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REVIEW

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Integrated Screening Approach for House Dust Mite Allergy in Low-Resource Settings: Symptoms, Environment, and Dust Sampling

Cahyani Amalia PUTRI[1], Azwin Mengindra PUTERA[2], Deasy FETARAYANI[3]

[1] Medical Program, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[2] Department of Child Health, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[3] Department of Internal Medicine, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia

Corresponding Author: Azwin Mengindra Putera ✉ azwin-m-p@fk.unair.ac.id

ABSTRACT

Allergy caused by exposure to house dust mite (HDM) is a global health problem, with sensitization rates reaching 60-80% among patients with allergic disease. However, access to conventional methods such as skin prick testing and specific IgE remains limited in many regions due to constraints related to cost, infrastructure, and trained personnel. This situation underscores the need for simpler and more affordable screening strategies. Alternative approaches (including symptom questionnaires, household environmental assessments, and low cost dust sampling) can expand screening coverage and enhance detection sensitivity when used in combination. The effectiveness of these approaches depends heavily on instrument validation, integration into primary care services, community health literacy, and policy support. Moving forward, strengthening HDM screening requires three primary pillars: validation of instruments to ensure accuracy across populations; development of risk based algorithms that integrate clinical, environmental, and epidemiological data; and international collaboration to standardize methodologies. Integrating these components has the potential to produce a more precise, affordable, and sustainable screening system, particularly in low-resource settings.

Keywords: House dust mite, allergy, screening, low resource settings, questionnaire, environmental assessment

INTRODUCTION

House dust mites (HDM) allergy is recognized as one of the most prominent global health concerns, particularly as a leading cause of allergic rhinitis and asthma (1). This burden is especially evident in tropical and developing countries, where high humidity, household crowding, and poor indoor air quality create an ideal ecological niche for HDM proliferation (2). These conditions make HDM sensitization highly prevalent, with rates reaching 60-80% among patients with allergic rhinitis in Indonesia (3) and exceeding 70% in Thailand (4). A similar pattern is observed in Latin America, particularly in Colombia, where sensitization rates of 60-80% have been reported among patients with asthma, reinforcing the dominant role of HDM as a major allergen in tropical and subtropical regions (5).

The clinical impact of HDM allergy directly contributes to reduced quality of life and substantial economic burden (6). In Southeast Asia, the annual cost of allergic rhinitis is estimated at USD 1100-2000 per patient, largely driven by productivity loss (7). During periods of severe symptoms, presenteeism has been reported to reduce productivity by more than 60%, underscoring the urgency of addressing HDM allergy as a multidimensional public health issue (8).

Despite the high prevalence, the diagnosis of HDM allergy in low-resource settings continues to face major challenges (1,9). Standard diagnosis methods such as skin prick testing (SPT) and specific IgE measurement require financial resources, laboratory infrastructure, and trained personnel that are not consistently available, resulting in

ORCID Cahyani Amalia Putri / 0009-0002-3249-5290, Azwin Mengindra Putera / 0000-0002-8698-720X, Deasy Fetarayani / 0009-0007-3401-7782

limited diagnostic access and epidemiological data that are often biased toward urban populations (1,9,10).

This gap underscores the need for simpler, low-cost, and context-adapted screening strategies (11,12). Approaches such as symptombased questionnaires, household environmental assessments, and lowcost dust sampling methods offer opportunities to reach broader populations, although their effectiveness depends heavily on instrument validation, integration into primary care, and supportive health policies (13).

Furthermore, future research directions emphasize multidimensional strategies, including instrument validation, development of riskbased algorithms supported by machine learning, and international collaboration to achieve methodological standardization (1). With a strong scientific foundation and adaptive operational innovations, HDM allergy screening has the potential to evolve into a more inclusive, precise, and sustainable system, particularly in countries with low-resource settings.

EPIDEMIOLOGY OF HDM ALLERGY IN LOWRESOURCE SETTINGS

HDM, particularly *Dermatophagoides pteronyssinus* (Der p), *Dermatophagoides farinae* (Der f), and *Blomia tropicalis*, proliferate optimally in warm and humid climates (14). Studies indicate that HDM survival requires a minimum relative humidity (RH) of 50-60%, while their populations increase two to three-fold at RH levels exceeding 70% (15). This condition is further exacerbated by poor household ventilation, which significantly elevates HDM density in Southeast Asia, Latin America, and Sub-Saharan Africa (16). Beyond climatic factors, urbanization in developing countries also contributes to increased exposure through household crowing and air pollution, both of which aggravate allergic symptoms (17,18).

