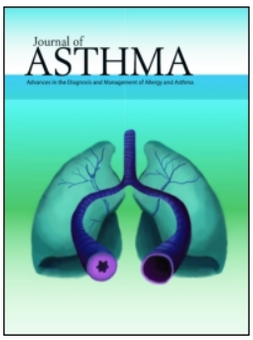

Journal of Asthma

ISSN: 0277-0903 (Print) 1532-4303 (Online) Journal homepage: https://www.tandfonline.com/loi/ijas20

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To cite this article: Richelle C. Kosse, Ellen S. Koster, Ad A. Kaptein, Tjalling W. de Vries & Marcel L. Bouvy (2019): Asthma control and quality of life in adolescents: the role of illness perceptions, medication beliefs, and adherence, Journal of Asthma, DOI: 10.1080/02770903.2019.1635153

To link to this article: https://doi.org/10.1080/02770903.2019.1635153

Accepted author version posted online: 21 Jun 2019.

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Article

Factors associated with adolescent asthma outcomes

Asthma control and quality of life in adolescents: the role of illness perceptions, medication beliefs, and adherence

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Keywords: adolescents; asthma outcomes; illness perceptions; medication adherence; medication beliefs; quality of life

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Abstract

Objective: Asthma control and quality of life (QoL) are important disease outcomes for asthma patients. Illness perceptions (cognitive and emotional representations of the illness) and medication beliefs have been found to be important determinants of medication adherence, and subsequently disease control and QoL in adults with asthma. In adolescents, this issue needs further elucidation. Therefore the aim of the current study was to explore the relation between illness perceptions, medication beliefs, medication adherence, disease control, and QoL in adolescents with asthma.

Methods: In this cross-sectional study, we used baseline data of adolescents with asthma (age 12-18 years) who participated in the ADolescent Adherence Patient Tool (ADAPT) study. Questionnaires were administrated online, and included sociodemographic variables and validated questionnaires measuring self-reported illness perceptions, medication beliefs, medication adherence, disease control, and QoL.

Results: Data of 243 adolescents with asthma were available; age 15.1±2.0 years and 53% females. More than half of these adolescents (62%; n=151) reported to be non-adherent (Medication Adherence Report Scale ≤23) and 77% (n=188) had uncontrolled asthma. There was a strong positive correlation between disease control and QoL (r=0.74). All illness perceptions items were correlated with disease control and QoL, with the strongest correlation between 'identity' (symptom perception) and QoL (r=-0.66). Medication adherence was correlated to medication beliefs (r=0.38), disease control (r=0.23), and QoL (r=0.14). Whereas medication beliefs were only associated with adherence.

Conclusions: Stimulating positive illness perceptions and medication beliefs might improve adherence, which in turn might lead to improved disease control and better quality of life.

Keywords: adolescents; asthma outcomes; illness perceptions; medication adherence; medication beliefs; quality of life

Introduction

Well-controlled symptoms are an important outcome for asthma patients. Obtaining sufficient asthma control implies fewer asthma symptoms and exacerbations, decreased use of rescue medication, fewer nighttime awakenings, and improved quality of life [1–3]. A number of factors are related to uncontrolled asthma, among which are smoking, allergic rhinitis, female gender, and poor adherence [4–7]. Medication adherence (i.e. the degree to which the person's behavior corresponds with the agreed upon recommendations from a health care provider) is in particular a strong determinant of asthma control, because daily use of controller medications, such as inhaled corticosteroids (ICS), suppresses the chronic airway inflammation [8, 9].

Adherence to medication is complex and affected by multiple factors [10–12]. Non-adherence is caused by a combination of unintentional (related to practical barriers) and intentional (related to motivation and beliefs) barriers to take medication [5]. The Common Sense Model of Self-Regulation (CSM) is used to understand patient's response to their illness. CSM propose that cognitive and emotional illness representations, and medication beliefs (personal medication convictions) directly influence coping strategies (by using feedback mechanisms), thus they can affect intentional non-adherence (health behavior) [13]. There are in general five cognitive domains; identity (symptom perception), timeline, consequences, perceived controllability, and the cause.

