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PROF. CLAUS BACHERT (Orcid ID : 0000-0003-4742-1665)
DR. VICTORIA CARDONA (Orcid ID : 0000-0003-2197-9767)
PROF. ALVARO A CRUZ (Orcid ID : 0000-0002-7403-3871)
PROF. WYTSKE WJ FOKKENS (Orcid ID : 0000-0003-4852-229X)
DR. DÉSIRÉE ERLINDA LARENAS-LINNEMANN (Orcid ID : 0000-0002-5713-5331)
PROF. RALPH MOSGES (Orcid ID : 0000-0002-1928-810X)
DR. NIKOLAOS G PAPADOPOULOS (Orcid ID : 0000-0002-4448-3468)
DR. PETER VALENTIN TOMAZIC (Orcid ID : 0000-0001-6445-4800)
DR. SANNA TOPPILA-SALMI (Orcid ID : 0000-0003-0890-6686)
PROF. OLIVER PFAAR (Orcid ID : 0000-0003-4374-9639)

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Correlation between work impairment, scores of rhinitis severity and asthma using the MASK-air® App

Original article

Short title: Scores in rhinitis and asthma using an mHealth app

Annabelle Bédard PhD (1,2,3), Josep M Antó MD (1-4), Joao A Fonseca MD (5), Sylvie Arnavielhe PhD (6), Claus Bachert MD (7), Anna Bedbrook BSc (8), Carsten Bindslev-Jensen MD (9), Sinthia Bosnic-Anticevich PhD (10), Victoria Cardona MD (11), Alvaro A Cruz MD (12), Wytske J Fokkens MD (13), Judith Garcia-Aymerich MD (1,2,3), Peter W Hellings MD (14), Juan C Ivancevich MD (15), Ludger Klimek (16), Piotr Kuna MD (17), Violeta Kvedariene MD (18), Désirée Larenas-

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Linnemann MD (19), Erik Melén MD (20), Ricardo Monti MD (21), Ralf Mösges MD (22), Joaquim Mullol MD (23), Nikos G Papadopoulos MD (24), Nhân Pham-Thi MD (25), Boleslaw Samolinski MD (26), Peter V Tomazic MD (27), Sanna Toppila-Salmi MD (28), Maria Teresa Ventura MD (29), Arzu Yorgancioglu MD (30), Jean Bousquet MD (8, 31, 32), Oliver Pfaar MD (33), Xavier Basagaña PhD (1,2,3)*, and the MASK study group

1. ISGlobal, Barcelona, Spain.
2. Universitat Pompeu Fabra (UPF), Barcelona, Spain.
3. CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain.
4. IMIM (Hospital del Mar Research Institute), Barcelona, Spain.
5. CINTESIS, Center for Research in Health Technology and Information Systems, Faculdade de Medicina da Universidade do Porto; and Medida, Lda Porto, Portugal
6. KYomed INNOV, Montpellier, France.
7. Upper Airways Research Laboratory, ENT Dept, Ghent University Hospital, Ghent, Belgium.
8. MACVIA-France, Montpellier, France.
9. Department of Dermatology and Allergy Centre, Odense University Hospital, Odense Research Center for Anaphylaxis (ORCA), Odense, Denmark.
10. Woolcock Institute of Medical Research, University of Sydney and Woolcock Emphysema Centre and Sydney Local Health District, Glebe, NSW, Australia.
11. Allergy Section, Department of Internal Medicine, Hospital Vall d'Hebron & ARADyAL research network, Barcelona, Spain.
12. ProAR – Nucleo de Excelencia em Asma, Federal University of Bahia, Brasil and WHO GARD Planning Group, Brazil.
13. Department of Otorhinolaryngology, Amsterdam University Medical Centres, AMC, Amsterdam, the Netherlands, Euforea, Brussels, Belgium.
14. Dept of Otorhinolaryngology, Univ Hospitals Leuven, Belgium, and Academic Medical Center, Univ of Amsterdam, The Netherlands and Euforea, Brussels, Belgium.
15. Servicio de Alergia e Immunologia, Clinica Santa Isabel, Buenos Aires, Argentina.
16. Center for Rhinology and Allergology, Wiesbaden, Germany.

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17. Division of Internal Medicine, Asthma and Allergy, Barlicki University Hospital, Medical University of Lodz, Poland.
18. Institute of Biomedical Sciences, Department of Pathology, Faculty of Medicine, Vilnius University, and Institute of Clinical Medicine, Clinic of Chest diseases and Allergology, Faculty of Medicine, Vilnius, Lithuania.
19. Center of Excellence in Asthma and Allergy, Médica Sur Clinical Foundation and Hospital, México City, Mexico.
20. Sachs' Children and Youth Hospital, Södersjukhuset, Stockholm and Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.
21. Department of Medical Sciences, Allergy and Clinical Immunology Unit, University of Torino & Mauriziano Hospital, Torino, Italy.
22. Institute of Medical Statistics, and Computational Biology, Medical Faculty, University of Cologne, Germany and CRI-Clinical Research International-Ltd, Hamburg, Germany.
23. Rhinology Unit & Smell Clinic, ENT Department, Hospital Clínic; Clinical & Experimental Respiratory Immunoallergy, IDIBAPS, CIBERES, University of Barcelona, Spain.
24. Division of Infection, Immunity & Respiratory Medicine, Royal Manchester Children's Hospital, University of Manchester, Manchester, UK.
25. Allergy department, Pasteur Institute, Paris, France.
26. Department of Prevention of Envinronmental Hazards and Allergology, Medical University of Warsaw, Poland.
27. Department of General ORL, H&NS, Medical University of Graz, Austria.
28. Skin and Allergy Hospital, Helsinki University Hospital, and University of Helsinki, Helsinki, Finland.
29. University of Bari Medical School, Unit of Geriatric Immunoallergology, Bari, Italy.
30. Department of Pulmonary Diseases, Celal Bayar University, Faculty of Medicine, Manisa, Turkey
31. University Hospital, Montpellier, France.
32. INSERM U 1168, VIMA : Ageing and chronic diseases Epidemiological and public health approaches, Villejuif, Université Versailles St-Quentin-en-Yvelines, UMR-S 1168, Montigny le Bretonneux, France, Euforea, Brussels, Belgium, and Charité, Universitätsmedizin

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Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health, Comprehensive Allergy Center, Department of Dermatology and Allergy, Berlin, Germany.

33. Department of Otorhinolaryngology, Head and Neck Surgery, Section of Rhinology and Allergy, University Hospital Marburg, Phillipps-Universität Marburg, Germany.

Address for correspondence:

* Correspondence to: X Basagaña, PhD. ISGlobal, C/ Doctor Aiguader 88, 08003 Barcelona, Spain. Telephone: (+34) 932147306; Fax: (+34) 932147302. E-mail: xavier.basagana@isglobal.org

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Abstract

Background: In allergic rhinitis, a relevant outcome providing information on the effectiveness of interventions is needed. In MASK-air (Mobile Airways Sentinel Network), a visual analogue scale (VAS) for work is used as a relevant outcome. This study aimed to assess the performance of the work VAS work by comparing VAS work with other VAS measurements and symptom-medication scores obtained concurrently.

Methods: All consecutive MASK-air users in 23 countries from June 1, 2016 to October 31, 2018 were included (14,189 users; 205,904 days). Geolocalized users self-assessed daily symptom control using the touchscreen functionality on their smart phone to click on VAS scores (ranging from 0 to 100) for overall symptoms (global), nose, eyes, asthma and work. Two symptom-medication scores were used: the modified EAACI CSMS score, and the MASK control score for rhinitis. To assess data quality, the intra-individual response variability (IRV) index was calculated.

Results: A strong correlation was observed between VAS work and other VAS. The highest levels for correlation with VAS work and variance explained in VAS work were found with VAS global, followed by VAS nose, eye and asthma. In comparison to VAS global, the mCSMS and MASK control score showed a lower correlation with VAS work. Results are unlikely to be explained by a low quality of data arising from repeated VAS measures.

Conclusions: VAS work correlates with other outcomes (VAS global, nose, eye and asthma) but less well with a symptom-medication score. VAS work should be considered as a potentially useful AR outcome in intervention studies.

Key words: asthma, rhinitis, MASK, Visual analogue scale, score

Abbreviations

AR: allergic rhinitis
ARIA: Allergic Rhinitis and its Impact on Asthma
CSMS: combined symptom and medication score
EAACI: European Academy of Allergy and Clinical Immunology

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EQ-5D: EuroQuol

ICT: information and communications technology

IER: Insufficient effort responding

IRV: Intra-individual response variability

MASK: Mobile Airway Sentinel NetworK

SMS: Symptom-medication score

VAS: visual analogue scale

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Introduction

In allergic rhinitis (AR) and asthma, a relevant outcome providing information on the cost-effectiveness of interventions is needed. EQ-5D, a validated measure of quality of life, has been used in AR (1-7) but it cannot be assessed daily.

