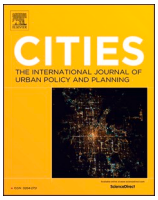
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The effects of urban areas, neighborhood and housing on urban health: A systematic review and meta-analysis on asthma

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ABSTRACT

The World Health Organization estimates that asthma will affect 5 % of the global population by 2025 when the number of patients will reach 400 million. In the past ten years, there has been a rise in the number of studies explaining the substantial development of illness in the 21st century (excluding hereditary causes) via urban structure components, and several pieces of evidence have been published on this subject. This study intends to perform a systematic review and meta-analysis to identify urban asthma risk factors. From April to November 2022, databases on PubMed, Scopus, and WoS were examined in this context. Only studies examining asthma and urbanization-related factors were included in the study. 127 articles were examined from 3276 studies obtained from databases. The analysis revealed that the pace of urbanization, air pollution, transportation network components, housing situation, and the locations of industrial regions were the most often highlighted risk factors. As conclusion; several urban factors were shown to have a substantial link with asthma. However, it was suggested that some of the urban risk variables used to define the urban area were insufficient and that the risk factors used to define the urban space should be varied or altered.

1. Introduction

As one of the chronic respiratory diseases, asthma has grown more prevalent during the previous 40 years (D'Amato, 2011; Guarnieri & Balmes, 2014). Numerous etiological and pathogenic studies have been done to discover the origins of the disease's rising tendency (von Mutius, 1998). Since the beginning of 20th century, it is believed that gender, age, heredity, air/water pollution, and occupation have been the primary risk factors for the disease. However; since the beginning of the 21st century, research has been conducted to determine whether environmental and urbanization components cause asthma in addition to the previously discussed risk factors.

In some studies examining the relationship between asthma and urbanization, it is stated that urban components such as western lifestyle, decrease in physical activity, industrialization and pollution, and socio-economic inequalities have a significant share in the increase in asthma (Delfino, 2002; Ponte et al., 2018; Weisel, 2002). However, in some studies, it is stated that there is no relationship between asthma and urban components and that asthma should be explained by genetic factors (Bener et al., 1992; Bener et al., 1996; Pedersen & Weeke, 1983; Strachan, 2000). Although there are different views on the relationship between asthma and urbanization and environmental factors; this study is grounded on the hypothesis that there is a linear relationship between urbanization and asthma.

In this context, studies, which are indexed in Scopus and Web of Science and have focused on the conceptual analysis of the relationship between urbanization and asthma, were subjected to content analysis (Table 1). After a gradual process was followed in the analysis (Cihangir-Çamur et al., 2023; Malecki, 2018); publications focusing on the target subject of the study were identified (Table 1). The content of the search is given in detail in the footnotes, and the results of the preliminary analysis are presented below.

As a result of the preliminary analysis, it was determined that compared to the limited number of studies in 1970–1990, there was an increase in 1990–2000 with the global awareness in urban health discussions in the 1990s and the second upward break was between 2010

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Table 1
Scopus and Web of Science (WoS) scan results from April to November 2022 (produced within the scope of the study).

Years	ASTHMA					
	Urban Air Pollution[a]		Urban Design[b]		Urban Morphology[c]	
	Scopus	WoS	Scopus	WoS	Scopus	WoS
1970–1980	5	1	0	1	0	0
1980–1990	6	0	5	0	0	0
1990–2000	58	114	78	102	1	0
2000–2010	171	418	137	226	5	6
2010–2022	320	1020	170	579	5	10
Total Score	560	1553	390	908	11	16
	Urban Transportation[d]		Urban Land Use[e]		Urban Planning[f]	
	Scopus	WoS	Scopus	WoS	Scopus	WoS
1970–1980	0	0	1	0	2	0
1980–1990	0	0	0	0	0	0
1990–2000	7	6	2	2	5	10
2000–2010	13	47	28	52	14	48
2010–2022	45	163	42	187	48	112
Total Score	65	216	73	241	69	166

[a] research terms: "Urban area pollution AND asthma" or "asthma AND pollution" or "Urban heat pollution AND asthma
[b] research terms: "Urban design AND asthma" or "Urban design planning AND asthma 'or' Urban design project AND asthma"
[c] research terms: "Urban morphology AND asthma"
[d] research terms: "Urban transport AND asthma" or "Urban highway AND asthma"
[e] research terms: "Urban Land use AND asthma" or "Land use AND asthma 'or' land use planning AND asthma"
[f] research terms: "Urban Planning AND asthma" or "landspace and urban planning AND asthma" or "Urban planning AND legislation AND asthma"

and 2020. It is seen that the number of publications between 2010 and 2022 constitutes approximately 40 % of the total studies on this subject, and studies and conceptualizations that relate asthma and urbanization dynamics maintain their importance and currency by increasing it.

The analysis revealed that studies examining the relationship between asthma and urbanization between 1970 and 2000 began to be evaluated within the scope of air pollution and these studies were generally conducted in North America and East Asia. Since the beginning of the 2000s, studies have centered on the relationship between transportation and asthma. And, since the 2010s, the relationship between urban morphology, land use, and asthma has begun to be investigated.

Most of the current quantitative studies focus on the relationship between asthma and various urban components such as urban open spaces, land use, transportation network, air pollution components and climate indicators. However, regarding the relationship between the mentioned urban components and asthma, it has been seen that each urban component is examined individually and there is no holistic assessment of the urban space.

The analysis indicates that literature and meta-analysis studies have been designed to explain the relationship between air pollution and asthma in general since the late 1990s. Thus, it can be inferred that the studies were produced in the field of health sciences and were frequently researched in America and China. However, relatively few review studies have been conducted on the transportation network and housing structure in the last decade. In addition, different urban components were examined separately in literature studies and meta-analysis studies examining the relationship between urbanization and asthma. Therefore, it is seen that the urban risk factors thought to trigger asthma are limited in number and cannot evaluate the urban space holistically.

In studies examining the effects of urban components on asthma, the definition of urbanization or urban areas is often evaluated with some conceptual and methodological restrictions (Rodriguez et al., 2019; Sá-Sousa et al., 2014). The varied and multilayered nature of urbanization processes has led to a restricted analysis of the relationship between urbanization and asthma because it is stated that urbanization is a highly complex process affecting all levels of human activity, and no single definition can fully describe the multidimensional nature of this process. In addition, there is no universally accepted definition of what constitutes an urban area. Different countries use different definitions for urban areas, often based on the demographic, political, or economic characteristics of their populations. In this context, in some studies in the related literature, urbanization or built environment while defining based on population (urban, rural, suburban); in some studies, it is defined as built environment density (lowest urban area, medium, highest).

The analysis reveals the need for a holistic evaluation of the relationship between asthma and urban space/built environment. It has also been observed that the existing studies are generally conducted in the field of health and environmental sciences and there is scarcity of research in the field of social sciences. For this reason, the relationship between urban space and asthma should be examined with a multidisciplinary approach.

