# Sensory Processing Patterns in Preterm Toddlers

Ayse YILDIZ[*], Zehra Ebrar BAKIRCI[**], Ramazan YILDIZ[***]

**Abstract**

**Aim:** This study aimed to investigate the sensory processing patterns of preterm toddlers aged 12 to 24 months and compare them with term peers. Sensory processing difficulties in this population may contribute to developmental delays and behavioral challenges later in life; thus, early identification is critical.

**Method:** A total of 49 preterm toddlers born before 37 weeks of gestation and 45 healthy term toddlers were included in the study. Sensory processing skills were evaluated using the Toddler Sensory Profile-2, a caregiver-reported assessment tool that examines responses to sensory input across multiple domains, including auditory, visual, tactile, vestibular, and oral. The sensory quadrants of low registration, sensory sensitivity, sensory avoidance, and sensory seeking were also analyzed.

**Results:** Atypical sensory processing patterns were seen more frequently in preterm toddlers than in their peers ($p<0.05$). Atypical sensory processing patterns in the low registration, sensory sensitivity, sensory avoidance, and sensory seeking sensory quadrants were statistically higher in preterm toddlers ($p<0.05$). In addition, atypical sensory processing patterns were statistically more common in preterm toddlers in all sensory processing areas, such as auditory, visual, tactile, verbal, behavioral, and movement ($p<0.05$).

**Conclusion:** The study highlights that preterm toddlers process sensory stimuli atypically compared to their counterparts. These differences may hinder the child's ability to adapt to their environment and affect their participation in daily activities.

**Keywords:** Premature birth, sensory processing, child.

## Yürümeye Yeni Başlayan Preterm Çocuklarda Duyusal İşlemleme Paternleri

**Öz**

**Amaç:** Bu çalışmanın amacı, 12 ila 24 aylık preterm bebeklerin duyusal işleme modellerini araştırmak ve term akranlarıyla karşılaştırmaktır. Bu popülasyondaki duyusal işleme problemleri, yaşamın ilerleyen dönemlerinde gelişimsel gecikmelere ve davranışsal zorluklara katkıda bulunabilir; bu nedenle erken teşhis kritik öneme sahiptir.

**Yöntem:** Çalışmaya 37 haftadan önce doğan toplam 49 preterm bebek ve 45 sağlıklı term bebek dahil edildi. Duyusal işleme becerileri, işitsel, görsel, dokunsal, vestibüler ve oral olmak üzere birden fazla alanda duyusal girdiye verilen yanıtları inceleyen, bakıcı tarafından bildirilen bir değerlendirme aracı olan Yeni Yürümeye Başlayan Çocuk Duyu Profili-2 kullanılarak değerlendirildi. Düşük kayıt, duyusal duyarlılık, duyusal kaçınma ve duyusal arama kadranları da analiz edildi.

**Bulgular:** Preterm bebeklerin duyusal işleme performansı term bebeklerden önemli ölçüde farklıydı ($p<0,05$). Düşük kayıt, duyusal hassasiyet, duyusal kaçınma ve duyusal arama gibi örüntüler preterm

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*ETHICAL STATEMENT: The Erzurum Technical University Ethics Committee approved the study to conduct the study (Meeting number: 7, Decision number: 5, Date: 06.06.2024).*



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bebeklerde daha sık gözlendi. Preterm bebekler işitsel, görsel, dokunsal, oral, davranışsal ve hareket işleme alt alanlarında atipik puanlar aldı ($p<0,05$).

**Sonuç:** Çalışma, preterm bebeklerin duyusal uyaranları akranlarına kıyasla atipik olarak işlediğini vurgulamaktadır. Bu farklılıklar çocuğun çevresine uyum sağlama yeteneğini engelleyebilir ve günlük aktivitelere katılımını etkileyebilir.

**Anahtar Sözcükler:** Erken doğum, duyusal işlemleme, çocuk.

## Introduction

Preterm birth is a birth that occurs before 37 weeks of pregnancy[1]. Preterm infants were at greater risk for developmental and cognitive problems[2]. Although advances in perinatal care have improved survival rates for these infants, these infants are at greater risk of neurodevelopmental disorders and sensory processing problems than term infants. Due to their immature nervous systems, these infants are not ready to process the intense sensory input in neonatal intensive care units (NICU). Therefore, their sensory development is likely slower than in term infants[3].

