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# SENSORY PROCESSING DISORDERS IN PREMATURE INFANTS

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## SUMMARY

**Introduction.** Children born prematurely have an increased risk of immediate medical complications, as well as socio-emotional, cognitive, linguistic and sensory processing disorders later in life. Studies have examined the effects of prematurity on developmental outcomes, such as cognition, however, there is a need for a more detailed examination of sensory processing disorders in preterm infants. Not only is prenatal neurosensory development interrupted in utero, but these children may also experience intense stimulation in the neonatal unit, which can further alter the development and function of the sensory system.

**Objective.** The paper presents an overview of research on sensory processing disorders in premature infants, with special emphasis on the impact of the environment of the neonatal unit.

**Method.** Insight into the relevant literature was performed by specialized search engines on the Internet and insight into the electronic database. Results. Sensory processing disorders affect 39% to 52% of newborns born prematurely, with some evidence to suggest that children born before 32 weeks are most at risk. The literature to date has consistently reported difficulties in sensory modulation of preterm infants, within the tactile, vestibular, auditory, oral, and visual domains.

**Conclusion.** Sensory processing disorders in preterm infants appear to occur as a result of their immature neurological and biological system and being in the environment of a neonatal intensive care unit, which is unable to meet the sensory needs of preterm infants. Altered sensory experiences, during periods of neurodevelopmental vulnerability and fragility, can result in sensory processing disorders, which may include enhanced responses or less response to stimuli (hyper or hyposensitivity).

**Key words:** sensory processing, premature babies, neonatal unit

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### SAŽETAK

**Uvod.** Deca rođena prevremeno imaju povećan rizik od neposrednih medicinskih komplikacija, kao i socijalno-emocionalnih, kognitivnih, jezičkih i smetnji u senzornoj obradi kasnije u životu. Studije su ispitivale efekte prematuriteta na razvojne ishode, poput kognicije, međutim, postoji potreba za detaljnijim ispitivanjem smetnji na planu senzorne obrade kod dece rođene pre vremena. Ne samo da je prevremenim rođenjem neurosenzorni razvoj in utero prekinut, već ta deca mogu iskusiti i intenzivnu stimulaciju u neonatalnoj jedinici, što dalje može promeniti razvoj i funkciju senzornog sistema.

**Cilj.** U radu je dat pregled istraživanja poremećaja senzorne obrade kod prevremeno rođene dece, sa posebnim naglaskom na uticaj okruženja neonatalne jedinice.

**Metod.** Uvid u relevantnu literaturu izvršen je specijalizovanim pretraživačima na internetu i uvidom u elektronsku bazu podataka.

**Rezultati.** Poremećaji senzorne obrade pogađaju 39% do 52% novorođenčadi rođene prevremeno, sa nekim dokazima koji ukazuju na to da najveću opasnost nose deca rođena pre 32 nedelje. Dosadašnja literatura dosledno izveštava o poteškoćama senzorne modulacije prevremeno rođene dece, u okviru taktilnog, vestibularnog, slušnog, oralnog i vizuelnog domena. Zaključak. Čini se da se poremećaji senzorne obrade kod prevremeno rođene dece javljaju kao rezultat njihovog nezrelog neurološkog i biološkog sistema i boravka u okruženju neonatalne jedinice za intenzivnu negu, koje nije u stanju da zadovolji senzorne potrebe prevremeno rođene dece. Izmenjena čulna iskustva, tokom perioda neurorazvojne ranjivosti i krhkosti, mogu rezultirati poremećajem senzorne obrade, što može uključivati pojačane odgovore ili manje reagovanje na stimuluse (hiper ili hiposenzitivnost).