This review aims to conduct a meta-analysis that presents asthma risk variables in urban areas in a holistic way by combining studies that define urban space and built environment in different ways. In this context, it was designed to contribute to previous meta-analysis studies by expanding the number of urban risk factors identified in the relationship between urbanization and asthma. Upon the conclusions from the meta-analysis, the study also makes suggestions for the consideration of more comprehensive and different approaches for future research on the relationship between asthma and urbanization.

2. Methods

2.1. Search strategy

In the research to characterize urbanization and asthma risk factors, Prisma guidelines, one of the reporting components in systematic reviews and meta-analysis publications, were used (Khan et al., 2003; Malekpour & Newig, 2020; Moher et al., 2009). The Prisma checklist is supplied in Table Appendix 1. Between April and November of 2022, the Web of Science, PubMed, and Scopus databases were reviewed for all publications studying the risk factor between urbanization and asthma. The search terms used in the databases are defined as "asthma" and "urbanization". During the search phase, only English texts were permitted, although publication dates were not restricted. The screening content is displayed in Appendix 2.

2.2. Content selection

In determining the research, first, the titles and abstracts of non-topic studies were eliminated, and then the full texts of papers pertinent to the issue were obtained. The analysis includes publications examining (1) urban air pollution and asthma, (2) transportation networks and asthma, (3) land use and asthma and (4) urban green space/vegetation and asthma relations. Publications researching non-human subjects, publications exploring just risk variables related to asthma severity, publications with unclear study designs, and meta-analysis studies were omitted from the research selection.

2.3. Data extraction

In meta-analysis and systematic review studies, various software programs (SPSS, CMA, RevMan, and Cochrane Collaboration Review Manager) are used to create databases from publication information. Among these programs, Comprehensive Meta-Analysis Software (CMA) was developed only for meta-analysis, and it is frequently used in meta-analysis studies.

Within the scope of the study, Comprehensive Meta-Analysis (CMA) V3.7 program was used to create a database for the selected studies

containing relevant information. In this context, all authors evaluated the studies, and those with unclear designs or insufficient data were removed from the review. In the selected publications, the names of the authors, year of publication, country of study, sample size and basic characteristics of the study group, study design, disease definition, risk factors and their correlating effect sizes, confidence intervals, and *p*-values of asthma coexistence were categorized.

2.4. Assessment of study quality

Study quality was assessed using Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Seven criteria were considered (study design, population description, sample method, sample size, urban definition, disease definition and adequacy of risk factor remarks) to classify study quality as high, medium or low (Appendix 3). High-quality studies were those providing complete information for these criteria while medium-quality studies lacked information for one criterion. Studies lacking information on more than two criteria were considered to be of low quality.

2.5. Statistical analysis

In the meta-analysis, there are two different impact models to analyze the findings. These are known as fixed-effects models and random-effects models. While calculating the effect size, the fixed-effects model is used if the data are homogeneous; if the data are not homogeneous, the random-effects model is preferred. The fixed-effects model is often used under conditions when the sample size does not change and the standard deviations are assumed to be zero. However, when the sample size is different and the standard deviation is not zero, the random-effects model is preferred. In the context of this study, a random-effects model was used since the sample sizes of studies examining asthma risk variables in urban areas were different.

In the first step of the analysis, the OR (odds ratio) and 95 % CI (confidence interval) findings in the studies selected for meta-analysis were extracted. Simultaneously, the inconsistency index I^2 was calculated to examine heterogeneity in the studies used in the analysis. In line with the results of the I^2 test, the effect type model used in the study was also confirmed. If the I^2 test results are high, the publications selected for analysis should be heterogeneous and a random-effects model should be used[1] (Rodriguez et al., 2019).

To illustrate the standard errors of the asthma risk factors described in the studies, a bias graph was drawn and the publication status of the chosen studies was analyzed. In addition, Kendall's tau *p*-value values were analyzed to assess publication bias. To have precise information about publication bias in meta-analysis studies, Kendall's tau *p*-value should be examined. In the analysis, Kendall's tau *p*-value is expected to be higher than 0.05. Otherwise, it is stated that there is publication bias in the analysis and the results may be misleading (Karagöz, 2019).

3. Analysis results

3.1. Study characteristics

As a result of the search terms entered into the Web of Science, Scopus, and PubMed databases, 3276 possible studies addressing the association between asthma and urbanization risk factors have been identified. After eliminating duplicates from the search publications and reviewing the titles and abstracts, 503 articles were chosen for a detailed review. As a result of the last review, 127 articles were examined, and the characteristics and risk factors of the selected studies are given in Appendix 4. Fig. 1 illustrates the study's general search and examination procedure 6 of the chosen studies were cohort-based and longitudinal, five were case-control studies, and the other 116 were cross-sectional. It was established that the majority of studies were conducted on the Asian and North American continents, whereas Africa and Europe had very few studies. It has also been discovered that the subject is frequently brought up in China and the US.

3.2. Results overview

As a consequence of the selected studies, asthma is described as ongoing wheezing, physician diagnosis, questionnaire diagnosis, or prediagnosed asthma. In studies defining urban asthma risk factors, various elements have been identified. These elements, shown in Fig. 2, are listed under the categories of urbanization rate, air pollution, transportation network and other urban factors. Appendices 4 and 5 contain the data derived from random impact meta-analyses for the selected urban risk variables.

The relationship between urbanization rate and asthma risk factors has been defined in the form of rural-urban separation or urban stratification (rural-suburban-urban). In most studies, it has been observed that there is a linear increase in asthma in urban areas. Only a few studies suggested no linear relationship between asthma and urbanization. In the relationship between air pollution and asthma, $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3, which are the components of air pollution, were examined. NOX, CO and CO_2 components were not included in the analysis as they have been investigated in few studies. It has been understood that the pollutant components that are the subject of the analysis have a linear relationship with asthma.

In the relationship between the transportation network and asthma, it has been understood that the studies are associated with the road network. The analysis indicated that the degree of proximity to road transportation was examined in those studies and the proximity to truck/bus routes and transportation density were frequently studied. The analysis also pointed to the linear relationship between asthma and the transportation network defined among the risk factors in related studies. In the relationship of other urban factors with asthma, it is seen that factors including land use such as proximity to industrial facilities and green areas are examined. In addition, risk factors related to the housing structure such as the size of the house, the way the house is heated, the state of mold in the house and the state of humidity are examined. Among these risk factors, only the mold status in the residence and the risk factor of proximity to industrial areas were examined. Other risk factors were not included in the meta-analysis due to heterogeneity testing. In addition to the summary content presented above, all risk factors are discussed in detail in sub-sections.