MASK-air (Mobile Airways Sentinel NetworK) is an information and communication technology (ICT) system centred around the patient (online supplement) (8-13) and operational in 23 countries. It uses a treatment scroll list which includes all medications customized for each country as well as visual analogue scales (VASs) to assess global allergy, rhinitis, eye and asthma control. Over 30,000 users and 250,000 VAS days have been recorded. A pilot study found a highly significant correlation between VAS work and other VAS measurements (global, nose, eyes and asthma) (14).

Symptom-medication scores (SMSs) are also needed to investigate the effect of AR treatments, in particular allergen immunotherapy (AIT) (15). The European Academy of Allergy and Clinical Immunology (EAACI) has defined the combined symptom and medication score (CSMS) for AIT trials (16).

Surveys collect information but data quality is a concern: in particular, insufficient effort responding (IER), a phenomenon by which respondents try to complete the questionnaire with the shortest time without providing reliable information (17). This can result in respondents providing the same value for all questions, which will artificially increase the correlation between items (18). Several methods are used to assess data quality including the intra-individual response variability (IRV) index, a flexible way to detect IER (17).

This study aimed to compare VAS work with other VAS measurements and SMSs obtained concurrently. In order to investigate data quality, we also assessed the IRV index (17).

Methods

Users

All consecutive MASK-air users from June 1, 2016 to October 31, 2018 were included with no exclusion criteria, according to methods previously described (19-21). MASK-air® was used by people who found it on the internet, Apple store, Google Play or in any other way. Some users were clinic patients who were asked by their physicians to use the app. This was the case for the transfer of innovation project (22).

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However, due to anonymization of data, no specific information could be gathered, as previously described in detail (19, 23).

Setting

Users from 23 countries filled in the MASK-air *Allergy Diary* (Table 1).

Ethics

The Allergy Diary is CE1. CE marking indicates conformity with health, safety, and environmental protection standards for products made in the EU and meets the essential requirements of all relevant European Medical Device Directives (24). The data were anonymized.

An independent Review Board approval was not required since the study is observational and users agreed to have their data analysed (terms of use).

MASK-air® and outcomes

Geolocalized users self-assessed daily symptom control using the touchscreen functionality on their smart phone to click on VAS scores (ranging from 0 to 100) for overall symptoms (global), nose, eyes, asthma and work - asked in this order - with several other screens in between (Figure 1 online). Users input their daily medications using a scroll list containing all country-specific OTC and prescribed medications for each country.

Two SMSs were used: the modified EAACI CSMS score (16), accounting for a new medication that did not exist when it was devised (Table 2), and the MASK control score for rhinitis proposed according to existing data (13) (Table 3). Medications considered in the study are detailed in online Table 1.

Statistical methods and analyses

A non-Gaussian distribution was found for the data. Non-parametric tests and medians (and percentiles) were used. Some users reported VAS scores more than once a day and we used the highest level (13).

For each score, we calculated and compared: (i) the within-subject correlation with VAS work (calculated using fixed-effect models using the Stata xtreg command) and (ii) the variance explained in VAS work (which corresponds to the correlation measured in (i) squared). Only person-days with a reported VAS work were tested. Differences in correlations by gender, age (above *versus* below median age – i.e. 32 years-old) and season (pollen season – i.e. from March 15 to the end of June, *versus* the period outside pollen season – i.e. from August to December) were investigated. Regarding VAS asthma, since not all

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users are asthmatic, a lot of non-asthmatic users will fill in a VAS asthma of 0 (no missing information is allowed) when using the app. Therefore, differences in the correlation between VAS work and VAS asthma by asthma status were investigated.

The intra-individual response variability (IRV) index was calculated, based on answers to the five VAS scores, to detect IER (17). All person-days were tested. The IRV is the standard deviation of responses across a set of consecutive item responses for an individual. It is an indicator of insufficient effort responding.

The number of days of reporting per user was examined and a Mann–Whitney U test was used to make comparisons in countries where physicians were including patients using the transfer of innovation (Twinning) project (22) and in countries where this was not the case. This analysis was repeated after excluding countries with low numbers of users (e.g. Canada and Czech Republic).

Results

Users

The study included 14,189 users and 205,904 days (Table 1). Approximately 5% of users did not report their age or reported an age below 10. Users ranged in age from zero to 92 years (mean, SD: 32.1 ± 15.3 years). There were 55.3% women and 44.7% men. 98,303 days were tested for VAS work correlations. In this group, there were 53,241 (54.2%) days without treatment (Figure 1).

Main results

A strong correlation was observed between VAS work and other VAS (Table 4). The highest levels for correlation with VAS work and variance explained in VAS work were found with VAS global, followed by VAS nose, eye and asthma. In comparison to VAS global, the mCSMS and MASK control score showed a lower correlation with VAS work and explained less variance in VAS work.

The within-subject correlation between VAS work and VAS global did not vary by age, gender or season. For the other outcomes, the within-subject correlation with VAS work did not vary substantially between males and females (i.e. difference of less than 5%) or between days recorded during and outside the pollen season (i.e. difference of less than 4%). When we stratified by median age (i.e. 32 years-old), the correlation varied the most between VAS work and VAS eyes (i.e. within-subject correlations of 0.60 for days recorded by older users and 0.52 for days recorded by younger users) and between VAS work and

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VAS asthma (i.e. within-subject correlations of 0.48 for days recorded by older users and 0.40 for days recorded by younger users).

The within-subject correlation between VAS work and VAS asthma was higher in days recorded by users who reported asthma when they started using the app, compared to days recorded by users who did not report asthma (r=0.54 *vs* 0.38).

Intra-individual response variability

Of the 205,904 person-days, there was no variability in 35,592 days (17.3%) (users respond with the same value to all five VAS). 35,373 (99.4%) of them corresponded to a value of zero (no symptoms) answered to all questions. Without counting person-days with all variables at zero, 48,086 person-days (23.4%) had an IRV≤3.6 (Table 5). An IRV of 3.6 implies a difference of up to 10 points (on a 0-100 point scale) in at least one of the VAS measures.

As a *post hoc* analysis, we recalculated the correlations with VAS work and variances explained in VAS work, after excluding person-days with low intra-individual response variability (i.e. defined as IRV≤3.6) and similar results were obtained (online Table 2).

Number of days of reporting

The number of days of reporting per user was significantly greater in countries where a transfer of innovation was carried out than in those that did not perform this project (p for Mann–Whitney U test =0.0001) (Table 1). When this analysis was repeated after excluding countries with low numbers of users (e.g. Canada and Czech Republic), the difference remained highly statistically significant (p for Mann–Whitney U test<0.0001).

Discussion

The strengths of the study are the sample size and the wide distribution of users in 23 countries and 17 languages. There is one strong message and two extra messages. First, there is a high correlation between VAS work and rhinitis control assessed by VAS global or nose. Second, the strong correlations we observed between VAS work and other VAS scores are unlikely to be explained by a low quality of data

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arising from repeated VAS measures. Third, in comparison to VAS global, the two SMSs showed a lower correlation with VAS work, and explained less variance in VAS work.

Our results are unlikely to be explained by a low quality of data arising from repeated VAS measures: (i) VAS work is the last VAS measure assessed, and it is measured after 5 screens without any VAS question, which makes it more difficult to reproduce the previous VAS (Figure 1 online); (ii) Correlations differ between outcomes; (iii) Over 99% of the person-days with no variation in the five VAS measures corresponded to a value of zero answered to all of them, which is plausible in days with no symptoms; (iv) A very low variability in VAS measures was assessed by taking a cutoff of IRV index below 3.6. Although other cutoff values could be used, this represents a realistic maximal difference of 10 points on a 0-100 point scale of some of the VAS measures. Only 23.4% of person-days had a low variability in the response to several questions and were suspected of engaging in IER. However, this is an upper bound, as low variability in responses is actually possible in reality (i.e. on days in which the patient has the same or similar degree of impairment for all questions); (v) The strong correlations found between the different scores and VAS work were not substantially reduced when person-days with low intra-individual response variability were excluded from the analyses, suggesting that they are not "artificially" driven by IER.
In order to determine the relative cost-effectiveness of new interventions, many countries propose to conduct a health economic evaluation either by adopting a health care perspective only or by adding a societal perspective aiming to include all relevant effects and costs (25). Productivity costs are frequently omitted from economic evaluations, despite their often strong impact on cost-effectiveness outcomes, partly because of the lack of standardization regarding the methodology of estimating productivity costs (26). Allergic rhinitis impairs quality-of-life (27) but never induces death. Thus the Decision Analytic Modelling (DAM) model may be difficult to apply (28). EQ5D is impaired in severe AR whereas work productivity is often impaired in moderate AR (29). Thus, VAS work may be a more sensitive surrogate end point to assess the economic evaluation of an intervention in AR. Moreover, a *daily* assessment of work productivity can be carried out with VAS. Using the novel feature of MASK, the integration of pollen season and air quality the same day as VAS work will provide a very sensitive outcome on health economics for clinical trials. In clinical practice, VAS global may be more relevant. To our knowledge, limitations of real-word data using an app are the same for all VAS measurements. VAS work validation was not done since this criterion was not included in the first version of the app.

