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# Environmental Tobacco Smoke Exposure and Respiratory Complaints in Children Aged 0-13 Years: A Cross-sectional Study in South-Limburg, The Netherlands

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## Abstract

**Background:** Two forms of environmental tobacco smoke (ETS) exposure have been described: second-hand smoke (SHS), which is the direct exposure to tobacco smoke; and third-hand smoke (THS), which is the exposure to residuals from tobacco smoke after the cigarette has been extinguished. The effects of SHS exposure on children's respiratory health are known, but not of THS exposure. We evaluated the association between both exposures and respiratory complaints in children aged 0-13 years, and assessed whether the risk of respiratory complaints due to these exposures was higher in children with predisposition for asthma compared to those without.

**Methods:** A cross-sectional survey (91 items) was performed in 10,000 families with a child aged 0-13 years living in South-Limburg, the Netherlands, assessing child and family characteristics, child's respiratory health, and parental smoking behaviour. Data were analyzed with multiple logistic regressions.

**Results:** 1899 families responded. SHS exposure was not associated with an increased risk of respiratory complaints in children. THS exposure was associated with respiratory tract infections in the past 12 months ($OR_{adjusted}$: 2.13; 95% CI: 1.04-4.36; $p$=0.04) and recent wheezing ($OR_{adjusted}$: 2.61; 95%CI: 1.19-5.71; $p$=0.02) in children. There was no interaction between predisposition for asthma and ETS exposure.

**Conclusions:** Unlike previous studies, our study could not reveal a significant association between SHS exposure and increased risk of respiratory complaints in children, most likely due to study limitations concerning cross-sectional design, response rate, selection bias and parental underreporting of SHS exposure to their children. THS exposure was significantly associated with increased risk of respiratory complaints in children. This adds to the limited knowledge about the health effects of THS exposure in children and suggests that more research on this topic is needed. Finally, a predisposition for asthma combined with ETS exposure did not seem to increase the risk of respiratory complaints in children.

**Keywords:** Environmental tobacco smoke; Children; Asthma; Wheezing; Respiratory infections

**Abbreviations:** ETS: Environmental Tobacco Smoke; SHS: Second-Hand Smoke; THS: Third-Hand Smoke; OR: Odds Ratio; CI: Confidence Interval

## Introduction

Respiratory complaints such as respiratory tract infections, wheezing, and asthma, are common in young children. Especially, environmental tobacco smoke (ETS) exposure, contributes to the onset or worsening of respiratory complaints in children. Worldwide, 40-50% of children are exposed to ETS [1,2]. The burden of disease due to ETS exposure in children is large [2]. Maternal smoking during pregnancy has been associated with an increased risk of recurrent wheezing and asthma during the first years of life [3], and even reduction in lung function [4]. Furthermore, ETS exposure has been associated with an increased risk of childhood upper and lower respiratory tract infections compared to children without ETS exposure [5]. Limited studies have evaluated the effects of ETS exposure in children with a genetic predisposition for asthma [6-8]. In asthma predisposed children aged 0-2 years, a six to seven times higher risk of 'wheezing ever' and 'attacks of wheezing' when exposed to ETS as compared to non-exposed children [6]. Maternal smoking in presence of the child increased the risk of wheezing six-fold in children with both parents suffering from allergy, and twofold in children with one parent suffering from allergies [7]. Interestingly, in this study ETS exposure seemed not to affect children without genetic atopic predisposition.

In the past, ETS exposure studies were limited to second-hand smoke (SHS). SHS is the inhalation of cigarette smoke by a non-smoker, which is exhaled by a smoker or which originates from the burning end of a cigarette. Recently, another form of ETS exposure has been described, third-hand smoke (THS), which is defined as the inhalation, ingestion, or dermal uptake of residuals from tobacco smoke after the cigarette has been extinguished [9,10]. Residuals of the cigarette smoke remain in dust, on walls, furniture and textile, of the smoking area and even on clothes and skin of the smoker [11]. Studies concerning the effects of THS exposure on children's respiratory health are scarce. This

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present study examined the relationship between respiratory complaints (respiratory tract infections, wheezing, and asthma) and ETS exposure (both SHS and THS) in children aged 0-13 years living in South Limburg, the Netherlands. The association between ETS exposure and respiratory complaints was assessed for all children and also separately for children with predisposition for asthma. We hypothesize that children exposed to ETS have more respiratory complaints than children without ETS exposure, especially when predisposed for asthma.

