# Modification of the Sniffin Kids Test for olfactory testing in a population of Polish children

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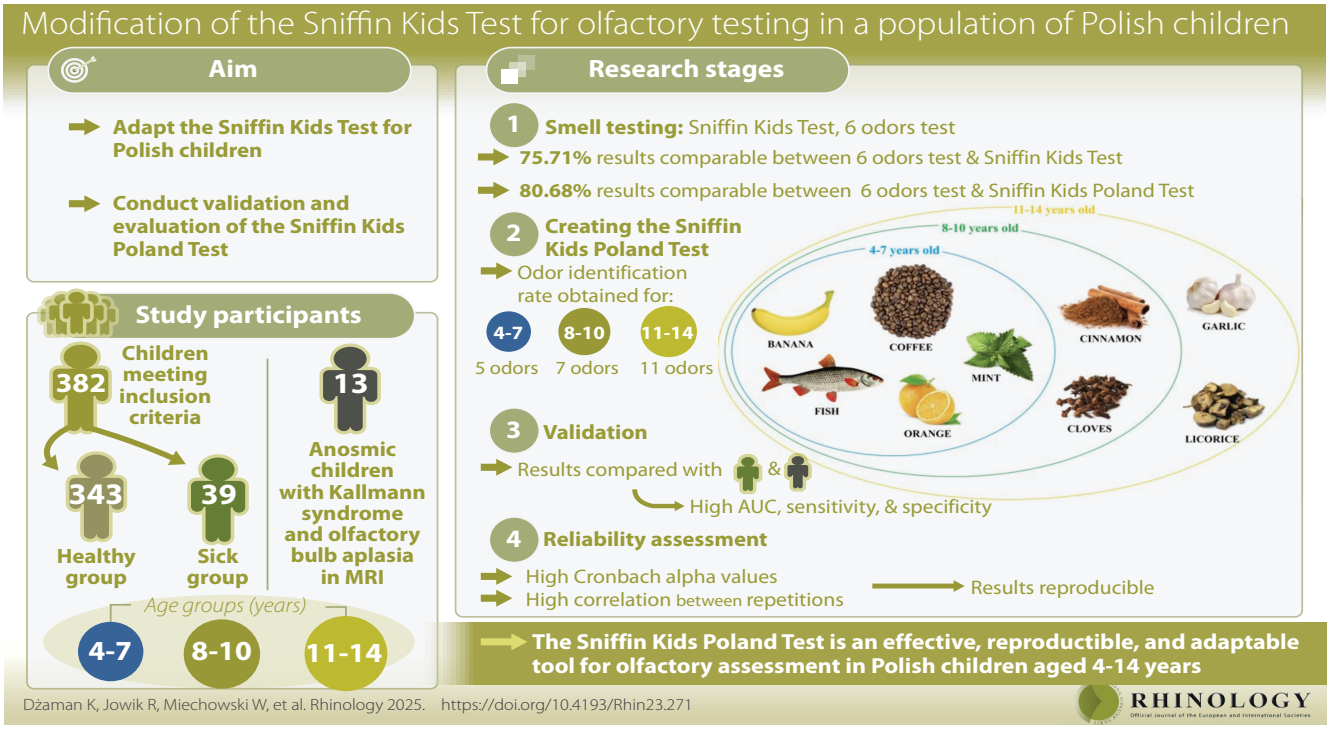
**Rhinology 63: 6,** 0 - 0, 2025

https://doi.org/10.4193/Rhin23.271




## Abstract

**Background**: Smell tests in children need to be standardized and validated, include odors familiar to children, and be defined by age-dependent standards. This study aimed to adapt the Sniffin Kids Test (SKT) for Polish children and conduct validation and evaluation of the Sniffin Kids Poland Test (SKPOL). **Methodology**: The study included 382 children (4-14 years old) recruited in Poland, who were allocated into healthy (n=343) and sick (with subjective olfactory disorders, n=39), divided into 3 age subgroups, but also 13 anosmic children with Kallmann syndrome (KS) and olfactory bulb aplasia. Firstly, the smell testing was performed in 382 children using SKT, and subsequently, SKPOL was created using odors identified by at least 75% of healthy individuals. The 10th percentile of SKPOL results in healthy children was adopted as a cutoff point between norm and pathology. SKPOL validation and reliability were assessed using the KS group results. **Results**: Odor identification score in SKT of Polish children in healthy 6-14-year-olds did not meet the criteria for a test adapted for population studies. An odor identification rate was obtained for 5 odors in 4-7 years old, 7 odors in 8-10 years old, and 9 odors in 11-14 years old. SKPOL was created using these odors. Age-dependent norms for SKPOL were ≥4, ≥5, and ≥7, respectively. All KS children had SKPOL results below the 10th percentile. **Conclusions**: Validation and evaluation of SKPOL confirmed good adaptation and high reproducibility of the test for Polish children aged 4-14 years.