3.3. Urbanization rate

30 of the 127 evaluated studies focused on the association between urbanization rate and asthma. 8 of these studies were done on adult cases (Desalu et al., 2021; Gorski-Steiner et al., 2022; Huang et al., 2019; Kausel et al., 2013; Menezes et al., 2015; Son et al., 2015; Tilahun et al., 2022; Timm et al., 2015; Wang et al., 2019), while 22 were conducted on pediatric cases (Larson et al., n.d.; Ekici et al., 2012; El-Sharif et al., 2002; Gaviola et al., 2016; Guddattu et al., 2010; Han et al., 2017; Hijazi et al., 2000; Idani et al., 2020; Kausel et al., 2013; Keet et al., 2015; Kolokotroni et al., 2011; Lamnisos et al., 2013; Lin et al., 2019; Masoompour et al., 2018; Norback et al., 2018; Rodriguez et al., 2015; Rodriguez et al., 2020; Tilahun et al., 2022; Toizumi et al., 2019; Wang et al., 2021; Zhu et al., 2015). 1 research used a questionnaire-based, retrospective study methodology, whereas 29 studies utilise a cross-sectional approach based on health control data. In addition, while the risk factor of urbanization rate was examined through the urban-

[1] In the I^2 test results; Results between 0 % and 40 % indicate that publications can be considered homogeneous. Results between 30 and 60 % represent moderate heterogeneity. Ratios between 50 % and 90 % represent significant heterogeneity, and results between 75 % and 100 % indicate critical heterogeneity.

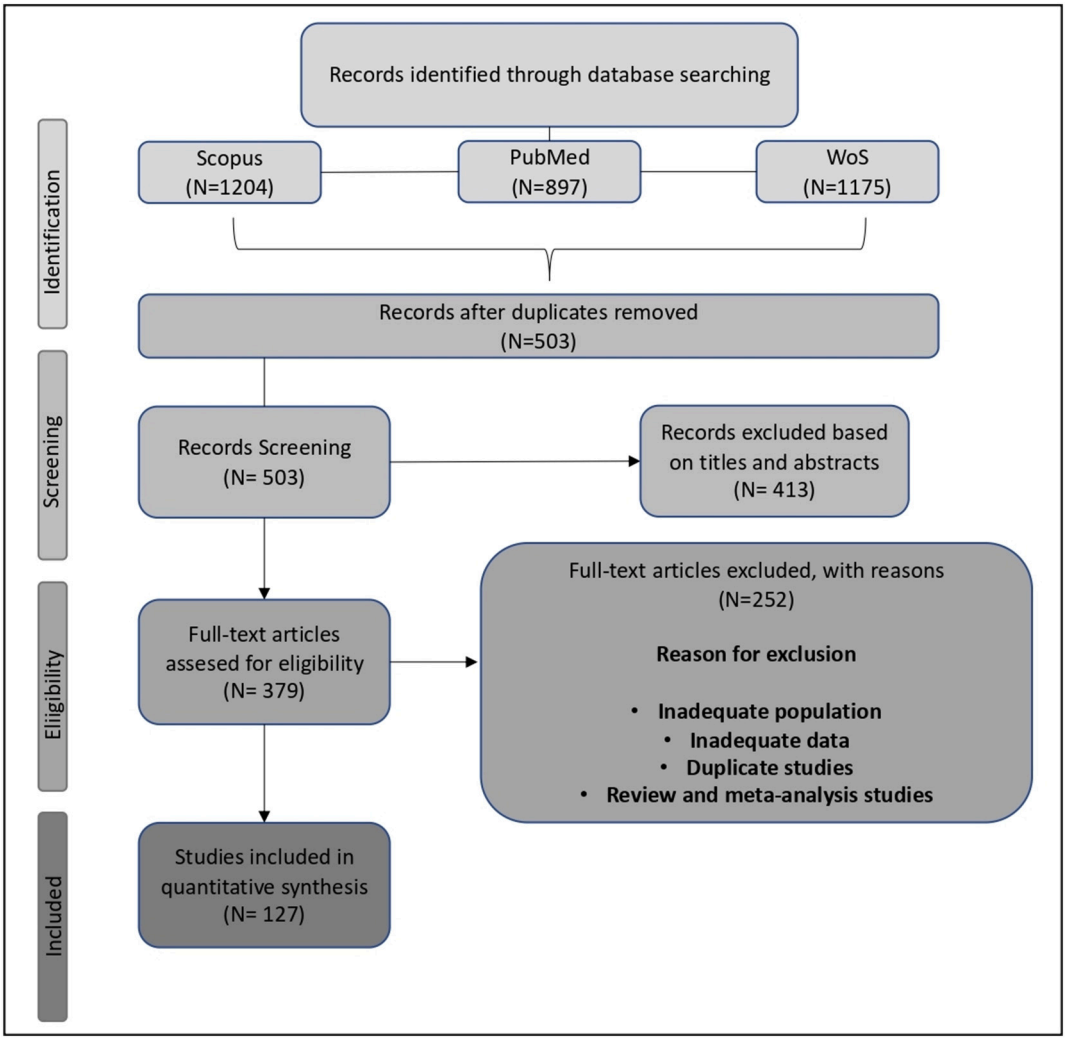


Fig. 1. The procedure of selecting studies for systematic review and meta-analysis of asthma and urbanization risk factors (Produced within the scope of the study).

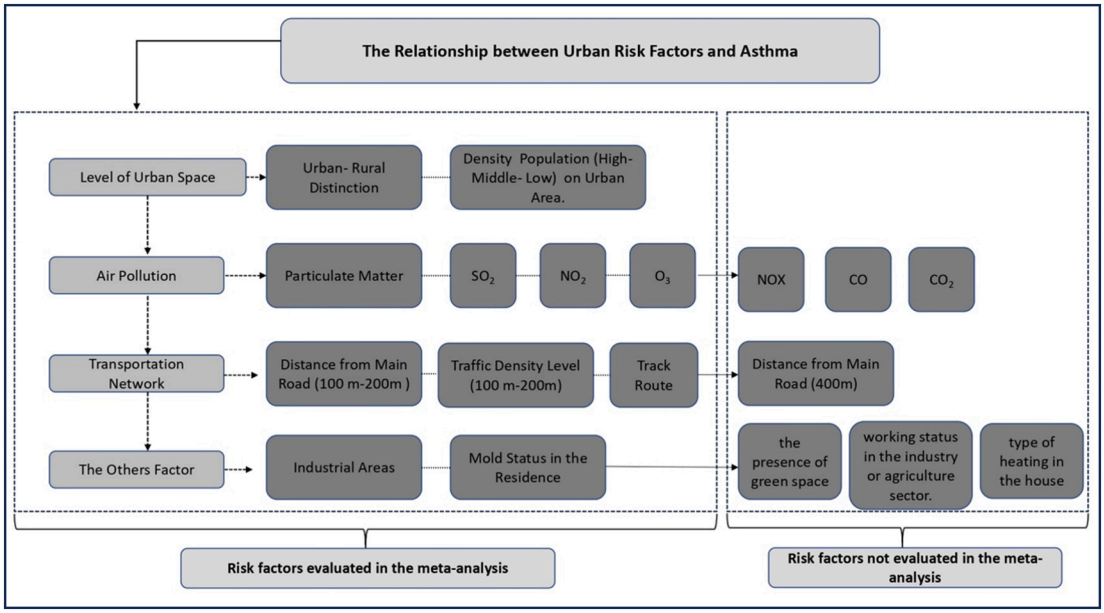


Fig. 2. Asthma and urbanization components discussed in the literature (Produced within the scope of the study).

rural settlement parameter in (Larson et al., n.d.; Ekici et al., 2012; Gaviola et al., 2016; Hijazi et al., 2000; Huang et al., 2019; Idani et al., 2020; Kolokotroni et al., 2011; Lamnisos et al., 2013; Masoompour et al., 2018; Menezes et al., 2015; Rodriguez et al., 2020; Toizumi et al., 2019; Wang et al., 2019; Wang et al., 2021; Zhu et al., 2015) 23 studies, it was associated with asthma disease through the urban space hierarchy (metropolis, city, suburban, town, rural) in 7 studies (Guddattu et al., 2010; Han et al., 2017; Kausel et al., 2013; Keet et al., 2015; Lin et al., 2019; Rodriguez et al., 2020; Timm, Frydenberg, Janson, Campbell, et al., 2016a). As a consequence of the investigations, 7 of 30 studies were excluded from the meta-analysis because they were asymmetrical (Desalu et al., 2021; Ekici et al., 2012; Norback et al., 2018; Rodriguez et al., 2020; Son et al., 2015; Tilahun et al., 2022; Zhu et al., 2015). The remaining 23 studies were submitted to a random meta-analysis.

