Leoh Pei Wen, Lorraine
Year 4
Business Administration

A Singaporean's Guide to Mosquito Bites

The Singaporean student experience can be best described with the scent of mosquito repellent patches. Ever since I was in primary school, it was commonplace to see all my classmates donning colourful circular patches of mosquito repellent on days we had learning journeys outside of school. Owing to our tropical climate, mosquitos thrive in Singapore and many of us fall victim to the insufferable itch of mosquito bites when we spend the day outdoors.

Growing up, I've always heard from my mother that my Type-O blood and my propensity for sweet treats made my blood "sweet-tasting" and resulted in my countless mosquito bites, essentially becoming the "mosquito magnet" of my friends and family. Even to my adolescent brain, this explanation sounded like it was rooted in fiction, hence, I decided to satisfy my curiosity and dive deeper into the real reason behind my exceptional attractiveness to mosquitos.

Introduction

Its endemic status, coupled with the expectation that dengue cases will peak in the coming months, have resulted in people being more sensitive than ever before when it comes to a mosquito bite. So, what makes some people more attractive to mosquitos than others? Moreover, what can one do to protect themselves against mosquitos, especially in the coming months with the looming threat of dengue?

To answer that question, we must understand the complexity of our skin microbiome, and what exactly in our skin microbiome attracts mosquitos, before analysing the mosquito-human interaction. Lastly, we will also take a look at solutions to prevent or rather, minimise mosquito bites and determine its effectiveness.

The Skin Microbiome

The skin is the largest organ of our bodies, and billions of bacteria, fungi and viruses live on our skin to protect us against potential pathogens and environmental issues. Bacteria like *Staphylococcus epidermidis* and *Corynebacterium* species produce biofilms and maintain skin's moisture levels to protect the skin from the growth of harmful microbes (Boxberger et al., 2021). Other commensal microbes can communicate with our immune system to respond to potential pathogens by producing antibiotics to prohibit colonisation of the pathogen. For instance, *Staphylococcus lugdunensis* produces the antibiotic lugdunin to prohibit the growth

of *Staphylococcus aureus*, one of the leading causes of skin and soft tissue infections (Byrd et al., 2018).

As the skin lacks many nutrients typically found in other environments like our intestines, microbes on the skin have adapted to utilise resources found in sweat, sebum and on the stratum corneum (outermost layer of epidermis). For example, *Staphylococcus* species have evolved to be halotolerant, meaning they can survive in environments with high salt content such as sweat on skin (Byrd et al., 2018). Hence, the skin microbiome hosts a diverse community of microbes, each with unique adaptations to survive on our skin.

Just like the gut microbiome, the skin microbiome is unique to each individual, and furthermore, its composition changes depending on many intrinsic factors (such as skin site, age, and gender) and extrinsic factors (such as lifestyle, hygiene routine, and geographic location).

1 Skin Site

Depending on the type of microenvironment, different bacteria thrive on different parts of the skin. Moist sites like the bend of our elbows and toe webbing on feet were found to have a relatively higher abundance of *Staphylococcus* and *Corynebacterium* species, as these bacteria thrive in humid environments. Meanwhile, sebaceous microenvironments such as our foreheads were dominated by *Propionibacterium* species, linked to skin conditions like acne. On the other hand, dry sites like our forearms showed a mixed population of bacteria (Byrd et al., 2018). Interestingly, fungi compositions on the skin microbiome were found to be relatively similar despite their ecological conditions.

2 Age

As we age, the conditions of the skin change, such as the increase in spots and wrinkles, epidermis thickness, and pH level. Conversely, we observe a decreasing level of sebaceous gland activity and collagen and elastin in the skin. This affects the aforementioned skin microenvironment and can alter the composition of bacteria found in the skin microbiome. For example, the decreased production of sebum would result in lowered nutrients available for lipophilic bacteria like *Cutibacterium*, hence leading to a relatively higher abundance of such bacteria in elderly women (Ratanapokasatit et al., 2022).

3 Lifestyle & Hygiene Routine

Depending on our daily activities or profession, our skin microbiome can be affected. People who work in outdoor environments, like farmers, have constant contact with soil and water, and their skin microbiome was found to be dominated with environmental bacteria such as *Rhodobacteraceae* and *Nocardioidaceae*. On the other hand, city dwellers likely led sedentary lifestyles and stayed indoors, and their skin microbiomes were found to be dominated by

Staphylococcus, *Propionibacterium*, and *Streptococcus* (Skowron et al., 2021). Together with urbanisation, diversity in the microbiome typically decreases due to stricter hygiene habits.

4 Seasonality

Environmental conditions like temperature, humidity, and UV radiation may alter our skin microbiome. In particular, prolonged or intense exposure to UV radiation is shown to destroy skin cells, disrupting the skin's homeostasis and increasing our susceptibility to infections. Microbes like *Cyanobacteria* are resistant to UV exposure due to its ability to produce UV-absorbing compounds, and we can see a relatively higher composition of *Cyanobacteria* in UV-exposed skin microbiomes (Burns, et al., 2020).

Combining the above factors, it is likely that people living in sunny Singapore would sweat more and have higher sebaceous activity due to our humid climate. This would result in greater compositions of *Staphylococcus, Streptococcus,* and *Propionibacterium* in our skin microbiome as compared to people living in colder, dryer climates. Moreover, depending on individual characteristics such as age, use of cosmetics, and hygiene routines, this composition could change further to produce our own unique skin microbiome composition.