**Key words**: child, olfaction disorders, olfactory perception, sensory function, smell

## Introduction

The smell is an important sense for development, but smell testing in children is challenging, and some of the methods used are adopted from adults despite children's inability to recognize some odors [1]. Therefore, a good pediatric test should meet the following criteria [2-4]: easy availability, a limited number of familiar test items, age-specific norms, and easy performance. Subjective methods (quantitative and qualitative) of olfactory testing are the most commonly used [5, 6]. Smell tests initially developed in adults are gradually transferred to pediatrics [7, 8], but their results in children raise concerns. Cultural diversity influences children's familiarity with odors [8, 9], necessitating tailored olfactory tests for specific populations [10-13].

In recent years, various diagnostic tests are being used, e.g.: Sniffin' Test variations [8, 14-16] including the Universal Sniff (U-Sniff) Test [17, 18] and Sniffin' Kids Test (SKT) [10], or smell wheel [11], Toyota-Takagi (T&T) test [19], Connecticut Chemosensory Clinical Research Center (CCCRC) test [20], NIH Toolbox [21], tests of odor in a bottle [5, 22], Lyon Clinical Olfactory Test (LCOT) [13], California Odor Learning Test (COLT) [23], odorant discrimination or identification tasks [24-26], the University of Pennsylvania Smell Identification Test (UPSIT) [3], and the Alcohol Sniff Test [12]. Validated tests for Polish children are the U-Sniff test [17] and the 6 odors test (6OT), used for children aged 3-10 years [5]. The use of pediatric olfactory tests in Poland is limited to the U-Sniff test [17]. A study on its use in younger children aged 3 years and older has been published [18]. The U-Sniff test, for ages 6–17, includes 12 odors and is gaining popularity.

In Europe, the mean odor identification score was 10.2 ± 1.7 points, while in Poland it was 9.64 ± 2.35 points, among the lowest recorded [17]. The normosmia-pathology cut-off was 8 points in Europe but 6 in Poland [17].

SKT, based on the odors used in the Sniffin' Test, the most widely used among adults in Poland, has only been validated in children in some countries (Germany, Belgium, Turkey, USA) [8, 10, 14, 27-29]. This study aimed to adopt SKT for Polish children to develop the Sniffin Kids Poland Test (SKPOL), and perform its validation and evaluation.

## Materials and methods

### Materials

Approval was obtained from the Bioethics Committee of the Military Institute of Aviation Medicine in Warsaw, no 06/2019. The study was conducted between September 2019 and January 2022 on children aged 4 to 14 years, attending 5 different educational institutions (kindergartens and primary schools) in Poland. Children were included in the analysis based on the questionnaire and physical examination. Exclusion criteria were infections or impaired nasal patency, history of ENT surgery, chronic diseases, and/or failure to complete a full smell testing. Of the 516 children, inclusion criteria were met by 382. Based on repeated observations by their parents, these children were divided into two groups: the healthy group (HG: 169 girls, 174 boys; mean age 9.48, SD±2.38) without subjective olfactory disorders (n=343) and the sick group (SG: 20 girls, 19 boys; mean age 8.31, SD±2.30) with subjective olfactory dysfunction (n=39). Additionally, 13 anosmic children with Kallmann syndrome and olfactory bulb aplasia in MRI (KS: 1 girl and 12 boys, mean age was 10.8±2.7) were included (Table 1). In 343 healthy and 39 sick children, 2 or 3 tests appropriate to their age, i.e., 4-5 years old - 6 OT and SKPOL, were performed; 6-10 years – 6 OT, SKT, SKPOL; 11-14 years old - SKT and SKPOL. We had no children under 3 or over 15 years of age. SKPOL was analyzed in 13 children with KS. All the children were consequently divided into 3 age subgroups based on the Polish education system, separating preschool (4-7 years old), early school (educational stage I, 8-10 years old), and older children (educational stage II, 11-14 years old).

### Methods

The process of adapting SKT to the Polish pediatric population consisted of:

- 6OT and SKT examination,
- SKPOL creation,
- SKPOL validation,
- assessment of SKPOL reliability.

#### Smell testing using the 6 odors test

The 6 odors test (6OT) consists of 6 odors: cola, bubble gum, toffee, mint, fish, and lemon. Normosmia is when at least 4 out of 6 odors are identified correctly [5].

#### Smell testing using the Sniffin Kids Test

SKT consisted of 14 odors applied in pens [10]. At the same time, 4 pictures of the substances were presented, along with a description and a verbal message, from which the child chose the one. To exclude uncertainty, testing of each odor was carried out three times, in different sequences [30]. At least two correct identifications were considered a correct result. The final result was the number of odors identified correctly (verbal or by indicating the picture). The term normosmia varied by age group and was >7 for 6-8 years old, >8 for 9-14 years old, and >10 for 15-17 years old [10].

In our study, there were no children from the oldest age group (15-17 years), so SKT was conducted in two younger age groups. SKT was also conducted on children aged 4-5 years, but they were not classified as normosmia or olfactory disorders because this test is not validated for such young children.

