U.PORTO

MESTRADO INTEGRADO EM MEDICINA

Lung auscultation using smartphone embedded microphone versus digital stethoscope: a feasibility study

Beatriz Vieira Baptista

M

2023

INSTITUTO DE **CIÊNCIAS BIOMÉDICAS ABEL SALAZAR**

Lung auscultation using smartphone embedded microphone versus digital stethoscope: a feasibility study

Maio de 2023

AUTORA:

Beatriz Vieira Baptista

Endereço de correio eletrónico: up201705334@up.pt

Mestrado Integrado em Medicina

Instituto de Ciências Biomédicas Abel Salazar, Universidade do Porto

ORIENTAÇÃO:

Prof. Doutor Manuel José Ferreira de Magalhães

Centro Hospitalar Universitário de Santo António, Portugal

Instituto de Ciências Biomédicas Abel Salazar, Universidade do Porto

CINTESIS/MEDICDS – Faculdade de Medicina, Universidade do Porto

Lung auscultation using smartphone embedded microphone versus digital stethoscope: a feasibility study

Assinatura da estudante:

Beatriz Baptista

Assinatura do Orientador:

Assinado por: **MANUEL JOSÉ FERREIRA DE MAGALHÃES**
Num. de Identificação: 12516934
Data: 2023.06.02 20:36:32 +0100

Acknowledgments

I want to express my gratitude to my supervisor, Professor Manuel Ferreira Magalhães, for including me in this project and for teaching me his innovative style of thinking through helpful and encouraging criticism.

I would also like to thank Doctor Cristina Jacomé for her constant availability and support during this process.

Finally, I am grateful to my friends and family for their love, support, and encouragement.

Resumo

Introdução e objetivos

A auscultação pulmonar através do microfone do smartphone (SP) é promissora na monitorização domiciliar de doenças respiratórias, especialmente na população pediátrica. Os objetivos deste estudo foram comparar os sons respiratórios adquiridos por um SP com os de um estetoscópio digital (DS), relativamente à sua qualidade e presença de sons adventícios (AS).

Metodologia

Estudo transversal com crianças recrutadas numa escola pública de Portugal. Auscultação pulmonar realizada em 7 localizações (traqueia, ântero-inferiores, póstero-superiores e póstero-inferiores dos hemitóraces). Dois investigadores fizeram gravações simultâneas com o SP e DS, classificando-as independentemente em relação à qualidade do som e presença de AS. Um terceiro investigador foi envolvido sempre que existia discordância. Avaliou-se a concordância inter-avaliador e inter-dispositivo.

Resultados

Recrutadas 27 crianças (20 sexo masculino, 10.2 ± 0.6 anos), 8 com asma auto-reportada. Gravados 378 sons respiratórios (SP n=190 e DS n=188). Elevada proporção de sons com qualidade em ambos os dispositivos, sendo superior no DS (97% vs SP 93%, p<0.001) e variando nos locais de auscultação. AS em 11% das gravações com SP e em 19% com DS (p<0.001). Concordância moderada entre SP e DS para presença de AS (89%, k=0.596, IC95% 0.55-0.88). No SP, concordância inter-anotador de 94% para a presença de AS (DS 71%, k=0.08, IC95% -0.09-0.25).

Conclusões

A auscultação com SP parece viável para a gravação de sons respiratórios e identificação de AS em crianças. Investigação futura é essencial para o desenvolvimento desta tecnologia com potencial de controlo de doenças respiratórias à distância.

Abstract

Introduction and objectives

Lung auscultation through smartphone (SP) embedded microphone is promising for at-home respiratory disease monitoring, particularly in the pediatric population. This study aims to compare the respiratory sounds acquired by a SP and a digital stethoscope (DS), evaluating quality of sounds and presence of adventitious sounds (AS).

Methods

Cross-sectional study with children from a public school in Portugal. Lung auscultation conducted in 7 locations (trachea, anterior inferior, posterior superior, and posterior inferior regions of both hemi-thoraxes). Two investigators made simultaneous DS and SP recordings, and independently classified them for sound quality and presence of AS, with a third investigator resolving the disagreements. Inter-observer and inter-device concordance was evaluated.

Results

27 children (20 male, 10.2 ± 0.6 years old) were recruited, 8 had self-reported asthma. 378 respiratory sounds (SP n=190 and DS n=188) were recorded. The proportion of sounds with quality was high in both devices, being higher in DS (97% vs SP 93%, p<0.001), and varying through auscultation sites. AS were found in 11% of the recordings with SP and in 19% with DS (p<0,001). There was moderate agreement (89%, k=0.596, 95%CI 0.55-0.88) between SP and DS for the presence of AS. SP results show 94% agreement between the two annotators for the presence of AS (DS 71%, k=0.079, 95%CI -0.09-0.25).

Conclusion

SP auscultation seems like a viable technology for recording respiratory sounds and identifying AS in children. Further investigation is required to develop this useful technology for remote respiratory disease monitoring.