Our Attractiveness to Mosquitos

Mosquitos thrive in our tropical climate, and the most common species include the Aedes, Culex, and Anopheles mosquito. However, each of these common species are potentially dangerous in their own right – its females being carriers of diseases like dengue, Japanese encephalitis, and malaria respectively. Interestingly, mosquitos are not attracted to the literal "smell" of our blood, but a combination of odours produced from skin bacteria. Mosquitos interpret these odours through olfactory receptors to guide their flight, landing and feeding. These human signals are known as kairomones, which are volatile products released by sebaceous, eccrine, and apocrine glands metabolised by our skin bacteria (Ellwanger et al., 2021). Essentially, bacteria on our skin produce a combination of volatile compounds that attract mosquitos depending on the composition of our skin microbiome, amongst other factors like pregnancy, plasmodium infection and more.

Skin Microbiome: There are over 500 volatile organic compounds produced by our skin microbiome (Showering et al., 2022), and it's likely a unique combination and abundance of odours which complete our unique scent markers and determine our susceptibility to mosquito bites. Research has shown that skin bacteria like *Staphylococcus epidermidis* and *Corynebacterium minutissimum* produce mosquito attractants like butyl acetate. We can assume that people who have high susceptibility to mosquito bites have relatively higher sweat activity, as *Corynebacterium* dominates skin sites with a higher concentration of eccrine and apocrine (sweat) glands. Furthermore, only this bacteria is capable of transforming skin lipids into volatile compounds causing odour (Verhulst et al., 2010).

Environment: While mosquitos exist in all corners of Singapore, where we live is also a decisive factor in how susceptible we are to mosquitos. NEA has released a map highlighting areas with a higher mosquito population such as Ang Mo Kio and Toa Payoh (NEA, 2023). Unsurprisingly, it is mainly residential neighbourhoods that are swarmed with mosquitos given that breeding sites of mosquitos are typically found in close proximity but outside of homes (eg. in stagnant water in containers or plants). Hence, living in neighbourhoods with a high mosquito population would increase one's susceptibility to mosquito bites.

Socioeconomic Status (SES): Moreover, our susceptibility to mosquito bites also depends on our lifestyle and social environment. People who have relatively higher SES and live, work and sleep in air-conditioned environments are less likely to be bitten in home environments given that the act of cooling the air and shutting the windows would decrease humidity and temperature in the home, thus reducing the likelihood of mosquito breeding and abundance (Fernandez et al., 2023). On the other hand, people who are less privileged, such as foreign workers living in dormitories, are particularly susceptible given their cramped living conditions and humid environment without air-conditioning. Even as far back as 2007 during a dengue outbreak, foreign workers made up almost 40% of dengue cases, likely as a result of their living conditions allowing infected mosquitos to continue feeding and mass infecting other workers living in the dormitories (TWC2, 2016). We can see from the recent Covid-19 outbreak in dormitories that the living conditions are still cramped and too suitable for hungry mosquitos looking for their next meal.

How to Prevent the Bite

Unfortunately, our susceptibility to mosquito bites is likely to remain stagnant throughout our lives (Ellwanger et al., 2021). Moreover, there is no fool-proof way to prevent mosquito bites – unless you have superhuman-level reflexes and mastered the ability of killing every mosquito that lands on you before it bites. Despite this, there are some commercial products that help to reduce the likelihood of a mosquito bite.

The most popular one being mosquito repellents containing DEET (or N,N-diethyl-meta-toluamide), which are effective and come highly recommended by NEA. It works in at least two ways: repelling mosquitos by its smell and taste. The latter results due to mosquitos having taste receptors on their legs, deterring them from biting even when landing (Letzter, 2019). Spray-on mosquito repellent containing 98% DEET was highly effective compared to other natural methods (citronella, organic repellent) or other concentrations of DEET repellent (7%, 25%). On initial application, the 98% DEET repellent resulted in a significantly reduced attraction of mosquitos of 10% compared to the control of 61%. Four hours from application, the 98% DEET repellent was able to offer maximum protection, attracting just 14% of mosquitos (Rodriguez et al., 2015). Other than DEET products, products containing picaridin may be even more effective as mosquitos are unlikely to even land on skin containing

picaridin (Brink, 2018). Hence, be sure to pack a DEET repellent for days when you will be enjoying the great outdoors to prevent the itch.

Other more unconventional preventative methods would include avoiding fragrances or products containing decanal and undecanal. These compounds are kairomones and are volatile compounds produced by sebaceous glands on our skin, attracting mosquitos to land and bite. Known for its sweet or floral citrus scent, decanal and undecanal are popular aldehydes found in beloved perfumes like Chanel No°5, Chanel No°22 (Fessi, 2022), and other fragrant products like the Air Wick Automatic Air Freshener Spray in Pure Sparkling Citrus (CPID, n.d.). It is important to note that while decanal and undecanal are mosquito attractants, research shows that other factors are likely at work when the mosquito draws closer and decides whether to land. But to stay on the safe side, it might be time to retire that classic Chanel perfume.

Conclusion & Reflections

Ultimately, mosquitos will always be a part of Singapore's ecosystems, given our humid climate and urban environment. How we choose to co-exist with these pesky insects depends on our perceived susceptibility to mosquito bites. Given the talks of an upcoming spike of Dengue cases, it seems that it is more vital than ever to stay protected, especially if you have pre-existing medical conditions or are elderly, or are living with people who are. Moreover, it is important to address the larger issue of our socioeconomic status being linked to our susceptibility to mosquito bites to ensure that no population in Singapore is particularly predisposed to illness, as we have seen in countless public health crises previously.

Unfortunately, there is no cure for dengue nor is there a concrete solution to prevent all mosquito bites, but through understanding our unique skin microbiome and other external factors that affect our attractiveness to mosquitos, perhaps we can take action to protect ourselves better and practice greater caution starting today.

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