These environmental conditions are reflected in regional epidemiological data. HDM is the dominant allergen among patients with allergic rhinitis and asthma in tropical countries (19). In Southeast Asia, for example, the prevalence of allergic rhinitis in children reaches 20-30%, with more than 70% of patients demonstrating sensitization to HDM (4,20). Country-specific data are similarly consistent: Thailand reports 74% HDM sensitization among patients with allergic rhinitis, Vietnam reports a rate of 62% among children, and Indonesia reports 68-80% sensitization to Der p and Der f (3,4,21). A similar pattern is observed in Latin America, where HDM sensitization among asthma patients with asthma in Colombia reaches 60-80% (5). Globally, HDM is recognized as the leading trigger of allergic rhinitis in children in developing countries, with substantial impacts on quality of life and household economic burdens (3,19).

Despite consistent prevalence data, epidemiological information on HDM allergy in lowresource settings remains limited. Major barriers include restricted access to skin prick testing (SPT) and specific IgE measurement, high costs, and a shortage of allergy specialists (22,23). Populationbased surveys are uncommonly conducted, resulting in available data that predominantly originate from urban referral centers and fail to represent rural populations (10). Low health literacy further contributes to frequent misinterpretation of allergic symptoms, such as recurrent respiratory infections (24). Collectively, these combined create a substantial gap between the actual disease burden and official reports, preventing HDM allergy from becoming a health policy priority in many countries (24,25).

CONVENTIONAL DIAGNOSTIC STANDARDS AND THEIR LIMITATIONS

Internationally, the diagnosis of HDM allergy relies on a combination of SPT and serum specific IgE measurement as the primary conventional methods (26). SPT is considered the gold standard for initial screening as it offers rapid, sensitive, and costeffective assessment, with results available within 15–20 minutes (27). Multicenter studies report SPT sensitivity ranging from 70% to 90%, although its specificity is lower (40-60%) due to extract variability and biological factors. In contrast, specific IgE assays (such as ImmunoCAP or ELISA) provide quantitative results with high specificity and sensitivity of 60-85%, and are unaffected by antihistamine or skin conditions (28). Receiver operating characteristic (ROC) analyses demonstrate an area under the curve of 0.8-0.9, reinforcing its role as a confirmatory diagnostic method (29).

From a cost and turnaround-time perspective, SPT is substantially more affordable (USD 5-15 per panel), whereas specific IgE testing is more expensive (USD 20-60 per allergen) and requires 1-7 days due to laboratory processing (30,31). These differences make SPT more feasible for initial screening, while specific IgE testing is used for diagnostic confirmation and monitoring during immunotherapy. A comparative summary of both methods is presented in Table I (31,32).

However, in lowresource settings, the constraints of cost, limited laboratory access, and scarcity of trained specialist restrict the use of these conventional methods. Therefore, alternative screening approaches, such as standardized symptom questionnaires, household environmental assessment, and pointofcare rapid tests, are needed as preliminary strategies capable of reaching broader populations (33-35). Although these approaches do not replace conventional diagnostics, they primarily serve as an initial pathway to identify atrisk individuals before referral to more comprehensive diagnostic facilities (1,9). To provide a more structured overview of the stage screening and management, these processes are summarized in the algorithm in the presented in Figure 1.

ALTERNATIVE SCREENING TOOLS IN LOWRESOURCE SETTINGS

SymptomBased Questionnaires

Symptom-based questionnaires serve as essential initial screening instruments for detecting the likelihood of HDM allergy, particularly in resourcelimited settings. The International Study of Asthma and Allergies in Childhood (ISAAC) is the most widely used global questionnaire

Table I: Comparison between skin prick test (SPT) and serum specific IgE (ImmunoCAP/ELISA) (31,32).

Aspect	Skin Prick Test (SPT)	Specific IgE
Principle	Exposure of the skin to allergen extracts, with reactions observed as wheal/flare.	Detection of allergenspecific IgE levels in serum using immunological methods.
Advantages	▪ Rapid (results within 15-20 minutes). ▪ Relatively inexpensive ▪ High sensitivity. ▪ Applicable to both children and adults.	▪ Quantitative and objective results. ▪ High specificity. ▪ Not affected by antihistamines or skin conditions. ▪ Suitable for monitoring immunotherapy.
Limitations	▪ Requires highquality standardized reagents. ▪ Dependent on trained personnel. ▪ Cannot be performed in patients with severe dermatoses. ▪ Lower specificity compared to IgE assays.	▪ High cost. ▪ Requires laboratories with adequate infrastructure. ▪ Longer turnaround time for results. ▪ Not always available in primary care settings.
Feasibility in Developing Countries	More feasible due to lower cost, though limited by reagent availability and trained personnel.	More accurate, but difficult to access due to cost and laboratory constraints.
Clinical Application	Initial screening for sensitization to inhalant allergens.	Confirmation of diagnosis, evaluation of sensitization levels, and monitoring of therapy.

