

1 **Opinions of patients with persistent asthma regarding the use of mobile applications for disease**
2 **monitoring**

3

4 **Abstract**

5 **BACKGROUND:** We assessed adherence to treatment and management needs of adults with persistent
6 asthma and their interest in using apps for asthma management. Secondly, we explored patients'
7 opinions about an app to assess and improve adherence to treatment. **METHODS.** A cross-sectional
8 study was conducted with 40 adults with persistent asthma (49.9±15.8 years) recruited at outpatient
9 clinics from a district hospital. Participants answered a survey on sociodemographic, asthma control,
10 treatment adherence and use of mobile devices, social networks and apps. Four patients participated in
11 a prospective extension of the study, in which they were invited to use the InspirerMundi app. **RESULTS:**
12 48% of the participants had at least ≥1 exacerbation in the previous year and 85% had uncontrolled
13 asthma. Self-reported adherence to treatment showed that one in four participants had low adherence.
14 At least daily, 55% of participants navigated on the internet with their smartphone/tablet, 35% used
15 apps and 93% social networks. Nine (22%) participants had previously used health/fitness apps and 65%
16 would like to use apps to improve in their adherence. **CONCLUSIONS:** Most participants had
17 uncontrolled asthma, reported high adherence to treatment and were daily users of social networks and
18 the internet. Only 1/4 used apps but 2/3 would like to use apps to support asthma management.

19

20 **Keywords**

21 Asthma; Medication adherence; Mobile applications; Cell phone use; Smartphone

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1 Opinions of patients with persistent asthma regarding the use of mobile applications for disease 2 monitoring

3 Introduction

4 Asthma affects around 235 million people worldwide.¹ Regular disease monitoring and its proper
5 management may allow a normal life.^{1,2} Inhaler controller medications are the cornerstone of effective
6 asthma treatment. However, there is low adherence to medication in patients with asthma, which leads
7 to worse outcomes and higher disease burden.^{3,4,5}

8 One of the main factors contributing to the difficulty in adhering to asthma treatment is poor patients'
9 perception of asthma, since asthma attacks are episodic, which may constitute a barrier to
10 understanding the need of control medication.^{6,7} There is a need to improve our understanding of the
11 patterns of adherence to inhaled controller medications and to identify the specific reasons for non-
12 adherence and other needs among patients with persistent asthma. It is also important to develop
13 patient-centred solutions, allowing patients to be actively involved in the control of their asthma,
14 through the implementation of self-monitoring strategies.⁸

15 Interactive asthma monitoring tools, through the use of internet-based and social media solutions, have
16 been associated with better outcomes in patients with asthma.⁹ A simple daily text message reminder
17 was associated with increased adherence to treatment.¹⁰ In addition, most patients with asthma show a
18 preference for using internet applications for future self-monitoring.¹¹ However, it is important to
19 improve our understanding of the preferences, interest and usage of web-based strategies in daily
20 routine of people with persistent asthma, to improve adherence to treatment.

21 Apps can be a feasible solution, since they can be used at any time, are easily integrated into daily life,
22 can combine mechanisms to determine treatment adherence, interactive communication and
23 gamification that can influence patients' behaviour changes.¹² In fact, the use of mobile applications
24 made patients feel that their health care continued even outside the hospital.¹¹ It is therefore
25 hypothesised that an app, with gamification and peer-support elements, may improve adherence to
26 treatment in patients with asthma. However, usefulness and acceptability by end users needs to be
27 assessed in a real-world study.

28 The main aims of this study were to evaluate adherence to treatment and management needs of adults
29 with persistent asthma; to assess their interest in using apps for management and adherence to

1 treatment, and to describe the use of mobile devices, social networks and apps. The secondary aim was
2 to investigate users' opinions about an app to assess and improve adherence to treatment.

3 **Material and Methods**

4 Study design and participants

5 A cross-sectional study with 40 adults with asthma and a pilot extension study with four of those
6 patients were performed. Patients were recruited during 120 appointment periods of allergy and
7 pulmonology outpatient clinics of *Hospital Pêro da Covilhã*, between September 2017 and June 2018.
8 Patients were included if they had persistent asthma, were ≥ 18 years old, had an active prescription of
9 inhaled controlled medication and had access to mobile devices (smartphone/tablet). Patients with a
10 diagnosis of other chronic conditions with possible interference with the study aims were excluded. In
11 the prospective extension study, patients had additionally to answer positively to the question about
12 interest in using apps to improve inhaler adherence. All participants were informed about the study and
13 written informed consent was obtained prior to data collection. The Ethics Committee of *Hospital Pêro*
14 *da Covilhã* approved the study.

