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Allergenic Properties of Hair Portion of House Dust Mites

Edho Yuwono [a], Jessica Levina [a], Ronny [a] and Forman Erwin Siagian [a*]

[a] *Department of Parasitology, Faculty of Medicine, Universitas Kristen Indonesia, Jakarta, Indonesia.*

Authors' contributions

This work was carried out in collaboration among all authors. Author FES designed the study, performed the literature analysis and wrote the first draft of the manuscript. Author Ronny managed the isolation of house dust mites from fresh dust sample and conduct detailed analyses of the study. Authors EY and JL taking the microscopic appearance of house dust mites and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: to propose the house dust mite's hair or setae contribution of causing allergy in vulnerable people, and starting with its biological positioning among other insect.

Discussion: House dust mites (HDM) are allergenic arthropods for atopic individuals. The most common species of HDM are *Dermatophagoides farinae, Dermatophagoides pteronyssinus, and Euroglyphus maynei*. with preference to humid, warm and temperate climates, that responsible for allergy episodes in atopic individual. Beside their feces, allergenic properties also found in house dust mite's shed skin and decaying bodies. Along their shedding exoskeleton, its hair or setae perhaps also contributes to or even augment the allergogenic properties. Insect setae, which are hair-like structures on the insect's body, have a wide range of functions beyond simple sensory perception. These functions include defense, locomotion, camouflage, and pheromone dispersal. In

**Corresponding author: Email: forman.siagian@uki.ac.id;*

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the context of house dust mites, at least there are three condition that might facilitate the setae's potency to cause allergy, including easily to detach, anatomical location and its homeostatic function. Further focused research need to be conducted in order to explore the mechanism of its setae in causing or at least contributing to its allergogenic properties in order to support the hypothetical we proposed.

Keywords: Setae; sensilla; bristles; allergogenic; sensory; protective; Dermatophagoides farina; Dermatophagoides pteronyssinus.

1. INTRODUCTION

House dust mites (HDM or DM) possess allergenic properties (Aggarwal & Senthilkumaran, 2022). It is a predominant source of indoor aeroallergens (Thao et al., 2023). Some of the allergic diseases that have been associated with the HDM are allergic rhino-conjunctivitis (Imoto et al., 2024), allergic asthma (Caraballo, 2024), and atopic dermatitis (Bumbacea et al., 2020). This insect's excrements and body parts contain proteins that act as allergens (Vrtala, 2022), triggering allergic reactions in hypersensitive atopic individuals (Krupka Olek et al., 2024), particularly through inhalation; HDM, either proteolytically active or inactive, acts as an adjuvant favoring allergenic reaction to other substance such as egg white (Benedé et al, 2025) a condition of which simultaneous sensitization to two or more allergens occur at the same time (Sideneus et al., 2001).

People are primarily exposed to these allergens by inhaling them when dust is disturbed, such as during bed-making or vacuuming (Wilson & Platts-Mills, 2018). When inhaled, these allergens can trigger an immune response in sensitive individuals, leading to various allergic symptoms (Bumbacea et al., 2020; Thao et al., 2023; Imoto et al., 2024; Caraballo, 2024). Dust mite allergens can persist in the environment, especially in areas with high humidity (Arlian et al., 1999) and dust accumulation in conjugation with lost human epidermis (Strzelczyk, et al., 2020), making them a whole season attention. Avoidance of allergens is actually a recommended environmental method in the prevention of inhaled allergy symptoms (Strzelczyk, et al., 2020).

House dust mites produce allergens primarily concentrated in their feces (Rutten, 2018), which contain proteins that are highly allergenic (ovey et al., 1981; Rutten, 2018). Dust mite excrements contain undigested food particles and digestive enzymes (Bessot & Pauli, 2011; Thomas, 2015; Rutten, 2018; Sarwar, 2020), which are highly potential to trigger allergic reactions (Miller, 2019). Their small size facilitates their spread, making them to become airborne effortlessly, and also enabling them to be readily inhaled. These proteins can also be found in their body parts and shed exoskeletons (Thomas, 2015; Aggarwal & Senthilkumaran, 2023).