## Methods

### Study design

A cross-sectional survey was performed among 10,000 families with children aged 0-13 years in South-Limburg, The Netherlands to assess respiratory complaints in children and parental smoking behaviour. The survey was distributed between March 2010 and August 2010. Families were selected from the Registration Network of Family Practices (RNH, Dutch acronym [12]) and from the civil affairs department registries from three communities in South-Limburg; Heerlen, Maastricht and Sittard-Geleen.

### Participants

Families with a child aged 0-13 years were eligible to participate. Parents completed the survey for their youngest child. 3013 families from the RNH and 6987 families randomly selected from the community registries, received an information package consisting of an information letter, an informed consent form, two questionnaires (A and B) and a prepaid return envelop. Parents were instructed to complete questionnaire A. Parents rejecting participation were asked to complete questionnaire B for analysis of non-response. Parents were informed that their participation was voluntary, but that non-responders would receive a reminder letter after two weeks.

### Definitions of ETS exposure

SHS exposure is defined as 1) current SHS exposure due to parent(s) or others smoking at ≥ 1 per week in the presence of their child and or 2) in utero SHS exposure caused by maternal smoking during pregnancy (ETS exposure through placenta). SHS exposure was categorized as no SHS, in utero SHS exposure, current SHS exposure, and, combined in utero and current SHS exposure. Maternal SHS exposure in utero was measured with the question "Did you or your partner smoke during pregnancy? (yes or no)", and coded "Yes" if the mother smoked during pregnancy and "No" if the mother did not smoke during pregnancy. Current SHS exposure was measured with the following questions: "Do you or your partner smoke in the presence of your child? (yes or no)", and, "On average, how many times is your child present in a room where others are smoking at that moment? (never, occasionally, or, ≥ 1 time(s) per week)", and coded "Yes" if parents or others smoke ≥ 1 per week in the presence of the child, and "No" if parents reported not to smoke in the presence of the child and the child is never/occasionally present in a room where others are smoking at that moment.

THS exposure is defined as parents or others smoking but not in the direct presence of the child. THS exposure is categorized into no THS exposure and THS exposure by parent(s) and/or other people at least once per week. In addition to the questions asked for SHS, THS was measured with the question: "On average, how many times is your child in a room where people have smoked, when your child was not present at that moment? (never, occasionally, or, ≥ 1 time(s) per week)." THS exposure was coded "Yes" if parents reported to smoke but not in the direct presence of the child and the child is ≥ 1 per week in rooms where people have smoked, and "No" if parents do not smoke or the child is never/occasionally present in a room where others have smoked.

### Study questionnaires

Questionnaire A, included 91 items and was composed of three parts: general questions (the child's gender and birth-date, relationship of the caregiver(s) to the child, birth-date of the caregiver(s), number and birth-date of siblings, education level and working situation of the caregiver(s), and ethnicity); questions on the child's general and respiratory health (Dutch version of the ISAAC questionnaire [13,14]), questions concerning physician diagnosed respiratory tract infections in the past 12 months, vitamin use, gestational age at birth, birth weight, complication(s) during pregnancy, breast feeding, perinatal SHS exposure, diagnosis of syndrome(s) or congenital disease(s), day-care use, and, the presence of physician diagnosed asthma, eczema or hay fever in the biological parents and or siblings of the child); and question about parental smoking behaviour [15] and ETS exposure to the child (source and location of ETS exposure [16,17] (also based on expert opinions)). Questionnaire B consisted of 12 items (the child's birth-date, relationship of the caregiver(s) to the child, respiratory complaints in the past 12 months, physician diagnosed asthma, current ETS exposure and reasons for not participating in the study).