15 Data collection

16 First, sociodemographic and clinical (smoking habits, body mass index-BMI, age of asthma diagnosis,
17 asthma self-monitoring and written asthma treatment plan) data were collected. To assess management
18 needs, patients' asthma control, exacerbations and use of health care resources were collected.
19 Clinicians reported patients' asthma clinical characteristics and control according to Global Initiative for
20 Asthma (GINA).¹³ Patients completed the Control of Allergic Rhinitis and Asthma Test (CARAT).¹⁴ CARAT
21 total (CARAT-T, 0-30), upper airways (CARAT-UA, 0-12) and lower airways (CARAT-LA, 0-18) scores were
22 calculated. Scores ≥ 24 on CARAT-T and ≥ 16 on CARAT-LA defined good disease control. Number of
23 exacerbations (defined as episodes of progressive increase in shortness of breath, cough, wheezing,
24 and/or chest tightness, requiring change in maintenance therapy¹⁵), treatment with oral corticosteroids,
25 days of work/school lost due to routine medical visits, unscheduled medical visits, hospitalisations and
26 day of work/school lost due to asthma attacks in previous year were also assessed.

27 To assess inhaler adherence, patients answered the 4-item Morisky Medication Adherence Scale
28 (MMAS-4).^{16,17} The scores range from 0 to 4 (0 indicates high adherence, 1-2 medium adherence and 3-4
29 low adherence). In addition, patients assessed their global adherence to inhaled controller medication

1 for asthma during the previous week (“how would you classify your adherence to your daily inhaler
2 during the last week?”) using a Visual Analogic Scale (VAS), ranging from 0 (worst) to 100 (best)
3 millimetres¹⁸. Satisfaction with inhaler was assessed through a questionnaire previously used in patients
4 with asthma.¹⁹ This questionnaire includes 4 VAS (0 worst -100 best) questions, which evaluate patients
5 self-perception of inhaler technique (“I perform correctly the technique of my inhaler”), satisfaction with
6 the inhaler device (“I feel satisfied with my inhaler”), comfort with public use of the inhaler (“I feel
7 comfortable using my inhaler in public”) and perception of how his/her preferences were taken into
8 account at the time of inhaler’s prescription (“I feel that my physician took into account my opinion and
9 preferences when choosing my inhaler”).¹⁹ Then, the participants completed the specific Beliefs about
10 Medicines Questionnaire (BMQ-Specific).²⁰ The BMQ-Specific includes a 5-item Necessity scale (score 5-
11 25) and a 6-item Concerns scale (score 6-30). Higher scores represent greater patient’s beliefs in the
12 represented concept.

13 Finally, participants filled in the Smartphone Usage Scale and the General Social Media Usage Subscale
14 of the Media and Technology Usage and Attitudes Scale (MTUAS).²¹ Patients were also asked about
15 previous use of health/fitness apps and asthma apps, if they would like to use apps to manage their
16 asthma and, and if they would like to use apps to improve inhaler adherence.

17 In the prospective extension study, four patients installed the InspirerMundi app on their mobile devices
18 and were invited to use the app daily for 6 months. At the end of this time period, patients were
19 interviewed by phone to answer a survey about the app. The survey included questions regarding
20 satisfaction with each of the app components; suggested app improvements and also the System
21 Usability Scale (SUS).²² SUS score range from 0 to 100, and scores >68 mean good system usability.

22 InspirerMundi App

23 InspirerMundi aims to transform adherence to treatment into a positive experience through immediate
24 and enjoyable feedback (gamification), while allowing for verified inhaler adherence monitoring.¹² The
25 app, available for iOS and Android, integrates 3 main components: monitoring, gaming, and social/peer
26 support. In the monitoring component, users can add their current medications and record performed
27 inhalations using the image-based inhaler adherence detection tool. The mobile app allows patients to
28 view statistics on the adherence to medications and gives alerts of scheduled medication. Patients can
29 also record relief medication use, asthma-related symptoms and exacerbations, and can share data with

1 their physician. In the gaming component, the aim is to increase the sphere of influence by the network
2 of Inspirers and Warriors. The app engages patients with a customisable “Warrior” (beginner player),
3 which can become an Inspirer (advanced player) that gives support to his/her Warriors. Points are given
4 when users take their medication according to plan. In the social/peer support component, users can
5 share and demonstrate their points/badges and achieve social recognition; exchange messages and alert
6 their warriors regarding missing medication doses.