In comparison to VAS global, the two SMSs showed a lower correlation with VAS work, and explained less variance in VAS work. This is probably because we used simple methods to assess SMSs and more sophisticated analyses are needed. In particular, it seems that adding the same coefficient to a symptom score or a VAS level may not be optimal. From the real-word evidence from MASK (13, 21), it appears

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that (i) medications may have a different efficacy depending on rhinitis control level: higher impact for a lower VAS level and lower impact for a higher VAS level and (ii) co-medication may be considered. New SMS are therefore needed.

One of the major problems with apps is the low adherence to their use. Achieving sufficient mHealth App engagement and user retention rates is a difficult task. In MASK, over 50% of the users use the app only once. Differences in the duration of reporting were found. It is clear that in countries where many patients have been enrolled by physicians during a transfer of innovation, the duration of reporting is longer than in countries where this protocol was not used. This information should be carefully considered to increase adherence to MASK use.

Generalisability

The data obtained were retrieved from 23 countries. Although there was no specific study in the different countries, the results appear generalizable.

Conclusion

This study suggests that VAS work can be used as a surrogate end-point for the assessment of health economics in rhinitis and that symptom medication scores tested with real-world data need to be improved.

Statement of author contribution :
A Bédard, JM Anto, JA Fonseca, X Basagana and J Bousquet conceived the study and drafted the manuscript. A Bédard and X Basagana conducted the statistical analyses. O Pfaar and J Bousquet designed the symptom-medications scores used in the analyses. All authors reviewed the study design and the manuscript and have approved the final version of the manuscript".

Conflicts of Interest :

Dr. Bousquet reports personal fees from Chiesi, Cipla, Hikma, Menarini, Mundipharma, Mylan, Novartis, Purina, Sanofi-Aventis, Takeda, Teva, Uriach, other from KYomed-Innov, outside the submitted work.

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Dr. Fonseca being a partner in a company developing mobile technologies for monitoring airways diseases

Dr. Hellings reports grants and personal fees from Mylan, during the conduct of the study; personal fees from Sanofi, Allergopharma, Stallergenes, outside the submitted work.

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Dr. Bousquet reports personal fees from Chiesi, Cipla, Hikma, Menarini, Mundipharma, Mylan, Novartis, Purina, Sanofi-Aventis, Takeda, Teva, Uriach, other from KYomed-Innov, outside the submitted work

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Dr. Pfaar reports personal fees from MEDA Pharma/MYLAN, ASIT Biotech Tools S.A. Laboratorios LETI/LETI Pharma, Anergis S.A, Mobile Chamber Experts (a GA^{2}LEN Partner), Indoor Biotechnologies, Astellas Pharma Global, grants and personal fees from ALK-Abelló, Allergopharma, Stallergenes Greer, HAL Allergy Holding B.V./HAL Allergie GmbH, Bencard Allergie GmbH/Allergy Therapeutics, Lofarma, grants from Biomay, Nuvo, Circassia, from, Glaxo Smith Kline, outside the submitted work.

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Table 1: Number of users recording Visual Analogue Scale score using MASK-air® by country

Country	Number of Days	Number of Users	Number of days per user (median, p25-p75)	Transfer of innovation
Argentina	1,522	136	2 [1-6.5]	No
Austria	5,348	498	1 [1-4]	No
Australia	2,080	180	2 [1-7.5]	No
Belgium	1,456	168	1 [1-6]	No
Brazil	8,299	1,336	1 [1-4]	No
Canada	204	31	2 [1-4]	No
Czech republic	1,078	51	3 [1-17]	Yes
Denmark	993	103	2 [1-6]	No
Finland	3,612	360	2 [1-5]	No
France	6,794	911	1 [1-3]	No*
Germany	14,877	895	2 [1-13]	Yes (partly)
Greece	7,824	320	10 [2-28]	RCT
Italy	29,889	1,562	2 [1-11]	Yes
Lithuania	20,881	572	9.5 [2-36]	Yes
Mexico	44,123	1,225	15 [4-45]	Yes
Netherlands	7,509	944	2 [1-5]	No
Poland	10,295	914	2 [1-6]	No
Portugal	11,310	1,506	2 [1-4]	No
Spain	14,880	771	4 [1-17]	RCT
Sweden	1,359	131	2 [1-7]	No
Switzerland	3,955	815	1 [1-2]	No
Turkey	2,595	238	2 [1-5]	No
UK	5,021	522	2 [1-8]	No
Total	**205,904**	**14,189**		

RCT: trial was carried out in the country

*: The transfer of innovation was started late and could not be considered in the study

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Table 2: Definition of the modified EAACI CSMS

mCSMS = $\frac{\text{Symptom Score + Medication Score}}{2}$, where Symptom Score is the 0-100 global VAS score, and Medication Score is a 0-100 score depending on the medication taken. For the latter, we used the following proposed scoring system:

- no medication = 0 points;
- oral non-sedative H1 antihistamines (H1A) lone = $100 \times \frac{1}{4} = 25$ points;
- intra-nasal corticosteroids (INCS) – except Azelastine-Fluticasone Proprionate combination (MPAzeFlu) - with/without H1A = $100 \times \frac{2}{4} = 50$ points;
- MPAzeFlu = $100 \times \frac{3}{4} = 75$ points;
- oral corticosteroids with/without INCS, with/without H1A, with/without MPAzeFlu = 100 points.

Table 3: Definition of the MASK rhinitis control score

The MASK rhinitis control score was equal to 1 if:

1. VAS global ≥ 50/100

or

2. VAS global ≥ 35 with the use of INCS-containing medication

or

3. VAS global ≥ 20 with the use of at least 3 medications

The MASK rhinitis control score was equal to 0 otherwise.

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Table 4. Within-subject correlations between VAS work and other rhinitis scores

		Continuous scores					Binary score
	Number of days	**VAS global**	**VAS nose**	**VAS eyes**	**VAS asthma**	**mCSMS**	**MASK control score**
Median, 25-75% (continuous outcomes) or % (binary outcome)	98,303	11 [1-29]	12 [1-30]	3 [0-18]	0 [0-9]	25 [3-56]	84% controlled 16% uncontrolled

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Within-subject correlation with VAS work	98,303	0.73	0.68	0.56	0.45	0.56	0.54
Variance explained in VAS work	98,303	0.53	0.46	0.32	0.20	0.31	0.29

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Table 5. Intra-individual response variability (i.e. based on answers to the five VAS scores)

IRV	Number of person-days	Example of VAS values in a representative patient
0.44	2,422	One of the VAS measures differs in 1 unit (i.e. on a 0-100 point scale) from the rest. E.g. providing the following values for the five VAS measures: (0,0,1,0,0)
0.5	2,622	One of the VAS measures differs in 1 unit from the rest (among person-days that have one missing value) E.g. providing the following values for the five VAS measures: (0,0,1,0,missing)
0.548	1,003	Two VAS measures differ in 1 unit from the rest. E.g. providing the following values for the five VAS measures: (8,7,8,8,7)
1	1,330	Variations of 3 units among the VAS measures E.g. providing the following values for the five VAS measures: (42,41,42,40,40)
1.5	1431	One of the VAS measures differs in 3 units from the rest (among person-days that have one missing value) E.g. providing the following values for the five VAS measures: (22,22,19,22,missing)
2	690	Variations of 5 units among the VAS measures. E.g. providing the following values for the five VAS measures: (26,24,27,22,26)
3.6	44	Variations of up to 10 units among the VAS measures. E.g. providing the following values for the five VAS measures: (56,52,50,51,46)
Total ≤3.6	**48,086 (23.4%)***	