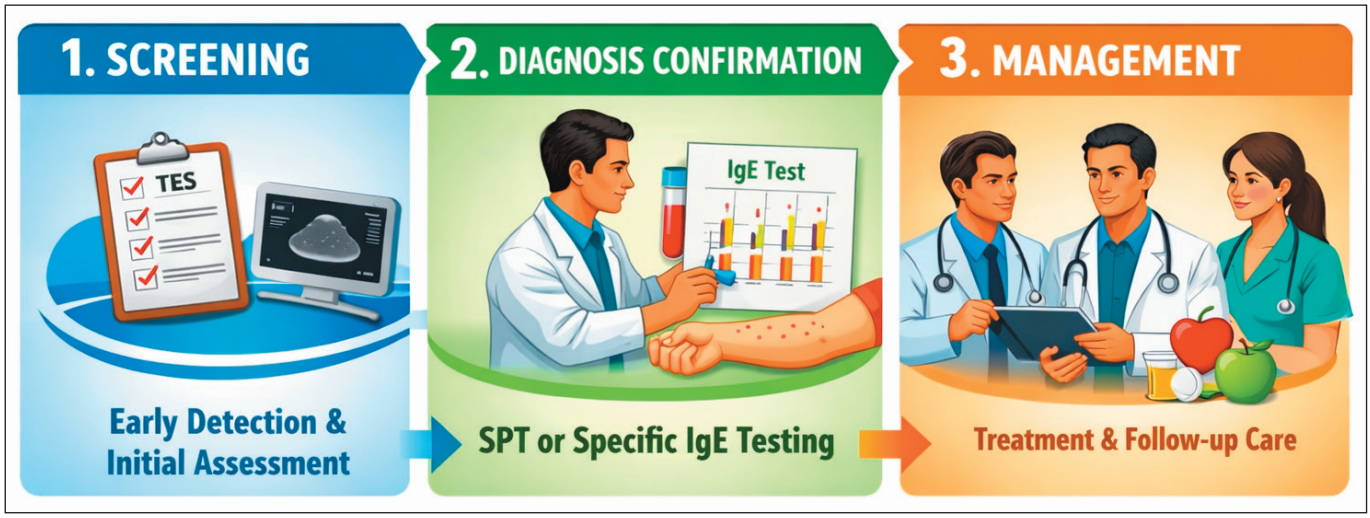

Figure 1: Integrated clinical pathway for HDM allergy evaluation, illustrating the sequential process from screening, diagnostic confirmation (SPT or specific IgE), to management and follow up care in primary care settings.

for assessing symptoms of asthma, allergic rhinitis, and atopic dermatitis (36). Although not specific to HDM, the symptom patterns it captures (such as recurrent wheezing, persistent rhinitis, and chronic dermatitis) often correlate with HDM exposure, making it a relevant tool for populationlevel surveillance (19).

Other instruments, including the Allergic Rhinitis and its Impact on Asthma (ARIA) and the Asthma Control Test (ACT), can complement screening efforts, particularly for identifying allergic rhinitis and asthma control issues frequently influenced by HDM exposure (37,38). In addition, the HDM Allergy Screening Questionnaire offers a more specific approach by assessing symptoms that worsen upon waking, during household cleaning, or when staying in the bedroom. This questionnaire was designed for easy implementation in primary care and is particularly suitable for lowresource settings (39).

Differences in the characteristics of each questionnaire are summarized in Table II (36-39). Based on symptom coverage, international validity, ease of cultural adaptation, and minimal resource requirements, ISAAC is recommended as the primary tool for initial screening (40,41). This instrument enables early identification of at-risk groups before confirmatory testing such as SPT or dust allergen measurement is performed (31).

Environmental Assessment Tools for House Dust Mite Exposure

Screening for HDM exposure risk can be performed through simple assessment of mattress and pillow conditions, the presence of carpets or fabric-covered furniture, natural ventilation, and indoor humidity levels (42,43). Although these observations do not provide direct allergen quantification, their combined evaluation predicts HDM density reasonably well, particularly in low-resource settings (42,44).