Abbreviations

AS: adventitious sounds
CRDs: chronic respiratory diseases
DS: digital stethoscope
mHealth: mobile health
RPS: right posterior superior
SP: smartphone
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology
k: Cohen's kappa
95% CI: 95% confidence interval

Index

Figure List

Table List

Introduction

Lung auscultation has had a fundamental role in clinical practice ever since the invention of the conventional stethoscope by Laennec. It is an essential part of the physical examination as it links pre-existing clinical information to the detected respiratory sounds, allowing for a more accurate diagnosis.[1] However, even though some successful efforts have been made towards out-of-office auscultation[2-4], as with any other diagnostic technique, it requires interpretation by a trained physician.

The growing demand for optimization of remote patient monitoring is notable in the pediatric population given the inherent susceptibility to respiratory diseases and the potential for long-term health repercussions.[5] This is increasingly relevant as chronic respiratory diseases (CRDs) are one of the current leading causes of mortality and morbidity in children, requiring frequent monitoring for improved control and outcomes.[6, 7]

Telemedicine has great potential to help tackle this problem and has experienced significant advances in recent years as a result of technological evolution and the COVID-19 pandemic, but patient adherence has been a challenge.[8] Studies report the lack of proper physical assessment as a big barrier to the success of this new field. Even though phones are widely accessible and an appealing tool for caregivers and older children, diagnostic precision and quality of care must be ensured.[9, 10]

This challenge has been slowly mitigated by the rise of mobile health (mHealth), particularly with newer smartphone (SP) apps created for health monitoring and patient engagement that integrate information acquired from smart sensors and other emerging medical devices and provide personalized feedback.[10-12] Recent research uses SPs as sound receivers through coupling with external microphones, such as the ones in a digital stethoscopes (DS)[2] or others[3, 4]. The current verified recording tools that use SP embedded microphones mainly allow lung function assessment and evaluate isolated respiratory sounds[12]. Our team has conducted two feasibility studies for the use of a mobile app with the pulmonary auscultation functionality[13, 14]. However, because they were set in a clinical environment, there is still need for community-based research, in healthy pediatric populations.

The present study aims to assess the feasibility of the acquisition and interpretation of lung sounds using a SP embedded microphone. Specifically, the aims were to compare the respiratory sounds acquired simultaneously by a SP and a DS, evaluating the quality of sounds and the presence of adventitious sounds (AS).

Methods

Study design and setting

This was an observational cross-sectional study, conducted in November 2019 in a public school in the North of Portugal (S. Lourenço school group, Ermesinde). The responsible teachers presented the study to the children and caregivers, assessing their willingness to participate. Then, an informed consent was signed by the caregivers and an assent form by each child (Appendix). The study was approved by the Ethics Committee of the Faculty of Medicine of University of Porto. This study is reported according to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[(15)]

AIRDOC Mobile App

The AIRDOC app, available on Android and iOS, is a mHealth project designed to provide patients with self-monitoring tools to manage CRDs. Its multiple functionalities include validated health assessment questionnaires and an evidence-based coaching system, as well as an interface that allows medical professionals to access the latest research.[(16)] It also enables the recording of respiratory sounds via the free recording and lung auscultation functions, the latter being the one used in our study. Lung auscultation can be performed in the 7 locations recommended by the CORSA guidelines for respiratory sounds recording: trachea, anterior inferior, posterior superior and posterior inferior regions of the right and left hemi-thoraxes[(17)]. AIRDOC users can register and adjust the duration of each recording, as well as information on the place of auscultation and patient data. Additional information can also be added in the "Notes" compartment. App specificities are shown in Figure 1.

Participants and Data collection

The participants were recruited from a convenience sample of 5th and 6th grade students. Inclusion criteria included only the willingness to participate in the study by the children and caregivers to whom the study was presented. There were no exclusion criteria.

The complete set of data was collected in a quiet room over the course of one day. A digital stethoscope (Littmann® model 3200, 3M, Cerritos, CA, USA) and a smartphone (iPhone 7, MN902ZD/A, iOS 12.1.2) were used to record respiratory lung sounds. Pulmonary auscultation was conducted in the 7 previously stated locations. Each child sat upright, breathing deeply through the mouth, while the two researchers (C.J. physiotherapist/lung sound expert, and M.F.M. pediatrician/lung sound expert) concurrently used the two devices in each location to perform pulmonary auscultation (Figure 2). One of the researchers was registered and logged in to our mobile app, AIRDOC, for immediate annotation of relevant information, such as auscultation duration and site, sound interferences, and patient details (gender, height, weight, and ID). For each recording, both devices were pressed directly onto the skin for about 5-10 seconds, allowing the suggested 1-5 respiratory cycles to be captured[(17)]. Every smartphone recording was instantly saved to AIRDOC and transferred to a secure server at the Faculty of Medicine of the University of Porto as soon as an internet connection became available. Stethoscope sound files were transferred to a computer using Bluetooth and the Littmann® 3200 software at the end of individual data collection. Authorized researchers could later access these files.

