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Wing loading functions and wingbeat frequency of local synanthropic dipteran fly *Musca domestica* Linn. (Diptera: Muscidae)

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Abstract
The synanthropic fly, *Musca domestica* was locally collected and reared, and were used to study the correlations between wingbeat frequency, body weight, wing loading and wing area. Wingbeat frequency tended to decrease with increase in body mass, length, and wing area in both sexes The body was significantly longer in females (7.40±.02 mm) than in males (7.27±.03 mm), $t_{158.973}$=-3.86, p<.001. Similarly, the wing length ($t_{172.89}$=--13.78, p<.001) and wing area ($t_{182.225}$=--5.54, p<.05) was also significantly larger in females than in males. However, wing width ($t_{192.765}$=--11.10, p=.121) and wing loading ($t_{197.376}$=1.26, p=.43) were not statistically significantly different between males and females. Wing width and wing area showed statistically significant linear relationship (p< .001) with positive correlation for both sexes. Regression for the linear relationship between *Musca* male wing width and wing area was calculated to be y = .678 + .87x and for females y = 1.083 + .149x. Analysis of wing length and wing area also showed statistically significant linear relationship (p< .001) with positive correlation for both sexes. Regression between WBF and wing loading indicated negative relationship, meaning that the wingbeat frequency tends to drop with increase in wing loading. The wing loading in *M. domestica* ranged from 0.99 to 1.37 and 1.06 to 1.78mgmm^{-2} in males and females respectively with means of 1.37±.14 and 1.34±.13 mgmm^{-2}. There was fairly moderate positive correlation between wing loading and body mass in both sexes. Wingbeat frequency and wing loading in dipterans reflects are important parameters influencing flight dynamics, and they depend directly on various morphometric parameters of the insect wing and body.

Keywords: *Musca*, *Sarcophaga*, wingbeat frequency, wing loading

Introduction

Synanthropic flies live in close proximity to humans and are usually associated with unsanitary conditions. More than 50 species of such synanthropic flies have been reported to be capable of transmitting pathogens either mechanically or biologically through this close relationship. Species of flies in the families Muscidae, Calliphoridae, and the Sarcophagidae have evolved to live in close association with human development. Being synanthropic, their niche overlaps and they compete for resources. The intense competition among the fly species results in unique species packing due to resource continuum (Majumdar *et al*, 2011) [5]. Dipteran flies are impressive flyers of class Insecta,.and for them flight is as vital as for any winged insect, as it impacts longevity and fitness, the ability of forage and hunt, compete for a mate and evade predators (Mathew, 2017; Pollack, 2017) [6,7]. Fundamental knowledge on the behavioral aspects of insects is more important today than ever, not only because of academic interest, but also because of recent advances by means of which control or eradication of pest species is possible. Although aerodynamics of insect flight has been extensively researched, the flight characteristics of flies at regional local habitat levels has received less attention. Kinematic mechanism of aerodynamics and several other factors determine and govern the survival and efficiency of many insect vectors. Wingbeat frequencies (WBF) and wing loading is a function of several characteristics such as, body weight and size, wing structure, and metabolic condition, etc. It is usually observed that mass-specific metabolic rates and wingbeat frequencies both decline with increasing body mass. However, there may be several other factors, and not the body mass alone that is responsible for species variation in metabolic rate or wingbeat frequency (Darveau *et al*, 2005) [3]. Similarly, wing loading in insects is a key factor in determining how well an insect can maneuver while flying, and it is the ratio of an insect's body mass to the total area of its wings.

House flies (*Musca domestica* L.) belong to the order Diptera, family Muscidae; and are cosmopolitan, ubiquitous, synanthropic insects that have long been considered mechanical or biological vectors for various microbes, due to their coprophagous habits (West, 1951) [13]. Adults carry numerous kinds of pathogens which causes serious diseases in humans. The larvae cause myiasis, which can be oral, pelvic, intestinal, cutaneous, scalp, furuncular, and umbilical (Upakut, 2017) [11]. In agricultural settings, adult flies are the prime nuisance pest associated with dairy and other confined animal facilities (Hinkle & Hickle, 1999) [4]. Strict control measures are needed to manage the fly numbers below the action threshold, at which pathogen transmission or nuisance to humans and/ or animals occurs (Upakut, 2017) [11]. This present study on morphometry and wing loading aspects of local *Musca* in the eastern part of Uttar Pradesh in India, is an effort to understand the aspects of this insect's flight.