Beside their feces, allergenic properties also found in house dust mite's shed skin and decaying bodies (Sidenius et al., 2002; Sarwar, 2020). These allergens can become airborne when disturbed (de Blay et al., 1991) and increased the risk of exposure (Eggleston, 2005) and also inhaled, which can further provoke allergic reactions. The body, legs and mouth apparatus actually bear various hairs (Bergmann, 2022), which are differently noticeable in all dust mite species (Sarwar, 2020). The possible functional significance of the hairs has still debatable to date and this paper aimed to proposed its hair contribution of causing allergy in vulnerable people, and starting with its biological positioning among other insect.

2. SHORT DESCRIPTION ON THE BIOLOGY OF HOUSE DUST MITE

Any attempt to describe the house dust mites would lower than complete without a brief overview of its classification and also its biological positioning relationship to other arthropods. The subphylum Arthropoda is generally classified into four extant subphyla: Chelicerata (arachnids, horseshoe crabs, etc.), Crustacea (crabs, lobsters, etc.), Hexapoda (insects, springtails), and Myriapoda (centipedes, millipedes) (sollai, et al., 2024). An additional subphylum needed to be mention was the unfortunate extinct subphylum, Trilobitomorpha, includes the trilobites in rock enroll (Chipman & Drage, 2023).

House dust mites are arthropods belonging to the subphylum Chelicerata, class Arachnida, order Acari, suborder Astigmata. Other suborders of mites can be further classified into Mesostigmata, Metastigmata (ticks), Prostigmata, and last but not least Oribatida (Arlian & Platts-Mills, 2001). The chelicerae that belongs for the house dust mite are pincer-like and armed with both movable and fixed digits (Chang & Kaufman, 2005). For comparison, other chelicerates have either stylet-like chelicerae adjusted for piercing (e.g., spider mites and chiggers) (Mullen & Vetter, 2019) or sickle-shaped chelicerae function in grasping, cutting and also tearing (Schmidt & Melzer, 2024) which dangerously making the host skin's vulnerable (e.g., as the one used by ticks to reach under the host's skin) (Richter, et al., 2013). In addition to the mites, the subphylum Chelicerata also accommodate such familiar groups as spiders, scorpions, mites, and ticks, as well as an array of bizarre and unfamiliar forms (Sharma, 2018). On the other hand, some classifications used to group insects, centipedes, and millipedes all belong to the subphylum Uniramia (Ramzan, 2024), but unfortunately this classification is not always universally accepted. But at least on that account, some experts postulate that mites can be considered not intimately related to insects. Mites, while often resembling insects in very basic and general form, exhibit distinct differences in morphology and physiology feature (Chown & Terblanche, 2006). In particular, guanine is the main nitrogenous waste excreted by arachnids, including mites (Pauli et al., 1988), whereas terrestrial insect's excrement largely consists of uric acid (Ren et al., 2022), as a breakdown of purine. Because of the differences in physiology, some common insecticides and growth regulators applied successfully to control insect populations (Singh & Kumar, 2024) are unfortunately lack in effectivity for controlling dust mite populations (Downing, et al., 1990).

in the natural environment, the acari are actually a very variegated group of organisms that have exploited some unusual microenvironments where their adaptations include specialized feeding habits that modify its morphology adaptation (Liu et al, 2021), host's condition (Retzinger & Retzinger, 2024) resistance to harsh conditions (Rojas-Cabeza, et al., 2025), and compensatory behavioral mechanisms to enhance resource utilization (Tian, et al., 2020). For instance, some species infect:

1. Human, e.g., inhabit the hair follicles of humans (Smith, et al., 2020) and the human skin due to scabies mites (Paichitrojjana, 2022),
2. Animal, e.g., the nasal passages of birds and mammals (Hilario Perez, 2016), the trachea of insects such as found in ground beetle (Carabidae) (Gudowska, et al., 2016), the skin scales of reptiles (Mendoza-Roldan, et al., 2020), the feathers of birds (Doña, et al., 2019), and the list still continue.
3. Plant (as a plant parasite which commonly starts as spontaneous vegetation as reservoir for predatory mites) some of which are major pests for mango (Abo-Shnaf, et al., 2022), apple (Rode, et al., 2024), strawberry (Zhou, et al., 2020), citrus (Affandi & Corpuz-Raros, 2005), rice (Kayal, et al., 2021), and the list continue.