Adherence rates in asthma patients are generally low, e.g. on average 50% of asthma patients are adherent [4]. It has been reported that adherence is especially low during adolescence [14]. Some barriers for medication adherence, such as forgetfulness are not specific for adolescents (age 12-18 years), but are more prevalent among them. Furthermore, developmental norms can contribute to adolescent specific barriers for medication adherence, e.g. they have a high desire for peer conformity, and they experience feelings of insecurity or invincibility. Moreover, they have unique medication beliefs (e.g. girl aged 14 years said *"There are moments I do not feel better from using my inhaler, those times I use nothing"*) [15–17]. Additionally a large proportion of adolescents experience a reduction of asthma symptoms [18]. This may affect medication adherence, illness perceptions, and medication beliefs.

Factors, such as self-efficacy and perceptions on illness and medication use, have independently been shown to be associated with medication adherence and asthma control in adults and to a lesser extent in adolescents [19, 20]. However, the exact relation between illness perceptions, medication beliefs, and adherence (and subsequently disease control and quality of life) is unknown, especially in adolescents. Clarification of this relation may improve the understanding of how disease control can be achieved in this unique patient population, and thereby provide valuable insights for future interventions aimed at improving asthma control, and might highlight factors that can contribute to life-long correct disease management [21]. Therefore the aim of this study was to explore the relation between illness perceptions, medication beliefs, medication adherence, disease control, and quality of life in adolescents with asthma.

Materials and methods

Study design, population, and setting

In this cross-sectional exploratory study we used baseline data of patients who participated in the ADolescent Adherence Patient Tool (ADAPT) study, a randomized controlled trial to evaluate the effectiveness of a mobile health intervention on medication adherence. The complete rationale and design of the ADAPT study are described elsewhere [22, 23]. In short: adolescents aged 12-18 years who filled two or more prescriptions for ICS or a fixed combination of ICS with a long-acting beta-

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agonist (ICS/LABA) during the previous 12 months (defined as asthma patients)[24] were recruited by mail from community pharmacies belonging to the Utrecht Pharmacy Practice Network for Education and Research (UPPER) [25].

After receiving the signed informed consent form by mail, patients had access to the online questionnaire. For patients younger than 16 years, both parents also had to sign informed consent. Baseline data were collected between July 2015 and February 2016. The ADAPT study is approved by the Medical Review Ethics Committee of the University Medical Centre Utrecht (NL50997.041.14) and by the Institutional Review Board of UPPER, Department of Pharmaceutical Sciences, Utrecht University. The ADAPT trial is registered at the Dutch Trial Register (NTR5061).

Questionnaire items

The online questionnaire contained sociodemographic questions (e.g. age, gender, education, sport participation) and questions on adolescents' health status and asthma medication use. It also contained validated questionnaires on illness perceptions (Brief Illness Perception Questionnaire [Brief-IPQ]) [26], medication beliefs about ICS (Beliefs about Medicines Questionnaire-specific [BMQ-specific]) [27], adherence (Medication Adherence Report Scale [MARS-5]) [11], disease control (Control of Allergic Rhinitis and Asthma Test [CARAT]) [28, 29], and asthma-related quality of life (Pediatric Asthma Quality of Life Questionnaire [PAQLQ]) [30, 31].

Outcomes measures

The *Brief-IPQ* was used to assess adolescents' illness perceptions. This questionnaire consists of eight 11-point Likert scale items divided in three domains (Table 1): cognitive representation (illness consequences, duration, personal control, treatment control, and symptom perception), illness comprehensibility (understanding of illness), and emotional representation (emotional representation and illness concern). The ninth item was an open-ended item on the causes of the illness. We excluded this open-ended item from the analysis, because this item was perceived as complicated by young adolescents [32]. For the other items, a total score between 0 and 10 was obtained, where a higher score represented more agreement with the item.

The *BMQ-specific* was used to assess adolescents beliefs about the necessity and concerns regarding their ICS asthma treatment. This questionnaire consists of ten questions, divided in two subscales; five items on necessity and five items on concerns. All items are scored on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), resulting in a total score between 5 and 25 per subscale. Generally, scores above the scale midpoint (>15) were considered as strong beliefs, resulting in four attitudinal groups: accepting (high necessity, low concerns), ambivalent (high necessity, high concerns), indifferent (low necessity, low concerns), and skeptical (low necessity, high concerns) [33]. Moreover we calculated the necessity-concern differential (i.e. total necessity score minus total concerns score) to get an insight in the necessity beliefs and concerns of an individual patients, and to study the correlations. A positive differential indicated more necessity beliefs than concerns and a negative differential indicated more concerns than necessity beliefs. The BMQ-specific is previously used in adolescents with asthma [8].