As a result of the analysis, it was found that the relationship between the urbanization rate and the level of urban space was significant (OR = 1.34, 95 % CI: 1.14–1.58, I^2 = 98.55, heterogeneity *p*-value <0.001, Kendall's tau p-value 0.1350 values Appendix 5 F1). The research revealed that neither heterogeneity nor publication bias existed (over heterogeneity p-value and Kendall's tau *p*-values). In the studies examined, the association between allergic respiratory diseases, such as asthma, and urbanization rate is explained by excessive road traffic and vehicle-emitted urban air pollution. It has been reported that the risk of asthma is greater in urban settings than in rural places (Larson et al., n.d.; Desalu et al., 2021; Gaviola et al., 2016; Gorski-Steiner et al., 2022; Hijazi et al., 2000; Idani et al., 2020; Kausel et al., 2013; Lamnisos et al., 2013; Lin et al., 2019; Masoompour et al., 2018; Menezes et al., 2015; Norback et al., 2018; Rodriguez et al., 2020; Timm, Frydenberg, Janson, Campbell, et al., 2016b; Toizumi et al., 2019; Wang et al., 2021; Zhu et al., 2015). According to certain studies, urban-rural spatial dynamics did not demonstrate a substantial correlation with asthma risk factors (Huang et al., 2019; Keet et al., 2015; Son et al., 2015). In one research, rural spatial dynamics of the asthma risk factor were shown to be greater than in urban areas (Rodriguez et al., 2015).

3.4. Air pollution

The connection between air pollution and asthma was analyzed using $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3 variables. NOX and CO components are eliminated due to a lack of sufficient testing. 41 research have investigated the association between $PM_{2.5}$ and PM_{10} and asthma (Alman et al., 2016; Canova et al., 2012; Chen et al., 2013; Chen et al., 2018; Cheng, Narzo, Howell, Yevdokimova, et al., 2022a; Correa-Agudelo et al., 2022; Deng et al., 2018; Ding et al., 2017; Fuertes et al., 2013; Gehring et al., 2010; Gleason et al., 2014; Gruzieva et al., 2013; Ho et al., 2007; Huang et al., 2019; Hwang et al., 2005; Iskandar et al., 2012; Krmpotic et al., 2011; Laurent et al., 2008; Lavigne et al., 2012; Lewin et al., 2013; Li et al., 2011; Liu et al., 2014; Liu et al., 2021; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Norback et al., 2018; Raun et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2015; Squillacioti et al., 2020; Wang et al., 2021; Yang et al., 2019; Zhao et al., 2020); 28 studies have investigated the relationship between NO_2 and asthma (Cheng, Narzo, Howell, Yevdokimova, et al., 2022a; Clougherty et al., 2007; Deng et al., 2015; Deng et al., 2016; Deng et al., 2018; Ding et al., 2017; Fuertes et al., 2013; Gehring et al., 2010; Iskandar et al., 2012; Jy et al., 2013; Krmpotic et al., 2011; Laurent et al., 2008; Lavigne et al., 2012; Li et al., 2011; Liu et al., 2014; Liu et al., 2021; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Norback et al., 2018; Ranzi et al., 2014; Raun et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2015; Wang et al., 2021; Young et al., 2014). There are 14 research studying the association between SO_2 and asthma (Chen et al., 2019; Deng et al., 2018; Ding et al., 2017; Hwang et al., 2005; Jy et al., 2013; Laurent et al., 2008; Lavigne et al., 2012; Lewin et al., 2013; Li et al., 2011; Liu et al., 2014; Lovinsky-Desir et al., 2019; Portnov et al., 2012; Samoli et al., 2011; Santus et al., 2012) and 19 studies examining the association between O_3 and asthma (Chen et al., 2013; Chen et al., 2019; Ding et al., 2017; Fuertes et al., 2013; Gleason et al., 2014; Ho et al., 2007; Hwang et al., 2005; Laurent et al., 2008; Lavigne et al., 2012; Liu et al., 2014; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Raun et al., 2014; Sacks et al., 2014; Samoli et al., 2011; Santus et al., 2012; Singh et al., 2016; Son et al., 2013).

3.4.1. Particle material ($PM_{2.5}$ - PM_{10})

One of the studies examining the relationship between $PM_{2.5}$, PM_{10} and asthma has a retrospective questionnaire-based study design (Zhao et al., 2020), one has a case-control design (Lovinsky-Desir et al., 2019), and 39 studies have a cross-sectional study design based on health control data. 11 of the studies (Canova et al., 2012; Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Gleason et al., 2014; Huang et al., 2019; Krmpotic et al., 2011; Künzli et al., 2009; Laurent et al., 2008; Raun et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2015) were based on the adult case group, 2 on the female case group (Liu et al., 2021; Young et al., 2014), and 26 on the pediatric case group. As a result of the examinations, 5 of the 41 studies were not included in the meta-analysis because they were asymetrical (Correa-Agudelo et al., 2022; Ho et al., 2007; Iskandar et al., 2012; Lavigne et al., 2012; Squillacioti et al., 2020). The analysis revealed a significant association between PM and asthma (OR = 1.093, 95 % CI: 1.061–1.125, I^2 = 94.2 heterogeneity p-value 0.001, Kendall's tau p-value 0.31342 values Appendix 5 F2). By examining the heterogeneity p-value and Kendall's tau p-value, it was determined that there was neither heterogeneity nor publication bias.