The abundance and variation of its preference are very enormous. Many species of mites are actually blood- or fluid-feeding ectoparasites of poultry (Ribeiro, et al., 2023), mammals, and reptiles (Wang, et al., 2022) and can transmit diseases, such as Lyme disease (ticks) (Gulia-Nuss, et al., 2016) and scrub typhus (chiggers) (Elliott, et al., 2019). Some live in root, leave and soil litter (Bluhm, et al., 2019), where they are function as natural predators that play a significant role in soil ecosystems as predators of other soil-dwelling organisms (Beretta, et al., 2022), and also function as trophic interaction with fungal and detritus feeders (Velez, et al., 2018).

In the context of our focus, the house dust mites belong to the suborder Astigmata and family Pyroglyphidae (Bergmann, 2022). Nonetheless, mites belonging to other families are also present in house dust, and they often referred to as "domestic mites" (Cui, 2014) and include mites from the Glycyphagidae (Wurst & Pfsiter, 1990), Acaridae (Skelton, et al., 2007) and Chortoglyphidae families (National Center for Biotechnology Information, 2025). Besides that, predatory mites (Cheyletidae) (Zhou, et al., 2022) may also be present in domestic setting.

Astigmatid mites are atypical in the condition of lacking well organized respiratory systems and associated external openings for ventilation (Bergmann, 2022). Even though they are aerobic organisms but unfortunately they don't have specialized organs for gas exchange and apparently exchange O_2 and CO_2 through their general body surface by passive diffusion across their cuticle (Portnoy, et al., 2013). Anatomically, all mites (Acari) belong to the arthropods (arthropods) and here to the arachnids

(Arachnida: Chelicerata), are divided into a variety of orders especially under the aspect of the formation of their respiratory openings: Astigmata (none), Prostigmata (anterior), Cryptostigmata (hidden), Mesostigmata (middle), Metastigmata (posterior). Domestic mites all have well-developed and sophisticated systems of respiration, digestion and water balance, enabling them to live and survive in the various habitats of houses.

Astigmatid heteromorphic nymphs also lack a mouth, and so oral feeding is not possible. Still, feeding as a parasite can occur during phoresy via the attachment organ suckers, anus or genital papillae (Sendi, et al., 2025). Their favorite and primary source of food came ultimately on human or pets skin scales and other organic detritus that collects in homes (Sarwar, 2020; Bergmann, 2022). At least there are several species have been found in house dust, three of which are very common in homes worldwide and are the major source of mite allergen (Krzysztof, 2011). The most common of these species are *Dermatophagoides farinae, Dermatophagoides pteronyssinus,* and *Euroglyphus maynei* (Sarwar, 2020), with preference to humid, warm and temperate climates (Gwiazdowicz, 2021).

In tropical setting, the storage mite *Blomia tropicalis* (Family Echymyopodidae) can be an endemic mite in house setting dwellings (Guilleminault &Viala-Gastan, 2017), also along with other Pyroglyphid mites (Sánchez, et al., 2017; Sarwar, 2020). In addition to the previously mentioned species, other astigmatid mites (storage mites) may be isolated in homes and are a potent source of allergens (Krzysztof, 2011; Thao, et al., 2023). Most notable are species in the families Acaridae (*Tyrophagus putrescentiae* and *Acarus siro*), Glycyphagidae (*Glycyphagus domesticus* and *Lepidoglyphus destructor*), and Chortoglyphidae (*Chortoglyphus ancutatus*) (Fernández-Caldas, et al., 2007). Predaceous mites (e.g., Cheyletus spp) (Henszel, et al., 2010) may also be found in homes. The significance of these as sources of indoor allergens (Bumbacea, et al., 2020; Vrtala,2022; Thao et al., 2023; Aggarwal & Senthilkumaran, 2023) is yet to be clearly determined.

House dust mites are typically about 0.1–0.4 mm in size, and as a consequence of their small, diminutive size, mites (Acari) are able to exploit specific habitats and ecological niches unavailable to larger arthropods (Mullen & ‘O Connor, 2019). Storage mites can grow to approximately 0.6 mm in size (Vrtala, 2022) and as their counterparts the house dust mite, both are thus pragmatically unnoticed to the naked eye.