Table II: Characteristics, validation, and utility of symptom-based instruments for HDM allergy screening.

Instrument	Purpose	Domains assessed	Advantages	Limitations	Validity and reliability	Relevance for lowresource settings
ISAAC (International Study of Asthma and Allergies in Childhood) (Pedersen, 2020 (36)).	Surveillance of allergic symptoms in pediatric and adolescent populations.	Asthma, allergic rhinitis, atopic dermatitis.	- Used in >100 countries. - Easily adaptable. - Does not require diagnostic equipment.	- Not specific to HDM. - Symptoms are influenced by other environmental factors.	Cronbach's alpha 0.70-0.85	Detects symptom patterns (wheezing, persistent rhinitis, dermatitis) that are frequently triggered by HDM.
ARIA (Allergic Rhinitis and its Impact on Asthma) (37).	Identification of allergic rhinitis.	Symptom frequency, duration, severity, and impact on quality of life.	- Focused on allergic rhinitis. - Demonstrated good clinical sensitivity.	- Not HDM specific. - Requires cultural adaptation.	Sensitivity ~75%, specificity ~80%.	Relevant as allergic rhinitis is most common clinical manifestation of HDM sensitization.
ACT (Asthma Control Test) (38).	Assessment of asthma control.	Daily symptom burden, frequency of exacerbations, and pattern of medication use.	- Easy to administer. - Validate for monitoring purposes.	- Do not assess allergen exposure. - Shows limited correlation with lung-function parameters.	- FEV1 correlation r=0.39 – 0.52. - FeNO correlation r ≈ -0.20.	Relevant as asthma control often deteriorates with HDM exposure.
HDM Allergy Screening Questionnaire (Delphi Consensus, 2025) (39).	Screening for HDM-specific resulting from allergen exposure	Symptoms that worsen upon waking, during house cleaning, or while in the bedroom	- HDM-specific, - Suitable for primary care settings, - Does not require laboratory facilities.	- Limited cross-cultural validation. - Not yet globally standardized.	Sensitivity 65-75%, specificity 60-70% (early validation).	Highly relevant for the rapid identification of HDM exposure and sensitization in lowresource settings.

1) Condition of Mattresses and Pillows

Mattresses and pillows serve as primary reservoirs for HDM due to the accumulation skin flakes, sweat, and moisture trapped within fibers (45). HDM destiny in mattresses has been reported to reach 100-500 mites per gram of dust, particularly in older or infrequently cleaned bedding (15,46). Intervention such as the use of anti-allergen encasings and routine washing of bed linens at a temperature ≥60 ^{0}C can reduce *Der p 1* and *Der f 1* levels by 60-100% (47,48). Although airborne allergen exposure during sleep is relatively low, it increases substantially when present due to particle dispersion into the air (42).

2) Presence of Carpets or Upholstered Furniture

Thick carpets, fabric sofas, and upholstered furniture act as longterm dust reservoirs that are difficult to clean thoroughly. HDM density in carpets may reach 200-1000 mites per gram of dust, while fabric sofas may contain 50-200 mites per gram (15, 49). Plush toys and decorative pillows also serve as additional reservoirs (48). Regular cleaning using HEPAfiltered vacuums, sundrying, or steam cleaning can reduce allergen levels by 40-50%, whereas replacing carpets with hard flooring remains the most effective strategy (44,50,51).

3) Natural Ventilation

Adequate ventilation helps maintain humidity below 50% and reduces airborne allergen concentrations (48). Poorly ventilated rooms retain high humidity that supports HDM reproduction, whereas natural ventilation also reduces the accumulation of mite-related and other indoor pollutants such as mold and volatile organic compounds (15,48).

Humidity Levels

Humidity is the most critical environmental factor for HDM survival. Mite populations increase at RH ≥50% and may expand two- to three-fold at RH >70% (15). Simple indicators that can be used to assess high humidity include musty odors, mold growth (52), and condensation on windows or walls (53). Maintaining indoor humidity below 45-50% is the key strategy for inhibiting HDM proliferation (15,48).

Low Cost Dust Sampling Methods

Lowcost dust sampling methods have been developed as practical alternatives for detecting the presence of HDM in the domestic environment, particularly in low-resource settings. Simple portable vacuum devices have been shown to be effective for collecting dust from mattresses, carpets, sofas, and pillows. Sandel et al. demonstrated that economical vacuum models such as Eureka Mighty Mite (EMM) yield results comparable to those of the highvolume small surface sampler (HVS4), while still providing consistent results for allergen detection, including HDM (54,55). The sensitivity of vacuum sampling has been reported to reach 70-80%, making it a reliable low-cost method. In addition, portable vacuum devices can be obtained for approximately USD 20-40, making them suitable for community-based screening (56).