*: not counting person-days with all 0 values

Figure 1. Flow chart of the study population

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MASK Study group

J Bousquet [1-3], PW Hellings [4], W Aberer [5], I Agache [6], CA Akdis [7], M Akdis [7], MR Aliberti [8], R Almeida[9], F Amat [10], R Angles [11], I Annesi-Maesano [12], IJ Ansotegui [13], JM Anto [14-16-17], S Arnavielle [18], E Asayag [19], A Asarnoj [20], H Arshad [21], F Avolio [22], E Bacci [23], C Bachert [24], I Baiardini [25], C Barbara [26], M Barbagallo [27], I Baroni [28], BA Barreto [29], X Basagana [14-16-17], ED Bateman [30], M Bedolla-Barajas [31], A Bedbrook [2], M Bewick [32], B Beghé [33], EH Bel [34], KC Bergmann [35], KS Bennoor [36], M Benson [37], L Bertorello [23], AZ Białoszewski [38], T Bieber [39], S Bialek [40], C Bindslev-Jensen [41], L Bjermer [42], H Blain [43,44], F Blasi [45], A Blua [46], M Bochenska Marciniak [47], I Bogus-Buczynska [47], AL Boner [48], M Bonini [49], S Bonini [50], CS Bosnic-Anticevich [51], I Bosse [52], J Bouchard [53], LP Boulet [54], R Bourret [55], PJ Bousquet [12], F Braido [25], V Briedis [56], CE Brightling [57], J Brozek [58], C Bucca [59], R Buhl [60], R Buonaiuto [61], C Panaitescu [62], MT Burguete Cabañas [63], E Burte [3], A Bush [64], F Caballero-Fonseca [65], D Caillaud [67], D Caimmi [68], MA Calderon [69], PAM Camargos [70], T Camuzat [71], G Canfora [72], GW Canonica [25], V Cardona [73], KH Carlsen [74], P Carreiro-Martins [75], AM Carriazo [76], W Carr [77], C Cartier [78], T Casale [79], G Castellano [80], L Cecchi [81], AM Cepeda [82], NH Chavannes [83], Y Chen [84], R Chiron [68], T Chivato [85], E Chkhartishvili [86], AG Chuchalin [87], KF Chung [88], MM Ciaravolo [89], A Ciceran [90], C Cingi [91], G Ciprandi [92], AC Carvalho Coehlo [93], L Colas [94], E Colgan [95], J Coll [96], D Conforti [97], J Constantinidis[383], J Correia de Sousa [98], RM Cortés-Grimaldo [99], F Corti [100], E Costa [101], MC Costa-Dominguez [102], AL Courbis [103], L Cox [104], M Crescenzo [105], AA Cruz [106], A Custovic [107], W Czarlewski [108], SE Dahlen [109], G D'Amato [279], C Dario [110], J da Silva 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1. University Hospital, Montpellier, France.
2. MACVIA-France, Fondation partenariale FMC VIA-LR, Montpellier, France.
3. VIMA. INSERM U 1168, VIMA : Ageing and chronic diseases Epidemiological and public health approaches, Villejuif, Université Versailles St-Quentin-en-Yvelines, UMR-S 1168, Montigny le Bretonneux, France and Euforea, Brussels, Belgium and Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health, Comprehensive Allergy Center, Department of Dermatology and Allergy, Berlin, Germany.
4. Laboratory of Clinical Immunology, Department of Microbiology and Immunology, KU Leuven, Leuven, Belgium.
5. Department of Dermatology, Medical University of Graz, Graz, Austria.
6. Transylvania University Brasov, Brasov, Romania.
7. Swiss Institute of Allergy and Asthma Research (SIAF), University of Zurich, Davos, Switzerland.
8. Project Manager, Chairman of the Council of Municipality of Salerno, Italy.
9. Center for Health Technology and Services Research- CINTESIS, Faculdade de Medicina, Universidade do Porto; and Medida, Lda Porto, Portugal.
10. Allergology department, Centre de l'Asthme et des Allergies Hôpital d'Enfants Armand-Trousseau (APHP); Sorbonne Université, UPMC Univ Paris 06, UMR_S 1136, Institut Pierre Louis d'Epidémiologie et de Santé Publique, Equipe EPAR, Paris, France.
11. Innovación y nuevas tecnologías, Salud Sector sanitario de Barbastro, Barbastro, Spain.
12. Equipe EPAR-IPLESP, Sorbonne Université, Paris, France.
13. Department of Allergy and Immunology, Hospital Quirónsalud Bizkaia, Erandio, Spain.
14. ISGlobAL, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain.
15. IMIM (Hospital del Mar Research Institute), Barcelona, Spain.
16. CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain.
17. Universitat Pompeu Fabra (UPF), Barcelona, Spain.
18. KYomed INNOV, Montpellier, France.
19. Argentine Society of Allergy and Immunopathology, Buenos Aires, Argentina.
20. Clinical Immunology and Allergy Unit, Department of Medicine Solna, Karolinska Institutet, Stockholm, and Astrid Lindgren Children's Hospital, Department of Pediatric Pulmonology and Allergy, Karolinska University Hospital, Stockholm, Sweden.
21. David Hide Asthma and Allergy Research Centre, Isle of Wight, United Kingdom.
22. Regionie Puglia, Bari, Italy.
23. Regione Liguria, Genoa, Italy.
24. Upper Airways Research Laboratory, ENT Dept, Ghent University Hospital, Ghent, Belgium.
25. University of Genoa, Department of Internal Medicine (DiMI) and IRCCS Ospedale Policlinico San Martino, Genova, Italy.
26. PNDR, Portuguese National Programme for Respiratory Diseases, Faculdade de Medicina de Lisboa, Lisbon, Portugal.
27. Director of the Geriatric Unit, Department of Internal Medicine (DIBIMIS), University of Palermo, Italy.
28. Telbios SRL, Milan, Italy.
29. Universidade do Estado do Pará, Belem, Brazil.
30. Department of Medicine, University of Cape Town, Cape Town, South Africa.
31. Hospital Civil de Guadalajara Dr Juan I Menchaca, Guadalarara, Mexico.
32. iQ4U Consultants Ltd, London, UK.
33. Section of Respiratory Disease, Department of Oncology, Haematology and Respiratory Diseases, University of Modena and Reggio Emilia, Modena, Italy.
34. Department of Respiratory Medicine, Academic Medical Center (AMC), University of Amsterdam, The Netherlands.
35. Charité - Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health, Comprehensive Allergy Center, Department of Dermatology and Allergy, Global Allergy and Asthma European Network (GA^2LEN), Berlin, Germany.
36. Dept of Respiratory Medicine, National Institute of Diseases of the Chest and Hospital, Dhaka, Bangladesh.
37. Centre for Individualized Medicine, Department of Pediatrics, Faculty of Medicine, Linköping, Sweden.
38. Department of Prevention of Environmental Hazards and Allergology, Medical University of Warsaw, Poland.
39. Department of Dermatology and Allergy, Rheinische Friedrich-Wilhelms-University Bonn, Bonn, Germany
40. Dept of Biochemistry and Clinical Chemistry, Faculty of Pharmacy with the Division of Laboratory Medicine, Warsaw Medical University, Warsaw, Poland.

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41. Department of Dermatology and Allergy Centre, Odense University Hospital, Odense Research Center for Anaphylaxis (ORCA), Odense, Denmark.
42. Department of Respiratory Medicine and Allergology, University Hospital, Lund, Sweden.
43. Department of Geriatrics, Montpellier University Hospital, Montpellier, France.
44. EA 2991, Euromov, University Montpellier, France.
45. Department of Pathophysiology and Transplantation, University of Milan, IRCCS Fondazione Ca'Granda Ospedale Maggiore Policlinico, Milan, Italy.
46. Argentine Association of Respiratory Medicine, Buenos Aires, Argentina.
47. Division of Internal Medicine, Asthma and Allergy, Barlicki University Hospital, Medical University of Lodz, Poland.
48. Pediatric Department, University of Verona Hospital, Verona, Italy.
49. UOC Pneumologia, Istituto di Medicina Interna, F. Policlinico Gemelli IRCCS, Università Cattolica del Sacro Cuore, Rome, Italy, and National Heart and Lung Institute, Royal Brompton Hospital & Imperial College London, UK.
50. Institute of Translational Pharmacology, Italian National Research Council, Rome, Italy.
51. Woolcock Institute of Medical Research, University of Sydney and Woolcock Emphysema Centre and Sydney Local Health District, Glebe, NSW, Australia.
52. Allergist, La Rochelle, France.
53. Associate professor of Clinical Medecine, Laval's University, Quebec city, Canada.
54. Quebec Heart and Lung Institute, Laval University, Québec City, Quebec, Canada.
55. Centre Hospitalier Valenciennes, France.
56. Head of Department of Clinical Pharmacy of Lithuanian University of Health Sciences, Kaunas, Lithuania.
57. Institute of Lung Health, Respiratory Biomedical Unit, University Hospitals of Leicester NHS Trust, Leicestershire, UK; Department of Infection, Immunity and Inflammation, University of Leicester, Leicester, UK.
58. Department of Health Research Methods, Evidence and Impact, Division of Immunology and Allergy, McMaster University, Hamilton, ON, Canada.
59. Chief of the University Pneumology Unit- AOU Molinette, Hospital City of Health and Science of Torino, Italy.
60. Universitätsmedizin der Johannes Gutenberg-Universität Mainz, Mainz, Germany.
61. Pharmacist, Municipality Pharmacy, Sarno, Italy.
62. University of Medicine and Pharmacy Victor Babes, Timisoara, Romania.
63. Instituto de Pediatria, Hospital Zambrano Hellion Tec de Monterrey, Monterrey, Mexico.
64. Imperial College and Royal Brompton Hospital, London, UK.
65. Centro Medico Docente La Trinidad, Caracas, Venezuela.
66. Regional Director Assofarm Campania and Vice President of the Board of Directors of Cofaser, Salerno, Italy
67. Service de pneumologie, CHU et université d'Auvergne, Clermont-Ferrand, France.
68. Department of Pulmonology, Division of Allergy, Hôpital Arnaud de Villeneuve, University Hospital of Montpellier, Montpellier, France.
69. Imperial College London - National Heart and Lung Institute, London, UK.
70. Federal University of Minas Gerais, Medical School, Department of Pediatrics, Belo Horizonte, Brazil
71. Assistant Director General, Montpellier, Région Occitanie, France.
72. Mayor of Sarno and President of Salerno Province, Director, Anesthesiology Service, Sarno "Martiri del Villa Malta" Hospital, Italy.
73. Allergy Section, Department of Internal Medicine, Hospital Vall d'Hebron & ARADyAL Spanish Research Network, Barcelona, Spain.
74. Department of Paediatrics, Oslo University Hospital and University of Oslo, Oslo, Norway.
75. Hospital de Dona Estefânia, Centro Hospitalar de Lisboa Central, EPE, Lisbon, and Nova Medical School, CEDOC, Integrated Pathophysiological Mechanisms Research Group, Lisbon, Portugal.
76. Regional Ministry of Health of Andalusia, Seville, Spain.
77. Allergy and Asthma Associates of Southern California, Mission Viejo, CA, USA.
78. ASA - Advanced Solutions Accelerator, Clapiers, France.
79. Division of Allergy/Immunology, University of South Florida, Tampa, Fla, USA.
80. Celentano pharmacy, Massa Lubrense, Italy.
81. SOS Allergology and Clinical Immunology, USL Toscana Centro, Prato, Italy.
82. Allergy and Immunology Laboratory, Metropolitan University Hospital, Branquilla, Columbia.
83. Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, The Netherlands