### Outcome variables

#### Respiratory complaints in children

1. Respiratory tract infections in the last 12 months. Questions on respiratory tract infections were asked as follows: "Has a physician diagnosed one or more of the following complaints: common cold, ear infection, throat infection, infection of the sinuses, bronchitis, and/or lung infection in your child in the past 12 months? (Yes or No)"

2. Wheezing ever. The question on wheezing ever was asked as follows: "Has your child ever had wheezing in the chest? (Yes or No)"

3. Recent wheeze. Question on recent wheeze was asked as follows: "Has your child had wheezing in the chest in the past 12 months? (Yes or No)"

4. Asthma ever. The question on asthma was asked as follows: "Did a physician ever diagnose asthma in your child? (Yes or No)"

### Data analysis

Data were analysed using SPSS 18 (SPSS inc., Chicago IL, USA). Descriptives of the study population were calculated as frequencies and percentages of specific variables. The ages of the children were not normally distributed. Therefore, we categorized age into preschool aged children (<6 years) and school aged children (≥ 6 years). Preschool children spent more time at home with their parents and may therefore be more exposed to ETS. There were no significant interactions between the age categories and ETS exposure, therefore age was included as a variable in the analyses. For the analysis of the relationship between ETS exposure and respiratory complaints in children, unadjusted and adjusted logistic regression models were applied. The unadjusted model included SHS or THS exposure. The adjusted model included SHS or THS exposure and the following potential confounders: age of the child (<6 years or ≥ 6 years); sex of the child (male or female); birth weight (<2500 grams [low] or ≥ 2500 grams [normal]); gestational age at birth (<37 weeks [preterm] or ≥ 37 weeks [a term]); complications during pregnancy or delivery (yes or no); breast feeding (less than 6 months, 6-12 months or more than 1 year); current vitamin D supplementation to the child (never, sometimes or daily); day-care attendance (yes or

no); highest parental educational level (primary school or preparatory vocational education [low], lower general secondary education or lower secondary vocational education [middle], higher general secondary education or higher vocational education [high], or, university or academic education [academic]); physician's diagnosed allergic disease (asthma, hay fever and or eczema) in one or more first degree relative(s) (at least one parent, at least one biological sibling, or, both parent(s) and biological sibling(s) (yes or no).

All variables were placed simultaneously in the logistic regression analyses. The results are presented as unadjusted and adjusted odds ratios (ORs) with their corresponding 95% confidence intervals (CIs). A probability value (*p*-value) less than 0.05 was considered statistically significant. Missing values were addressed with pairwise deletion method. Children with current SHS exposure were excluded from the analysis. To analyze if children with a predisposition for asthma were at higher risk of respiratory complaints due to ETS exposure, we tested if there was a significant interaction between a predisposition for asthma and ETS exposure. No significant interaction was found; therefore we did not perform further sub-analysis for this group.

## Results

### Population characteristics

The total response rate was 19% (N=1899). Most questionnaires (84%) were completed by mothers. The population characteristics are presented in table 1. Response was minimal for the families with low education. Therefore, the low and the middle education group were combined for further analysis. A quarter of the physician diagnosed respiratory tract infections in the last 12 months were due to flu or cold, and 15.1% due to ear infections. Among the children with reported recent wheezing, 68% had 1-3 attacks of wheezing during this period. Active smoking was reported by 14.3% of the parents, and current SHS exposure in 20.5% of the children. About half (53.1%) of the children with current SHS exposure were from families with low-middle education level, 37.1% from families with high education level and 9.8% from families with academic education level. SHS exposure occurred mostly in the living room, kitchen, dining room, and in the garden. Five percent (n=78) of the children without current SHS exposure were exposed to THS.

### Relationship between ETS exposure and respiratory complaints

No significant associations were found between SHS exposure and respiratory complaints in children (Table 2). THS exposure by parents and/or others at least once to three times per week was associated with increased risk of respiratory tract infections in the past 12 months ($OR_{adjusted}$: 2.13; 95%CI: 1.04-4.36; $p$=0.04) and recent wheezing ($OR_{adjusted}$: 2.61; 95%CI: 1.19-5.71; $p$=0.02) in children (Table 3). THS exposure was also associated with increased risk of wheezing ever in the unadjusted analysis ($OR_{unadjusted}$: 1.70; 95%CI: 1.06-2.73; $p$=0.03). This latter association, however, disappeared when adjusting for potential confounders.