Lung sounds classification

The two researchers later independently classified the recordings in terms of sound quality and the presence of AS. At the time of sound classification, the investigators were blinded to patient data other than ID and auscultation site. For sound quality to be assumed (yes/no) and additional analysis to be performed, at least one respiratory cycle had to be present.[(18)] Quality assessment was determined by consensus, and a third annotator (I.A., pediatrician/lung sound expert) had the final say in case of disagreement. The selected recordings were then evaluated for the presence of AS: (1) wheezes or (2) crackles, according to the existent CORSA validated nomenclature. A crackle was defined as a discontinuous and explosive sound occurring usually during inspiration. Wheezes, that can be lower pitched (previously known rhonchi), were defined as continuous musical sounds with durations greater than 100 ms.[(17)] In the event of disagreement, the recordings were classified by the third investigator (I.A.) and the final decision was determined by the majority rule.

Data Analysis

Descriptive statistics were used to characterize the participants regarding gender, age, height, and weight. The inter-rater agreement between the two first annotators (C.J. and M.F.M) was analyzed using percentage of agreement and concordance, through Cohen's kappa (k) and the respective 95% confidence intervals (95% CI), and p-values. The aim was to assess concordance when answering to two main questions: (i) "do the captured sounds have quality?"; and (ii) "are AS identifiable?". To do so, we determined inter-rater agreement for each device separately (SP and DS).

Inter-device agreement was then analyzed through comparison of the proportion of sounds with quality acquired by SP and DS, after final classification by the third annotator in case of disagreement. The same was done to evaluate the proportion of detected AS by each device. For the inter-device agreement for the presence of AS, k, 95% CI and p-values were also used.

All the analysis was performed for the totality of the sample sounds and for each one of the 7 auscultation sites.

The statistics software used was IBM® SPSS® Statistics (version 29, Chicago, IL, USA). The following ranges were used to interpret the k values: 0-0.020 slight, 0.210-0.400 fair, 0.410-0.600 moderate, 0.610-0.800 substantial and 0.810-1.000 almost perfect agreement. The level of significance was set at 0.05.

Results

There were 27 children (21 male / 6 female) included, with a mean age of 10.2 years (± 0.6) and a mean body mass index of 17.9 (±4.8) kg/m^2. Nineteen children didn't report any respiratory problem, and 8 children reported asthma. A total of 378 respiratory sounds (190 with smartphone and 188 with stethoscope) were recorded. After exclusion of 12 recordings, due to file corruption and inadequate duration (less than 5 seconds), a total of 366 respiratory sounds (187 with smartphone and 179 with stethoscope) were included for the final analysis. All the included sounds were listened to and classified by C.J. and M.F.M, and then I.A. did the same for the 99 sounds on which the first 2 annotators disagreed in: i) the assessment of quality, or ii) the presence of AS. A study flowchart is presented on Figure 3.

The proportion of inter-rater agreement for sound quality was higher in SP (87%; k 0.233, 95%CI [0.027-0.439], p<0.001) when compared to DS (84%; k -0.052, 95%CI [-0.083-0.016], p=0.456). The smartphone also had a greater proportion of inter-rater agreement for the presence of AS (94%; k 0.714, 95%CI [0.547-0.881], p<0.001) comparatively to DS (71%; k 0.079, 95%CI [-0.090-0.247], p=0.329). The comprehensive result for the inter-rater agreement is presented in Table 1.

The proportion of sounds with quality was high with both devices (93% in SP and 97% in DS), but small differences were identified between thoracic points of the recorded sound (between 88-100%; Figure 4a).

AS were identified in 11% and 19% of the sounds with SP and DS, respectively, with the trachea and the right posterior superior (RPS) site being the ones with higher disagreement in the proportion of AS identified (trachea: SP 4% vs. DS 20%; RPS: SP 8% vs. DS 33%) and the inferior sites being the ones with higher agreement (Figure 4b). The overall proportion of inter-device agreement for the presence of AS was 89% (k 0.596, 95%CI [0.420-0.772], p<0.001).

Discussion

This was the first study to do a direct concurrent comparison between the SP embedded microphone and the lung auscultation gold-standard (stethoscope), showing that this type of technology is feasible for the use in children in a community setting. The quality of respiratory lung sounds and the presence of AS acquired from SP showed a statistically significant moderate to substantial inter-rater agreement, having performed better than the sounds acquired from DS. Also, the inter-device agreement between SP and DS for the identification of AS was moderate.

Two other previous studies have also demonstrated the feasibility of smartphone auscultation[13, 14], but have done so through the assessment of different respiratory cycles, as conventional and SP auscultation were not conducted simultaneously. Also, these studies were performed in a hospital outpatient clinic and controlled setting. The concurrent assessment of the same respiratory cycle with both devices in our study may have led to a higher inter-device agreement for AS identification when comparing with studies from Ferreira-Cardoso H et al. Additionally, the positive results we have obtained in sound quality on a non-clinical setting increase the potential for the future use of this tool in remote patient care.