Materials and method

Insect Collection and rearing

Dipteridae member, *Musca domestica,* were captured using an insect collecting sweep net. Collection was done during March-April at locations frequently sighted around like, fruit juice stands and chicken shops, in the eastern part of the state of Uttar Pradesh, India (26.85°N 80.91°E). The species was identified and reared according to Sahin *et al* (2024) in controlled environment at 27±2°C in a 12:12 LD photoperiod at 60% relative humidity in Centre for Environmental and Applied Entomology (CEAE) Lab, Department of Zoology, St. Andrew's College.

Free flight wingbeat frequency recording

The recordings of 100 flies each of each sex were carried out at 27±2°C and 60% relative humidity in BOD chamber in microphone equipped 250ml container. The audio produced during flight was recorded at sampling rate of 44.1 kHz at 16-bit resolution using high-quality condenser microphone connected to a PC through a four-channel Behringer U-Phoria UMC404HD USB audio interface. The audio was recorded in wav. format without data compression. The microphone was placed within the bioclimatic chamber and a single allowed, one at a time, to fly freely within. Audio sample clips were taken of about 15 second duration. The flies were allowed spend time in the cabin along with the recorder. The filtered audio files were analysed using spectrogram analysis (Mathew & Singh, 2017) [6].

Morphometric measurements

The weight and physical dimensions were measured after acquisition of wingbeat frequency data, and the latter was done by digital image measurement using ImageJ (Abramoff *et al*., 2004; Rasband, 2018) [1, 8].

Statistical Analysis

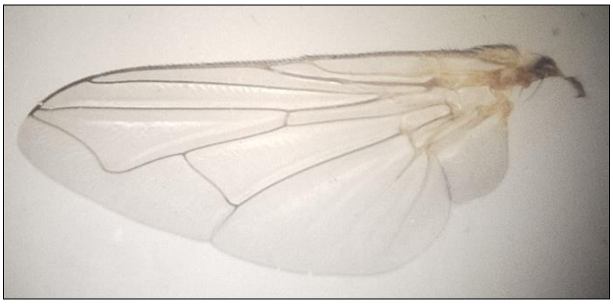
Obtained data were subjected to appropriate statistical analysis using SPSS Statistics version 20.0 (SPSS Inc., Chicago, IL, USA) statistical analysis software. Tests for normality and independent samples t-tests were performed. Both simple and multiple linear regression analyses were conducted to determine the relationships between morphological variables, wingbeat frequency and wing loading.

Observation and results

As already observed by Ujma *et al* (2024) [9]**,** t-test revealed that *Musca* flies had statistically significantly higher wingbeat frequency, mean±SE (268.46±.99 Hz) than females (263.45±.73 Hz), $t_{182.146}$=4.067, p<.05. It tended to decrease with increase in body mass, length, and wing area in both sexes (Fig.2). Although the body mass ranged from 14 to 28mg, with females generally heavier than the males, there was no statistically significant difference between the body weights of *Musca* males (22.37±.25 mg) and females (23.14±.24 mg), $t_{197.936}$=-2.20, p=.874. The WBF was found to increase with decrease in body weight in both sexes, with the slope steeper for males. The body length was greater and statistically highly significant in females (7.40±.02 mm) than in males (7.27±.03 mm), $t_{158.973}$=-3.86, p<.001. Similarly, the wing length ($t_{172.89}$=--13.78, p<.001) and wing area ($t_{182.225}$=--5.54, p<.05) was also greater and statistically highly significant in females than in males. However, wing width ($t_{192.765}$=--11.10, p=.121) and wing loading ($t_{197.376}$=1.26, p=.43) were not statistically significantly different between males and females (Fig.1).