Self-reported ICS adherence was assessed using the *MARS-5*, which consists of five items. All items were scored on a five-point Likert scale ranging from 1 (always) to 5 (never), with a total score between 5 (not adherent) and 25 (completely adherent)[11]. Additionally, MARS sum scores were dichotomized (adherent versus non-adherent patients) by using a threshold for the sum scores of ≥23 for sufficient adherence, based on previous studies [8, 34]. The MARS-5 was originally

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developed for adults, however previous studies also used MARS as a tool for children and adolescents [35].

Disease control was assessed using the *CARAT*, which consists of ten items. A total score between 0 and 30 was obtained, where a score >24 indicates good disease control. The total score can be divided in allergic rhinitis symptoms (item 1-4, score >8 indicate good control) and asthma symptoms (item 5-10, ≥16 indicate good control) [28, 29]. The *CARAT Kids* was developed for children age 6 to 12 years, therefore we used the *CARAT*.

Asthma related quality of life was assessed using the *PAQLQ* [31], which consists of 23 items divided in three domains: symptoms, activity limitations, and emotional function. All items were scored using a seven-point Likert scale, resulting in a total mean score (and per domain) between 1 and 7, where seven indicated the highest quality of life. The PAQLQ was designed for children aged 7 to 17 years.

Data analysis

Descriptive statistics were calculated. For skewed data, the median with interquartile range (IQR) is shown instead of the mean with standard deviation (SD). Pearson correlation coefficients were calculated. Additionally, fitting (generalized) linear models were used for secondary analysis, for example to compare adherent and disease control groups. We used the Kruskal-Wallis test to test for differences in disease control and medication adherence between the four attitudinal groups. These secondary analysis were performed to provide a clear and complete overview of our data and findings. Statistical analysis were performed using R (version 3.4.3). P-values <0.05 were considered statistically significant.

Results

In total, 1,204 adolescents were invited to participate in the ADAPT study of which 243 adolescents (20.2%) from 54 pharmacies completed the baseline study measurement (on average 4.5 ± 2.7 adolescents per pharmacy). The characteristics of the study population are shown in Table 2: half of the patients were male (46.9%), the mean age was 15.1 ± 2.0 years, and most had a Dutch ethnicity (88.5%). A small number of patients (n=15) reported not having been diagnosed with asthma, however they collected at least two ICS or ICS/LABA in the previous year, and they reported symptoms which were very likely asthma symptoms, such as shortness of breath (n=12), allergy symptoms (n=6), and/or exercise induced symptoms (n=3).Therefore we included them in the analysis.

Almost half of the adolescents (44.0%) used asthma medication for more than 10 years. Four patients reported that they did not use their inhaler in the previous six months, because they ("thought they") did not need it (n=3) or forgot to take it (n=1). All remaining patients used ICS; either monotherapy or ICS in fixed combination with a long-acting beta-agonists (Table 2).

Illness perceptions

All illness perceptions scores are shown in Table 1. Adolescents scored the highest on timeline (i.e. *how long do you think your illness will continue?*), indicating that they expected a chronic course of their illness. Thereafter the highest scores were obtained for personal control, treatment control, and coherence (i.e. *how well do you feel you understand your illness?*). The lowest scores were on the domain emotional representation, suggesting that their asthma did not emotionally affect them.

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Beliefs about medication

The mean BMQ-necessity score was 14.4 ± 5.1 (range 5-25) and the mean BMQ-concerns score was 9.2 ± 3.4 (range 5-23). Almost half of the adolescents (42.8%; n=104) reported high necessity beliefs (above scale midpoint), while only 11 adolescents (4.5%) reporting high concerns. Subsequently the majority of adolescents had a positive necessity-concern differential (81.9%; n=199), thus the majority felt medication necessity outweighed medication concerns. Moreover, most adolescents had an indifferent or accepting attitude (95.5%; n=232; Figure 1). There were significant differences between the percentages of controlled (p=0.047) and adherent (p=0.002) patients in the four attitudinal groups (Figure 1). That is, half of the adolescents with an accepting attitude and 32% of the indifferent adolescents were adherent, while 29% of the indifferent adolescents and 17% of the accepting adolescents had controlled disease (Figure 1).

Self-reported medication adherence

The median MARS score was 22.0 (IQR 5) and 37.9% (n=92) of the adolescents were defined as adherent (MARS sum score ≥23). The percentage of adolescents scoring 1 to 3 (always to sometimes) was the highest at item 1, 3, and 5 (Table 3, last column). The median of intentional non-adherence (items 2-5) was five, whereas the median of unintentional non-adherence, i.e. forgetting, was three.