Other methods, such as sticky tape sampling and swab sampling, are easier to use, whereas they exhibit lower sensitivity. Sticky tape achieves only 30-50% sensitivity, while swab sampling reaches 40-60%, and both methods depend heavily on the skill of the person collecting the sampling (57, 58). Nevertheless, sticky tape remains useful for preliminary screening in remote areas, due to its low cost of less than USD 1 per sample (56). For laboratory analyses such as *Der p 1* or *Der f 1* quantification, a dust volume of 0.1-0.5 gram is sufficient for ELISA-based or simple immunoassay testing (59). The main limitations of low-cost sampling methods include variability in results and lower sensitivity compared with standard methods, meaning they do not always accurately reflect true HDM density (60). Accordingly, low-cost dust sampling methods function primarily as initial screening tools to identify households with potentially high HDM exposure. These methods do not replace standard laboratory diagnostics, whereas they help determine which locations require further evaluation (56,60).

Combined Approaches

A single-method approach is often insufficient to accurately identify the risk of HDM allergy in low-resource settings (1, 42). Therefore, a screening strategies that integrate symptombased questionnaires, household environmental assessments, and lowcost dust sampling techniques provides a more comprehensive risk profile while maintaining low costs and ease of implementation in primary care settings (9, 15, 48). A practical algorithm for this approach is presented in Figure 1 (1,15,48,54).

The recommended stepwise model begins with a symptom questionnaire as an inexpensive and implemented initial filter, suitable for use by general healthcare providers or nonmedical personnel (37,39,61,62). Individuals

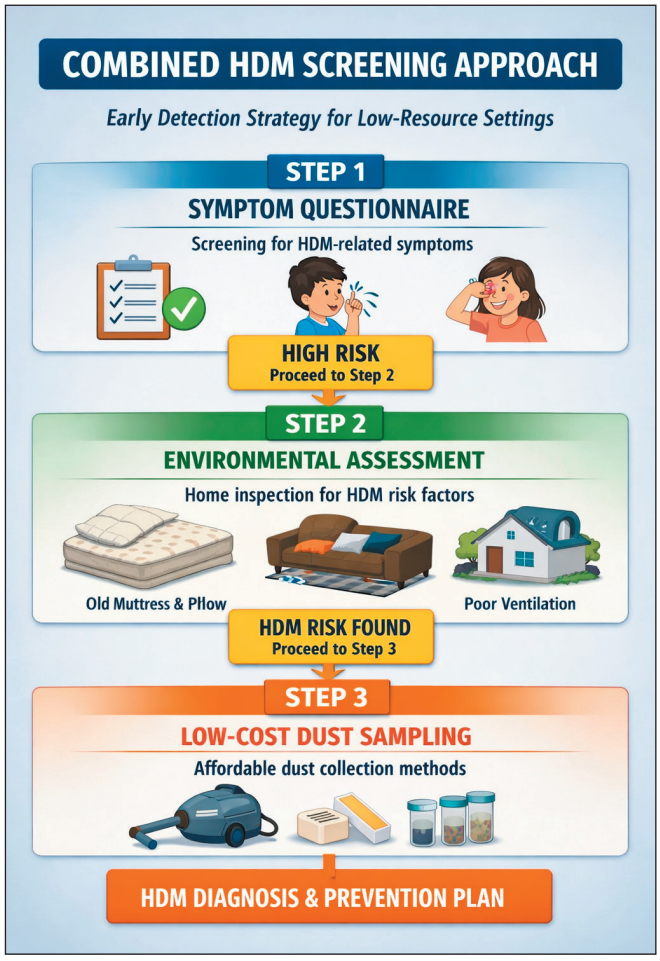

Figure 2: Integrated stepwise algorithm for HDM allergy screening combining symptom questionnaires, household environmental assessment, and low-cost dust sampling to identify HDM exposure for use in primary care settings.

presenting with relevant symptoms can then undergo a household environmental inspection to assess risk factors that cannot be captured through questionnaires alone (15, 63). In high risk cases, lowcost dust sampling methods may be used as an additional step to provide an early indication of HDM allergen presence, particularly in areas lacking access to specific IgE testing or SPT (54,57,58).