Inter-rater agreement was ensured in terms of sound quality and AS identification and even proved to be higher on the SP. When evaluating the SP recordings for the presence of AS, our study showed higher agreement (94% k=0.714) than in previous literature, in which kappa ranged from 0.41-0.61[19]. This might be influenced by the fact that our study did not assess concordance for the categorization of AS (i.e., we did not analyze differences in wheezes or crackles sounds because of the small sample) as the study from Melbye H *et al* did. However, our concordance was still superior to the study from Ferreira-Cardoso *et al* (93% k=0.66), where the AS presence/absence was the variable in study. [13]

Children recordings have been shown to have better inter-rater agreement when compared to adult populations in AS classification[19], but the same cannot be said for quality[13]. Despite having identified a high percentage of sounds with quality, our annotators had poor agreement (k=0.233). The fact that there was only elimination of corrupted files, with the possibility of inclusion of recordings with sound interferences, may have contributed to the disagreement[17], but this was done to understand the possible feasibility of a real-world applicability of this technology. To overcome this limitation in future investigations, mobile applications should include an integrated system for sound filtering and amplification, to allow immediate classification.

When comparing both devices, the agreement for the presence of AS was moderate and slightly higher than past research. The lower chest regions showed better inter-device agreement when compared to the upper ones. Although we found no particular reasoning for this, alveoli ventilation is known to be better at the lung bases[20], which might justify a better sound conduction. A study that compared the same DS that was used in our study to an analogic stethoscope, in a population of sick children, had agreement that ranged from 75-100% with kappa 0.44-1.0[21]. Our proportion of identified AS with SP was low (SP 11% vs. DS 19%), which is expectable since our study was conducted in a small population of predominantly healthy children. Ferreira-Cardoso *et al* had similar results, reporting a discrepancy between a high percentage of agreement (85%) and a low kappa (0.35)[13]. Our observed difference was lower (89%, k=0.596), which might be attributable to the concurrent aspect of auscultation. Also, when they used children as an unit of analysis, their percentage of agreement was still inferior to ours.[13] These findings strongly support the feasibility of this mobile application for remote use in the monitoring of children CRDs.

Nevertheless, limitations to our study must be addressed. Although it is a strength that both healthy and non-healthy children were included, our sample was too small, leading to a small number of recorded AS. A larger sample size would enable comparison with the existing computerized respiratory sound analysis database, which would help us to better infer about the utility of the SP in each disease.[22] Since asthma was the only respiratory disease reported, we couldn't accurately correlate our findings to disease presentation or chance, as we lacked proper assessment of the participants' current clinical status. With asthma being the most prevalent CRD[10], any resulting conclusions would be of great interest. We are also aware that kappa seems to vary inversely to the amount of detail in AS classification[19] and is dependent on prevalence[23], which may have falsely improved our values. The specialization of our annotators in lung sound analysis may have also contributed to a globally higher agreement.[24]

Mobile auscultation is extremely advantageous, as it includes almost every benefit of current wearable technologies but is more accessible and user-friendly.[25] There are current mHealth applications that minimize some of our identified limitations, with embedded sound processing filters for respiratory sounds and machine learning algorithms for diagnostic purposes, although none of these are specialized in SP lung auscultation[26]. Our work addresses an acknowledged issue in the computerized lung sound analysis community by being undertaken in an underrepresented population[22], with an innovative technology in an non-clinical setting, therefore strengthening the foundation for the development of artificial intelligence.

Conclusion

Our study showed that the use of SP embedded microphones might be a feasible alternative to conventional auscultation, with similar sound quality and similar identification of AS. Also, our data showed good quality and good inter-rater agreement for the assessment of AS using the SP. Nonetheless, more effort should be mobilized to improve the discriminative capacity for AS identification with the SP. Future investigation should also focus on the enrichment of the children respiratory sound database, for the continuous development of machine learning technologies.