#### Creation of the Sniffin Kids Poland Test

The creation of SKPOL included two stages: choosing the odors and setting the limit for normosmia. Both included only 343 who were divided into 3 age groups: 4-7 years, 8-10 years, and 11-14

Table 1. Number of healthy and sick children for 6OT, SKT, and SKPOL, children with Kallmann syndrome for SKPOL, and healthy children used to assess SKPOL reliability, in specific age groups.

| Age (years) | 6OT | | SKT | | SKPOL | | | |
|---|---|---|---|---|---|---|---|---|
| | Healthy children | Sick children | Healthy children | Sick children | Healthy children | Sick children | Children with KS | Healthy children included in the reliability assessment |
| 4 | 233 | 31 | | | 51 | 17 | 2 | 10 |
| 5 | | | | | | | | |
| 6 | | | 124 | 25 | | | | |
| 7 | | | | | | | | |
| 8 | | | | | 182 | 14 | 4 | 11 |
| 9 | | | 204 | 12 | | | | |
| 10 | | | | | | | | |
| 11 | | | | | 110 | 8 | 7 | 10 |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| **Total** | **233** | **31** | **328** | **37** | **343** | **39** | **13** | **31** |

years (Table 1).

The first stage was to choose the odors out of the 14 odors available in SKT. According to the literature, a reliable smell test should include odors that are recognized by a minimum of 75% of the healthy population [6, 31]. Therefore, the threshold of 75% odor recognition in SKT by HG was taken as the basis for including an odor in SKPOL. A set of odors was determined for each age group separately, creating an age-appropriate test consisting of odors recognized by Polish children.

The second stage was to set the limit for normosmia. The borderline between normosmia and pathology was established for each age group, based on the SKPOL result. In the study, for HG, the cut-off threshold was the 10th percentile of the SKPOL score for each age group separately.

### Validation of the Sniffin Kids Poland Test

Validation of SKPOL was conducted for each age group in 4 ways:

1. by comparing SKPOL scores between HG and SG (the Mann-Whitney U test);
2. by evaluating how well the SKPOL separates HG from SG (ROC analysis);
3. by comparing SKPOL scores between HG and KS (the Mann-Whitney U test);
4. by calculating how many children obtained comparable results in SKPOL and SKT, then in SKPOL and 6OT (the chi-square test).

### Assessment of the Sniffin Kids Poland Test reliability

SKPOL was carried out four times (the first and after 2, 4, and 8 weeks) on a group of 70 children including 39 sick children (SG1: 17 aged 4-7 years, SG2: 14 aged 8-10 years, SG3: 8 aged 11-14 years) and 31 healthy children (10 aged 4-7 years, 11 aged 8-10 years, 10 aged 11-14 years) (Table 1). These children were randomly selected from HG. Test-retest reliability for each age group was assessed using the correlation coefficient and Cronbach's alpha for internal consistency.

### Statistical analysis

Data were collected and processed using Statistica 13.1 (Statsoft, Poland). The following statistical methods were used:

- Mann-Whitney U test to compare numerical scores of tests between HG and SG, and between HG and KS;
- Chi-square test to compare 6 OT with SKT and SKPOL diagnoses;
- Kruskal-Wallis H test to compare numerical scores of tests between 3 age groups;
- Pearson correlation coefficient to correlate the number of correctly recognized odors with age, mutual correlation between 4 test attempts;
- 10th percentile to set the limit for normosmia;
- ROC analysis to assess how well each test separates sick from healthy children, including sensitivity, specificity, AUC, and percent of correct classifications;
- Cronbach's alpha to assess test-retest reliability.

The significance level was assumed at 0.05.

Table 2. Results of ROC analysis for 6OT, SKT, and SKPOL in specific age groups.

| Test | Age group (years) | Sick children (n) | Healthy children (n) | True positive (n) | True negative (n) | Sensitivity | Specificity | AUC | Correct classification (%) |
|---|---|---|---|---|---|---|---|---|---|
| 6OT | 4-10 | 31 | 233 | 15 | 209 | 0.484 | 0.897 | 0.690 | 84.9 |
| SKT | 6-8 | 25 | 124 | 24 | 99 | 0.960 | 0.798 | 0.879 | 82.6 |
| | 9-14 | 12 | 204 | 12 | 175 | 1.000 | 0.857 | 0.929 | 86.6 |
| SKPOL | 4-7 | 17 | 51 | 9 | 46 | 0.529 | 0.902 | 0.716 | 80.9 |
| | 8-10 | 14 | 182 | 12 | 174 | 0.857 | 0.956 | 0.907 | 94.9 |
| | 11-14 | 8 | 110 | 7 | 106 | 0.875 | 0.964 | 0.924 | 95.8 |
| SKPOL | *4-6 | 6 | 31 | 4 | 26 | 0.667 | 0.839 | 0.753 | 81.1 |
| | *7-10 | 25 | 202 | 17 | 194 | 0.680 | 0.960 | 0.820 | 93.0 |

* calculations for a different age distribution in order to be able to compare with other olfactory test results that used a different age distribution

## Results

### Comparison of smell results using the 6 odors test with the Sniffin Kids Test and the Sniffin Kids Poland Test

6 OT is for children aged 4-10, and we tested 264 children of this age using both 6OT and SKT.

A total of 187 out of 264 children i.e. 75.71% had comparable results in 6OT and SKT (Chi-square=41.232, p<0.001). In these 187 children, both tests indicated normal olfaction in 159 children and olfactory dysfunction in 28 children.

A total of 213 out of 264 children i.e. 80.68% had comparable results in 6OT and SKPOL (Chi-square=9.58, p=0.002). In these 213 children, both tests indicated normal olfaction in 202 children and olfactory dysfunction in 11 children.

