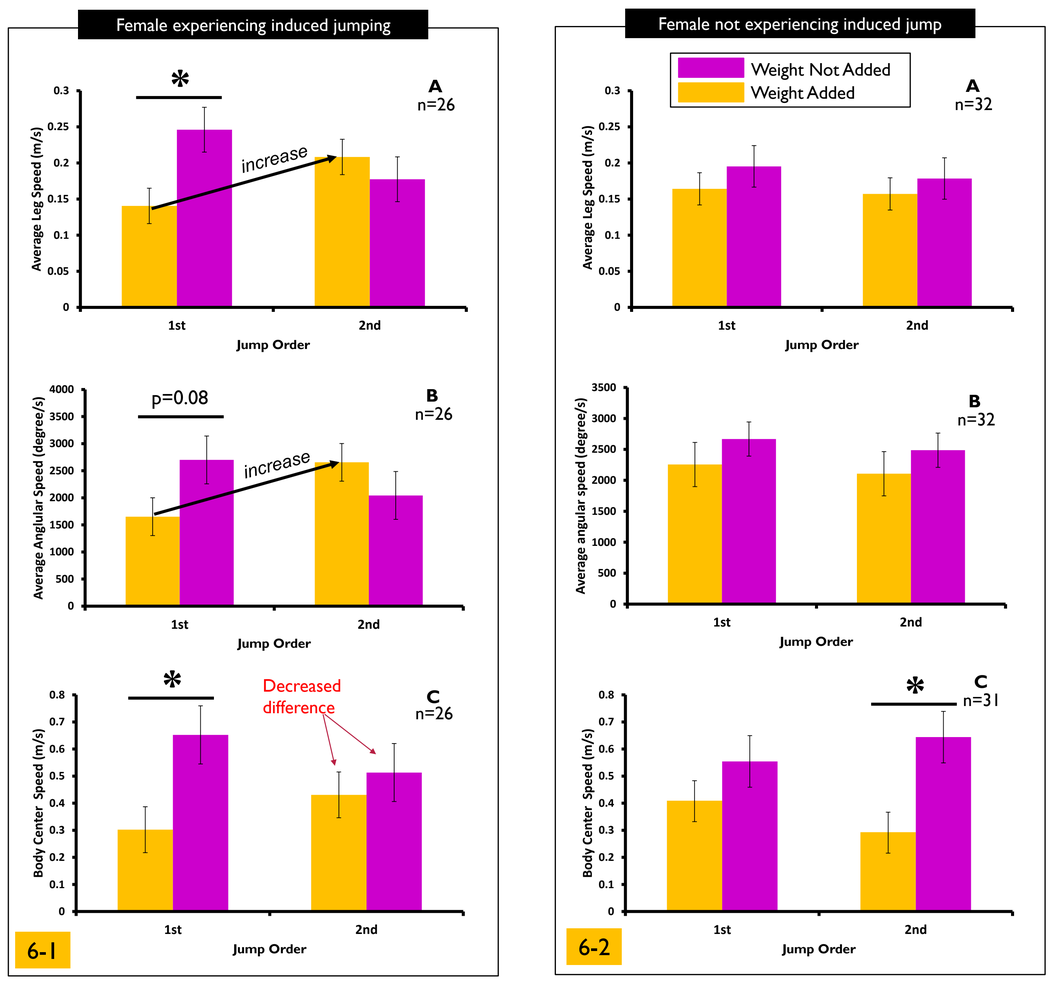

Figure 6. Effects of weight adding and jump induced treatment on (a) average leg speed (b) average angular speed (c) body center speed. (6-1) induced-jumping female (6-2) no-induced-jumping female

* In response to adding a weight females immediately **slowed down** their leg movements (Fig. 6-1: A- significant; B- marginally significant). This resulted in slower jump speed (Fig. 6-1 C).
* After 3 days of induced jumping the weight-added females, unlike no-weight-added females, increased their speed of leg movements in comparison to the first day (interactions weight * order significant in Fig. 6-1, A and B at $p<0.04$)
* Body speed was slower in weight-added females right after adding the weight (in first jump: $t=2.56$, $p=0.0265$), but this difference disappeared after 3 days (in the second jump: $t=0.6$, $p=0.5588$). For no-induced-jumping females, the differences increased after 3 days (Fig. 6-2C)

Conclusions

- Inducing jump treatment made weight-added-female water striders increase their leg speed and resulted in faster body movement. This adjustment compensate for the decrease in body speed caused by weight adding treatment. This adjustment did not statistically affected the risk of surface breaking (results not shown here).
- **Results suggest that female water striders can adjust to their new body weight by individual experience (Induced jump)**

Further questions

- ✓ Do males, and do other species, also adjust their jumping to additional weight through experience?
- ✓ Why experienced group shows different speed of leg movement with weight treatment in the first jump attempt?