Self-reported disease control

In total, 22.6% of the adolescents (n=55) had sufficient disease control (CARAT >24), with more adolescents having control over allergic rhinitis symptoms (38.3%), than over their asthma symptoms (21.8%; Table 2). The mean CARAT total score was 19.6 ± 5.5 (range 0-30), the mean allergic rhinitis score was 7.2 ± 3.1 (range 0-12), and the mean asthma score was 12.4 ± 3.6 (range 0-18). All these means were below the standardized thresholds for sufficient control.

Asthma related quality of life

The mean total PAQLQ score was 5.9 ± 0.9 (range 1.4 – 7.0), indicating a sufficient to good quality of life. The highest mean score was on emotional function 6.5 ± 0.9 (range 1.4 – 7.0), thereafter on symptoms 5.7 ± 1.1 (range 1.4 – 7.0), and subsequently on activity limitation 5.4 ± 1.1 (range 1.4 – 7.0).

Correlation illness perceptions, medication beliefs, adherence, disease control, and quality of life

There was a strong correlation (r=0.74) between disease control and quality of life (p<0.001). A weak correlation was found between adherence and the necessity-concern differential (r=0.38; p<0.001), thus necessity was positively correlated with adherence (r=0.28; p<0.001), while concerns were negatively correlated (r=-0.14; p=0.026). Other weak correlations were found between adherence and disease control (r=0.23; p<0.001), and adherence and quality of life (r=0.14; p=0.035). Within the PAQLQ domains, only "symptoms" was correlated with adherence (r=0.14; p=0.027). All correlations are summarized in Figure 2 (and Appendix 1).

All illness perceptions items were correlated with disease control and quality of life (Table 1), with the strongest correlations between identity (i.e. symptom perception) and quality of life (r=-0.66; p<0.001), illness concern and quality of life (r=-0.64; p<0.001), and emotional representation

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and quality of life (r=-0.63; p<0.001). Thus being more emotionally affected, having more asthma symptoms, and having more concerns are all associated with a decrease in quality of life. Duration of the illness (timeline; r=0.25; p<0.001) and treatment control (r=0.28; p<0.001) were both correlated with the necessity-concern differential. Moreover, treatment control (r=0.30; p<0.001) and coherence (i.e. *how well do you feel you understand your illness?*) were correlated with adherence (r=0.13; p=0.045; Figure 2).

Adherent versus non-adherent

Adherent adolescents (MARS ≥23; n=92) had significant higher scores on the CARAT (median 21) compared to the non-adherent adolescents (n=151; median 19; p=0.006). The asthma control subscale was significantly higher for adherent adolescents (median 14 versus 13; p=0.007), while there was no difference on the allergic rhinitis subscale (p=0.082). In total, 21% of non-adherent patients had controlled asthma and 75% of adherent patients had uncontrolled asthma. These findings support the weak correlation between adherence and disease control (r=0.23; Figure 2). Moreover, adherent adolescents had a higher necessity-concern differential (median 7.0 versus 3.0; p<0.001) and a higher quality of life score (median 6.4 versus 6.0; p=0.004). They perceived more personal control (median 8 versus 7; p=0.009) and more treatment control (median 8 versus 7; p<0.001) than non-adherent adolescents. Adherent adolescents also perceived fewer symptoms (identity; median 2 versus 3, p=0.003) and were less emotionally affected by their asthma (median 0 versus 1, p=0.006) compared to non-adherent adolescents.

Controlled versus uncontrolled

Adolescents with disease control (CARAT >24; n=55) had a higher quality of life (median 6.7) compared to those without disease control (n=188; median 5.9; p<0.001). No differences were found in the medication beliefs (necessity-concern differential; p=0.359) and adherence scores (p=0.089) of controlled and uncontrolled patients. However, patients with disease control had higher scores on personal control, treatment control, and coherence, while they scored lower on consequences, timeline, identity, emotional representations, and illness concerns (coherence p=0.002, others p<0.001).