7 Statistical analysis

8 Statistical analyses were conducted with IBM SPSS Statistics v21 (Chicago, USA). Categorical variables
9 were described with absolute and relative frequencies and continuous variables with mean and
10 standard deviation or median with interquartile range, according to data distribution. Differences
11 between patients with or without interest in using apps were tested using the χ^2 test for categorical
12 variables and Mann-Whitney U Test for continuous variable. Logistic regression analysis was used to
13 explain the interest in using asthma apps. Adjusted odds ratio (OR) with 95% confidence interval (95%
14 CI) were calculated. All variables possibly related to interest in using apps were considered. The level of
15 significance was $\alpha < 0.05$.

16 Results

17 Participants

18 Forty patients (31 females) with a mean age of 49.9 ± 15.8 years participated. Most were married, had an
19 education level ≥ 10 years and were employed. Almost two thirds of the participants had never smoked.
20 An association between interest in using apps for asthma and age, marital/civil status, education level
21 and BMI was observed (Table 1).

22 Treatment adherence and management needs

23 The mean age at asthma diagnosis was 29.6 ± 15.6 years. According to CARAT, 85% (n=34) of the
24 participants had uncontrolled disease (75% considering solely the lower airways) and almost half had
25 exacerbations in the previous year. Yet, almost none had lost a work/school day due to asthma attacks.

26 A relation between interest in using mobile applications for asthma and age of asthma diagnosis was
27 observed (table 2). The BMQ necessity score had a mean of 19.1 ± 3.3 and the BMQ concern score a
28 mean of 15.6 ± 3.9 . In terms of the 4-MMAS, most patients (55%) had medium adherence to treatment,
29 and one fifth had high adherence. Most participants had at least one problem regarding adherence to

1 treatment and most patients (68%) forgot to take their medication (Figure 1). Self-perception of
2 adherence to inhalers in the previous week was high (median 91%) as were self-evaluation of inhaler
3 technique (median 99%), satisfaction with the inhaler device (median 99%), patient's perceived
4 involvement in the choice of the device(s) (median 98%) and public use of the inhaler (median 100%).
5 Association between interest in using apps for asthma and self-perception of adherence to inhalers in
6 the previous week, self-evaluation of inhaler technique, patient's perceived involvement in the choice of
7 the device(s) and public use of the inhalers was observed (table 2).

8 Participants mostly browsed the web, searched for information and used apps on their smartphone
9 (Figure 2). Those who used their smartphone/tablet more also showed greater interest in using apps. A
10 relationship between interest in using mobile applications for asthma and browsing the web, listening to
11 music, recording video, using apps, searching for information and checking Facebook page was
12 observed. Most (93%) participants used Facebook, 22% used apps of health/fitness and only one
13 participant had used an app for asthma (Figure 3). However, most patients (65%) would like to use apps
14 to improve adherence to treatment.

15 The logistic regression model was statistically significant ($X^2=21.284$, $p<0.001$) and explained 59%
16 (Nagelkerke R^2) of the interest in use apps for asthma. The variables use of apps (OR=28.3; 95%CI 2.1-
17 374.9) and the frequency of Facebook use (OR=2.3; 95% CI 1.1-4.7) were the independent variables.

18 Pilot study

19 Four participants (1 male, 20-46 years; ≥ 10 education years) tested the InspirerMundi app. The SUS
20 score was 65 for one participant and >68 for the other participants (80, 82.5, 85). Concerning the
21 monitoring component three patients were completely satisfied/satisfied and one had no opinion.
22 Regarding the inhaler usage detection tool, two participants were completely satisfied/satisfied and the
23 other two had no opinion. Regarding the app gamification, two were satisfied, one had no opinion and
24 one was unsatisfied. As for the app social network, two were completely satisfied/satisfied, one had no
25 opinion and one was unsatisfied. All participants were globally satisfied with the app and all would
26 recommend it to others. One participant considered that the use of the app increased his/her
27 awareness of the importance of adherence to medication and two stated that the app increased their
28 motivation to adhere to it. Participants stated that the app allowed them to better control the
29 time/doses of the medication; to register their symptoms and to have greater perception of control of

1 their symptoms. Two participants considered that the game component should be more engaging, while
2 another participant considered that the app stalled several times. They suggested simplifying the record
3 of inhaled medication and the main screen presentation, with three menus: medication, CARAT and
4 weekly/daily symptoms.