References

1. Bohadana A, Izbicki G, Kraman SS. Fundamentals of lung auscultation. N Engl J Med. 2014;370(8):744-51.
2. Wagner R, Lima TC, Silva M, Rabha ACP, Ricieri MC, Fachi MM, et al. Assessment of Pediatric Telemedicine Using Remote Physical Examinations With a Mobile Medical Device: A Nonrandomized Controlled Trial. JAMA Netw Open. 2023;6(2):e2252570.
3. Reyes BA, Olvera-Montes N, Charleston-Villalobos S, González-Camarena R, Mejía-Ávila M, Aljama-Corrales T. A Smartphone-Based System for Automated Bedside Detection of Crackle Sounds in Diffuse Interstitial Pneumonia Patients. Sensors. 2018;18(11):3813.
4. Lu B-Y, Wu H-D. Auscultation Using Modern Mobile Communication. Acoustics Australia. 2015;43(3):303-9.
5. Zar HJ, Ferkol TW. The global burden of respiratory disease—impact on child health. Wiley Online Library; 2014. p. 430-4.
6. Chen X, Zhou CW, Fu YY, Li YZ, Chen L, Zhang QW, et al. Global, regional, and national burden of chronic respiratory diseases and associated risk factors, 1990-2019: Results from the Global Burden of Disease Study 2019. Front Med (Lausanne). 2023;10:1066804.
7. Papadopoulos NG, Mathioudakis AG, Custovic A, Deschildre A, Phipatanakul W, Wong G, et al. Current and Optimal Practices in Childhood Asthma Monitoring Among Multiple International Stakeholders. JAMA Netw Open. 2023;6(5):e2313120.
8. Greiwe J. Telemedicine Lessons Learned During the COVID-19 Pandemic. Current Allergy and Asthma Reports. 2022;22(1):1-5.
9. Mahmoud K, Jaramillo C, Barteit S. Telemedicine in Low- and Middle-Income Countries During the COVID-19 Pandemic: A Scoping Review. Front Public Health. 2022;10:914423.
10. Dauletbaev N, Oftring ZS, Akik W, Michaelis-Braun L, Korel J, Lands LC, et al. A scoping review of mHealth monitoring of pediatric bronchial asthma before and during COVID-19 pandemic. Paediatr Respir Rev. 2022;43:67-77.
11. Majumder S, Deen MJ. Smartphone Sensors for Health Monitoring and Diagnosis. Sensors. 2019;19(9):2164.
12. Sleurs K, Seys SF, Bousquet J, Fokkens WJ, Gorris S, Pugin B, et al. Mobile health tools for the management of chronic respiratory diseases. Allergy. 2019;74(7):1292-306.
13. Ferreira-Cardoso H, Jácome C, Silva S, Amorim A, Redondo MT, Fontoura-Matias J, et al. Lung Auscultation Using the Smartphone—Feasibility Study in Real-World Clinical Practice. Sensors. 2021;21(14):4931.
14. Ferreira-Cardoso H, Moniz AC, Almeida R, Alves-Correia M, Pereira AM, Lopes F, et al. Comparison of lung auscultation between smartphone and digital stethoscope in patients with asthma: a feasibility study. European Respiratory Journal. 2022;60(suppl 66):1859.
15. Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Int J Surg. 2014;12(12):1500-24.
16. Patient Centered Innovation and Technologies. Projects: PaCeIT; 2018 [Available from: https://paceit.med.up.pt/projetos/.
17. Sovijärvi A, Vanderschoot J, Earis J. Standardization of computerized respiratory sound analysis. Eur Respir Rev. 2000;10.
18. Pasterkamp H, Brand PL, Everard M, Garcia-Marcos L, Melbye H, Priftis KN. Towards the standardisation of lung sound nomenclature. Eur Respir J. 2016;47(3):724-32.
19. Melbye H, Garcia-Marcos L, Brand P, Everard M, Priftis K, Pasterkamp H. Wheezes, crackles and rhonchi: simplifying description of lung sounds increases the agreement on their classification: a study of 12 physicians' classification of lung sounds from video recordings. BMJ Open Respir Res. 2016;3(1):e000136.

20. Powers KA, Dhamoon AS. Physiology, Pulmonary Ventilation and Perfusion. StatPearls. Treasure Island (FL): StatPearls Publishing

Copyright © 2023, StatPearls Publishing LLC.; 2023.
21. Kevat AC, Kalirajah A, Roseby R. Digital stethoscopes compared to standard auscultation for detecting abnormal paediatric breath sounds. Eur J Pediatr. 2017;176(7):989-92.
22. Gurung A, Scrafford CG, Tielsch JM, Levine OS, Checkley W. Computerized lung sound analysis as diagnostic aid for the detection of abnormal lung sounds: a systematic review and meta-analysis. Respir Med. 2011;105(9):1396-403.
23. Guggenmoos-Holzmann I. The meaning of kappa: probabilistic concepts of reliability and validity revisited. Journal of clinical epidemiology. 1996;49(7):775-82.
24. Brooks D, Thomas J. Interrater reliability of auscultation of breath sounds among physical therapists. Phys Ther. 1995;75(12):1082-8.
25. Lee SH, Kim YS, Yeo MK, Mahmood M, Zavanelli N, Chung C, et al. Fully portable continuous real-time auscultation with a soft wearable stethoscope designed for automated disease diagnosis. Sci Adv. 2022;8(21):eabo5867.
26. Rajkumar P, Kenneth S, Nizam Uddin A. Machine learning in lung sound analysis: A systematic review. Biocybernetics and Biomedical Engineering. 2013;33(3):129-35.

