Forensic Science International 270 (2017) 129–138

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Optimising crime scene temperature collection for forensic entomology casework

Ines M.J. Hofer[a], Andrew J. Hart[b], Daniel Martín-Vega[c], Martin J.R. Hall[c,*]

[a] Department of Pharmacy and Forensic Science, King's College London, 150 Stamford Street, London SE1 9NH, United Kingdom
[b] Forensic Services, Metropolitan Police Service, 109 Lambeth Road, London SE1 7LP, United Kingdom
[c] Department of Life Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, United Kingdom

ARTICLE INFO

Article history:
Received 18 August 2016
Received in revised form 18 October 2016
Accepted 9 November 2016
Available online 17 November 2016

Keywords:
Forensic science
minPMI estimation
Stevenson Screen
Temperature data logger
Body temperature
Logger placement

ABSTRACT

The value of minimum post-mortem interval (minPMI) estimations in suspicious death investigations from insect evidence using temperature modelling is indisputable. In order to investigate the reliability of the collected temperature data used for modelling minPMI, it is necessary to study the effects of data logger location on the accuracy and precision of measurements. Digital data logging devices are the most commonly used temperature measuring devices in forensic entomology, however, the relationship between ambient temperatures (measured by loggers) and body temperatures has been little studied. The placement of loggers in this study in three locations (two outdoors, one indoors) had measurable effects when compared with actual body temperature measurements (simulated with pig heads), some more significant than others depending on season, exposure to the environment and logger location. Overall, the study demonstrated the complexity of the question of optimal logger placement at a crime scene and the potential impact of inaccurate temperature data on minPMI estimations, showing the importance of further research in this area and development of a standard protocol. Initial recommendations are provided for data logger placement (within a Stevenson Screen where practical), situations to avoid (e.g. placement of logger in front of windows when measuring indoor temperatures), and a baseline for further research into producing standard guidelines for logger placement, to increase the accuracy of minPMI estimations and, thereby, the reliability of forensic entomology evidence in court.

1. Introduction

The study of insects and other arthropods in a medico-legal context, also known as forensic entomology, is an essential tool in legal cases, especially in death enquiries [1]. Traditional forensic pathology methods for time of death estimation, using post-mortem changes such as rigor mortis, reach their limits within 48–72 h after death [2]. At that point forensic entomology becomes particularly important as knowledge of insect biology, ecology and identification can provide information such as post-mortem body relocations, environmental conditions at death occurrence and, most importantly, estimation of a minimum post-mortem interval (minPMI), i.e. the minimum time elapsed since death occurred, equivalent to when the indicator insects first infested the body. Recognition of the importance that insect specimens found on or in proximity to human cadavers are considered physical evidence and should be processed as such has been reported in the literature repeatedly over the years [3,4]. In forensic entomology, as in all branches of forensic science, a common frame of guidelines and standards for collection, packaging and transport, preservation and identification of insect evidence is essential to ensure good practice and applicability in legal cases [4–6]. It is important that these guidelines and standards are always amended to what is understood as 'best practice' to date.

The effects of seasonal temperature variations on decomposition of remains have been reported in a study in 2004, which observed that higher temperatures and rain increased decomposition rates [7]. As insect evidence involves working with living organisms, these are, naturally, influenced by external factors that determine their growth and development. The main factor influencing insect development rates and adult behaviouris temperature, because they are poikilothermic, i.e. their internal body temperature fluctuates with varying ambient temperatures [8,9]. The importance of temperature in entomological

* Corresponding author.
E-mail addresses: Ines.MJ.Hofer@outlook.com (I.M.J. Hofer), Andrew.Hart2@met.pnn.police.uk (A.J. Hart), d.martin-vega@nhm.ac.uk (D. Martín-Vega), m.hall@nhm.ac.uk (M.J.R. Hall).

http://dx.doi.org/10.1016/j.forsciint.2016.11.019
0379-0738/

investigations has been reported repeatedly in literature relating to this subject area — Hall et al. [10] provide a list of relevant publications. Not only is knowledge of scene temperatures essential for accurate minPMI estimations, it is also important for estimations of the pre-appearance interval (PAI) in insect succession patterns [11,12]. Developmental rates vary between lower and upper temperature thresholds specific to each species, and can cease completely if the temperature falls below or rises above these, respectively [13]. Temperature development rates may also vary within the same species among different geographic regions.

Blow flies (Diptera: Calliphoridae) are used predominantly in forensic entomology for minPMI estimations by use of larval lengths as 'biological clocks' [10,14]. The insect species mainly studied for forensic entomological purposes in the UK are the most commonly occurring blow fly species: *Calliphora vicina* Robineau-Desvoidy, 1830, which can be active in all seasons, *Calliphora vomitora* (Linnaeus, 1758) and *Lucilia sericata* (Meigen, 1826), both of which can be found only from early spring to late autumn. The minimum temperature threshold for development of *C. vicina*, the most common blow fly in urban areas in the United Kingdom, has been estimated to be 1 °C by Donovan et al. [14] and, based on their data, a variation in temperature of just ±1 °C at average temperatures of 21 °C can significantly affect the duration of development by ±5%. Thus, it is essential that the recording and analysis of temperatures affecting insect development provide accurate data for estimating development periods and hence minPMI [15].