5 **Discussion**

6 This study contributes to the much needed knowledge about adherence to treatment, asthma
7 management problems and about opinions on the use of apps in patients with asthma. A main finding
8 was that two thirds of the participants with access to mobile devices would like to use apps for asthma
9 to improve monitoring and adherence to treatment. Furthermore insufficient control of asthma, poor
10 monitoring between medical appointments and a possible overestimation of the participants regarding
11 treatment related perceptions were observed.

12 The main management needs identified were the high proportion of patients with insufficient asthma
13 control, the lack of self-monitoring between medical visits and the mismatch between clinical outcomes
14 and patients' perceptions about their management. Near half of the patients had an asthma
15 exacerbation in the previous year; however, patients reported very few days of missed work/school and
16 very high levels of written treatment plans. In addition, perceptions of their adherence and inhaler
17 technique were also very high. Therefore, there is a disassociation between patients' perceptions and
18 clinical outcomes. Most of the participants reported a high satisfaction with the inhaler device, were
19 confident about the correctness of their inhaler technique and about using their inhaler in public and
20 considered being involved by the physician in the choice of the device. Our results on inhaler technique
21 are apparently much better than those obtained by Chorão et al¹⁹, but this difference may reflect the
22 different methods used. In the study by Chorão et al, the inhaler technique was observed by the
23 researcher and included patients with asthma and with chronic obstructive pulmonary disease.¹⁹ Thus,
24 opinions and preferences of patients concerning their inhaler device may be over-estimated. One of the
25 most relevant management needs may be to improve patients' awareness of the importance of inhaler
26 techniques, adherence and involvement in treatment decisions. In fact, overestimation of disease control
27 by patients was apparent in a study by Sá-Sousa et al,²³ in which 88% of patients with uncontrolled
28 asthma considered their asthma to be under control.

1 The majority of participants had uncontrolled asthma, with CARAT scores similar to those observed in
2 other studies. A similar situation was also observed in both elderly and non-elderly asthmatic patients
3 from the region of Beira Interior.²⁴ A study carried out in 224 participants recruited in pharmacies
4 located in the same district of this study obtained similar results of CARAT (mean 17.8; 87% uncontrolled
5 asthma)²⁵. In another study, involving 200 patients with a mean age of 33.6±12.3 years, of which 136 had
6 allergic rhinitis and asthma, 86% had uncontrolled asthma.²⁶ There is a high percentage of patients with
7 uncontrolled asthma, which is a cause for concern and calls for measures to be taken to improve these
8 outcomes. The availability and use of tools to support asthma self-monitoring may be one of the
9 measures to improve asthma management.

10 We observed high values of treatment with oral corticosteroids in the previous year (38%) and visits
11 to the emergency department (27%), and relatively few hospitalisations (3%). A study by Price et al,
12 with 8000 patients with asthma from 11 European countries showed similar results in the
13 percentage of treatment with oral corticosteroids (44%) and of emergency department visits (24%), but
14 reported more hospitalisations (12%).²⁷ These differences may be explained by the fact that in the
15 European study, participants were recruited by an online survey which means that a broader spectrum
16 of patients was represented, whereas in the present study participants were regularly followed up by a
17 clinician at secondary care. It was observed that in the present study, according to GINA, 43% of the
18 participants had well controlled asthma and, according to 4-MMAS, approximately half of them had
19 medium adherence to treatment while in the European study only 20% had well controlled asthma and
20 many with low adherence to therapy. In our case this factor may contribute towards reducing
21 hospitalisations but adherence to treatment remains an important issue and we need objective data to
22 confirm the high levels of self-reported adherence observed.