### Results of smell testing using the Sniffin Kids Test

SKT scores ranged from 6 to 12 (mean 8.75±1.46) correctly recognized odors out of 14 in HG aged 6-8 years, while in SG of the same age, it ranged from 3 to 9 (mean was significantly lower: 5.64±1.04, Z=7.38, p<0.001). In ROC analysis, the sensitivity was 0.960, and the specificity was 0.789 (Table 2).

SKT scores ranged from 7 to 14 (mean 10.04±1.59) correctly recognized odors out of 14 in 204 HG aged 9-14 years, while in 12 SG of the same age, it ranged from 7 to 8 (mean was significantly lower: 7.50±0.52, Z=5.12, p<0.001). In ROC analysis, the sensitivity was 1, and the specificity was 0.857 (Table 2).

### Correlation of child age with smell test results

There was a strong positive correlation between the number of correctly recognized odors in SKPOL and the child's age (r=0.622, p<0.001).

The older the child was, the more odors were recognized correctly, on average.

### Choosing the odors for the Sniffin Kids Poland Test

The first stage of the creation of SKPOL was to choose the odors out of the 14 available in SKT. Figure 1A (a-c) presents the percentage of HG in specific age groups who recognized particular odors available in SKT correctly. The SKPOL was created considering only odors correctly recognized by at least 75% of HG and consisted of 5, 7, or 9 odors depending on the age group.

### Setting the limit in the Sniffin Kids Poland Test

The second stage of the creation of SKPOL was setting the limit for normosmia. The cut-off threshold was the 10th percentile of the SKPOL score in HG for each age group separately (Figure S1). Normosmia was defined as getting a score of at least 4 out of 5 for children aged 4-7, at least 5 out of 7 for children aged 8-10, and at least 7 out of 9 for children aged 11-14.

### Validation of the Sniffin Kids Poland Test

The first validation method compared the mean odor identification in SKPOL between HG and SG (Figure 2A). For each age group, SKPOL mean score was significantly lower in SG than in HG (aged 4-7 years: 3.18 vs. 4.45, Z=4.39, p<0.001), (aged 8-10 years: 4.14 vs. 6.13, Z=5.20, p<0.001), (aged 11-14 years: 6.13 vs. 8.12, Z=4.45, p<0.001).

The second validation method evaluated how well the SKPOL separated HG and SG using ROC analysis. SKPOL had high sensitivity, specificity, AUC, and percent of correct classification. We compared SKPOL with 6OT and SKT for age groups that were as similar as possible. SKPOL for children aged 4-7 and 8-10 had a higher sensitivity, a higher specificity, a larger AUC, and a higher percent of correct classification than 6OT for children aged 4-10. SKPOL for children aged 11-14 had a higher specificity and a higher percent of correct classification than SKT for children aged 9-14 (Table 2).