### Non-response analysis

Questionnaire B was completed by 508 parents (6.3% of the non-responders). 30.5% of the children were <6 years, 63.6% were ≥ 6 years and 5.9% did not report age. The majority of the questionnaires were completed by the mothers (80.5%). Respiratory tract infections in the last 12 months were reported in 40% of the responders, recent wheezing in 11.2% and 9.1% had asthma. Furthermore, 14.2% of the children

| | **Total N=1899 n (%)** |
|---|---|
| **Outcome variables** | |
| RI in the last 12 months | 691 (36.4%) |
| Wheezing ever | 538 (28.3%) |
| Recent Wheeze | 247 (13.0%) |
| Asthma diagnosis | 131 (12.2%)[a] |
| **Predictors** | |
| SHS exposure[b]: | |
| No | 1403 (73.9%) |
| In utero (maternal) | 50 (2.6%) |
| Current | 298 (15.7%) |
| Both in utero and current | 91 (4.8%) |
| THS exposure[b,c]: | |
| No | 1251 (83.4%) |
| Yes (≥ 1 per week) | 78 (5.2%) |
| **Potential confounders** | |
| Age | |
| <6 years | 821 (43.2%) |
| ≥ 6 years | 1073 (56.5%) |
| Genderb | |
| Male gender | 1018 (53.6%) |
| Female | 871(45.9%) |
| Gestational age[b] | |
| <37 weeks | 114 (6.0%) |
| ≥ 37 weeks | 1736 (91.4%) |
| Complications during pregnancy/birth | |
| No | 1616 (85.1%) |
| Yes | 83 (14.9%) |
| Birth weight[b] | |
| Low birth weight (<2500g) | 100 (5.3%) |
| Normal birth weight (≥ 2500g) | 1701 (89.6%) |
| Breastfeeding[b] | |
| No breastfeeding | 670 (35.3%) |
| <6 months | 688 (36.2%) |
| 6–12 months | 413 (21.7%) |
| >12 months | 108 (5.7%) |
| Atopic first degree relative | |
| No | 587 (30.9%) |
| Yes | 1312 (69.1%) |
| Child at high risk of asthma[b] | |
| No | 1141 (60.1%) |
| Yes | 473 (24.9%) |
| Vitamin D use: | |
| Never | 1209 (63.7%) |
| Sometimes | 167 (8.8%) |
| Daily | 523 (27.5) |
| | **Total N=1899 n (%)** |
| **Potential confounders cont.** | |
| ≥ 1 siblings | |
| No | 530 (27.9%) |
| Yes | 1368 (72.0%) |
| Day care attendance | |
| No | 285 (15.0%) |
| Yes | 1614 (85.0%) |
| Highest parental education | |
| Low | 72 (3.8%) |
| Middle | 530 (27.9%) |
| High | 858 (45.2%) |
| Academic | 425 (22.4%) |

[a]children <6 years, asthma diagnosis not applicable
[b]values may not add up to 100% because of missing values
[c]n=389 children with current SHS exposure excluded

**Table 1:** Characteristics of the study population.

| | Unadjusted OR ( 95%CI) | *p*-value | Adjusted[a] OR ( 95%CI) | *p*-value |
|---|---|---|---|---|
| **Respiratory tract infections in the last 12 months** | | | | |
| No SHS | reference | | reference | |
| SHS in utero | 1.66 (0.94-2.93) | *p*=0.08 | 1.46 (0.48-4.40) | *p*=0.50 |
| Current SHS | 1.27 (0.98-1.63) | *p*=0.07 | 1.17 (0.77-1.77) | *p*=0.46 |
| Both in utero and current SHS | 1.07 (0.69-1.67) | *p*=0.75 | 1.00 (0.50-1.98) | *p*=0.99 |
| **Wheezing ever** | | | | |
| No SHS | reference | | reference | |
| SHS in utero | 1.36 (0.75-2.47) | *p*=0.32 | 0.82 (0.25-2.73) | *p*=0.75 |
| Current SHS | 1.14 (0.87-1.50) | *p*=0.35 | 1.14 (0.73-1.77) | *p*=0.57 |
| Both in utero and current SHS | 1.30 (0.82-2.04) | *p*=0.26 | 1.17 (0.57-2.39) | *p*=0.67 |
| **Recent wheeze** | | | | |
| No SHS | reference | | reference | |
| SHS in utero | 1.05 (0.47-2.37) | *p*=0.90 | 0.86 (0.18-4.17) | *p*=0.85 |
| Current SHS | 0.97 (0.67-1.41) | *p*=0.89 | 0.93 (0.51-1.69) | *p*=0.82 |
| Both in utero and current SHS | 0.71 (0.35-1.44) | *p*=0.34 | 0.66 (0.21-2.02) | *p*=0.46 |
| **Asthmab** | | | | |
| No SHS | reference | | reference | |
| SHS in utero | 0.99 (0.34-2.89) | *p*=0.97 | 3.01 (0.25-35.75) | *p*=0.38 |
| Current SHS | 1.50 (0.86-2.62) | *p*=0.15 | 2.20 (0.86-11.84) | *p*=0.08 |
| Both in utero and current SHS | 0.99 (0.46-2.15) | *p*=0.98 | 2.28 (0.44-11.67) | *p*=0.32 |