Sensory processing skills involve managing sensory stimuli from the central and peripheral nervous systems and providing responses to sensory information. This process involves perceiving sensory input, communicating it to the brain, and integrating information from various sensory systems to produce appropriate responses[4]. The sensory processing conceptual model assumes a link between neurological threshold and behavioral response strategies[5]. This is defined in the quadrants where the neurological threshold continuum and response strategy form the axes. The neurological threshold represents the level of sensory stimulus required to trigger a neuronal arousal response. The brain becomes attuned to stimuli demanding immediate attention and response, while it becomes desensitized to familiar stimuli that do not require sustained focus. This balance is maintained through modulation, a brain regulatory process that facilitates some responses while inhibiting others. The behavioral response continuum ranges from passive to active regulatory strategies, reflecting the individual's temperament or personality traits. In the low-registration quadrant, a person has a high neurological threshold and a passive behavioral response strategy, making them unaware of their environment and disengaged. In the sensory sensitivity quadrant, a person has a low threshold and a passive response strategy, leading to easy distraction and difficulty handling intense situations with sensory stimuli. In the sensory-seeking quadrant, a person has a high threshold and an active response strategy, prompting them to seek out intense sensory experiences. In the sensory avoiding quadrant, a person has a low threshold and an active response strategy, leading them to control and limit sensory stimuli[5,6]. In general, deficits in sensory processing skills can lead to inattention, sensory-seeking behaviors, or sensory stimulus avoidance problems[4].

Studies on sensory processing skills in the literature have reported that preterm infants have higher rates of sensory processing problems than their term peers around the age of one[7,8]. Adams et al., who evaluated the sensory processing skills of preterm children in the preschool period, found that preterm children also experienced sensory problems during this period[9]. Sensory processing skills in preterm infants between 12 and 24



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months have not been investigated. The current study examined the sensory profiles of preterm infants between 12 and 24 months.

## Material and Methods

### *Participants*

The study included 49 preterm infants and 45 healthy infants with corrected ages ranging from 12 to 24 months. The study was conducted in the Department of Physiotherapy and Rehabilitation, Erzurum Technical University. It was calculated that 95% confidence and 95% power could be achieved when 45 preterm infants and 45 term infants were included in the study (G*power version 3.1.9.2, Axel Buchner, Universität Kiel). The study was completed with 49 preterm and 45 term infants. Informed consent was obtained from the families who agreed to participate in the study.

The study included infants born before 37 weeks of gestation and those with a history of at least 15 NICU visits. Those with congenital malformations, metabolic and genetic diseases, and diagnoses such as cerebral palsy were excluded from the study.

### *Measurements*

Toddler Sensory Profile 2: It is filled out by the baby's caregiver to obtain information about sensory processing skills. It evaluates the behavior and performance outputs of children between 7 and 36 months of age against sensory inputs. It consists of 54 items that measure sensory processing skills. It covers general, visual, auditory, vestibular, tactile, and oral sensory processing titles. The frequency of behaviors for each section is scored as 1: almost always, 5: almost never. A result is obtained from the recorded answers using standard scoring methods. The scores obtained in the test are interpreted by dividing them into sensory processing patterns (sensory quadrants) as sensory sensitivity, sensory seeking, sensory avoiding, and low registration[10]. The raw scores from the subparameter responses are documented and then categorized. These categories are based on the deviation from the standard deviation range indicated by the scores, with most falling between -1.0 and +1.0 standard deviation (SD). The categories include typical performance (scores within -1.0 to +1.0 SD), probable deviation (scores ranging from -1.0 to -2.0 SD or +1.0 to +2.0 SD), and definite deviation (scores below -2.0 SD or above +2.0 SD). These categories help to characterize the child's sensory processing traits[11].

### *Ethical Statement*

Permission was received from the Erzurum Technical University Ethics Committee to conduct the study (Meeting number: 7, Decision number: 5, Date: 06.06.2024).

### *Statistical Analysis*

The SPSS program 26 (SPSS Inc., Chicago, IL, USA) was used for data analysis. The conformity of the variables to normal distribution was examined visually and analytically. Descriptive statistics were presented as frequency and percentage for categorical variables and mean and standard deviation for continuous variables. The chi-square test was used to compare categorical variables between two groups, the Mann-Whitney test was used to compare numerical variables if not normally distributed, and



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the Student's t-test was used if normally distributed. A p-value less than 0.05 was considered statistically significant.

## Results

The birth information and demographic characteristics of the infants included in the study are presented in Table 1.