In the analyzed study findings, the relationship between allergic respiratory diseases, such as asthma, and particulate matter is explained by high levels of road traffic, sports activities near the road traffic, vehicle emissions, heating energy, and similar factors. (Alman et al., 2016; Bose et al., 2018; Canova et al., 2012; Chen et al., 2019; Cheng, Narzo, Howell, Yevdokimova, et al., 2022a; Correa-Agudelo et al., 2022; Deng et al., 2018; Ding et al., 2017; Fuertes et al., 2013; Gehring et al., 2010; Gleason et al., 2014; Gruzieva et al., 2013; Ho et al., 2007; Iskandar et al., 2012; Krmpotic et al., 2011; Lavigne et al., 2012; Lewin et al., 2013; Liu et al., 2014; Liu et al., 2021; Lovinsky-Desir et al., 2019; Norback et al., 2018; Raun et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2015; Squillacioti et al., 2020; Wang et al., 2021; Yang et al., 2019; Young et al., 2014). According to the results of the studies, PM_{10} values were not as effective as other pollutants on asthma in general, whereas $PM_{2.5}$ levels had a significant correlation with hospital admissions. According to other studies, PM_{10} values do not demonstrate a substantial correlation, particularly in adult cases (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Hwang et al., 2005; Krmpotic et al., 2011; Laurent et al., 2008; McConnell et al., 2010; Squillacioti et al., 2020). In one study, the PM_{10} value was shown to be significant above 10 mg/m3 (Portnov et al., 2012), while in another, the study between asthma and particulate matter over 40 mg/m3 was found to be significant (Zhao et al., 2020).

3.4.2. Nitrogen dioxide (NO_2)

Each of the 28 studies evaluating the study between NO_2 and asthma employs a cross-sectional design based on health control data. 10 of the studies were associated with adult cases (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Krmpotic et al., 2011; Künzli et al., 2009; Laurent et al., 2008; Li et al., 2011; McConnell et al., 2010; Raun et al., 2014; Samoli et al., 2011; Son et al., 2013), 2 with female cases (Liu et al., 2021; Young et al., 2014), and 16 with pediatric cases (Chen et al., 2019; Clougherty et al., 2007; Deng et al., 2016; Deng et al., 2018; Ding et al., 2017; Fuertes et al., 2013; Gehring et al., 2010; Iskandar et al., 2012; Laurent et al., 2008; Lavigne et al., 2012; Lewin et al., 2013; Lovinsky-Desir et al., 2019; Norback et al., 2018; Ranzi et al., 2014; Son et al., 2015; Wang et al., 2021). As a result of the examinations, 9 of the 28 studies were excluded from the meta-analysis because they were asymmetrical (Deng et al., 2016; Ding et al., 2017; Gehring et al., 2010; Krmpotic et al., 2011; Li et al., 2011; Liu et al., 2014; Samoli et al., 2011;

Son et al., 2013; Son et al., 2015). As a result of the analysis, it was found that the relationship between NO_2 and asthma (OR = 1.081, 95 % CI: 1.044–1.119, I^2 = 85.3 heterogeneity p-value <0.001, Kendall's tau p-value 0.9164 values Appendix 5 F3) was significant. The analysis revealed no heterogeneity or publication bias existed (over heterogeneity p-value and Kendall's tau p-value values).

In the analyzed studies, in general, $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3 pollutants were evaluated together and NO_2 was found to be the pollutants with the most significant results with asthma. According to the studies, nitrogen dioxide is evaluated within the context of transportation-related air pollution. In studies investigating the influence of transportation-related air pollution on asthma, the NO2 component was investigated across a range of trip modes (school-home, school, open-space-vehicle distance). According to some studies, NO_2 is the most significant pollutant correlated with asthma (Clougherty et al., 2007; Liu et al., 2021; Son et al., 2013). Nevertheless, in a small number of studies, it was mentioned that NO_2 pollutant was not associated with asthma or was at a limited level (Iskandar et al., 2012; Ranzi et al., 2014; Samoli et al., 2011).

3.4.3. Sulfur dioxide (SO_2)

Among the 14 studies that examine the association between SO_2 and asthma, one uses a case-control study design (Lovinsky-Desir et al., 2019), while the others use a cross-sectional study design based on health-control data. 5 of the studies were based on adult cases (Laurent et al., 2008; Li et al., 2011; Samoli et al., 2011; Santus et al., 2012; Son et al., 2013) and 9 were based on pediatric (Chen et al., 2019; Deng et al., 2018; Ding et al., 2017; Hwang et al., 2005; Lavigne et al., 2012; Lewin et al., 2013; Liu et al., 2014; Lovinsky-Desir et al., 2019; Portnov et al., 2012). Due to the evaluations, 3 of the 14 studies were excluded from the meta-analysis because they were asymmetrical (Chen et al., 2019; Lavigne et al., 2012; Son et al., 2013). As a result of the analysis, the relationship between SO_2 and asthma (OR = 1.047, 95 % CI: 1.006–1.089, I^2 = 75.03 heterogeneity p-value <0.001, Kendall's tau p-value 0.81533 values Appendix 5 F4) was identified to be significant. The research revealed that no heterogeneity nor publication bias existed (over heterogeneity p-value and Kendall's tau p-value levels). In the outcomes of the study, it was seen that the SO_2 component had a direct correlation with transportation networks and produced significant results in its connection with asthma. However, also some studies have indicated that sulfur dioxide is not related to asthma (Hwang et al., 2005; Portnov et al., 2012).

3.4.4. Ozone (O_3)

Among the 19 studies that examined the association between O_3 and asthma, one study had a case-control design (Lovinsky-Desir et al., 2019), and the others had a cross-sectional study design based on health-control data. 7 of the studies were based on adult cases (Laurent et al., 2008; McConnell et al., 2010; Raun et al., 2014; Sacks et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2013), while 12 were based on pediatric cases. Due to the examinations, 2 of the 19 studies were excluded from the meta-analysis because they were asymmetrical (Gleason et al., 2014; Santus et al., 2012). As a result of the analysis, it was found that the relationship between O ve asthma (OR = 1.083, 95 % CI: 1.047–1.121, I^2 = 90.997 heterogeneity p-value <0.001, Kendall's tau p-value 0.81533 values Appendix 5 F5) was significant. The research revealed that no heterogeneity nor publication bias existed (over heterogeneity p-value and Kendall's tau p-value levels). According to the outcomes of the studies, ozone causes greater asthma episodes in the spring and summer (Samoli et al., 2011). O_3 is unlike other contaminants in this regard. In comparison to other pollutants, some studies indicate that the effect of O_3 is either partially significant or nonexistent (Ding et al., 2017; Laurent et al., 2008; Liu et al., 2014; Lovinsky-Desir et al., 2019; McConnell et al., 2010).

3.5. Road network

Concerning the relationship between the road network and asthma, the main road connection 200 m from the residence as well as asthma criteria, transportation density, and proximity to truck/van routes were considered. Due to publication bias, the 400-m proximity to the main access road was excluded from the analysis. 15 studies (Dell et al., 2014; Freid et al., 2021; Gauderman et al., 2005; Idani et al., 2020; Idris et al., 2016; Künzli et al., 2009; Lee et al., 2018; Liu et al., 2014; Liu et al., 2020; Lovinsky-Desir et al., 2019; McConnell et al., 2006; Portnov et al., 2012; Ranzi et al., 2014; Yamazaki et al., 2014; Zhang et al., 2021) have examined the relationship between asthma and the main road connection 200 m from the residence, 9 studies (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Ciccone et al., 1998; English et al., 1999; Insaf et al., 2022; Lindgren et al., 2016; Liu et al., 2021; Mölter et al., 2014; Wang et al., 2021) have examined the relationship between transportation density and asthma, and 7 studies have examined the criterion of proximity to truck routes (Alqahtani et al., 2017; Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Huang et al., 2020; Lin et al., 2002; Liu et al., 2020; Maantay, 2007; Musharrafieh et al., 2009).