A prominent characteristics of the mites is the extensive abolition of the segmentation of their bodies, a significant reduction in external segmentation, particularly in the adult stage, which is characteristic of arthropods (e.g., insects). As the consequences, the clear boundaries between the head (caput), thorax, and hindquarters (abdomen) is impossible to be delineated (Bergmann, 2022). Adults and nymphs have four pairs of legs, larvae only three pairs of legs. The legs are composed of six limbs. The basal limb is fused to the body. The soles of the feet have great absorbency, allowing the mites to hold many times their body weight even on smooth surfaces (Waldvogel, et al., 2025). The body, legs and mouth apparatus bear numerous hairs, which are differently pronounced in all mite species (Bergman, 2022) and will be briefly discussed in the next section.

3. COMMON FUNCTION OF INSECT’S HAIR

Hair-like shape and composition are ubiquitous throughout insect’s biology properties and frequently function to sense or adjust or even alter interactions with an organism's environment (Seale, et al., 2018). The universal shape of a hair is basically plains: a cylindrical, straight, long, filamentous structure that originated from the inner part of the superficial facet of an organism; it is actually hair structure that affecting hair appearance (Nagase, 2019). Hair commonly consists of hierarchical fibers in a cortex surrounded by cuticle scales (Yang, et al., 2020) and this typical consistency may provide a wide array of functions, due to its flexibility and large superficial portion that it usually retains and covers. Due to this straightforward structural basis, a slight modifications in hair geometry, such as flexure, caliber, shaft and also inter-hair spacing, may enhance its mechanical capabilities, which adding functions such as attachment capabilities (Eimüller, 2008), mechanosensing (Chakilam, et al., 2020), physical barriers used for defense and protection (Sugiura & Yamazaki, 2014) and last but not least also motion or gesture which already stimulate the scholars to apply it in the advancement of mechanosensing in artificial systems, such as robotics. (Boublil, 2021).

In the context of higher insect, insect hairs, also known as setae or sensilla, are varied between species. Most arthropods have many hairs, often packed together at an unusually high density. Functional explanations for this high density depend on the type of hair (Casas, et al., 2010). It was proven that the abundant density of small setae in the foot of many insects ensure full contact establishment (Ji, et al., 2011) which results in increased adherence which is advantageous for their survival (Rajabi, et al., 2021), whereas a huge integer of aquatic arthropods such as marine crustaceans also use hairs for sensing and feeding (Hood et al., 2019) and terrestrial arthropods apply hair as biological machine for particle capture, flying or swimming (Seale et al., 2018).

Setae or sensilla has a variety of functions, basically as (1) sensory functions, (2) protective functions and (3) other non-sensory protective function, which will be described further as follows:

3.1 Sensory Function

3.1.1 Mechanoreception

Setae which are sensory apparatus (Vittori, et al., 2018) widely used to detect mechanical stimuli like touch, taste, smell (Winterton, 2009), vibration, and air currents (Boublil, et al., 2021) are called tactile hair (Barth, et al., 2004). They can be specialized to perceive different types of stimuli, such as benign touch (French & Torkkeli, 2009), wind velocity (Palmer, et al., 2021) and direction {Palmer, et al., 2023), or even sounds (Boublil, et al., 2021).

3.1.2 Chemoreception

Some setae are chemoreceptors, allowing insects to detect chemicals in the environment (Fonseca et al., 2024; Sokolinskaya, et al., 2020). These can be olfactory which means the capability to sense airborne chemicals (Rieder, 1987) or gustatory which refers to the ability to perceive chemicals in food or liquids (Garm, et al., 2003).

3.1.3 Thermoreception

Setae can also be used to sense temperature changes and practically for the blood-sucking arthropods utilize multimodal information for sensing and recognizing its potential hosts. The specific heat discharged by the body of endothermic vertebrates constitutes a major cue for correct orientation (Lazzari, 2019).

3.1.4 Proprioception

Proprioception or the sense of physical self is an important feature of living organism. This proprioceptive sensing maintenance by setae, which can can help insects sense the position and movement of their own body parts, contributing to balance and coordination (Gebehart, et al., 2022).