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84. Capital Institute of Pediatrics, Chaoyang district, Beijing, China.
85. School of Medicine, University CEU San Pablo, Madrid, Spain.
86. David Tvildiani Medical University - AIETI Highest Medical School, David Tatishvili Medical Center Tbilisi, Georgia.
87. Pulmonolory Research Institute FMBA, Moscow, Russia and GARD Executive Committee, Moscow, Russia.
88. National Heart & Lung Institute, Imperial College, London, UK.
89. Specialist social worker, Sorrento, Italy.
90. Argentine Federation of Otorhinolaryngology Societies, Buenos Aires, Argentina.
91. Eskisehir Osmangazi University, Medical Faculty, ENT Department, Eskisehir,Turkey.
92. Medicine Department, IRCCS-Azienda Ospedaliera Universitaria San Martino, Genoa, Italy.
93. Universidade Federal da Bahia, Escola de Enfermagem, Brazil.
94. Plateforme Transversale d'Allergologie, Institut du Thorax, CHU de Nantes, Nantes, France.
95. LANUA International Healthcare Consultancy, Northern Ireland, UK.
96. Innovación y nuevas tecnologías, Salud Sector sanitario de Barbastro, Barbastro, Spain.
97. Innovation and Research Office, Department of Health and Social Solidarity, Autonomous Province of Trento, Italy.
98. Life and Health Sciences Research Institute (ICVS), School of Medicine, University of Minho, Braga, Portugal; ICVS/3B's, PT Government Associate Laboratory, Braga/Guimarães, Portugal.
99. Servicio de Allergologia, Hospital Angeles del Carmen, Guadalajara, Mexico.
100. FIMMG (Federazione Italiana Medici di Medicina Generale), Milan, Italy.
101. UCIBIO, REQUINTE, Faculty of Pharmacy and Competence Center on Active and Healthy Ageing of University of Porto (Porto4Ageing), Porto, Portugal.
102. Allergologo, Mexico City, Mexico.
103. IMT Mines Alès, Université Montpellier, Alès, France.
104. Department of Medicine, Nova Southeastern University, Davie, University of Miami Dept of Medicine, Miami, Florida, USA.
105. Regional Director Assofarm Campania and Vice President of the Board of Directors of Cofaser, Salerno, Italy.
106. ProAR – Nucleo de Excelencia em Asma, Federal University of Bahia, Brasil and GARD/WHO Executive Committee and Federal University of Bahia, Brazil.
107. Centre for Respiratory Medicine and Allergy, Institute of Inflammation and Repair, University of Manchester and University Hospital of South Manchester, Manchester, UK.
108. Medical Consulting Czarlewski, Levallois, France.
109. The Centre for Allergy Research, The Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.
110. Azienda Provinciale per i Servizi Sanitari di Trento (APSS-Trento), Italy.
111. Department of Internal Medicine and Allergy Clinic of Professor Polydoro Ernani de São Thiago University Hospital, Federal University of Santa Catarina (UFSC), Florianópolis, Santa Catarina, Brazil.
112. Sleep Unit, Department of Neurology, Hôpital Gui-de-Chauliac Montpellier, Inserm U1061, France.
113. Department of Dermatology and Allergy, Technische Universität München, Munich, Germany; ZAUM-Center for Allergy and Environment, Helmholtz Center Munich, Technische Universität München, Munich, Germany.
114. Allergy Division, Chest Disease Department, University Hospital of Strasbourg, Strasbourg, France.
115. EFA European Federation of Allergy and Airways Diseases Patients' Associations, Brussels, Belgium
116. International Foundation for Integrated Care (IFIC), Wolfson College, Oxford, UK
117. Policlínica Geral do Rio de Janeiro, Rio de Janeiro – Brazil
118. Department of Medicine, Surgery and Dentistry "Scuola Medica Salernitana", University of Salerno, Salerno, Italy.
119. Peercode BV, Geldermalsen,The Netherlands.
120. Social workers oordinator, Sorrento, Italy.
121. Federal University of the State of Rio de Janeiro, School of Medicine and Surgery, Rio de Janeiro, Brazil
122. Allergology and Immunology Discipline, "Iuliu Hatieganu" University of Medicine and Pharmacy, Cluj-Napoca, Romania.
123. Department of Medicine, Division of Clinical Immunology and Allergy, McMaster University, Hamilton, Ontario, Canada.
124. Laboratoire de Pharmacologie Respiratoire UPRES EA220, Hôpital Foch, Suresnes, Université Versailles Saint-Quentin, Université Paris Saclay, France.
125. Farmacie Dei Golfi Group, Massa Lubrense, Italy.
126. Rangueil-Larrey Hospital, Respiratory Diseases Department, Toulouse, France.

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127. University Clinic of Pulmology and Allergy, Medical Faculty Skopje, Republic of Macedonia.
128. Allergologist, Mexico City, Mexico.
129. Service de Pneumo-Allergologie, Centre Hospitalo-Universitaire de Béni-Messous, Algiers, Algeria.
130. Clinic of infectious, chest diseases, dermatology and allergology, Vilnius University, Vilnius, Lithuania.
131. Allergy and Clinical Immunology National Heart and Lung Institute, Imperial College London, UK.
132. Guy's and st Thomas' NHS Trust, Kings College London, UK.
133. Section of Allergy and Immunology, Saint Louis University School of Medicine, Saint Louis, Missouri, USA.
134. Pediatric Allergy and Immunology Unit, Children's Hospital, Ain Shams University, Cairo, Egypt.
135. Department of Computing Science, Umeå University, Sweden and Four Computing Oy, Finland.
136. Clinic of Children's Diseases, Faculty of Medicine, Vilnius University, Vilnius, Lithuania.
137. University of São Paulo Medical School, Sao Paulo, Brazil
138. Andalusian Agency for Healthcare Quality, Seville, Spain.
139. Global Allergy and Asthma Platform GAAPP, Vienna, Austria.
140. Division of Allergy, Department of Pediatric Medicine - The Bambino Gesù Children's Research Hospital Holy see, Rome, Italy.
141. Department of Otorhinolaryngology, Academic Medical Centers, Amsterdam, the Netherlands, and EUFOREA, Brussels, Belgium.
142. CINTESIS, Center for Research in Health Technologies and Information Systems, Faculdade de Medicina da Universidade do Porto, Porto, Portugal and MEDIDA, Lda, Porto, Portugal.
143. Allergist, Reims, France.
144. Hospital General Regional 1 "Dr Carlos Mc Gregor Sanchez Navarro" IMSS, Mexico City, Mexico.
145. Regional hospital of ISSSTE, Puebla, Mexico.
146. National Center for Disease Control and Public Health of Georgia, Tbilisi, Georgia.
147. Allergologo, Guadalajara, Mexico.
148. Allergy Clinic, National Institute of Respiratory Diseases, Mexico City, Mexico.
149. Department of Pulmonary Diseases, Istanbul University-Cerrahpasa, Cerrahpasa Faculty of Medicine, Istambul,Turkey.
150. Allergology unit, UHATEM "NIPirogov", Sofia, Bulgaria.
151. Medical University, Faculty of Public Health, Sofia, Bulgaria.
152. Allergy and Immunology Division, Clinica Ricardo Palma, Lima, Peru.
153. Department of Internal Medicine, section of Allergology, Erasmus MC, Rotterdam, The Netherlands.
154. Allergy & Asthma Unit, Hospital San Bernardo Salta, Argentina.
155. Allergy Clinic, Hospital Regional del ISSSTE 'Lic. López Mateos', Mexico City, Mexico.
156. Head and Professor, Centro Regional de Excelencia CONACYT y WAO en Alergia, Asma e Inmunologia, Hospital Universitario, Universidad Autónoma de Nuevo León , Monterrey NL, Mexico.
157. Center of Allergy and Immunology, Georgian Association of Allergology and Clinical Immunology, Tbilisi, Georgia.
158. Latvian Association of Allergists, Center of Tuberculosis and Lung Diseases, Riga, Latvia.
159. Federal District Base Hospital Institute, Brasília, Brazil.
160. Institute of Health Policy and Management iBMG, Erasmus University, Rotterdam, The Netherlands.
161. University Hospital Olomouc – National eHealth Centre, Czech Republic.
162. Immunology and Allergy Division, Clinical Hospital, University of Chile, Santiago, Chile.
163. Skin and Allergy Hospital, Helsinki University Hospital, University of Helsinki, Helsinki, Finland.
164. Centich (Centre d'Expertise National des Technologies de l'Information et de la Communication pour l'autonomie), Groupe VyV, Conseil régional des Pays de la Loire, Centre d'expertise Partenariat Européen d'Innovation pour un vieillissement actif et en bonne santé, Nantes, France.
165. Autonomous University of Baja California, Ensenada, Baja California, Mexico.
166. Department of Paediatrics and Child Health, University College Cork, Cork, Ireland.
167. Hospital General Regional 1 "Dr. Carlos MacGregor Sánchez Navarro" IMSS, Mexico City, Mexico.
168. Université Paris-Sud; Service de Pneumologie, Hôpital Bicêtre; Inserm UMR_S999, Le Kremlin Bicêtre, France.
169. Dipartimento di medicina, chirurgia e odontoiatria, università di Salerno, Italy.
170. Division for Health Innovation, Campania Region and Federico II University Hospital Naples (R&D and DISMET) Naples, Italy.
171. Servicio de Alergia e Immunologia, Clinica Santa Isabel, Buenos Aires, Argentina.
172. President, Libra Foundation, Buenos Aires, Argentina.