Discussion

The aim was to study the relation between illness perceptions, medication beliefs, medication adherence, disease control, and quality of life in adolescents with asthma. This study showed complex relations between illness perceptions, medication beliefs, medication adherence, disease control, and quality of life in adolescents with asthma. Disease control and quality of life were highly correlated. Both adherence and illness perceptions were related to these disease outcomes, while medication beliefs were only associated with adherence (Figure 2). Necessity beliefs were positively associated with adherence, while concerns were negatively associated, which is also previously shown [11, 36]. Remarkably, adherence was only correlated to the disease outcomes, i.e. disease control and quality of life. Based on these complex relations (and individual differences), we suggest patient-centered care, such as shared-decision making [37], to improve disease outcomes.

Most illness perceptions were not associated with adherence in the current study. This finding seems contradictory to the CSM [13], which proposes that cognitive and emotional representations towards a health threat, result in illness representations and medication beliefs, which affect health behavior (e.g. adherence). Only “treatment control” (i.e. *how much do you think your medication can help your illness?*) and “coherence perceptions” (i.e. *how well do you feel you understand your illness?*) were slightly associated with adherence, which is shown before [38]. This shows that only

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one (of the five cognitive CSM domains) is related to adherence, that is perceived controllability. The other domain affecting adherence is illness comprehensibility.

Our findings also suggest that adolescents might not appraise 'adherence' as a health outcome [35], instead they might focus on 'health status' as an outcome. To illustrate this: illness representations did not emphasize the importance of ICS adherence for adolescents, therefore they did not improve their adherence (no coping strategy). However illness representations could be related to their health status, however their health status was perceived as acceptable (experience no symptoms), thus no coping strategy is needed (no improvement in adherence).

Adherence and illness perceptions were both associated with disease outcomes, such as disease control and quality of life [39]. These findings suggest that improving patient's behavior (increasing adherence) and their illness perceptions (improving cognitive illness representations and illness comprehensibility; Figure 2) might improve disease outcomes of adolescents with asthma. However, compared to adults and adolescents with other chronic conditions, adolescents with asthma had already high personal control and coherence (i.e., understanding of their illness), and low concerns and consequences [30]. Thus, there was not much to achieve in the illness perceptions of the current study population. However, adherence could be increased, as only 38% was defined as adherent. Although, sometimes it might be hard to motivate patients, as asthma care might not always help patients to feel good, as for example children can be ashamed to take medication in the classroom. A suggestion to improve adolescent's behavior and their illness perceptions is to use online influencer (i.e. someone who affects the way other people behave, via use of social media), as for example celebrities with chronic conditions may motivate adolescents in using their medication and improve their illness perceptions [40].

More than half of the current adolescent population (56%) had an indifferent attitude (low necessity and low concerns; Figure 1), which makes it hard to motivate them. This indifferent attitude might be age-specific, or it might be related to the long-term medication use, as for example in our study 44% used asthma medication for more than 10 years. The indifference could also be related to the high control perceptions (personal and treatment control) and low symptom perceptions (identity), i.e. they were feeling fine. However, only 23% of the adolescents had indeed sufficient disease control. This discrepancy between perceived and reported disease control, suggests that it is important to improve adolescent's insights into their disease control. For example by comparing their perceived asthma control with pulmonary function measurements, such as spirometry. The PAQLQ data suggest that especially activity limitation may be improved. These results suggest that adolescents accept some activity limitation, whereas activity limitation can be absent when asthma is controlled. Improved insights into their less controlled asthma may increase treatment necessity beliefs and treatment control perceptions (and thereby may subsequently support adherence and disease control). However, more research is needed to find effective ways to improve adolescent's insights into their disease control.

The current study emphasized the complex relation between medication adherence and disease control, because most adolescents in this study were non-adherent and had uncontrolled asthma, however 21% of the non-adherent adolescents had controlled asthma. This contradictory finding might be caused by the mechanism of action of ICS. Patients are advised to use daily controller medication to suppress their chronic airway inflammation. However, when they sometimes forget to use ICS, they will not directly experience wheezing or other asthma symptoms. The transition of asthma symptoms (i.e. decrease during adolescence) [18] might also explain why some non-adherent patients still had disease control. These patients may be over treated. On the other hand, 75% of adherent patients had uncontrolled asthma. These patients require special attention, because other factors may contribute to uncontrolled asthma, such as wrong inhaler techniques, seasonal effects, too low dose of ICS, or uncontrolled allergic rhinitis.