**Table 1.** Characteristics of the groups.

| | **Preterm (n=49)** | **Term (n=45)** | **p** |
|---|---|---|---|
| **Age (month) (Mean ± SD)** | 14.2 ± 4.2 | 14.0 ± 3.9 | 0.862[a] |
| **Gestational age (Week) (Mean ± SD)** | 31.38 ± 3.8 | 38.37 ± 1.1 | **< 0.001[b]** |
| **Gender (F/M) n (%)** | 25/24 (51/49) | 26/19 (57.8/42.2) | 0.511[c] |
| **Birth weight (g) (Mean ± SD)** | 2300.29 ± 1027.98 | 3078.50 ± 419.60 | **0.041[b]** |
| **Birth height (cm) (Mean ± SD)** | 43.45 ± 6.85 | 49.80 ± 2.44 | **0.007[a]** |
| **Mother's age (years)** | 30.82 ± 5.78 | 31.09 ± 5.40 | 0.820[b] |
| **Type of birth** | | | |
| **Spontaneous vaginal delivery** | 16 (32.7) | 23 (51.1) | 0.07[c] |
| **Cesarian section** | 33 (67.3) | 22 (48.9) | |
| **Length of stay in NICU (days)** | 31.12 ± 30.83 | - | - |
| **Mother's educational status (%)** | | | |
| **Primary school** | 7 (14.3) | 11 (24.4) | |
| **High school** | 20 (40.8) | 17 (37.8) | 0.627[c] |
| **University** | 20 (40.8) | 16 (35.6) | |
| **Master's Degree** | 2 (4.1) | 1 (2.2) | |
| **Father's educational status (%)** | | | |
| **Primary school** | 1 (2) | 3 (6.7) | |
| **High school** | 20 (40.8) | 18 (40) | 0.430[c] |
| **University** | 24 (49) | 23 (51.1) | |
| **Master's Degree** | 4 (8.2) | 1 (2.2) | |

p< 0.05 is shown in bold. a: b: c: a: Student's t-test, b: Mann-Whitney U Test, c: Chi-Square test, SD: Standard Deviation; g: Gram; cm: Centimeter; F: Female; M: Male.

Twenty-six infants (55.32%) were born less than 32 weeks of gestation, and 21 infants (44.68%) were born more than 32 weeks. The infants ' prenatal and/or perinatal risks are summarized in Table 2. Of the infants, 55.32% were classified as very preterm or extremely preterm (gestational age < 32 weeks), while 44.68% were categorized as moderate or late preterm (32 weeks ≤ gestational age < 37 weeks).



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**Table 2.** Risk factors for infants.

| **Risk factors** | **Preterm (n=49)** | |
|---|---|---|
| | **n** | **%** |
| **Germinal Matrix and Intraventricular Hemorrhage** | 6 | 12.77 |
| **Hyperbilirubinemia** | 8 | 17.02 |
| **Periventricular Leukomalacia** | 5 | 10.64 |
| **Intrauterine Growth Restriction** | 7 | 14.89 |
| **Bronchopulmonary Dysplasia** | 9 | 19.15 |
| **Perinatal Asphyxia** | 6 | 12.77 |
| **Patent Ductus Arteriosus** | 6 | 12.77 |
| **Necrotizing Enterocolitis** | 7 | 14.89 |

Both groups' sensory profiles (typical performance, probable difference, and defined difference) are shown in Table 3 and Figure 1. In the preterm group, the proportion of children who showed typical sensory processing patterns in all quadrants of poor registration, sensory seeking, sensory avoiding, and sensory sensitivity was significantly lower than in the control group. Similarly, the proportion of infants with typical performance in all sensory domains was higher in the control group ($p<0.05$).