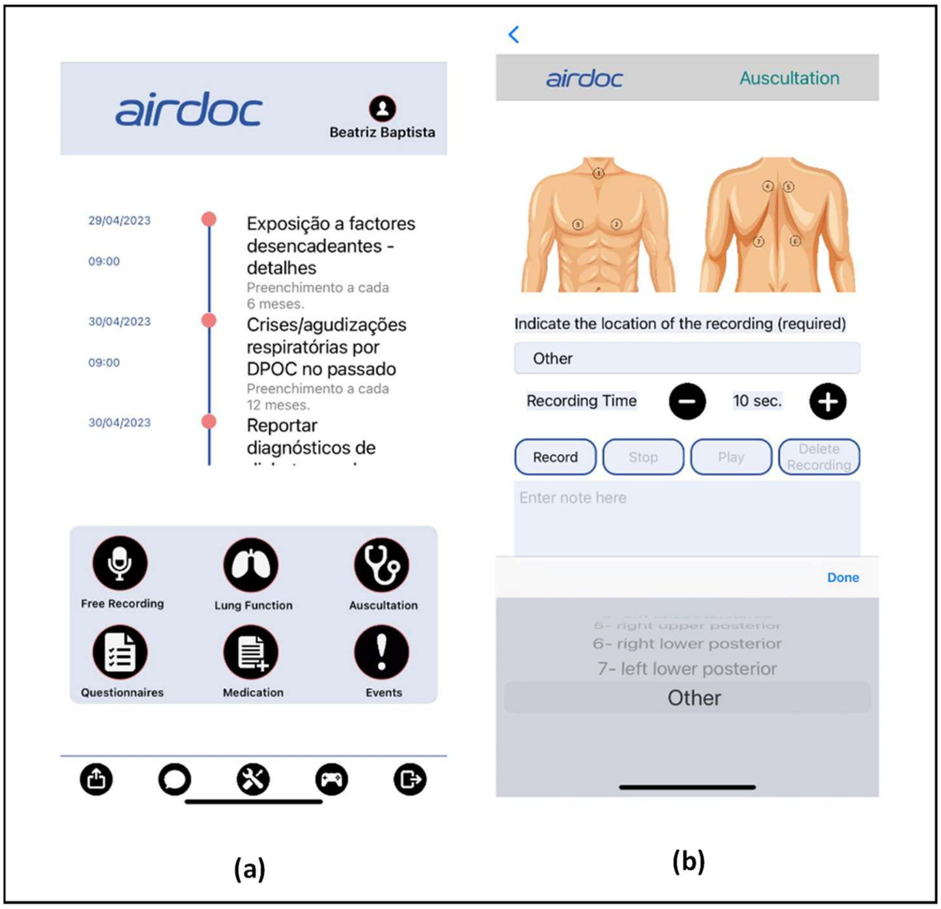


Figure 1 *- AIRDOC app screens used:* ***(a)*** *main screen;* ***(b)*** *lung auscultation feature.*

Figure 2 *- Example of a sound recording in the left posterior superior region at the school.*