Due to the different age divisions used in the literature, we addi-

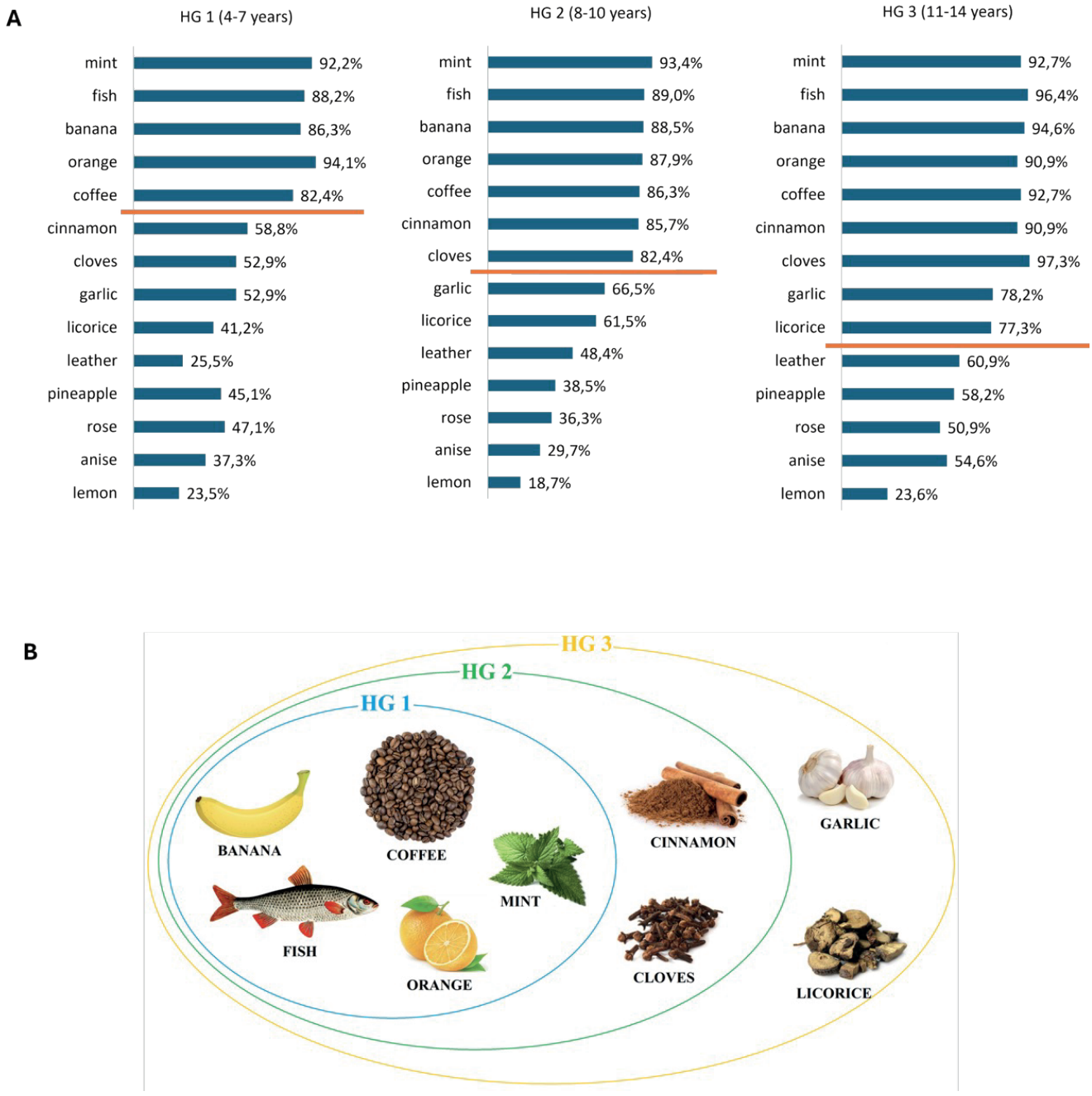



Figure 1. (A) Percentage of healthy children, who correctly identified the particular odors available in the SKT, by age group; red line - 75% , and (B) odors used in SKPOL for each age group (that met the 75% recognition criterion in SKT).

tionally conducted ROC analyses when 7-year-olds were moved to the early school group (Table 2). We received comparable results when 7-year-olds were in the early school group and when 7-year-olds were in the pre-school group.

The third validation method compared the mean odor identification in SKPOL between HG and KS (Figure 2B). For each age group, the SKPOL mean score was significantly lower in KS than in HG (aged 4-7 years: 1.00 vs. 4.45, Z=2.36, p=0.008), (aged 8-10 years: 1.25 vs. 6.13, Z=3.42, p<0.001), (aged 11-14 years: 2.57 vs. 8.12, Z=4.42, p<0.001).

The fourth validation method was the calculation of how many children obtained comparable results in SKPOL and SKT, then in SKPOL and 6OT.

Both SKPOL and SKT were conducted in children aged 6-14, and we tested 365 children at this age using both SKPOL and SKT. A total of 297 out of 365 children i.e. 81.37% had comparable results in SKPOL and SKT (Chi-square=67.52, p<0.001). In these 297 children, both tests indicated normal olfaction in 266 child-