[a]Analysis adjusted for: age, gender, birth weight, gestational age, complications during pregnancy or birth, breastfeeding, child vitamin D supplementation, presence of one/more sibling(s), day-care attendance, highest parental education, and atopy in the family
[b]N=1073 children ≥ 6 years of age included in the analysis.
*p<0.05

**Table 2:** Associations between SHS exposure and, respiratory tract infections in the last 12 months, wheezing ever, recent wheeze, and asthma.

| | Unadjusted OR ( 95%CI) | *p*-value | Adjusted[b] OR ( 95%CI) | *p*-value |
|---|---|---|---|---|
| **Respiratory tract infections in the last 12 months** | | | | |
| No THS | reference | | reference | |
| THS | 2.07 (1.31-3.27) | *p*<0.01* | 2.13 (1.04-4.36) | *p*=0.04* |
| **Wheezing ever** | | | | |
| No THS | reference | | reference | |
| THS | 1.70 (1.06-2.73) | *p*=0.03* | 1.71 (0.84-3.52) | *p*=0.14 |
| **Recent wheeze** | | | | |
| No THS | reference | | reference | |
| THS | 3.29 (1.97-5.48) | *p*<0.001* | 2.61 (1.19-5.71) | *p*=0.02* |
| **Asthma[c]** | | | | |
| No THS | reference | | reference | |
| THS | 0.64 (0.21-1.93) | *p*=0.43 | 1.31 (0.11-15.29) | *p*=0.83 |

[a]N=399Children with current SHS exposure were excluded from the analyses.
[b]Analyses adjusted for: age, gender, birth weight, gestational age, complications during pregnancy or birth, breastfeeding, child vitamin D supplementation, presence of one/more sibling(s), day-care attendance, highest parental education, and atopy in the family
[c]N=1073 children ≥ 6 years of age included in the analysis.
**p*<0.05

**Table 3:** Associations between THSa exposure and, respiratory tract infections in the last 12 months, wheezing ever, recent wheeze, and asthma.

were predisposed for asthma. Parental SHS exposure in children was reported by 22% of the responders. Reasons for not completing questionnaire A were, no interest 10.6%, no time 24.4%, child does not have respiratory diseases 49.8%, no smoking inside the house 61.0% and other reasons 23.8%.

## Discussion

### Main findings

We analysed the association between respiratory complaints (physician diagnosed respiratory tract infections in the past 12 months, wheezing ever, recent wheeze and asthma) and ETS exposure (SHS and THS) in children living in South-Limburg. Our prevalence of SHS exposure at home in children aged 6 years and younger was comparable to another Dutch study, which reported a prevalence of 10% for a slightly younger age group (0-4 years) in 2009 [18]. Our findings on SHS exposure deviate from the compelling evidence on the relationship between SHS and respiratory complaints [3,4,19-24], asthma and wheezing [4,23,24], and respiratory tract infections [5,19,25-27] in children. The lack of association in our study is most likely due to methodological issues such as the cross-sectional design of the study, the moderate participation rate, possible parental underreporting of their smoking behaviour and selective participation. For instance, SHS exposure is generally more prevalent in families with low social-economic status. Our study included mostly parents with higher education, who reported SHS exposure in children less frequently compared to parents with low education. Therefore the results of SHS exposure should be carefully interpreted.