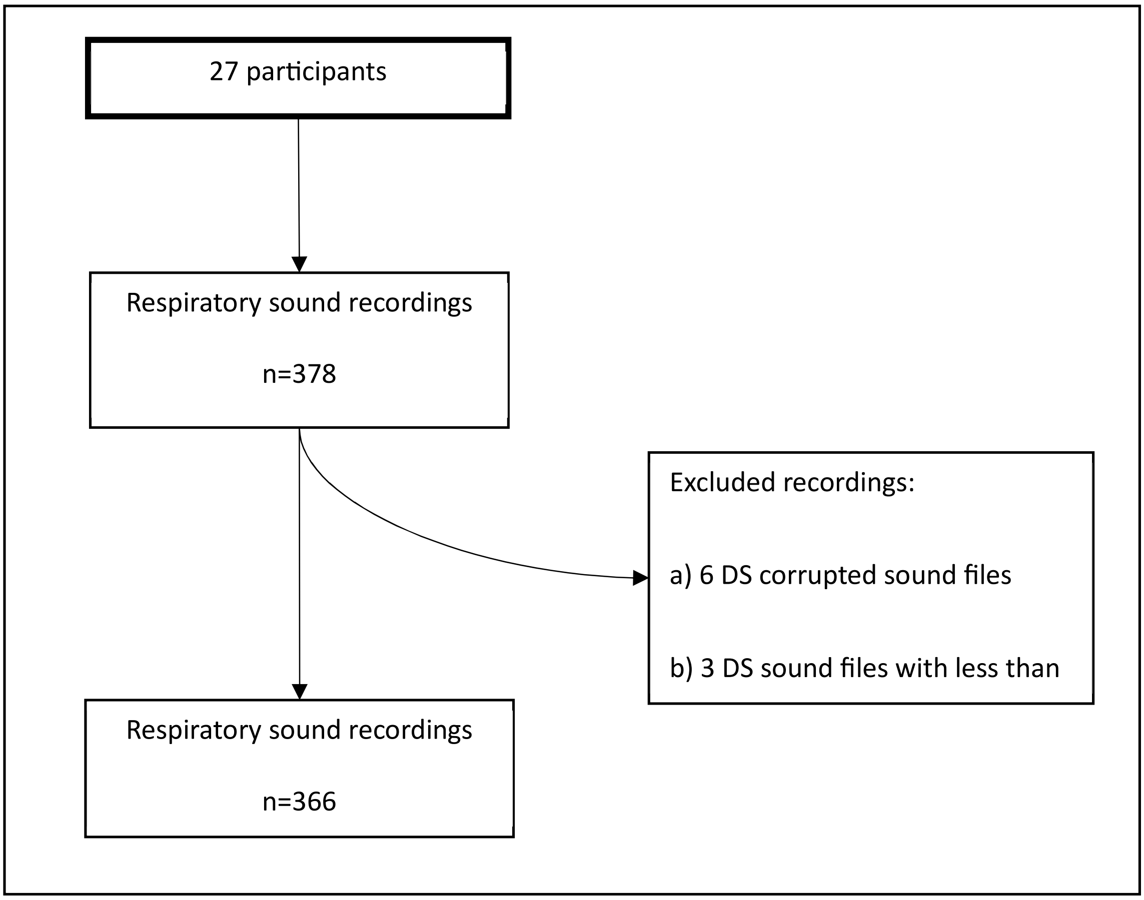
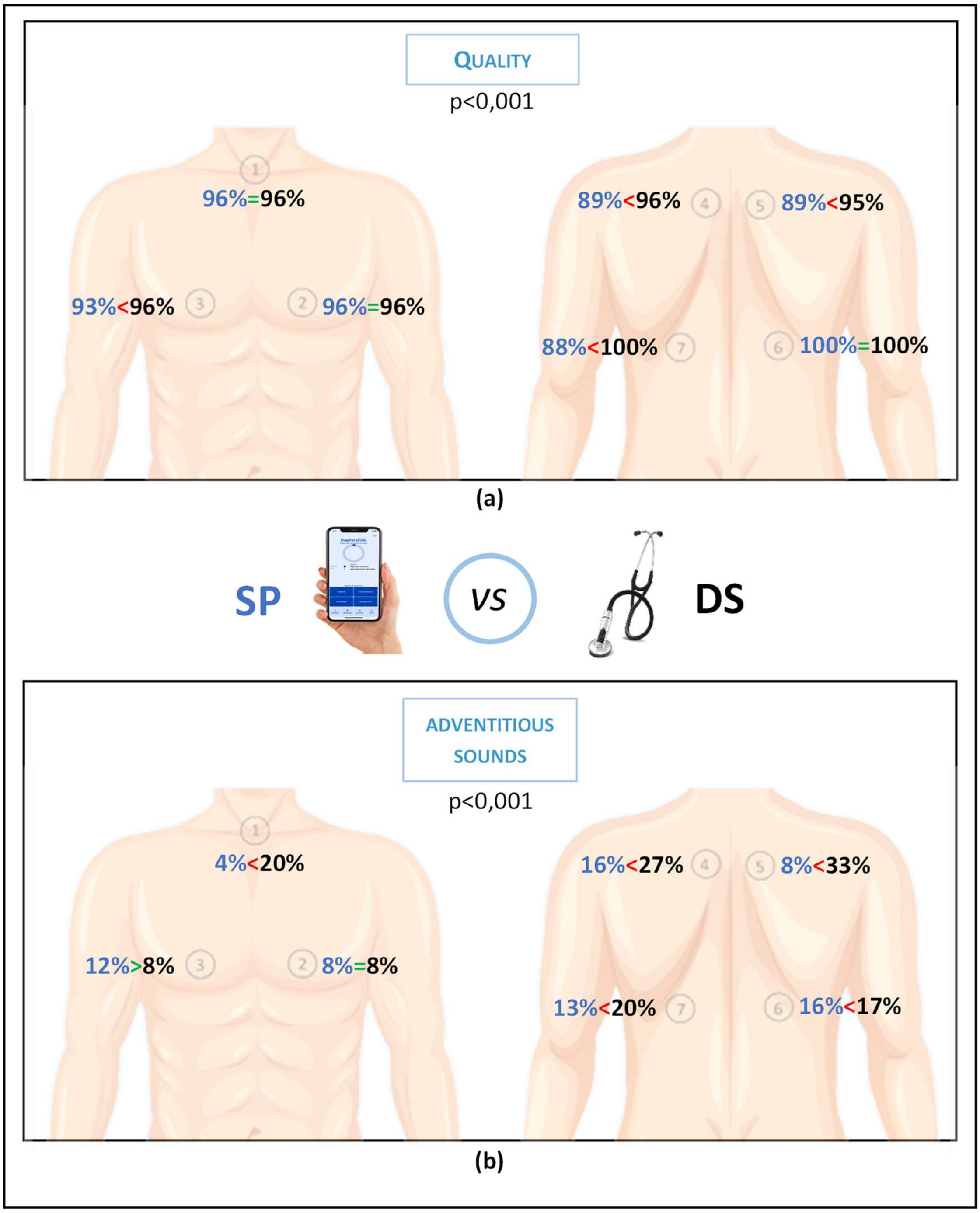


Figure 3 *- Study flowchart.*



(1) trachea, (2 and 3) anterior inferior, (4 and 5) posterior superior and (6 and 7) posterior inferior regions of the hemi-thoraxes.