3.5.1. Main road distance ≤200 m

All 15 studies examining the correlation between asthma and the main road connection 200 m from the residence utilized a cross-sectional design based on health control data. 3 of the studies (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Idani et al., 2020; Künzli et al., 2009) were based on adult cases, while twelve were based on pediatric cases. As a consequence of the evaluations, one of the 15 studies was excluded from the meta-analysis because they were asymmetrical (Ranzi et al., 2014). The investigation found that there was a significant association between asthma and the main road connection 200 m from the residence. (OR = 1.263, 95 % CI: 1.110–1.437, I^2 = 65.63 heterogeneity p-value <0.001, Kendall's tau p-value 0.4338 values Appendix 5 F6). According to the studies, the risk of asthma is enhanced when exhaust smoke, particulate matter, and nitrogen dioxide were present within 200 m of the residence, which is distant from the main road. According to studies, the distance from the residence to the main road with the highest risk rate is 20 m or less (Liu et al., 2014), and NO_2, SO_2, and PM exposure are significant at distances below 100 m (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Lee et al., 2018; Ranzi et al., 2014). Only one study (Gauderman et al., 2005) concluded that the correlation between asthma and the main road connection 200 m from the residence was not statistically significant.

3.5.2. Traffic density

All 9 studies investigating the relationship between transportation intensity and asthma had a cross-sectional study design based on health control data. 4 of the studies (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Insaf et al., 2022; Lindgren et al., 2016; Liu et al., 2020) were based on adult cases, while five were based on pediatric cases. As a result of the examinations, 3 of the 9 studies were excluded from the meta-analysis because they were asymetrical (Ciccone et al., 1998; Lin et al., 2002; Lindgren et al., 2016). As a result of the analysis, it was found that the relationship between transportation intensity and asthma (OR = 1.115, 95 % CI: 0.885–1.406, I^2 = 98.59 heterogeneity p-value <0.001, Kendall's tau p-value 0.85098 values Appendix 5 F8). It has been determined through studies that it is interpreted by traffic exhaust and PM. According to studies, traffic density increases hospitalizations for male and pediatric cases (Insaf et al., 2022; Lin et al., 2002). The connection between transportation density and asthma was shown to be insignificant in only one study (Mölter et al., 2014).

3.5.3. Truck route

All 7 studies examining the relationship between the truck/van route and residence have a cross-sectional study design based on health control data. Two of the studies (Cheng, Narzo, Howell, Yevdokimova,

et al., 2022b; Maantay, 2007) were based on adult cases, while five were based on pediatric cases. As a consequence of the examinations, 1 of the 7 studies was excluded from the meta-analysis because they were asymetrical (Musharrafieh et al., 2009). As a result of the analysis, it has been revealed that the relationship between the truck/van route and the residence is significant (OR = 1337, 95 % CI: 1.018–1.757, $I^2 = 80.05$ heterogeneity p-value <0.001, Kendall's tau p-value 0.57303 values Appendix 5 F9). As a result of the studies, it has been seen that truck/van routes are associated with NO_2 and PM, similar to the relationship between traffic density and the main road connection asthma, which is 200 m away from the residence. There was just one study (Lin et al., 2002) that did not discover a relationship between residence and the truck/van route.

3.6. Other urban factors

Out of a total of 127 studies reviewed; mold status in housing and proximity to industrial areas, which were not evaluated under the headings of urbanization rate, air pollution, and transportation network, were included in the meta-analysis. Due to publication bias and lack of heterogeneity, the meta-analysis did not include the main road connection at a distance of 400 m from the researched residence, the humidity rate in the house, the type of heating in the house, the size of the house, the presence of green space, and the working status in the industry/agriculture sector.

In the case of mold in the residence, 11 studies were examined, and it was concluded that all of the studies had cross-sectional designs based on health control data. As an outcome of the examinations, all 11 studies were subjected to meta-analysis (Bu et al., 2016; Hwang et al., 2005; Idani et al., 2020; Karvonen et al., 2009; Larsson et al., 2011; Lin et al., 2015; Norback et al., 2018; Rosenbaum et al., 2010; Wang et al., 2021). As an outcome of the examination, it was determined that there is a significant association between mold status and asthma in the house (OR = 1.596, 95 % CI: 1.363–1.869, $I^2 = 65{,}667$ heterogeneity p-value <0.001, Kendall's tau p-value 0.31151 values Appendix 5 F10). The association between proximity to industrial areas and asthma was studied in 5 studies, and it was concluded that all of the studies used a cross-sectional design based on health control data. As a consequence of the examinations, all 5 studies were subjected to meta-analysis (Fu et al., 2016; Huang et al., 2020; Liu et al., 2014; Middleton et al., 2014; Zhang et al., 2021). As a result of the analysis, it was found that the relationship between these two factors (OR = 2.315, 95 % CI: 1.146–4.677, $I^2 = 90.732$ heterogeneity p-value <0.001, Kendall's tau p-value 1.0000 values Appendix 5 F13) was significant. Due to publication bias, the relationship between asthma and the main road connection 400 m from residences was excluded (6 studies in total). Studies have shown that pediatric cases living 400 m away have an increased asthma exposure compared to adult cases. It has been shown that PM and nitrogen dioxide pollutants from transportation contribute to a boost in hospitalization rates (Correa-Agudelo et al., 2022; Freid et al., 2021; McConnell et al., 2006; Norback et al., 2018; Rodriguez et al., 2020).

There were 7 studies examining the association between house humidity and asthma (Cai et al., 2020; Lin et al., 2015; Norback et al., 2018; Takaoka et al., 2017; Wang et al., 2014; Wang et al., 2019; Wong et al., 2004) and house heating and asthma (Beridze et al., 2018; Fu et al., 2016; Guddattu et al., 2010; Liu et al., 2014; Zhang et al., 2021). Since the heterogeneity p-value 0.019, $I^2 = 65.910$, Kendall's tau p-value of 0.01431 value was found in the relationship between the type of heating in the house and asthma, it was excluded from the study. The asthma risk ratio has been investigated due to the use of coal in the form of heating in the house, and air pollution and heating style have been associated with asthma.

The association between the presence of green space and asthma was evaluated in 8 studies (Aryee et al., 2022; Commodore et al., 2021; Correa-Agudelo et al., 2022; DePriest et al., 2019; Idani et al., 2020; Paciência et al., 2022; Squillacioti et al., 2020; Zeng et al., 2020). Since the heterogeneity p-value was 0.086 $I^2 = 59.203$, Kendall's tau p-value was 0.60151, they were excluded from the study. Green space was identified as a protective factor in the association between the existence of green space and asthma as a result of the examination. It is thought that especially in areas 200 m from the residence, intensive green area analysis or the construction of a private garden of the residence affects the asthma risk factor positively (Idani et al., 2020; Squillacioti et al., 2020; Zeng et al., 2020).