This integrative approach offers an optimal balance between accuracy, cost-effectiveness, and feasibility (9). Beyond improving early detection, this strategy also provides opportunities to educate families about modifiable environmental risk factors (45,64). As such, it has strong potential to serve as an effective and sustainable framework for HDM allergy screening in lowresource settings (1,15,48,54).

CHALLENGES and BARRIERS

Implementation of HDM allergy screening in low-resource settings faces several structural challenges that affect both the accuracy and sustainability of programs (15,45,48). Instrument validity, particularly symptom-based questionnaires, is often hindered by cultural and linguistic differences. Variation in the interpretation of medical terminology and suboptimal linguistic adaptation can reduce response reliability and increase the risk of misclassification, especially when instruments are developed in high-income countries (65-67).

Low health literacy further affects data quality. In many communities, understanding of allergy-related concepts remains limited, with health literacy levels ranging from only 30% to 60% (68). This increases the likelihood of self-report bias, including underreporting of symptoms and misperceptions of environmental triggers. As a result, questionnaires often require guided administration or basic education to generate accurate data (69,70).

Human resource limitations also represent a major barrier. Many primary-care providers are not familiar with the fundamentals of inhalant, questionnaire interpretation, or environmental inspection (71). In Southeast Asia, the ratio of general practitioners is only 4-8 per 10,000 population, and the number of allergy-immunology specialist is extremely limited, for example, fewer than 200 in Indonesia (72). Without adequate training, inter-provider variability increases and screening sensitivity decreases (69,70).

Logistical constraints further exacerbate these challenges. Distribution of simple sampling tools is often limited by budget, transportation, and supply-chain issues. Distribution costs for sticky tape range from USD 2-5 per household, while portable vacuum devices cost USD 10-20 per site (56,60). In addition, laboratories capable of performing specific IgE testing are extremely limited (some provinces have only one or two referral facilities) making sample analysis impractical (12). These barriers slow the screening workflow and reduce overall program effectiveness (73).

FUTURE RESEARCH DIRECTIONS

Strengthening HDM allergy screening strategies requires a multidimensional approach that integrates scientific, operational, and collaborative foundations (73). Instrument validation is primary priority, as questionnaires

and lowcost sampling methods are effective when their reliability and accuracy have been demonstrated across diverse populations. The process includes assessments of internal consistency, test-retest reliability, and criterion validity against gold-standards such as SPT or specific IgE testing (74). Diagnostic performance analyses must also account for symptom heterogeneity and variation in environmental exposure. Without robust validation, the risk of misclassification increases, leading to biased estimates of disease burden (75,76).

The development of riskbased algorithms offers opportunities to enhance screening precision. Models that integrate clinical symptoms, exposure history, household characteristics, and local epidemiological data can generate more accurate risk stratification (77,78). However, the success of such algorithms depends on the availability of highquality data, rigorous external validation, and the readiness of health systems to incorporate these tools into screening workflows (1,79).

International collaboration to achieve standardization of screening instruments and methodologies is needed (1). Global consensus on minimum parameters, feasible sampling protocols, and culturally adaptable questionnaire formats would improve data consistency and accelerate global burden estimates (80). Collaboration also enables technology sharing, workforce training, and the development of more inclusive screening instruments (81,82).

Overall, validated instrument, riskbased algorithms, and international collaboration form the foundation HDM screening framework that is more accurate, affordable, and adaptable to the epidemiological diversity and health-system capacities of different countries (83).

CONCLUSION

HDM allergy screening remains a priority in lowresource settings given the substantial burden of allergic rhinitis and asthma in tropical regions. HDM sensitization affects 50-80% of individuals with allergic disease, while access to conventional diagnostic methods such as SPT and specific IgE measurement remains limited due to financial, infrastructure, and workforce constraints. In this context, alternative approaches, including symptombased questionnaires, environmental assessments, and lowcost dust sampling, represent the most feasible strategies for reaching broad populations. The future success of HDM screening relies on three core pillars. First, instrument validation is essential to ensure reliability and accuracy across diverse population contexts, thereby reducing the risk of misclassification. Second, the development of riskbased algorithms that integrate clinical data, environmental exposure, and local epidemiology (including the potential use of machine learning) can enable more precise and efficient risk stratification. Third, international collaboration is needed to strengthen the standardization of instruments, sampling protocols, and allergen cut-off values, while also expanding access to training and technology. Integrating these three components will yield HDM screening systems that are more accurate, adaptive, and sustainable, with the potential to deliver significant public health impact in countries with low-resource settings.

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Conflict of Interest

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