**Table 3.** Comparison of sensory profiles of the groups.

| **Sensory Quadrants** | **Groups** | **Typical n (%)** | **Probable n (%)** | **Define n (%)** | **p** |
|---|---|---|---|---|---|
| **Low Registration** | **Preterm** | 19 (38.8) | 18 (36.7) | 12 (24.5) | **0.006** |
| | **Term** | 32 (71.1) | 9 (20.0) | 4 (8.9) | |
| **Sensory Sensitivity** | **Preterm** | 15 (30.6) | 21 (42.9) | 13 (26.5) | **0.002** |
| | **Term** | 30 (66.7) | 11 (24.4) | 4 (8.9) | |
| **Sensory Avoiding** | **Preterm** | 11 (22.4) | 27 (55.1) | 11 (22.4) | **0.027** |
| | **Term** | 22 (48.9) | 16 (35.6) | 7 (15.6) | |
| **Sensory Seeking** | **Preterm** | 19 (38.8) | 13 (26.5) | 17 (34.7) | **0.047** |
| | **Term** | 28 (62.2) | 10 (22.2) | 7 (15.6) | |
| **Sensory Profile Sections** | | | | | |
| **General** | **Preterm** | 18 (36.7) | 15 (30.6) | 16 (32.7) | **0.003** |
| | **Term** | 31(68.9) | 10 (22.2) | 4 (8.9) | |
| **Auditory** | **Preterm** | 18(36.7) | 14(28.6) | 17 (34.7) | **0.009** |
| | **Term** | 29(64.4) | 11(24.4) | 5(11.1) | |
| **Visual** | **Preterm** | 25(51) | 12 (24.5) | 12(24,5) | **0.007** |
| | **Term** | 32(71.1) | 12 (26.7) | 1(2.2) | |
| **Touch** | **Preterm** | 17 (34.7) | 12 (24.5) | 20 (40,8) | **0.003** |
| | **Term** | 28 (62.2) | 12 (26.7) | 5 (25.5) | |
| **Movement** | **Preterm** | 20 (40.8) | 22 (44.9) | 7 (14.3) | **0.003** |
| | **Term** | 32 (71.1) | 13 (28.9) | - | |
| **Oral** | **Preterm** | 18 (36.7) | 13 (26.5) | 18 (36.7) | **0.007** |



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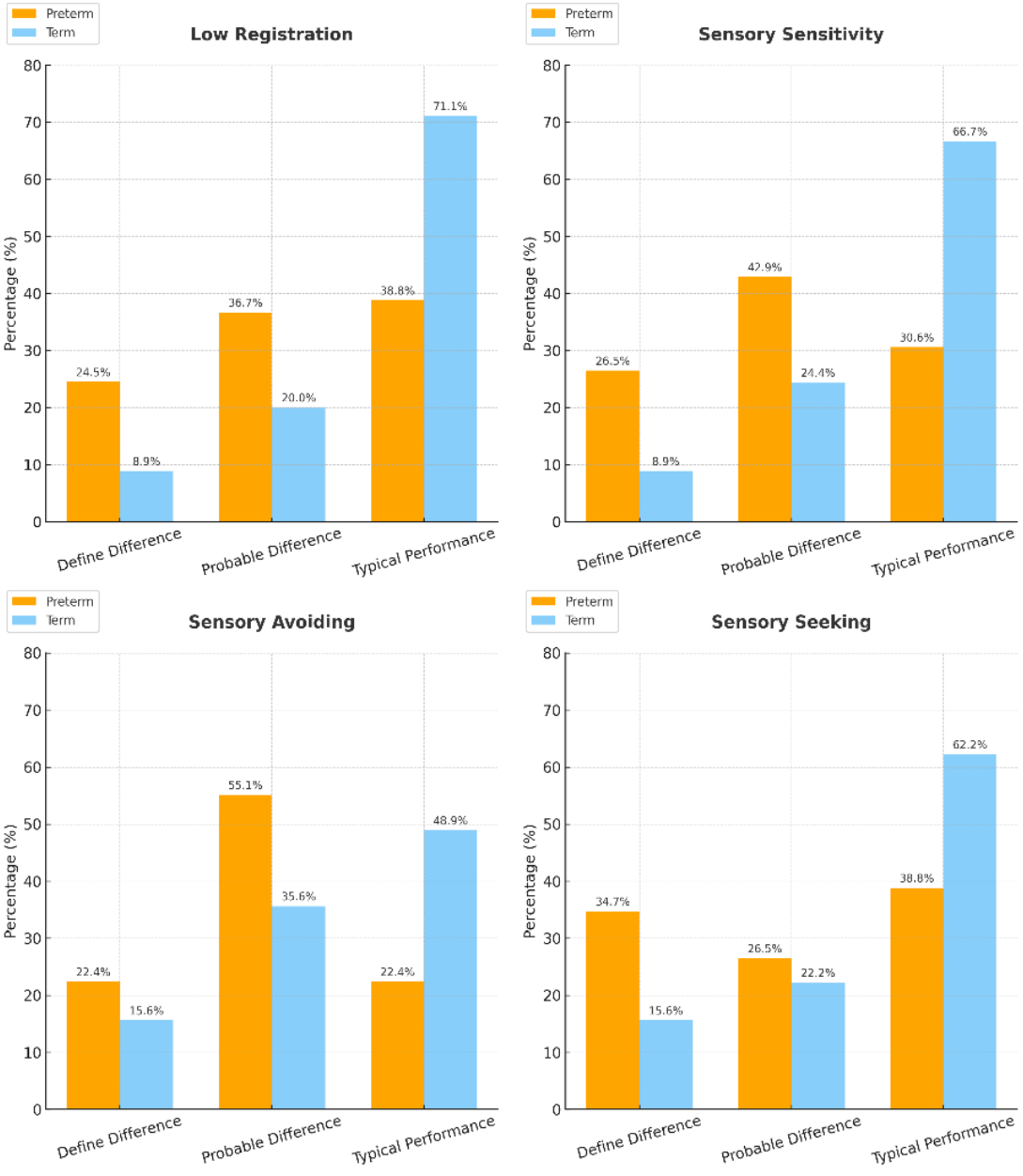
| | | | | | |
|---|---|---|---|---|---|
| | **Term** | 29 (64.4) | 11 (24.4) | 5 (11.1) | |
| **Behavioral** | **Preterm** | 16 (32.7) | 16 (32.7) | 17 (34.7) | **0.001** |
| | **Term** | 30 (66.7) | 11 (24.4) | 28.7 () | |