23 The mean scores for the Necessity and Concerns subscales are comparable to the study by Salgado et al,
24 carried out in 500 outpatients of several illness groups (19.9 for Necessity and 17.7 for Concerns), which
25 indicates that patients with asthma perceive necessity and concerns similarly to patients with other
26 chronic diseases.²⁰ The BMQ results are associated with poor medication adherence and highlight the
27 importance of addressing patients concerns during medical visits.

28 Mobile devices can be an instrument that helps asthma self-monitoring because they are part of
29 people's daily lives, allow the users to request data wherever they are, allow more timely health

1 monitoring and can associate personal and social contact.²⁸ We verified that most of the participants
2 used Facebook daily and that browsing the web, searching for information and using apps were daily
3 used on their smartphone. We observed that one third of the participants had already used apps of
4 health/fitness and despite the fact that only one participant had used an app for asthma, more than half
5 of the patients showed interest in using apps to improve inhaler adherence. Fonseca et al reported that
6 patients with moderate-to-severe asthma and with access to mobile phones had interest in using it for
7 self-monitoring asthma (91%) and for information about medication (88%).²⁹ The designs of the studies
8 and the 14-year difference in data collection do not allow direct comparisons, but there may be
9 differences in the interest of patients in using apps for different asthma related purposes. As apps
10 become instrumental in providing health care measures, further research is needed to prove the
11 importance of these tools. In addition, it is believed that the development of apps grounded in research
12 will probably have a role in increasing patients' interest in using these tools.

13 As an early pilot study, four patients reported on the use of the InspirerMundi app. The participants
14 liked the app and reported that it allows them to have better understanding of the
15 medication/symptoms. The gamification and the social network were the components with less positive
16 opinions from the users, but all components need to be improved in app future versions. Also, more
17 studies with larger samples are needed to further evaluate the app feasibility and validity.

18 This study has some limitations. First, the selection bias related to the inclusion criterion of having
19 access to mobile devices, since the site of recruitment has a high proportion of older patients. Another
20 limitation is the small sample size, especially of the pilot study. Nevertheless, we report relevant
21 information regarding asthma management issues and new approaches to improve them. Third,
22 adherence was assessed using subjective measures (4-MMAS and VAS), which are known to
23 overestimate of real adherence. Future studies should combine subjective and objective measures of
24 adherence. A fourth limitation involves the fact that most patients had self-management asthma plans
25 and their inhalation technique was regularly checked, a situation which is not often found in other
26 settings where patients are seen and which may hinder generalisation. Future studies will need to
27 recruit a larger sample with participants from several healthcare units with greater socio-economic and
28 clinical variety.

1 Two-thirds of the participants with access to mobile devices would like to use an app to improve
2 monitoring and adherence to treatment. Participants had a high daily usage of their mobile devices, and
3 social networks but only one third used other apps. The self-reported measures about treatment
4 adherence and perceptions had high scores which contrast with poor asthma control. Improvements in
5 self-monitoring between medical appointments are asthma management needs that are apparent from
6 this study and apps can be important tools.

7

8 **Conflicts of interest:** none.

9 **Acknowledgments**

10 We would like to acknowledge the patients for their participation in this study. We would like to
11 acknowledge Mundipharma-Portugal for funding the dissemination of the InspirerMundi app.

12

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1 **Table 1-** Characteristics of the participants.

Characteristics	Without interest (n=18)	With interest (n=22)	Total (n=40)
Age, mean±SD (range) years	59.6±11.1	41.9±14.8*	49.9±15.8 (20-77)
Female, n (%)	12 (67)	19 (87)	31 (78)
Marital/Civil Status, n (%)			
Married/ Civil union	16 (89)	12 (55)*	28 (70)
Singled/Divorced	2 (11)	10 (46)*	12 (30)
Education level, n (%)			
< 10 years	13 (72)	4 (18)*	17 (43)
≥10 years	5 (28)	18 (82)*	23(57)
Employment, n (%)			
Employed	7 (39)	14 (64)	21 (53)
Retired	8 (44)	2 (9)	10 (25)
Unemployed/Not working due to poor health	3 (17)	1 (3)	5 (13)
Student	0	3 (8)	3 (8)
BMI, mean±SD (range) kg/m ²	27.9±2.6	25±4.7*	26.3±4.1 (18.5-35.1)
Smoking status, n (%)			
Non-Smokers	12 (67)	13 (59)	25 (63)
Ex-smoker	4(22)	6 (27)	10 (25)
Current smoker	2 (11)	3 (14)	5 (12)
Passive smoking, n (%)	5 (28)	12 (55)	17 (43)

2 BMI-Body Mass Index ; *p<0.05

1 **Table 2-** Asthma control and patients' beliefs, adherence and preferences regarding inhalers.