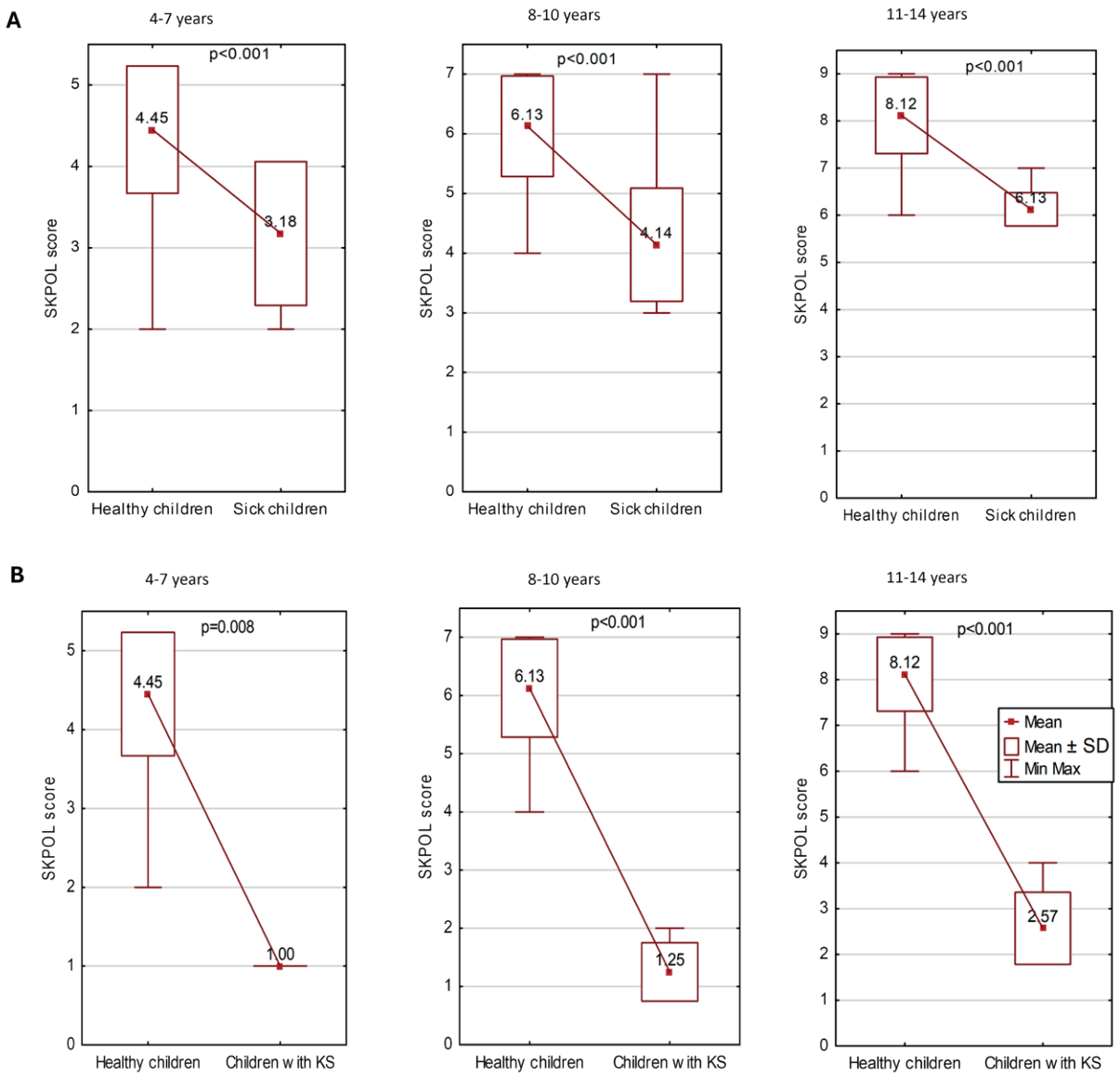



Figure 2. (A) Comparison of SKPOL scores between healthy and sick children, in specific age groups. (B) Comparison of SKPOL scores between healthy children and children with Kallmann syndrome, in specific age groups.

ren and olfactory dysfunction in 31 children.
6 OT is for children aged 4-10 and we tested 264 children of this age using both 6OT and SKT. A total of 213 out of 264 children i.e. 80.68% had comparable results in 6OT and SKPOL (Chi-square=9.58, p=0.002). In these 213 children, both tests indicated normal olfaction in 202 children and olfactory dysfunction in 11 children.

**Assessment of the reliability of the Sniffin Kids Poland Test**

The SKPOL reliability was assessed by performing the test four times on representatives of all age groups, both HG and SG, and by comparing the SKPOL scores between the 4 attempts (Figure 3). No significant differences were found between the four attempts of SKPOL in all age groups, which was confirmed by very high values of Cronbach's alpha. We also used the correlation coefficient in all age groups to confirm SKPOL reliability. All correlation coefficients were close to 1 in all age groups and significant at $p<0.05$, indicating a positive high degree of correlation in subsequent attempts in each age group. The SKPOL results appeared to be reproducible.
In our study, the sensitivity for SKPOL was 52.9% for children aged 4-7, 85.7% for children aged 8-10, and 87.5% for children aged 11-14. Meanwhile, the specificity for SKPOL was 90.2%, 95.6%, and 96.4% for the age groups, respectively.

## Discussion

The smell testing is an essential part of otolaryngological assessment in children, helping to diagnose congenital and develop-