3.2 Protective Function

3.2.1 Defense

Setae can be modified to provide physical protection against its enemies (Yano & Shirotsuka, 2013). Some setae are barbed (Ruzzier, et al., 2020) or poisonous (Poinar & Vega, 2019) and sometime called urticating hair (Battisti, et al., 2011), while others species generate a physical barrier that is difficult to penetrate or in other words principally as physical protection against predators. For example, *Hylesia metabus*, a species of moth, endemic mainly in the region of northeastern Venezuela. Female moths apply their abdominal setae to cover their egg masses. Exposure with these setae surely can produce a severe dermatitis in vulnerable humans. Setae from males actually do not cause these type of symptoms. Rodriguez, et al., reported that egg masses not covered by setae were examined and transported by Pheidole ants, whereas covered eggs were largely avoided (Rodriguez, et al., 2009). The morphology of the S3 and S4 setae types suggests that these may be related to the urticating properties reported for the moth. Ant avoidance of setae covered eggs suggests that these protect the eggs from at least some predators. In the context of self-defense, setae also help regulate body temperature. Setae, like the hairs or bristles found on some insects, can reduce the rate of convective heat exchange, but they do not eliminate it entirely. They primarily act as insulators, slowing down heat transfer through convection, but failed to block it completely (Casey, 1992).

3.2.2 Camouflage

The arrangement and structure of setae can help an insect blend into its environment, providing camouflage (Lianos, et al., 2022).

3.2.3 Grooming

Some type of setae can do the self-cleaning, e.g., like the one in Gecko, a type of lizard (Hu, et al., 2012), removing debris and preventing fouling which facilitated by its hydrophobicity properties (Bello, et al., 2022).

3.3 Other Non-sensory Protective Function

3.3.1 Locomotion

Setae which located on legs and other body parts of insect can facilitate its grip and traction (Voigt, et al., 2017), aiding in movement on various surfaces (Federle & Labonte, 2019).

3.3.2 Dispersal

Setae can aid the dispersal of pheromones (McKinney, et al., 2015) or other important chemical signals., by playing a crucial role in their basic communication and behavior. These hair-like structures, located on various body parts, house chemosensory neurons that detect specific chemical signals and trigger appropriate responses (Fleischer & Krieger, 2018).

3.3.3 Glandular-like secretory function

Some setae are associated with glands and may have other functions like lubrication to reduce friction (Cheng, et al., 2022) or secretion of substances (Urbanek, et al., 2011).

3.3.4 Support and flight

In insects, setae can play a role in supporting flight, detecting airflow patterns, and preventing stall (Bloublil, et al., 2021). Hairs specialized to detect airflow and trigger mechanosensory responses are often called sensory hairs or filiform hairs. These hairs are highly sensitive to even slight air movements and are found in various animals, including insects and bats. When deflected by air, they stimulate receptor cells at their base, sending a signal to the nervous system.

As previously mentioned, insect hairs, particularly those found on caterpillars and other arthropods, can indeed be allergenic, causing a range of reactions from mild skin irritation to severe, life-threatening anaphylaxis. These hairs, often barbed or needle-like, can penetrate the skin and release toxins, leading to inflammation, itching, and pain. The possible functional significance of the hairs of house dust mite has not been clarified to date but we proposed its allergenic potency in the next section.

4. PROPOSED ALLERGENIC POTENCY OF THE HAIR OF HOUSE DUST MITES

House dust mites (HDM) are a major cause of indoor allergies, with their allergenic potency stemming from specific proteins. These proteins, particularly Der p 1 and Der p 2, are the most common triggers for allergic reactions in sensitized individuals (Thomas, 2015; Thao, et al., 2023). The allergenic potency of HDM extracts can vary, and is often measured in terms of the concentration of these major allergens and their ability to induce an allergic response.

The main source of allergens in house dust mites (HDM) is their feces, shed skin and decaying body parts (Sidenius et al., 2002; Sarwar, 2020). These microscopic particles, containing previously mentioned specific proteins (Thomas, 2015), which become easily airborne when disturbed and can trigger allergic reactions in susceptible individuals.