Variables	Without interest (n=18)	With interest (n=22)	Total (n=40)
Age of asthma diagnosis, mean±SD (range) years	37±12.9	23.5±15.1*	29.6±15.6 (1-77)
Number of different inhalers, n (%)			
1	7 (39)	3 (14)	9 (23)
2	8 (44)	17 (77)	25 (65)
3	3 (17)	2 (9)	5 (12)
GINA classification of asthma control n (%)			
Well controlled	6 (33)	11 (50)	17 (43)
Partly controlled	7 (39)	5 (23)	12 (30)
Uncontrolled	5 (28)	6 (27)	11 (27)
CARAT, mean± SD (range)	19.9±6.7	17±8.3	17.9±7.7 (0-29)
CARAT, n (%)			
Controlled (>24)	2 (11)	2 (9)	6 (15)
Not controlled	16 (89)	19 (82)	34 (85)
CARAT Upper Airways	7.2±3.0	5.7±3.9	6.4±3.4
CARAT Lower Airways	11.7±5.9	11.5±5.8	11.5±5.8
Asthma self-monitoring, n (%)	1 (6)	1 (18)	5 (13)
Days of work/school lost due to routine medical visits past 12 months, n (%)			
0	16 (89)	17 (77)	33 (83)
1-4	2 (11)	5 (23)	7 (17)
Clinician explain how to use the inhaler past 12 months, n (%)	16 (89)	20 (91)	36 (90)
Asthma written treatment plan, n (%)	17 (83)	19 (86)	34 (85)
Exacerbations past 12 months, n (%)			
0	11 (61)	10 (46)	21 (53)
1-2	7 (39)	9 (40)	16 (40)
≥3	0 (0)	3 (14)	3 (7)
Treatment with oral corticosteroids past 12 months, n (%)	7 (39)	8 (36)	15 (38)
Asthma unscheduled medical care past 12 months, n (%)			
Emergency department visits past 12 months	5 (28)	5 (23)	11 (27)
Hospital admissions past 12 months	1 (6)	0	1 (3)
Days of work/school lost due to asthma attacks past 12 months, n (%)			
0	17 (94)	21 (96)	39 (98)
≥1	1 (6)	1 (5)	1 (2)
BMQ necessity, mean± SD (range)	19.6±2.1	18.7±3.9	19.1±3.3 (8-25)
BMQ concern, mean± SD (range)	15.6±2.2	15.5±4.8	15.6±3.9 (6-27)
4-MMAS, n (%)			
High adherence	4 (22)	4 (18)	8 (20)
Medium adherence	9 (50)	13 (59)	22 (55)
Low adherence	4 (22)	5 (23)	9 (22)
Adherence to inhaler last week ^a , Median (P25-P75)	100 (83-100)	83 (71-98)*	91 (74-100)
Preferences ^a , Median (P25-P75)			
I perform correctly the technique of my inhaler	100 (97-100)	97 (98-100)*	99 (92-100)
I feel satisfied with my inhaler	100 (90-100)	98 (94-100)	99 (94-100)
I feel that my physician took into account my opinion and preferences when choosing my inhaler	100 (95-100)	93 (49-100)*	98 (67-100)
I feel comfortable using my inhaler in public	100 (99-100)	96 (90-100)*	100 (94-100)

2 GINA- Global Initiative for Asthma; CARAT- Control of Allergic Rhinitis and Asthma Test; *p<0.05; BMQ-The Beliefs
 3 about Medicines Questionnaire; 4-MMAS-Morisky 4-item Medication Adherence Scale; ^aVisual analogic scale, range
 4 0-100(best).

- 1 **Figure captions**
- 2 **Figure 1** – 4-item Morisky Medication Adherence Scale.
- 3 **Figure 2** – Smartphone usage scale (9 items) and General social media usage subscale (1 item) of Media and Technology Usage and Attitudes Scale.
- 4
- 5 **Figure 3** – Use of social networks and apps and interest in using apps for asthma.

Manuscript accepted for publication