p< 0.05 is shown in bold

**Figure 1.** Comparison of sensory profile quadrants of groups.



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## Discussion

This study aimed to evaluate sensory processing skills in preterm toddlers. As a result of the study, it was found that preterm toddlers showed atypical sensory processing patterns in the low registration, sensory sensitivity, sensory avoidance, and sensory seeking quadrants and all sensory profile sections compared to their term peers.

Sensory processing skills are negatively affected in preterm infants. Crozier et al. investigated the prevalence of sensory processing in very preterm children and found that almost half (46%) exhibited atypical sensory processing patterns[12]. Ryckman et al. reported that half of premature infants born before 30 weeks of gestation had sensory processing disorder[13]. In another study evaluating children born prematurely with the Sensory Profile, preterm children reported a high risk of atypical scores in all Sensory Profile quadrants[14]. In the present study, preterm children were found to have atypical performance in all four sensory quadrants. In parallel with our findings, it has been reported that preterm children are more prone to sensory sensitization, resulting in higher responses to sensory experiences[15]. In the present study, the most common sensory behavior patterns in premature infants were avoidance and sensitivity. Recently, Niutanen et al. reported that the prevalence of possible atypical avoidance patterns in premature infants was 18-54%[16]. Similarly, Yardımcı-Lokmanoğlu et al. reported that sensory avoidance and sensitization patterns were most frequently observed in preterm children[17]. Preterm infants are not exposed to natural sensory experiences in late pregnancy and are likely to have sensory problems. In the NICU, preterm infants are exposed to adverse stimuli such as painful procedures, intubation, and exposure to light/sound in the environment. These altered sensory experiences during neurodevelopmental vulnerability and fragility can lead to sensory processing disorder. Early in life, altered sensory experiences and responses can affect development and influence how children respond to their environment[18,19].

Preterm children have been reported to be at high risk of atypical scores in auditory, tactile, and vestibular processing Section[14]. Preterm infants scored more atypical on the Sensory Profile's auditory and oral sensory processing components than their term peers[19]. Preterm school-age children have been reported to have more deficits in movement processing than term children[20]. In the present study, in parallel with the literature, infants were found to have atypical performance in auditory, visual, tactile, movement, oral, and behavioral processing areas. The presence of many risk factors accompanying prematurity in the present study may have led to atypical performance in all sensory domains in the present population. Especially among infants, there is a high number of those who experience brain damage due to ischemia and bleeding. Bleeding and ischemia-induced brain injury are well-known risk factors for adverse neurodevelopment[21]. Therefore, it is no coincidence that sensory processing problems were encountered in our study group.

Future research with larger sample sizes is necessary to distinguish children across different points on the spectrum and to evaluate the risk factors associated with an atypical Sensory Profile. It should be noted that the Toddler Sensory Profile is a caregiver-reported questionnaire rather than a direct assessment tool, making it



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inherently subjective. Consequently, incorporating both objective and subjective assessment methods in future studies will be crucial.

## Conclusion

The results indicate that preterm toddlers are at higher risk for atypical sensory processing, which may negatively affect their motor development, behavior, and participation in daily activities. These findings highlight the importance of including sensory processing evaluations in early developmental follow-ups. Early detection and targeted interventions, such as sensory integration therapy and caregiver education, may improve this population's developmental outcomes and quality of life.

## Supporting Organization

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## Conflict of Interest

The authors declared no conflict of interest.

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None.

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