For accurate estimations of minPMI it is therefore crucial to obtain measurements with the best possible confidence of the actual temperatures the insects developing on the body experienced at the scene [10]. However, this is complex because the relationship between ambient temperatures, measured by scene loggers, and body temperatures is poorly studied and there can be many confounding factors such as larval mass temperatures. The formation of larval masses inside cadaverous material can cause an increase in temperature, affecting both the body's decomposition rate and the larval development rate — this has been studied with increasing sophistication, but it is still difficult to account for on a case by case basis [10,16–21]. Suggestions for improvement in temperature estimation include optimal temperature data collection methods to increase accuracy of minPMI estimations as well as assessment of the reliability of data variability in different environmental and geographical conditions, seasonal differences, microhabitats, circumstances of death and decomposition rates [22,23]. Other studies have looked at the relationship between temperatures recorded at scenes and those recorded at the nearest meteorological stations, with the objective of establishing a reliable relationship so that ambient scene temperatures can be estimated from meteorological station data [24–26]. However, the relationship between ambient and body temperatures has been little researched and that is the focus of the present study.

In the UK the current recommended practice for temperature data collection at outdoor crime scenes in forensic entomology is the use of temperature data logging devices protected by a Stevenson Screen (SS) [10]. A SS is a naturally vented shelter designed for protecting meteorological devices against environmental conditions, mainly direct sunlight, which could influence and alter measurements. The SS can be made of wood or plastic and is available in many different sizes. The SS often used in forensic entomology casework in the UK is smaller than those used in meteorological observations as it is specifically designed for sheltering small digital data loggers (e.g. ACS-5050 Datamate Weather Screen; Fig. 1 — see unsheltered pig head).

Recent studies suggest that different factors, such as size of a SS [27] and sheltering/non-sheltering of data loggers [28], can have an impact on logger performance. The former study showed that medium-sized wooden SS tended to provide approximately 0.5 °C higher daily maximum air temperatures than large-sized SS, while the latter study concluded that data logger results are inaccurate when measurements are made without shelter or under shelters that do not meet World Meteorological Organization criteria. Currently, there is a lack of studies dealing with optimal logger positioning at crime scenes. This is a potentially important factor that, if optimised, could improve current practices in entomological casework used by police forces and/or forensic entomologists attending crime scenes. Furthermore, assessing and increasing the accuracy of estimating body temperature retrospectively from measurements of ambient temperature is essential in strengthening forensic entomological estimates made from insect evidence.

The applicability of forensic entomology in legal and medical cases relies on an emphasis of good practice using a common framework of guidelines and standards [1,4], with the improvement of data collection being an important factor in increasing inference strength and optimising results [29]. However, no standard practice protocol includes guidelines for where to place temperature collection devices at crime scenes. The objectives of this study were to investigate the accuracy of estimating body temperatures using the current practice in ambient temperature measurement at crime scenes (data logger sheltered in a SS) in comparison with unsheltered data loggers exposed to the environment in different locations at a scene. The results provide guidelines for optimised scene temperature collection with regards to measurement device location for practical applications by police forces and forensic entomologists, in casework and research. This optimisation will aim to increase the accuracy of minPMI estimations and therefore contribute to their validity and the ability of expert witnesses to defend the application of forensic entomological evidence in casework in court [30].

2. Material and methods

2.1. Experimental design

The natural body orifices, including those of the head, are the sites of initial blow fly colonization [2], where significant larval masses can form. Therefore, heads of adult pigs (4.7–7.2 kg; source, Turner & George, London) were used as a model for the heads of human cadavers [31,32]. Hourly temperature data, measured on the hour twenty-four times a day, was collected from in and around the heads using factory calibrated Tinytag Plus 2® data loggers. The heads were placed in the environment at 14:00–15:00 h on day 1 and checked each day at 10:00, 12:00, 14:00 and 16:00 h in the summer or at 12:00 in the winter. During each checking period the heads were carefully examined visually and the presence of adult activity or of fly eggs was recorded. The measurements were conducted over a period of eleven days (N = 10). The first five replicates were carried out from 16.06.2015 until 04.09.2015, and were termed the 'summer experiment'. The second five replicates were carried out from 22.09.2015 until 27.11.2015, and were termed the 'winter experiment'.

The collection of temperature data from pig heads was performed under the three following different environmental conditions on a 0.88–2.90 m wide balcony, 26.74 m above ground level, of the southwest tower of the Natural History Museum in London, United Kingdom (Fig. 1):

- Outdoors on the balcony in an area exposed to sunlight from approximately 11:00–17:00 h daily (unsheltered).