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Weak correlations were found in this study, suggesting complex relations. We suggest that "feedback mechanisms" might play a role here. For example, patients are adherent until a certain level of disease control, thereafter they become more negligent with their asthma medication (as they experience fewer asthma symptoms). To illustrate; the percentage of adherent patients in the indifferent group (32%) was lower than in the accepting group (50%), while the percentage of controlled patients (29%) was higher in the indifferent group than in the accepting group (17%); Figure 1. Such mechanisms may make it hard to obtain complete disease control, because patients can become more indifferent towards their medication when they experience fewer asthma symptoms. A ceiling effect might also contribute to the weak correlations.

This cross sectional study used validated questionnaires to measure study outcomes, which has some limitations. First of all, there might be a desirability bias. Suggestions to overcome this bias are to use direct measurements for adherence and disease control, such as refill records and spirometry measurements. Cognitive factors can only be measured by using self-report. Secondly, the participants in the current study participated in a clinical trial, suggesting that they were highly motivated (participation bias). This might partly explain why almost half of the adolescents (43%) reported high necessity beliefs and 82% had a positive necessity-concern differential. The latter percentage is high compared to other adolescent patient populations, as for example 62% of adolescents with ADHD had a positive necessity-concern differential and 11% reported high necessity beliefs [32]. However, there are always variations between patients, suggesting that there is ample room to discuss the specific illness perceptions and medication beliefs of individual adolescents. Thirdly, there might be a risk for multiple comparisons, however our focus was on exploring the relation between illness perceptions, medication beliefs, medication adherence, disease control, and quality of life in adolescents with asthma. Additionally we conducted descriptive analysis, to provide more information on the study population, therefore we did not correct for multiple comparisons. Lastly, the relations found in this study might be different for specific patient population, for example patients with a low socioeconomic status. Moreover, the results might be different for different inhaler devices. Therefore more research is needed to find associations in specific patient populations and for different inhaler devices.

In adolescents with asthma, the relation between illness perceptions, medication beliefs, adherence, disease control, and quality of life are complex. There was a strong positive correlation between disease control and quality of life. All illness perceptions items were correlated with disease control and quality of life, and medication adherence was correlated to medication beliefs, disease control, and quality of life. Based on these findings, we suggest that stimulating positive illness perceptions and medication beliefs might improve adherence, which in turn lead to improved disease control and better quality of life.

Declaration of interest

The authors have no competing interests to report.

Acknowledgements

The authors would like to thank the participants for their input. For the ADAPT study, funding was received from the Netherlands Organisation for Health Research and Development (ZonMw) and Umenz Benelux BV. Neither funding source played any role in the study, nor the decision to submit the article for publication.

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Table 1. The median score (response scale 0 to 10; not at all to very much) per item of the Brief Illness Perception Questionnaire (Brief-IPQ), with the correlation coefficients with medication beliefs, adherence, disease control, and quality of life.

Domains	**Items**	**Question**	**Median (IQR)**	**Correlation coefficient**			
				Necessity-concerns	***Adherence***	***Disease control***	***Quality of life***
Cognitive illness representations	Consequences	How much does your illness affect your life?	3 (5)	-0.01	-0.08	-0.48*	-0.53*
	Timeline	How long do you think your illness will continue?	9 (4)	0.25*	0.01	-0.25*	-0.22*
	Personal control	How much control do you feel you have over your illness?	8 (3)	-0.01	0.09	0.45*	0.45*
	Treatment control	How much do you think your medication can help your illness?	8 (3)	0.28*	0.30*	0.41*	0.41*
	Identity	How much do you experience symptoms from your illness?	3 (4)	0.05	-0.11	-0.54*	-0.66*
Illness comprehensibility	Coherence	How well do you feel you understand your illness?	8 (4)	0.09	0.13*	0.23*	0.22*
Emotional representations	Emotional representation	How much does your illness affect you emotionally? (e.g. does it make you angry, scared, upset, or depressed?)	1 (3)	-0.09	-0.11	-0.44*	-0.63*
	Illness concern	How concerned are you about your illness?	1 (3)	-0.03	-0.07	-0.50*	-0.64*

* Significant correlation ($p<0.05$).

IQR: Interquartile range.