Dust mite excrements specifically contain mixed undigested food particles and digestive enzymes (Bessot & Pauli, 2011; Thomas, 2015; Rutten, 2018; Sarwar, 2020), which are highly allergogenic (Miller, 2019). These specific allergogenic proteins can also be found in their body parts and shed exoskeletons (Bergmann, 2022).

House dust mites have specialized bristle-like hairs called setae. These setae are important for identification and are used to distinguish between different species of mites, including the common house dust mites, *Dermatophagoides pteronyssinus* and *Dermatophagoides farina* (Thao, et al., 2023). The setae on the dorsal (upper) side of the mite are typically long and serrated, while the ventral (lower) side has different arrangements of setae, including anal setae, which can be used to differentiate between male and female mites. Unfortunately, our literature searching regarding existing studies that investigates allergenic proteins in setae is lacking and unavailable.

House dust mites possess stiff, bristle-like hairs called setae, which are visible under a microscope. These setae are a key feature of their external structure and help in identification. The setae are distributed across the mite's body, with some longer than others. Hair or setae of the house dust mites also has the potency to precipitate even to augment the allergenic response in atopic individuals. The reasons for the statement are as follows:

Fig. 1. Setae of house dust mites, made from fresh dust sample (courtesy of Dept. of Parasitology, Faculty of Medicine, Universitas Kristen Indonesia, Jakarta-Indonesia)

1. Easily to detach: Dust mites, like other arthropods, molt as they grow, shedding their outer layer of skin or exoskeleton as they become mature. This process releases various components, including its setae. During shedding off their skin (ecdysis), their setae (bristles or hairs) on the part of detach skin can also detach from their bodies (Bessot & Pauli, 2011; Thomas, 2015; Rutten, 2018; Sarwar, 2020; Bergmann, 2022). These shed tiny microscopic parts, along with their feces, are a crucial component of house dust and commonly mixed together thus making it a perfect allergen for atopic individuals (Miller, 2019; Thao, et al., 2023). Their small size facilitates their spread, making them to become airborne easily, and also enabling them to be readily inhaled (Strzelczyk, 2020). Even after fifty years of storage, abandoned dust kept from the early study of house dust mite at the year of 1964, and in 2014 it is still detected, both the mites and also the allergens (Bergmann, et al., 2014)
2. Anatomical location: House dust mite's setae, which are bristle-like structures on the mite's body, are primarily located on the legs, particularly on the tarsi (the last segment of the legs). They also appear on other parts of the body, including the dorsal (upper) surface and around the genital and anal openings in both male and female mites. The structure and arrangement of setae vary between the sexes and are used in identification. Setae are found on all legs, with the sub tarsal seta being replaced by a pectinate (comb-like) seta on the tarsi. While on the dorsal surface, dorsal setae are found and described as long and serrated (whip-like), except for one specific seta (d2). Setae of the genital region are present around the genital opening, which is located between coxae III and IV (leg segments) while setae of the anal region of female house dust mites, there are 6 pairs of anal setae, while males have 3 pairs. Setae can also be found on other parts of the body, contributing to the overall structure and function.
3. Homeostatic function: Setae play a crucial role in the mite's ability to move, sense its environment, and reproduce. The specific structure of setae, such as the pectinate seta on the tarsi, helps the mite grip surfaces and move around effectively. The sensory setae likely help the mite detect changes in its environment, such as humidity and temperature, which are important for its survival. The genital setae are important for reproduction. In the context of homeostasis of house dust mites, their setae also play an indirect role in causing allergies.

The three statements above still need to be studied in more depth, especially in the context of isolating the allergogenic protein type and quantity of setae, how fragile and easily detached the setae are and whether setae in certain anatomical positions (for example near the anal region) play a role in triggering secretion. Although the hypothesis we proposed is actually captivating, it currently still lacks of sufficient direct experimental or observational support. This is the limitation of our review, but in the same time it provides space for the next scholar to explore and reveal the potency and involvement of house dust mite's setae in causing allergy among atopic individuals.

5. CONCLUSION

Insect setae, which are hair-like structures on the insect's body, have a wide range of functions beyond simple sensory perception. These functions include defense, locomotion, camouflage, and pheromone dispersal. In the context of house dust mites, further study need to be conducted to explore the potency of its setae in causing or at least contributing to its allergenic properties.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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