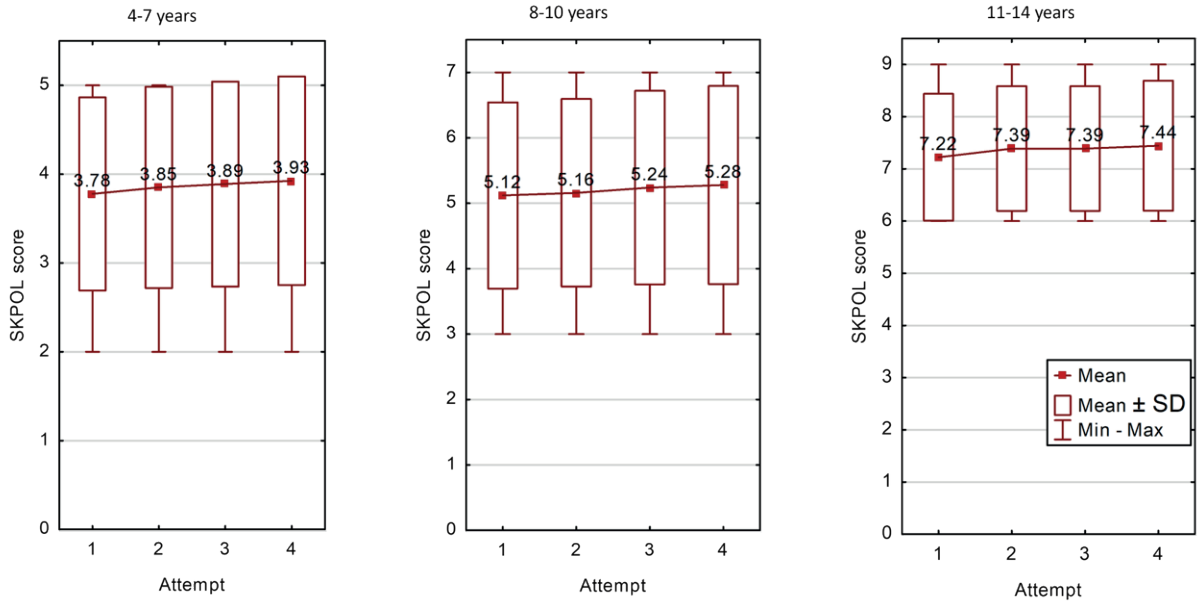



Figure 3. Reliability of SKPOL in healthy and sick children, in specific age groups. Healthy children: 4-7 years (n=10), 8-10 years (n=11), 11-14 years (n=10); Sick children: 4-7 years (n=17), 8-11 years (n=14), 11-14 years (n=8). 4-7 years: Cronbach alpha=0.993, average correlation coefficient = 0.975; 8-10 years: Cronbach alpha=0.995, average correlation coefficient = 0.983; 11-14 years: Cronbach alpha=0.990, average correlation coefficient = 0.993.

mental disorders [32, 33]. The smell disturbance can be associated with impaired appetite [14], eating disorders, hazard exposure, changing the child's behavior, and reduced quality of life [4, 34]. In our study, we did not use the U-Sniff test, although it appears to be a very useful tool, because when we started our research in 2018, there were only the first reports of the use of this test. The U-Sniff test in a study for Polish children showed the lowest cut-off point (6 points) for normosmia from hyposmia compared to other European countries, where the result was 8 points. This means that Polish children recognized the smells offered to them in the U-Sniff test worse than children from most other European countries. This was one of the motives for developing a smell test for Polish children among the smells they know. Moreover, the U-Sniff test is based on different odorants than SKT, commonly used in our country, so we assumed to make SKPOL based on it. Instead, the 14-item SKT, adapted from the 16-item Sniffin Test for adults, was validated for German children with a mean score of 11.22 points, representing 80.14% of correct answers [10]. In our analysis, including Polish children aged 4 to 14 years, the mean identification score of SKT was 8.75 for HG aged 6-8 years and 10.04 for HG aged 9-14 years. However, a comparison of the results of this study with the German study is only possible to a limited extent due to the changed test procedure in our study [14]. The mean SKT scores obtained for the Polish were lower than in Germany but higher than in the Americans and Malaysians [10, 14, 29]. It confirms that the olfactory results of children from various regions can differ, despite using the same diagnostic tool due to genetic diversity, environmental factors, and cultural differences [35-37].

Another aspect is the child's age for which the olfactory tests are validated. In our study, we wanted to include children who attend kindergarten (age 4-7 years) and pupils from educational stages I and II. Youngest children learn in separate places and are assessed based on a pictorial and descriptive system. From the age of 11, children are covered by educational stage II, which is based on percentage scoring, and specific teaching applies to all subjects. This is an important turning point in the development of the child due to the entry into the stage of adolescence, pubertal leap, and significant cognitive and social development. SKT is designed for children over the age of six, which is in line with the tendency to exclude the youngest patients from smell testing [10]. However, Dżaman et al. showed that olfactory testing is feasible in young children, but requires strict adaptation to the age group [5, 38].

Analysis of SKT results showed a significant correlation between the child's age and the ability to identify odors, which is in line with others [2, 9, 10, 39]. The disproportion in odor identification between the youngest and oldest groups was particularly evident for selective odors e.g.: clove 52.9% vs. 97.3% (Figure 1A). In the 4-7 age group, only five odors achieved an identification rate above 75%, in the 8-10 age group - seven, and in the oldest group 11-14 years - nine. On this basis, a set of SKPOL odors adapted to the child's age was created. A significant positive correlation between the child's age and the number of correctly recognized odors in the SKPOL was found. Therefore, it seems the poor performance of children in adult olfactory tests could be more a result of the inadequacy of these tests for the pediatric population [40, 41]. Therefore, we confirmed that the

lack of age categorization causes a tendency to over-diagnose olfactory disorders, particularly in the younger ones.

Similar adaptations of SKT for American children were carried out by Cavazzana et al. [14], who reduced the number of odors to the 11 best-recognized ones, eliminating three odors (fish, aniseed, leather) and adopted age-diverse norms (≥3 for children aged 3-7 years and ≥6 for children aged 8-10 years). In contrast, the Portuguese SKT eliminated the apple and cloves odor, obtaining a 14-odor test with cut-off values for olfactory dysfunction <6 (for 6-8 years old), <7 (for 9-11 years old), and <8 (for 12-17 years old) [42].

Therefore, an important element of the study was the establishment of age-specific norms separately to distinguish normosmia from pathology [8]. The 10th percentile of the olfactory test, commonly accepted as the cut-off value [5, 6, 30, 39, 43], determined age-specific norms for SKPOL (group I: ≥4, group II: ≥5, group III: ≥7). Setting the SKPOL norms allowed verification of olfactory disorders in the study group. As a result, 18 subjects were diagnosed with olfactory disorders, although not perceived by parents. Modifying SKT resulted in a reduction in the number of children diagnosed with hyposmia or anosmia. The SKPOL achieved very high specificity – over 90% for each age group. Although parents of SG children with subjective olfactory impairment answered questions about repeated situations in which the symptom was observed, the selection of children for SG was not ideal, as revealed by the olfactory test results – high but not full sensitivity and specificity. These differences are due to the choice of test components and the identification threshold distinguishing normosmia from pathology.