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173. Medical University of Gdańsk, Department of Allergology, Gdansk, Poland.
174. Airway Disease Infection Section, National Heart and Lung Institute, Imperial College; MRC & Asthma UK Centre in Allergic Mechanisms of Asthma, London, UK.
175. Dept of Respiratory Medicine, Ghent University Hospital, Ghent, Belgium.
176. Hallym University College of Medicine, Hallym University Sacred Heart Hospital, Gyeonggi-do, South Korea.
177. Department of Clinical Immunology, Wrocław Medical University, Poland.
178. Ukrainina Medical Stomatological Academy, Poltava, Ukraine.
179. Pediatric Allergy and Asthma Unit, Hacettepe University School of Medicine, Ankara, Turkey.
180. Hacettepe University, School of Medicine, Department of Chest Diseases, Immunology and Allergy Division, Ankara, Turkey.
181. Allergy Centre, Tampere University Hospital, Tampere, Finland.
182. First Department of Family Medicine, Medical University of Lodz, Poland.
183. Institute of Social Medicine, Epidemiology and Health Economics, Charité - Universitätsmedizin Berlin, Berlin, and Institute for Clinical Epidemiology and Biometry, University of Wuerzburg, and Institute of Health Resort Medicine and Health Promotion, Bavarian Health and Food Safety Authority, Bad Kissingen, Germany
184. Department of Medicine, McMaster University, Health Sciences Centre 3V47, West, Hamilton, Ontario, Canada.
185. National Research Center, Institute of Immunology, Federal Medicobiological Agency, Laboratory of Molecular immunology, Moscow, Russian Federation.
186. GARD Chairman, Geneva, Switzerland.
187. Allergy & Asthma Center Westend, Berlin, Germany.
188. Center for Rhinology and Allergology, Wiesbaden, Germany.
189. Department of Immunology and Allergy, Healthy Ageing Research Center, Medical University of Lodz, Lodz, Poland.
190. Children's Hospital and University of Helsinki, Finland.
191. Department of Clinical Science and Education, Södersjukhuset, Karolinska Institutet, Stockholm and Sach´s Children and Youth Hospital, Södersjukhuset, Stockholm, Sweden.
192. Institute of Biomedical Sciences, Department of Pathology, Faculty of Medicine, Vilnius University and Institute of Clinical medicine, Clinic of Chest diseases and Allergology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania
193. Department of Prevention of Envinronmental Hazards and Allergology, Medical University of Warsaw, Poland.
194. Center of Excellence in Asthma and Allergy, Médica Sur Clinical Foundation and Hospital, México City, Mexico.
195. Presidente CMMC, Milano, Italy.
196. Head of the Allergy Department of Pedro de Elizalde Children's Hospital, Buenos Aires, Argentina.
197. University of Medicine and Pharmacy, Hochiminh City, Vietnam.
198. Federal University of Bahia, Brazil.
199. Sifmed, Milano, Italy.
200. State Key Laboratory of Respiratory Diseases, Guangzhou Institute of Respiratory Disease, the First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China.
201. Departments of Internal Medicine and Pediatrics (Divisions of Allergy and Immunology), University of Tennessee College of Medicine, Germantown, TN, USA.
202. Scottish Centre for Respiratory Research, Cardiovascular & Diabetes Medicine, Medical Research Institute, Ninewells Hospital, University of Dundee, UK.
203. Oslo University Hospital, Department of Paediatrics, Oslo, and University of Oslo, Faculty of Medicine, Institute of Clinical Medicine, Oslo, Norway.
204. Department of Pulmonary Medicine, CHU Sart-Tilman, and GIGA I3 research group, Liege, Belgium.
205. Faculty of Health Sciences and CICS – UBI, Health Sciences Research Centre, University of Beira Interior, Covilhã, Portugal.
206. Department of Philosophical, Methodological and Instrumental Disciplines, CUCS, University of Guadalajara, Guadalajara, Mexico.
207. Department of Pulmonary Medicine, Rashid Hospital, Dubai, UAE.
208. Biomax Informatics AG, Munich, Germany.
209. Director General for Health and Social Care, Scottish Government, Edinburgh, UK.
210. Department of Respiratory Medicine, University of Bratislava, Bratislava, Slovakia.
211. Coimbra Institute for Clinical and Biomedical Research (iCBR), Faculty of Medicine, University of Coimbra, Portugal; Ageing@Coimbra EIP-AHA Reference Site, Coimbra, Portugal.

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212. Medical center Iskar Ltd Sofia, Bulgaria.
213. Department of Medicine (RCSI), Bon Secours Hospital, Glasnevin, Dublin, Ireland.
214. Kronikgune, International Centre of Excellence in Chronicity Research Barakaldo, Bizkaia, Spain
215. Division of Clinical Immunology and Allergy, Laboratory of Behavioral Immunology Research, The University of Mississippi Medical Center, Jackson, Mississippi, USA.
216. Tobacco Control Research Centre;Iranian Anti Tobacco Association, Tehran, Iran.
217. Argentine Association of Allergy and Clinical Immunology, Buenos Aires, Argentina.
218. Hospital de Especialidades, Centro Medico Nacional Siglo XXI, Mexico City, Mexico
219. University of Southeast Bahia, Brazil.
220. Allergie-Centrum-Charité at the Department of Dermatology and Allergy, Charité - Universitätsmedizin Berlin, Germany
221. Maputo Central Hospital, Department of Paediatrics, Maputo, Mozambique.
222. Allergologo, Veracruz, Mexico
223. Sachs' Children and Youth Hospital, Södersjukhuset, Stockholm and Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.
224. Allergy and Asthma Medical Group and Research Center, San Diego, California, USA.
225. CIRFF, Federico II University, Naples, Italy.
226. Department of Physiology, CHRU, University Montpellier, Vice President for Research, PhyMedExp, INSERM U1046, CNRS UMR 9214, France.
227. Croatian Pulmonary Society, Croatia.
228. National Institute of Pneumology M Nasta, Bucharest, Romania.
229. Clinic for Pulmonary Diseases, Clinical Center of Serbia, Faculty of Medicine, University of Belgrade, Serbian Association for Asthma and COPD, Belgrade, Serbia.
230. Regione Piemonte, Torino, Italy.
231. Col Jardines de Sta Monica, Tlalnepantla, Mexico.
232. National Center for Research in Chronic Respiratory Diseases, Tishreen University School of Medicine, Latakia, and Syrian Private University-Damascus, Syria.
233. Department of Public health and health products, Paris Descartes University-Sorbonne Paris Cité, HERA Team, Inserm 1153 and Paris Municipal Department of social action, childhood, and health, Paris, France .
234. Paris municipal Department of social action, childhood, and health, Paris, France.
235. Lead Respiratory Physician Mater Dei Hospital Malta, Academic Head of Dept and Professor of Medicine University of Malta, Deputy Dean Faculty of Medicine and Surgery University of Medicine, La Valette, Malta.
236. Department of Medical Sciences, Allergy and Clinical Immunology Unit, University of Torino & Mauriziano Hospital, Torino, Italy.
237. Instituto de Prevision Social IPS HC, Socia de la SPAAI, Tesorera de la SLAAI, Asuncion, Paraguay.
238. Allergy Center, CUF Descobertas Hospital, Lisbon, Portugal.
239. Universidade de São Paulo, São Paulo, Brazil.
240. Institute of Medical Statistics, and Computational Biology, Medical Faculty, University of Cologne, Germany and CRI-Clinical Research International-Ltd, Hamburg, Germany.
241. General Pathology Institute, Faculty of Medicine, University of Coimbra, Portugal; Ageing@Coimbra EIP-AHA Reference Site, Coimbra, Portugal.
242. Federal University of Bahia, Brazil.
243. Rhinology Unit & Smell Clinic, ENT Department, Hospital Clínic; Clinical & Experimental Respiratory Immunoallergy, IDIBAPS, CIBERES, University of Barcelona, Spain.
244. Danish Commitee for Health Education, Copenhagen East, Denmark.
245. Food Allergy Referral Centre Veneto Region, Department of Women and Child Health, Padua General University Hospital, Padua, Italy.
246. Research Fellow, OPC, Cambridge, UK and Director, Medscript, Paraparaumu, New Zealand.
247. Johns Hopkins School of Medicine, Baltimore, Maryland, USA.
248. General Manager of COFASER - Pharmacy Services Consortium, Salerno, Italy.
249. Scientific Centre of Children's Health under the MoH, Moscow, Russian National Research Medical University named Pirogov, Moscow, Russia.