Table 2. Basic characteristics of the study population (N=243)

Characteristics	% (n)
Male gender	46.9 (114)
Age, mean (SD)	15.1 (2.0)
Dutch ethnicity[a]	88.5 (215)
Environment	
Rural	51.4 (125)
Urban	45.3 (110)
Other	3.3 (8)
Education	
Elementary school	4.1 (10)
High school: vocational level	25.1 (61)
High school: pre-university level	53.9 (131)
Other	16.9 (41)
Lifestyle	
Alcohol use	34.2 (83)
Tobacco use	4.5 (11)
Playing sports	81.9 (199)
Sport hours per week, mean (SD)	4.7 (2.8)
Self-reported health status	
Very good to excellent	32.9 (80)
Good	53.1 (129)
Bad to moderate	14.0 (34)
Asthma diagnosis	93.8 (228)
Asthma age (n=223)[b], mean (SD)	7.5 (4.8)

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Asthma family history (n=145)	59.7 (145)
Father	34.5 (50)
Mother	42.1 (61)
Sibling	34.5 (50)
Medication used (n=239)[c]	98.4 (239)
ICS	100 (239)
SABA	74.5 (178)
LABA	46.9 (112)
Adherent (MARS)	37.9 (92)
Well-controlled disease (CARAT)	22.6 (55)
Well-controlled asthma	21.8 (53)
Well-controlled allergic rhinitis	38.3 (93)

[a] Adolescent and both parents have Dutch ethnicity. [b] n=5 age unknown. [c] Self-reported data on the previous six months.

CARAT: Control of Allergic Rhinitis and Asthma Test; ICS: inhaled corticosteroids; LABA: long-acting beta-agonists; MARS: Medication Adherence Report Scale; SABA: short-acting beta-agonists; SD: standard deviation.

Table 3. The median Medication Adherence Report Scale (MARS) scores per item, ranging from 1 to 5 (always to never).

MARS items (N=243)	Median (IQR)	Scoring 1-3 % (n)
1: I forget to take my medicines	3 (1)	53.9 (131)
2: I change the dosage of my medicines	5 (1)	21.4 (52)
3: I stop taking my medicines for a while	5 (2)	27.6 (67)
4: I decide to skip one of my medication dosages	5 (1)	16.9 (41)
5: I use my medication less than is prescribed	5 (1)	23.5 (57)

IQR: Interquartile range; MARS: Medication Adherence Report Scale.

Figure 1. Scatter plot of the Beliefs about Medicines Questionnaire (BMQ) necessity and concern scores, divided in four attitudinal groups with their corresponding percentage of adherent (Medication Adherence Report Scale [MARS] ≥ 23) and disease controlled patients (Control of Allergic Rhinitis and Asthma Test [CARAT] > 24).