Figure 4 *- Proportion of sounds with quality* ***(a)*** *and of detected AS* ***(b)*** *in the SP (blue) versus the DS (black) for each location.*

Table I *- Inter-rater agreement for quality of sound and presence of AS for the totality of recordings and for each auscultation site.*

	PA (%) SP|DS	kappa SP|DS	95% CI SP|DS	Inter-rater agreement for
Totality of recordings	87 | 84	0.233* | -0.052	[0.48, 0.03] | [-0.02, 0.08]	**Quality of sound**
Auscultation site				
Right anterior inferior	85 | 85	0.289 | n.a.	[0.74, -0.16] | n.a.	
Left anterior inferior	85 | 92	0.257*| n.a.	[0.76, -0.25] | n.a.	
Right posterior inferior	88 | 88	n.a. | n.a.	n.a. | n.a.	
Left posterior inferior	85 | 96	-0.061 | n.a.	[0.03, -0.16] | n.a.	
Right posterior superior	89 | 80	0.523* | n.a.	[0.97, 0.07] | n.a.	
Left posterior superior	79 | 65	n.a. | n.a.	n.a. |[-0.0003, -0.26]	
Trachea	100 | 85	1* | -0.083	[1, 1] |[-0.0006, -0.16]	
Totality of recordings	94 | 71	0.714* | 0.079	[0.88, 0.55] | [0.24, -0.09]	**Presence of AS**
Auscultation site				
Right anterior inferior	81 | 81	0.154 | -0.095	[0.64, -0.33] | [-0.003, -0.187]	
Left anterior inferior	85| 88	0.351*| -0.059	[0.87, -0.17] | [0.023; -0.141]	
Right posterior inferior	100 | 83	1* | 0.276	[1, 1] | [0.717; -0.165]	
Left posterior inferior	100 | 80	1* | 0.167	[1, 1] | [0.649; -0.315]	
Right posterior superior	100 | 52	1* | 0.237	[1, 1] | [0.476; -0.002]	
Left posterior superior	89 | 65	0.614*| -0.115	[1.10, 0.13] | [0.096; -0.326]	
Trachea	100 | 46	1* | 0.036	[1, 1] | [0.279, -0.207]	

PA – proportion of agreement; SP – smartphone; DS – digital stethoscope; 95% CI – 95% Confidence Intervals;

AS – adventitious sounds; n.a. – not applicable; *p<0,05.

FOLHA DE INFORMAÇÃO / CONSENTIMENTO AO PARTICIPANTE

- **Designação do estudo:** Cientificamente provável – Estudos de exequiblidade de aplicações móveis de monitorização da asma.

- **Descrição do estudo, sua natureza e objetivo:** Este estudo pretende avaliar a exequibilidade de diferentes aplicações móveis, em forma de jogo **para a monitorização da asma em crianças, jovens e adultos.** A informação recolhida durante o estudo é confidencial. O material recolhido será utilizado somente para fins de investigação e desenvolvimento, de acordo com a Lei de Proteção de Dados de Portugal (Lei n.º 67/98. de 26 de Outubro) e o Regulamento Geral de Proteção de Dados (RGPD). Na fase atual do projeto precisamos de recolher amostras sonoras de crianças a soprarem, independentemente de terem asma ou não. A sessão será realizada nas instalações do Agrupamento, com uma duração aproximada de 15 minutos por criança. Será guiada por um profissional de saúde que irá interagir com a criança, explicar como interagir com o jogo no dispositivo móvel, e como é suposto realizar a manobra respiratória. As gravações serão feitas pelo microfone do dispositivo móvel no momento em que a criança sopra, bem como noutros dispositivos móveis auxiliares em simultâneo. Nestas sessões estará também presente o engenheiro informático responsável pelo desenvolvimento da aplicação, que irá simplesmente observar a forma como a criança interage com o jogo, avaliando questões relacionadas com a usabilidade do mesmo. Oferecemos um rastreamento gratuito da capacidade respiratória do seu educando no final da atividade, a ser realizado pelo profissional de saúde. Numa segunda fase, após a análise dos dados recolhidos, gostaríamos de repetir a atividade com o seu educando para validação dos resultados.
- **Benefícios:** A sua participação poderá contribuir para:
  - Melhorar a vida das crianças, jovens e adultos que padecem desta doença;
  - Estar mais desperto para os sintomas que lhe são subjacentes, ajudando quem não sabe.
- **Riscos graves e riscos frequentes:** Neste estudo não é expectável qualquer efeito secundário, desvantagem ou risco específico. A sua participação é totalmente voluntária, podendo desistir a qualquer momento sem dar qualquer justificação.
- **Contacto para mais informações sobre o estudo:** João Almeida Lopes da Fonseca. Professor Auxiliar com Agregação da Faculdade de Medicina da Universidade do Porto. E-mail: fonseca.ja@gmail.com
- **Diretor de Turma**
  Confirmo que li as informações que constam nesta folha ao aluno para participar no estudo de exequibilidade de apps de monitorização da asma.
  Nome do DT: ____
  Data ___/___/______ Assinatura ____
- **Ao aluno / Encarregado de Educação**
  Por favor, leia com atenção a informação. Não hesite em solicitar mais informações se não estiver completamente esclarecido. Verifique se compreende todas as informações fornecidas. Se tudo estiver conforme, por favor assine este documento.

Declaro ter compreendido os objetivos do estudo.

Nome do aluno: ____

Data ___/___/______ Assinatura do aluno: ____

Nome do encarregado de educação: ____

Grau de parentesco ou tipo de representação legal:____

Data ___/___/______ Assinatura do E.E. ____

Autorizo ☐ **/ Não autorizo** ☐ a participação no estudo, bem como os procedimentos diretamente relacionados que sejam necessários.