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250. Director of Center of Allergy, Immunology and Respiratory Diseases, Santa Fe, Argentina Center for Allergy and Immunology, Santa Fe, Argentina.
251. Dept of Otorhinolaryngology, Medical University of Vienna, AKH, Vienna, Austria.
252. Hospital of the Hospitaller Brothers in Buda, Budapest, Hungary.
253. Die Hautambulanz and Rothhaar study center, Berlin, Germany.
254. Neumología y Alergología Infantil, Hospital La Fe, Valencia, Spain.
255. Center for Health Technology and Services Research - CINTESIS and Department of Internal Medicine, Centro Hospitalar Sao Joao, Porto, Portugal.
256. Caisse d'assurance retraite et de la santé au travail du Languedoc-Roussillon (CARSAT-LR), Montpellier, France.
257. Director of Department of Pharmacy of University of Naples Federico II, Naples, Italy.
258. ENT Department, University Hospital of Kinshasa, Kinshasa, Congo.
259. Department of Allergy, Immunology and Respiratory Medicine, Alfred Hospital and Central Clinical School, Monash University, Melbourne, Victoria, Australia; Department of Immunology, Monash University, Melbourne, Victoria, Australia.
260. Medical center "Research expert", Varna, Bulgaria.
261. National Hospital Organization, Tokyo National Hospital, Tokyo, Japan.
262. Dept of Otorhinolaryngology, Chiba University Hospital, Chiba, Japan.
263. Dept of Otolaryngology, Nippon Medical School, Tokyo, Japan.
264. Allergologo, Jalisco, Guadalajara, Mexico.
265. Centre Hospitalier Universitaire Pédiatrique Charles de Gaulle, Ouagadougou, Burkina Faso.
266. Dept of Comparative Medicine; Messerli Research Institute of the University of Veterinary Medicine and Medical University, Vienna, Austria.
267. Department of Immunology and Allergology, Faculty of Medicine in Pilsen, Charles University in Prague, Pilsen, Czech Republic.
268. Division of Infection, Immunity & Respiratory Medicine, Royal Manchester Children's Hospital, University of Manchester, Manchester, UK, and Allergy Department, 2nd Pediatric Clinic, Athens General Children's Hospital "P&A Kyriakou," University of Athens, Athens, Greece.
269. Department of Allergy and Clinical Immunology, Ajou University School of Medicine, Suwon, South Korea.
270. Respiratory Medicine, Department of Medical Sciences, University of Ferrara, Ferrara, Italy.
271. Allergy and Respiratory Diseases, Ospedale Policlino San Martino -University of Genoa, Italy.
272. Farmacias Holon, Lisbon, Portugal.
273. Department of Pediatrics, Nippon Medical School, Tokyo, Japan.
274. University of Southern Denmark, Kolding, Denmark.
275. Université Grenoble Alpes, Laboratoire HP2, Grenoble, INSERM, U1042 and CHU de Grenoble, France.
276. Allergy Unit, CUF-Porto Hospital and Institute; Center for Research in Health Technologies and information systems CINTESIS, Universidade do Porto, Portugal.
277. Sociologist, municipality area n33, Sorrento, Italy.
278. Department of Otorhinolaryngology, Head and Neck Surgery, Section of Rhinology and Allergy, University Hospital Marburg, Phillipps-Universität Marburg, Germany
279. Division of Respiratory and Allergic Diseases,Hospital 'A Cardarelli', University of Naples Federico II, Naples, Italy.
280. Centre for empowering people and communites, Dublin, UK.
281. Conseil Général de l'Economie Ministère de l'Economie, de l'Industrie et du Numérique, Paris, France.
282. Société de Pneumologie de Langue Française, Espace francophone de Pneumologie, Paris, France.
283. Département de pédiatrie, CHU de Grenoble, Grenoble ,France.
284. Medical School, University of Cyprus, Nicosia, Cyprus.
285. Children's Hospital Srebrnjak, Zagreb, School of Medicine, University J.J. Strossmayer, Osijek, Croatia.
286. Karl Landsteiner Institute for Clinical and Experimental Pneumology, Hietzing Hospital, Vienna, Austria.
287. University Hospital 'Sv. Ivan Rilski'", Sofia, Bulgaria.
288. Allergy Diagnostic and Clinical Research Unit, University of Cape Town Lung Institute, Cape Town, South Africa.
289. Vice-Presidente of IML, Milano, Italy.
290. Observational and Pragmatic Research Institute, Singapore, Singapore.
291. Department of Otorhinolaryngology University of Crete School of Medicine, Heraklion, Greece.
292. European Forum for Research and Education in Allergy and Airway Diseases (EUFOREA), Brussels, Belgium.

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293. Allergologo, cancun quintana roo, Mexico.
294. LungenClinic Grosshansdorf, Airway Research Center North, Member of the German Center for Lung Research (DZL), Grosshansdorf, Germany Department of Medicine, Christian Albrechts University, Airway Research Center North, Member of the German Center for Lung Research (DZL), Kiel, Germany.
295. Department of Nephrology and Endocrinology, Karolinska University Hospital, Stockholm, Sweden.
296. Farmácia São Paio, Vila Nova de Gaia, Porto, Portugal.
297. St Vincent's Hospital and University of Sydney, Sydney, New South Wales, Australia.
298. Allergologo, Mexico City, Mexico
299. Serviço de Pneumologia-Hosp das Clinicas UFPE-EBSERH, Recife, Brazil.
300. Universidade Federal de São Paulo, São Paulo, Brazil.
301. Centre of Pneumology, Coimbra University Hospital, Portugal.
302. Polibienestar Research Institute, University of Valencia, Valencia, Spain.
303. Pediatric Allergy and Clinical Immunology, Hospital Angeles Pedregal, Mexico City, Mexico.
304. Getafe University Hospital Department of Geriatrics, Madrid, Spain.
305. Association Asthme et Allergie, Paris, France.
306. Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil.
307. Primary Care Respiratory Research Unit Institutode Investigación Sanitaria de Palma IdisPa, Palma de Mallorca, Spain.
308. Allergy Unit, Presidio Columbus, Rome, Catholic University of Sacred Heart, Rome and IRCCS Oasi Maria SS, Troina, Italy.
309. Hospital General, Mexico City, Mexico.
310. Regione Piemonte, Torino, Italy.
311. Medical University of Graz, Department of Internal Medicine, Graz, Austria.
312. Serviço de Imunoalergologia Hospital da Luz, Lisboa, Portugal.
313. Hospital de Clinicas, University of Parana, Brazil.
314. Division of Allergy Asthma and Clinical Immunology, Emek Medical Center, Afula, Israel.
315. Honorary Clinical Research Fellow, Allergy and Respiratory Research Group, The University of Edinburgh, Edinburgh, UK.
316. Showa University School of Medicine, Tokyo, Japan.
317. Association of Finnish Pharmacies, Helsinki, Finland.
318. Allergy and Clinical Immunology Department, Centro Médico-Docente la, Trinidad and Clínica El Avila, Caracas, Venezuela.
319. Faculty of Medicine, Autononous University of Madrid, Spain.
320. The Royal National TNE Hospital, University College London, UK.
321. DIBIMIS, University of Palermo, Italy.
322. Allergy Unit, Department of Dermatology, University Hospital of Zurich, Zürich, Switzerland.
323. Asthma Reference Center, Escola Superior de Ciencias da Santa Casa de Misericordia de Vitoria - Esperito Santo, Brazil.
324. The Usher Institute of Population Health Sciences and Informatics, The University of Edinburgh, Edinburgh, UK.
325. Department of Pediatrics & Child Health, Department of Immunology, Faculty of Medicine, University of Manitoba, Winnipeg, Manitoba, Canada.
326. INSERM, Université Grenoble Alpes, IAB, U 1209, Team of Environmental Epidemiology applied to Reproduction and Respiratory Health, Université Joseph Fourier, Grenoble, France.
327. Sociedad Paraguaya de Alergia Asma e Inmunologia, Paraguay.
328. Division of Allergy, Clinical Immunology and Rheumatology, Department of Pediatrics, Federal University of São Paulo, São Paulo, Brazil.
329. European Health Futures Forum (EHFF), Dromahair, Ireland.
330. ENT, Aachen, Germany.
331. Kyrgyzstan National Centre of Cardiology and Internal medicine, Euro-Asian respiratory Society, Bishkek, Kyrgyzstan.
332. University Hospital Olomouc, Czech Republic.
333. Department of Paediatric and Adolescent medicine, University Hospital of North Norway, Tromsø, Paediatric Research Group, Deptarment of Clinical Medicine, Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway.
334. Presidente, IML (Lombardy Medical Initiative), Bergamo, Italy.
335. Pulmonary Division, Heart Institute (InCor), Hospital da Clinicas da Faculdade de Medicina da Universidade de Sao Paulo, Sao Paulo, Brazil.
336. Public Health Institute of Vilnius University, Vilnius, Lithuania.