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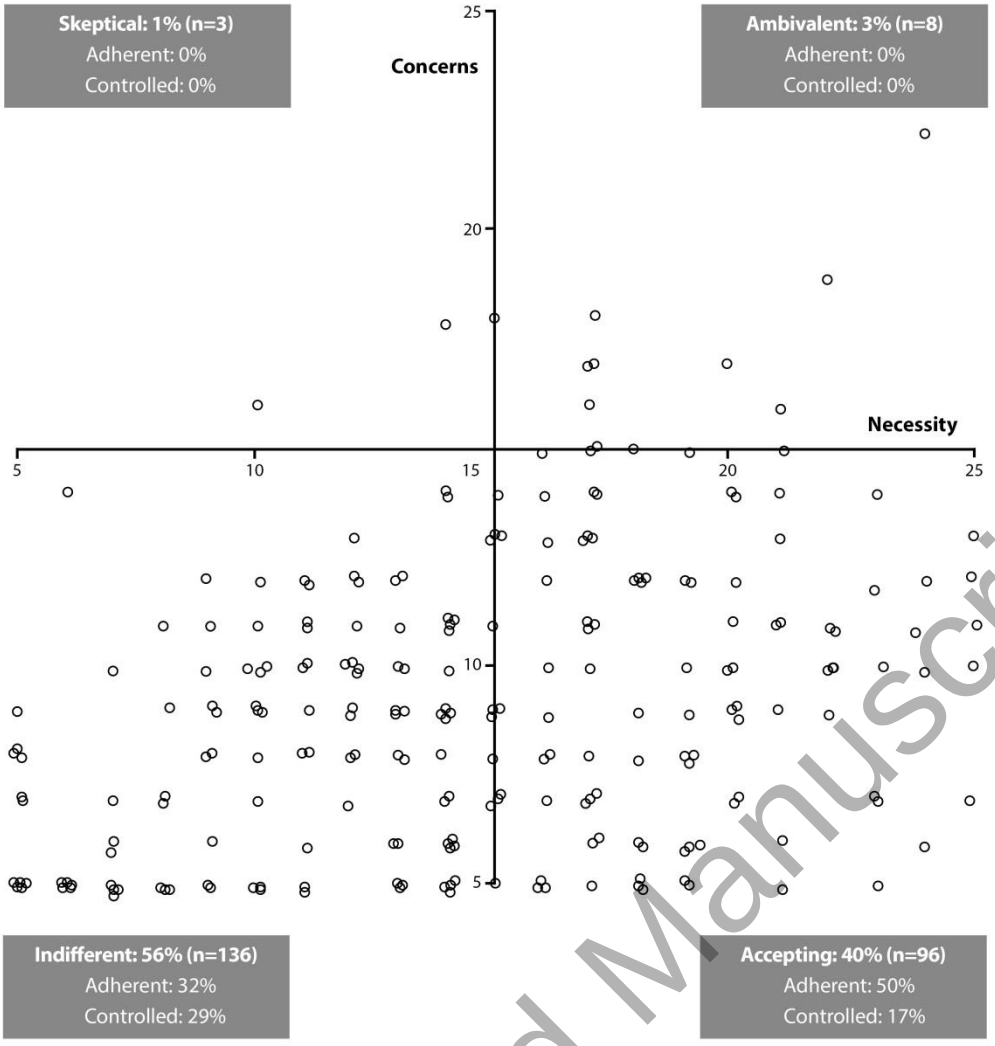
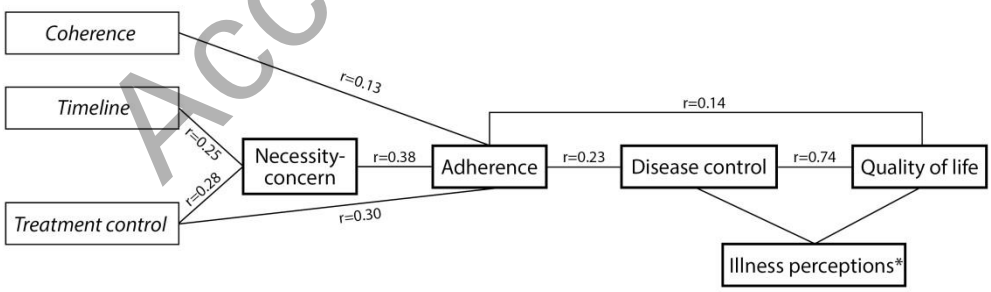


Figure 2. Relation between medication beliefs, adherence, illness perceptions, disease control, and quality of life in adolescents with asthma (N=243).



r: correlation coefficient.

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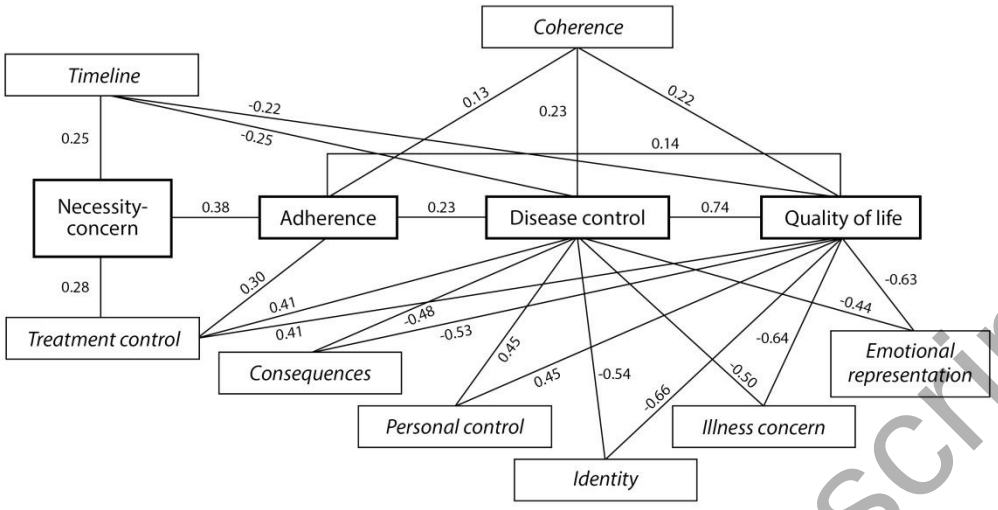
* All items of the Brief Illness Perception Questionnaire were correlated with disease control and quality of life (Table 1).

Appendix 1. Correlations between medication beliefs, adherence, disease control, quality of life, and all illness perceptions (*Italic)* in adolescents with asthma.



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