Lastly, the employment status in the industry/agricultural sector and the size of the residential area were excluded from the study due to the insufficient number of studies evaluating them. According to the residential area size (Ding et al., 2012) one study was included in the overall evaluation.

4. Discussion

The systematic review and meta-analysis aimed to summarize and estimate urban asthma risk factors. 127 studies published between 1998 and 2022 were incorporated into the analysis process. Random impact meta-analyses were conducted for most of the urbanization rate, rural-urban divide, air pollution components ($PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3), road network components(main road connection 200 m from residence and asthma, transportation density, proximity to lorry/truck routes and 400 m proximity to access road), housing condition (mildew, humidity, heating pattern), land use (presence of green areas, proximity to industrial areas), industrial and agricultural employment status, and mixed land use risk factor. Thus, numerous risk factors that describe the association between asthma and urban components have been identified. Asthma-preventative and modifiable factors are defined as factors that are stated to trigger asthma within the scope of the study. In another meta-analysis study, general risk factors for asthma in the Asian region were defined, while the identified factors were classified as modifiable (urbanization, housing status) and non-modifiable (genetics, gender) (Sio & Chew, 2021). In this context, it is anticipated that modifiable factors defined in the study, such as transportation network, air pollution, urbanization rate, housing situation, and land use, will be regarded as the key factor in the formulation of policies to prevent the disease. In this context, it should be aimed to examine the different urban risk factors as a result of the meta-analysis and to diversify the urban risk factors.

In 127 studies reviewed, it was seen that the relationship between urbanization rate and asthma in 41 studies was interpreted through the urban-rural distinction. (Larson et al., n.d.; Desalu et al., 2021; Gaviola et al., 2016; Gorski-Steiner et al., 2022; Hijazi et al., 2000; Idani et al., 2020; Kausel et al., 2013; Lamnisos et al., 2013; Lin et al., 2019; Masoompour et al., 2018; Menezes et al., 2015; Norback et al., 2018; Rodriguez et al., 2020; Timm, Frydenberg, Janson, Campbell, et al., 2016b; Toizumi et al., 2019; Wang et al., 2019; Wang et al., 2021; Zhu et al., 2015). In addition, asthma was associated with urban space hierarchy (metropolis, city, suburb, town, rural) in 7 studies (Guddattu et al., 2010; Han et al., 2017; Kausel et al., 2013; Keet et al., 2015; Lin et al., 2019; Rodriguez et al., 2020; Timm et al., 2015). The prevalence of asthma is higher in urban areas than in rural ones, and the rate of urbanization is significantly connected to asthma, according to a meta-analysis. However, it should not be ignored that when correlating urbanization dynamics or area density with asthma, the error margin will be substantial due to the inference of the urbanization rate component for the entire urban area, and general results will arise for the urban area. In addition, it remains unclear how to define urban and rural concerning the urban-rural distinction and asthma. In most studies, the distinction between urban and rural areas; defined by population change. Although urban and rural areas are not defined in studies, it is understood from the settlements where the fieldwork was carried out. In very few studies; The definition of urban area and rural area is defined by the size of the built environment. In these studies, the rural-urban distinction was made by evaluating the ratios of natural land structure

and built environment structure by taking the land use data as a reference. In this context, the urbanization rate risk factor should be replaced with parameters such as building density differentiation, figure-ground relationship, gross population density, and net population density. These parameters will allow more holistic interpretations with less margin of error in terms of describing the relationship between asthma and urban-rural area.

There are 41 studies examining the association between $PM_{2.5}$ and PM_{10} and asthma (Alman et al., 2016; Canova et al., 2012; Chen et al., 2018; Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Correa-Agudelo et al., 2022; Deng et al., 2018; Fuertes et al., 2013; Gehring et al., 2010; Gruzieva et al., 2013; Ho et al., 2007; Huang et al., 2019; Hwang et al., 2005; Lavigne et al., 2012; Liu et al., 2014; Liu et al., 2020; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Norback et al., 2018; Son et al., 2015; Squillacioti et al., 2020; Wang et al., 2021; Yang et al., 2019; Zhao et al., 2020), and 28 studies examining the relationship between NO_2 and asthma (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Clougherty et al., 2007; Correa-Agudelo et al., 2022; Deng et al., 2015; Deng et al., 2016; Ding et al., 2017; Fuertes et al., 2013; Gehring et al., 2010; Iskandar et al., 2012; Jy et al., 2013; Krmpotic et al., 2011; Laurent et al., 2008; Lavigne et al., 2012; Li et al., 2011; Liu et al., 2014; Liu et al., 2021; Norback et al., 2018; Ranzi et al., 2014; Raun et al., 2014; Samoli et al., 2011; Santus et al., 2012; Son et al., 2015; Wang et al., 2021; Young et al., 2014). There are 14 studies examining the relationship between SO_2 and asthma (Chen et al., 2013; Chen et al., 2019; Ding et al., 2017; Fuertes et al., 2013; Gleason et al., 2014; Ho et al., 2007; Hwang et al., 2005; Laurent et al., 2008; Lavigne et al., 2012; Liu et al., 2014; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Raun et al., 2014; Sacks et al., 2014; Samoli et al., 2011; Singh et al., 2016; Son et al., 2013), and 19 studies (Chen et al., 2013; Chen et al., 2019; Ding et al., 2017; Fuertes et al., 2013; Gleason et al., 2014; Ho et al., 2007; Hwang et al., 2005; Laurent et al., 2008; Lavigne et al., 2012; Liu et al., 2014; Lovinsky-Desir et al., 2019; McConnell et al., 2010; Raun et al., 2014; Sacks et al., 2014; Samoli et al., 2011; Santus et al., 2012; Singh et al., 2016; Son et al., 2013) investigating the relationship between O_3 and asthma. According to the studies, the indicated pollutants have a substantial association with asthma. However, in the examination of pollutants in urban areas, only the relationship between pollutants and asthma demonstrates that the dynamics of urban space are ignored. It should be mentioned that the urban area's morphological features (slope, elevation, air corridor) will influence the damage indices of pollutants. In this context, in the interaction between asthma and air pollution, the morphological aspects of the space should be analyzed and associated with the urban area in addition to the pollutant components.

There are 15 studies (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Dell et al., 2014; Freid et al., 2021; Gauderman et al., 2005; Idani et al., 2020; Idris et al., 2016; Künzli et al., 2009; Lee et al., 2018; Liu et al., 2014; Liu et al., 2020; McConnell et al., 2006; Portnov et al., 2012; Ranzi et al., 2014; Yamazaki et al., 2014; Zhang et al., 2021) (examining the relationship between the main road connection 200 m from the residence and asthma in the relationship between the transportation network and asthma; 9 studies (Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Ciccone et al., 1998; English et al., 1999; Insaf et al., 2022; Lindgren et al., 2016; Liu et al., 2021; Mölter et al., 2014; Wang et al., 2021) examining the relationship between transportation intensity and asthma and 7 studies examining the criterion of proximity to truck/van routes (Alqahtani et al., 2017; Cheng, Narzo, Howell, Yevdokimova, et al., 2022b; Huang et al., 2020; Lin et al., 2002; Liu et al., 2020; Maantay, 2007; Musharrafieh et al., 2009). According to studies, the aforementioned factors are significantly associated with asthma. However, within the urban macro form, the relationship between the road network and asthma should not be established, and the urban transportation systems should be examined holistically. In addition, it is required to express the road classification and risk factors in line with the international road hierarchy in the studies conducted. In this context, it is essential to examine the factors of proximity to the routes of public vehicles utilizing fossil fuels and proximity to rail system routes. In addition, it is necessary to calculate the traffic density over the traffic volume of the road network within the entire urban macroform and correlate it with the residence location. In addition, proximity to transportation areas and mixed land use rate of residence should also be associated with asthma. Thus, the interaction between housing areas with multiple spatial functions and transportation, as well as its impact on asthma, will be examined.