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337. Universidade Federal do Estado do Rio de Janeiro, Rio de Janeiro, Brazil.
338. RNSA (Réseau National de Surveillance Aérobiologique), Brussieu, France.
339. The Hospital for Sick Children, Dalla Lana School of Public Health, University of Toronto, Canada.
340. Imunoalergologia, Centro Hospitalar Universitário de Coimbra and Faculty of Medicine, University of Coimbra, Portugal.
341. Department ofGeneral ORL, H&NS, Medical University of Graz, ENT University Hospital, Graz, Austria.
342. Campania Region, Division on Pharmacy and devices policy, Naples, Italy.
343. Department of Respiratory Medicine, Hvidovre Hospital & University of Copenhagen, Denmark.
344. Universidade Federal dos Pampas, Uruguaiana, Brazil.
345. Division of Immunopathology, Department of Pathophysiology and Allergy Research, Center for Pathophysiology, Infectiology and Immunology, Medical University of Vienna, Vienna, Austria; NRC Institute of Immunology FMBA of Russia, Moscow, and Laboratory of Immunopathology, Department of Clinical Immunology and Allergy, Sechenov First Moscow State Medical University, Moscow, Russia.
346. Pneumology and Allergy Department CIBERES and Clinical & Experimental Respiratory Immunoallergy, IDIBAPS, University of Barcelona, Spain.
347. Vilnius University Medical Faculty Institute of Clinical Medicine and Institute of Health Sciences, Vilnius, Lithuania.
348. Department of Lung Diseases and Clinical Immunology Allergology, University of Turku and Terveystalo allergy clinic, Turku, Finland.
349. PELyon; HESPER 7425, Health Services and Performance Resarch - Université Claude Bernard Lyon, France.
350. Immunology and Allergy Unit, Department of Medicine Solna, Karolinska Institutet and University Hospital, Stockholm, Sweden.
351. Department of Chest Medicine, Centre Hospitalier Universitaire UCL Namur, Université Catholique de Louvain, Yvoir, Belgium.
352. University of Bari Medical School, Unit of Geriatric Immunoallergology, Bari, Italy.
353. Pulmonary Unit, Department of Medical Specialties, Arcispedale SMaria Nuova/IRCCS, AUSL di Reggio Emilia, Italy.
354. FILHA, Finnish Lung Association, Helsinki, Finland.
355. Pulmonary Environmental Epidemiology Unit, CNR Institute of Clinical Physiology, Pisa, Italy ; and CNR Institute of Biomedicine and Molecular Immunology "A Monroy", Palermo, Italy.
356. Medical University, Department of Otorhinolaryngology, Plovdiv, Bulgaria.
357. Sotiria Hospital, Athens, Greece.
358. Dept of Otorhinolaryngology, Universitätsklinikum Düsseldorf, Germany.
359. Asthma UK, Mansell street, London, UK.
360. Nova Southeastern University, Fort Lauderdale, Florida, USA.
361. Department of Otolaryngology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore.
362. Department of Medicine, Clinical Immunology and Allergy, McMaster University, Hamilton, Ontario, Canada.
363. Division of Immunodermatology and Allergy Research, Department of Dermatology and Allergy, Hannover Medical School, Hannover, Germany.
364. Department of Medicine Solna, Immunology and Allergy Unit, Karolinska Institutet and Department of ENT diseases, Karolinska University Hospital, Stockholm, Sweden.
365. Eshelman School of Pharmacy, University of North Carolina, Chapel Hill, NC, USA.
366. International Primary Care Respiratory Group IPCRG, Aberdeen, Scotland.
367. Bradford Institute for Health Research, Bradford Royal Infirmary, Bradford, UK.
368. Allergologyst - Medical College of Medical Faculty, Thracian University, Stara Zagora, Bulgaria.
369. Department of Research, Olmsted Medical Center, Rochester, Minnesota, USA.
370. Cyprus International Institute for Environmental & Public Health in Association with Harvard School of Public Health, Cyprus University of Technology, Limassol, Cyprus; Department of Pediatrics, Hospital "Archbishop Makarios III", Nicosia, Cyprus.
371. Celal Bayar University Department of Pulmonology, Manisa, Turkey.
372. The Allergy and Asthma Institute, Islamabad, Pakistan.
373. Department of Paediatrics and Child Health, Red Cross Children's Hospital, and MRC Unit on Child & Adolescent Health, University of Cape Town, Cape Town, South Africa.
374. Department of Otolaryngology Head and Neck Surgery, Beijing TongRen Hospital and Beijing Institute of Otolaryngology, Beijing, China.
375. Universidad Católica de Córdoba, Córdoba, Argentina.
376. University Clinic of Respiratory and Allergic Diseases, Golnik, Slovenia.
377. Gesundheitsregion KölnBonn - HRCB Projekt GmbH, Kohln, Germany.
378. Akershus University Hospital, Department of Otorhinolaryngology, Akershus, Norway.

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379. Chief of Staff, the Northern Health Science Alliance (NHSA) and Director and Founder of Northern Health Matters Ltd, Manchester, UK.
380. President of Kazakhstan Association of Allergology and Clinical Immunology, Department of Allergology and Clinical Immunology of the Kazakh National Medical University, Kazakhstan.
381. ICREA and Climate and Health (CLIMA) Program, ISGlobal, Barcelona, Spain
382. Department of Otorhinolaryngology, Head and Neck Surgery, Ankara, Turkey and Department of Otorhinolaryngology, Head and Neck Surgery, Salzburg Paracelsus Medical University, Austria
383. President of European Rhinologic Society, 1st Dept of ORL, Head & Neck Surgery, Aristotle University, Thessaloniki, Greece and Professor of FAU Erlangen-Nurnberg University, Germany
384. Thermofisher Scientific, Uppsala, Sweden
385. Institute of Health Resort Medicine and Health Promotion, Bavarian Health and Food Safety Authority, Bad Kissingen, Germany.

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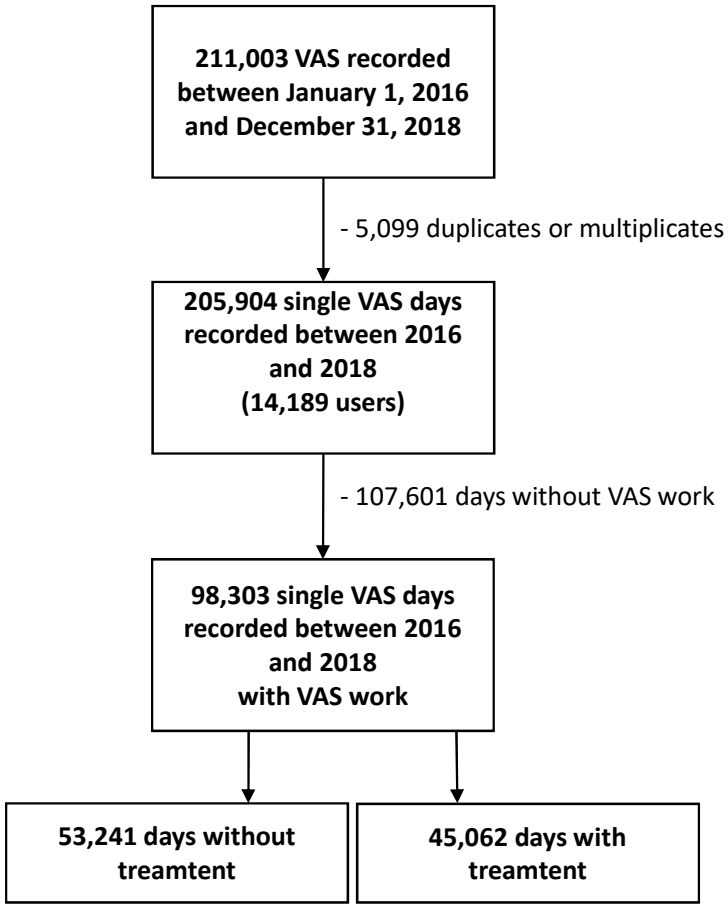

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