An extremely important stage of the research was the validation and assessment of the reliability of the newly developed test. The validation confirmed good adaptation of SKPOL for Polish children. A similar method of validation has been used by other researchers in Spain, Portugal, and Egypt [30, 42, 44]. In Germany, SKT validation was based on the analysis of children with objective anosmia, which is in line with one of our methods of validation. It should be noted that a significant proportion of olfactory tests do not have any validation [13, 15], so these tests should be interpreted with caution. This is particularly relevant in clinical settings, where these subjective tests should be supported by additional objective diagnostic tests. Test reliability assessment verifies that a test performed repeatedly will give a similar result each time [5, 10]. In the present study, four repetitions of SKPOL were performed at intervals of 2-4 weeks, and consecutive results were not significantly different (high values of Cronbach's alpha and high positive correlation coefficients), which demonstrates the high reproducibility of the method. A similar evaluation of the olfactory test was conducted by German researchers (single replication studies) [10] and Dżaman et al. (four replications) [5].

Our study and SKPOL have their limitations. Reducing the number of Sniffin Sticks may have the effect of reducing the test's relevance. The SKPOL results obtained in this group allow only preliminary information that should be interpreted with caution. SKPOL used for the youngest group allows identification of patients at risk of olfactory disorders, whose diagnosis should be expanded and verified at subsequent development stages. When the results of the smell test for children indicate olfactory dysfunction, we perform a brain MRI.

To summarise, our modification of SKT allowed the development of SKPOL adapted to the study of Polish children aged 4-14 years. The test was validated, which showed it to be well-adapted. The evaluation of SKPOL showed high reproducibility of the method. Therefore, SKPOL may become a useful diagnostic tool in pediatric otolaryngology and neurology.

## Conclusions

Smell testing of Polish children using SKT showed that HG aged 6-8 years recognized correctly 8.75 odors on average, HG aged 9-14 years - 10.04 odors on average. It did not meet the criteria for a test adapted to population studies (75%).

Only 5 odors out of 14 were recognized correctly by at least 75% of HG aged 4-7 years, while 7 odors by aged 8-10 years, and 9 odors by aged 11-14 years. Therefore, SKPOL, adapted to Polish children, was created using these odors.

The 10th percentile cut-off point was adopted to establish age-dependent norms for SKPOL (group I: ≥4, group II: ≥5, group III: ≥7).

SKPOL validation and evaluation confirmed good adaptation and high reliability of the test for Polish children aged 4-14 years.

SKPOL is recommended for Polish children because of their similar knowledge of odors.

## Acknowledgements

All phases of this study were supported by the Centre of Postgraduate Medical Education, grant number 501-1-019-56-23 to K.D.

## Authorship contribution

KD conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed, reviewed the literature and revised the manuscript for important intellectual content. RJ conceptualized and designed the study, designed the data collection instruments, collected data, carried out the initial analyses, and critically reviewed and revised the manuscript. WM carried out the initial analyses.

KPZ reviewed the literature and critically reviewed and revised the manuscript. MSC collected data. DR performed statistical calculations, and critically reviewed and revised the manuscript. KC drafted the initial manuscript and critically reviewed and revised the manuscript.

## Conflict of interest

The authors have no conflicts of interest to disclose.

## Funding

All phases of this study were supported by the Centre of Postgraduate Medical Education, grant number 501-1-019-56-23 to K.D. The Centre of Postgraduate Medical Education had no role in the design and conduct of the study.

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**Rhinology 63: 6,** 0 - 0, 2025
https://doi.org/10.4193/Rhin23.271

**Received for publication:**
July 27, 2023
**Accepted:** July 16, 2025

**Associate Editor:**
Basile Landis

**This manuscript contains online supplementary material**

## SUPPLEMENTARY MATERIAL

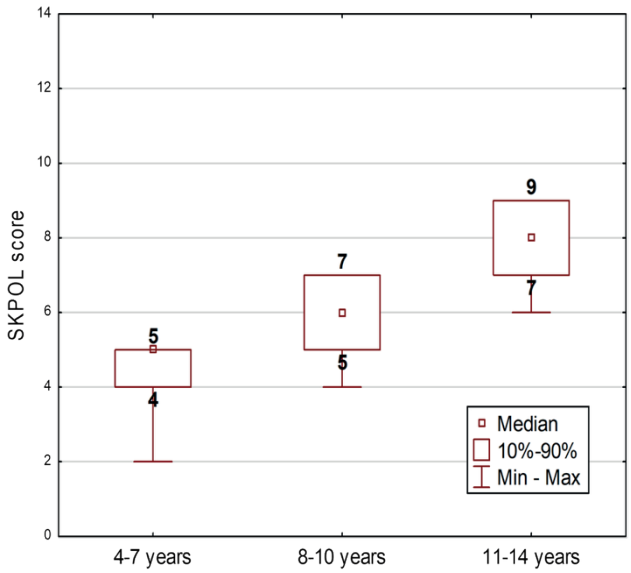


Figure S1. Distribution of SKPOL scores in healthy children in specific age groups.