Mold status, humidity status, and heating style were found as factors in the association between housing status and asthma; however, humidity status and heating style were excluded from the meta-analysis due to publication bias. According to the studies stated, the presence of mold in the house has a significant relationship with asthma. In addition to this situation, the association between the building quality, building material, and construction history factors related to the housing situation with asthma should be examined. The existence of green areas and mixed land use were not included as risk factors in the meta-analysis of the current study. Instead of the green space factor, the amount of green space per capita among urban small parts, and the presence of passive green spaces that serve as protection (green bands installed on noise-reducing highway roads, etc.) should be examined in terms of asthma.

As a consequence of the evaluation, the diversification of asthma and urban risk factors, risk factors should be assessed using more specific parameters. In addition, the systematic review and meta-analysis study conducted for the study has several limitations related to urban risk factors. The majority of risk factor meta-analyses showed substantial heterogeneity. Cultural, behavioral, regional, and ethnic variations that may influence the association between various factors and asthma are believed to be the cause of this phenomenon. In this context, further research is required to substantiate the urban risk factors for asthma.

5. Conclusion

In the systematic review study designed to determine the urban risk factors of asthma, the current review of the studies discussing the risk factors in the association between the city and asthma is presented. Since the beginning of the 21st century, the urbanization-related increase in asthma has spurred interest in finding a solution. However, as the majority of studies on this topic do not examine urban components and urbanization processes from a multifactorial perspective, they are unable to establish the complex causality of urban risk factors in an all-encompassing manner. In another meta-analysis study that brought this issue to the fore, it was stated that the complexity of urban areas should be resolved (Rodriguez et al., 2019). In this approach, it is required to diversify urban components, calculate the chain effects of urban risk factors, and analyze every part of the area. In addition, distinct risk factors should be defined in the association between asthma and urbanization, from building scale to neighborhood scale, from urban macroform to regional scale, and study patterns should be created based on the spatial scale defined. In this context, the factors discussed in the relevant literature or the factors that could be suggestions were classified according to the spatial scale (Fig. 3).

In addition; the identification and classification of chain risk factors within the scope of such causality will lead to a better understanding of the space and place-based policies to be established for the prevention of asthma. In studies that will examine the relationship between asthma and urbanization; urban planning standards should be discussed, and solutions that direct the space should be focused on. Consequently, in the creation of necessary solutions, besides health scientists, spatial scientists (urban and regional planners, architects, and landscape architects) should concentrate on spatial analysis, search for urban models, and alter the plan regulations following the legal administrative ground in local governments.

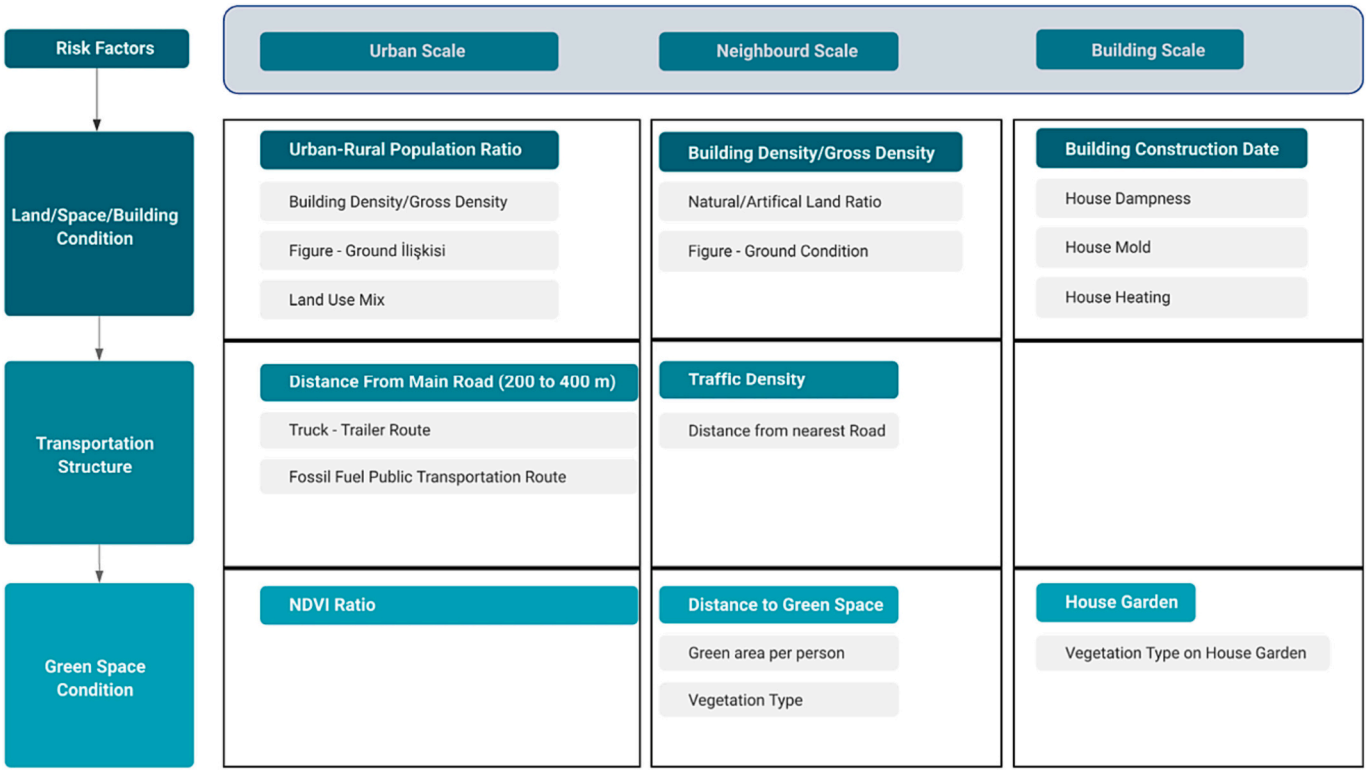


Fig. 3. Urban risk factors of asthma (Produced within the scope of the study).

CRediT authorship contribution statement

Ahmet Burak Kaya: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Kübra Cihangir Çamur:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Hasan Murat Çetin:** Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Saltuk Buğra Kaya:** Conceptualization, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft. **Fatma Erdoğanaras:** Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

No conflicts of interest to disclose.

Data availability

supporting material file uploaded

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2023.104583.

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