THS exposure by parents or others was associated with increased risk of respiratory tract infections in the past 12 months and recent wheeze in children aged 0-13 years. To the best of our knowledge, only one study has assessed the associations between THS exposure and respiratory complaints in children [28]. They found an increased risk of coughing symptoms due to THS exposure. Our findings also suggest that THS exposure has negative effects on children's respiratory health. Yet, it is remarkable that we have found significant associations between THS exposure and respiratory complaints in children, but not between SHS exposure and respiratory complaints in children. Perhaps, parents may have underreported their current smoking behaviour (and SHS exposure of their children), due to for example shame. For instance, we have received questionnaires where parents reported that they were non-smokers, but the questionnaires smelled like tobacco. Some parents might not know that THS exposure is harmful for their children [9], and therefore could have reported THS exposure more accurately than SHS exposure in children. Consequently, the associations found in this study between THS exposure and respiratory complaints in children could partially also be caused by SHS exposure.

As there is no safe tolerable level of ETS exposure, the effects of THS exposure in children should not be underestimated. THS and SHS exposure are closely related and coexist during the early period of THS formation, but they have different chemical and toxicological features [10]. THS consists of chemical compounds similar to those in mainstream smoke, SHS, and also new toxins created through secondary reactions [29]. These new toxins may be even more hazardous [10]. Therefore, the associations found in this study between THS exposure and respiratory complaints in children could be plausible. However, because of the cross-sectional design of the study, reverse causation cannot be excluded. It is not clear if THS exposure preceded the respiratory complaints or that parents started THS exposure (by stopping SHS exposure) due to existing respiratory complaints in their children. More research is necessary to establish this finding further. If the effects of THS exposure on children's respiratory health are also confirmed by other studies this would result in an important consequence, namely that efforts to prevent SHS exposure should also include prevention of THS exposure in children.

### Strengths and limitations

The main strength of our study is that we are one of the first studies to analyse the effects of THS on respiratory complaints in children. Furthermore, we were able to adjust our analysis for the majority of possible confounding factors associated with respiratory complaints in children. However, there are some limitations to this study and the results should be cautiously interpreted. Our response rate was moderate. We tried to check for selection bias by doing a non-response analysis. But, the response rate for the non-response analysis was also low. Main reasons for not participating in the study were parents reporting not to smoke inside the house and because the child did not have respiratory complaints. Since July 2008, smoking in public places has been prohibited in the Netherlands. This might have led to higher levels of perceived social unacceptability of smoking [30], particularly in the presence of young children. Furthermore, 27% of the Dutch populations smoked in 2010 [31]. Only 14% of the parents reported to smoke in our study. Thus, selective participation may be likely. Parents who smoke might have been less motivated to participate in the study compared to parents who do not smoke, because of feelings of shame or guilt, especially if their children also have respiratory complaints. Parents who do not smoke and do not have children with respiratory complaints could have also been less motivated to participate in the study, because they did not see the importance of participation. Also, growing awareness of the adverse effects of ETS exposure to children's health may have led to false reporting and social desirable answers. Moreover, misclassification might have also occurred due to recall bias. Generally, as a result of underreporting and the limited sample size, the effects seen in this study could be an underrepresentation of the true effects of the relationship between ETS exposure and respiratory complaints in children. The effects of ETS exposure on children's respiratory health depends also on other factors that were not possible to include in our questionnaire, such as: the size, ventilation quality and amount of people in the room and the exact time spent in a room in which smoking has occurred. This also implies that the true effects of ETS exposure on children's respiratory health may have been underestimated.

## Conclusion

In this study, we were not able to find a significant association between SHS exposure and respiratory complaints in children 0-13 years of age living in South Limburg, most likely due to limitations of the cross-sectional study design, moderate response rate, possible selection bias and parental underreporting. Despite these limitations, THS exposure was significantly associated with increased risk of respiratory tract infections in the past 12 months and recent wheeze in children. This provides an important contribution to the limited knowledge about the health effects of THS exposure in children. According to the literature, THS exposure remains long after a cigarette has been extinguished and undergoes secondary reactions that produces pollutants that might be toxic as well. Therefore, interventions to prevent SHS exposure in children may consider also including strategies and education to prevent THS exposure in children. Last, ETS exposure in children with predisposition for asthma did not result in an increased risk of respiratory complaints in children.

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