Analysis of wing width and wing area showed statistically significant linear relationship (p< .001) with positive correlation for both sexes. The direction of relationship was positive, and the magnitude, or strength of association was stronger in males (r^2 linear=.919) than females (r^2 linear=.765). Regression for the linear relationship between *Musca* male wing width and wing area was calculated to be y = .678 + .87x and for females y = 1.083 + .149x. Analysis of wing length and wing area also showed statistically significant linear relationship (p< .001) with positive correlation for both sexes. Correlations between wing loading and body length showed different trends in male and females. Regression between WBF and wing loading was also performed and showed negative correlation (r^2 linear>.3) in both sexes. The direction of relationship was negative, meaning that the WBF tends to drop with increase in wing loading. The wing loading in *M. domestica* ranged from 0.99 to 1.37 and 1.06 to 1.78mgmm^{-2} in males and females respectively. The wing loading values (mean±SD) were 1.37±.14 and 1.34±.13 mgmm^{-2}. The wing width and wing area showed statistically significant linear relationship (p< .001) with positive correlation for both sexes. There was fairly moderate positive correlation between wing loading and body mass in both sexes (Fig.3).

(a) Male



(a) Female

Fig 1: Wing of *Musca domestica*

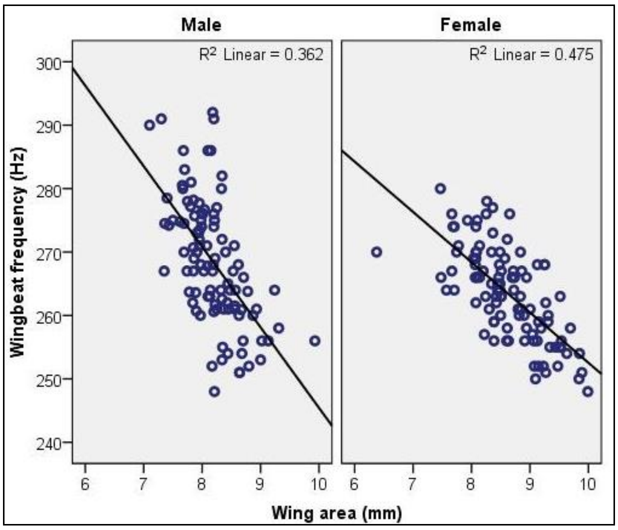


Fig 2: Correlation between wingbeat frequency and wing area of *Musca domestica*

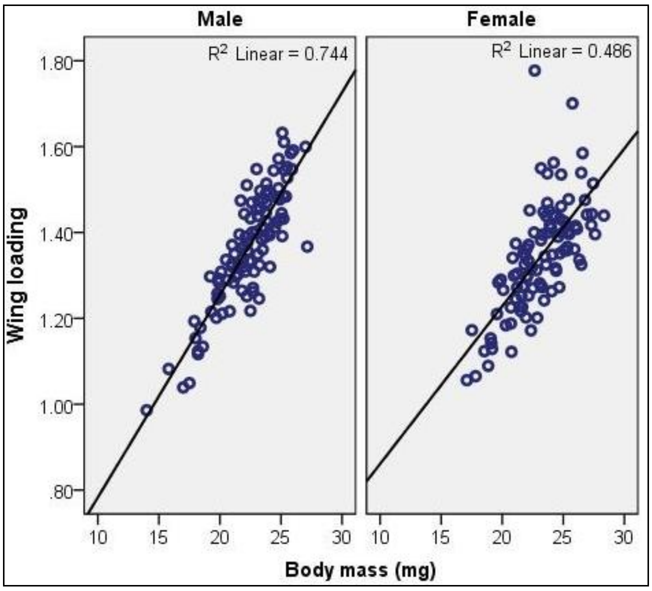


Fig 3: Correlation between wing loading (mg/mm^{-2}) and body mass of *Musca domestica*

Discussion

In this study the wing loading of *M. domestica* was found to be affected by morphometric variables. Wing shape was also found to differ between sexes in several parameters. In insects the wingbeat frequency tends to vary with body mass and wing area within and between species, from 5.5 Hz to over 1000 Hz (Tercel *et al*, 2018) [10]. It is an important variable when considering the biomechanics and physiology of insect flight (Vogel, 2013) [12]. Variables such as wing length, wing area, wing loading (body mass/wing area), wingbeat frequency and stroke amplitude can differ substantially with body mass and are significantly affected by the energetics and biomechanics of insect flight. The wing loading feature showed some differences between sexes but was not significant statistically. Females showing higher wing loading clearly hints to the fact that their body mass is larger and has a greater impact. Wing loading was not much dependent on body length. Wing shape data also suggest sexual dimorphism and this is supported by other earlier studies (Bagbag, 2024) [2].

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