**Ključne reči:** senzorna obrada, prevremeno rođena deca, neonatalna jedinica

## INTRODUCTION

In recent years, with the progress of medicine, and especially perinatology and neonatology, the survival rate of children born prematurely has significantly increased, and at the same time, the rate of complications of neurological development has decreased [1]. However, the risk of sensory disturbances and neurocognitive impairment remains high. Not only is prenatal neurosensory development interrupted in utero, but these children may also experience intense stimulation in the neonatal unit, which can further alter the development and function of the sensory system [2].

Babies born prematurely must function in a new, extrauterine environment, but with immature organ systems [3]. Premature babies depend on intensive care to survive, but they are also vulnerable and sensitive to the environment of the neonatal unit. The normal development of somatosensory and pain management depends on sensory activity in early life. Sensory perception plays a crucial role in the normal development of the fetus and newborn [4].

## PREMATURE BABIES

On average, pregnancy lasts 40 weeks (37-42). Childbirth before 37 weeks of gestation is considered premature [5]. The upper limit of prematurity is 36 weeks and 6 days of pregnancy. The lower limit of survival, viability, is determined by the degree of development of fetal organs at the time of birth and the progress of modern possibilities of neonatal intensive care.

Gestational age at birth can determine the outcome and prognosis, as well as the weight of the newborn. Thus, moderate prematurity implies childbirth of 32-36 gestational weeks. Childbirth from 28 to 31 weeks of gestation is considered very premature birth, while childbirth before 28 weeks is considered an extremely premature birth and it accounts for about 5% of all prematurity [6].

Complications of prematurity stem from the immaturity of all organ systems, which are not fully prepared for extrauterine life. The lower the gestation, the greater the immaturity of the organism, as well as the risks of numerous short-term and long-term diseases and problems. The risk of acute and chronic consequences of prematurity reflects the fragility and immaturity of the central nervous system, lungs, immune system, liver, kidneys, skin, and gastrointestinal system.

Modern science believes that the crucial period of brain development, which is forced to take place prematurely on the outside instead of in a warm, watery intrauterine environment, receives inadequate signals from the environment that affect the formation of synapses. The premature central nervous system is subjected to different sensory inputs - such as visual stimulation, gravity, noise - from what nature intended at a given stage of development. Paradoxically, many of these "unnatural" sensory signals originate precisely from intensive medical procedures in the neonatal intensive care unit, which in turn is necessary for such a distinctly immature newborn to survive at all.

## SENSORY PROCESSING

Sensory development is complex, with morphological and neural components. It is conditioned genetically, but also by environmental factors. The senses begin to develop before birth and mature rapidly in the first year [7].

Sensory integration is a term for the process by which the nervous system processes information that arrives in our brain at any moment through the senses (sense of sight, hearing, smell, taste, touch, vestibular and proprioceptive). The brain integrates and organizes all sensory stimuli, and thus uses them integrated for movement, learning and behavior.

Each of the sensory systems has its own sequence and schedule of events, which are crucial in creating the basic neural architecture of each system. Sensory systems are developed in close cooperation with each other, because many aspects of sensory stimulation require coordination or integration to function optimally [8].

In 2007 [9], Miller and co-workers proposed the adoption of a new concept - sensory processing disorder, instead of the concept of sensory integration disorder, representing a new taxonomy in diagnosis. Sensory processing disorder is the inability of the brain to organize sensory inputs for the proper use and can be associated with learning, developmental and emotional disorders. According to the new classification, sensory processing disorder includes: 1) sensory modulation disorder, 2) sensory discrimination disorder and 3) motor disorders due to sensory processing disorder. Each of them has its subtypes [9].

Sensory modulation is the ability of the central nervous system that allows a person to focus on some stimuli, while ignoring others, thus responding to the demands of a particular situation. In sensory modulation disorders, there is a mismatch between environmental requirements and responses [10]. It has three subtypes: 1) sensory hypersensitivity, which is characterized by rapid and intense responses to sensory input 2) sensory insensitivity or lack of response to sensory input and 3) which is manifested by an insatiable desire for sensory input, so behavior can be disruptive and socially unacceptable [10]. This can apply to any sensor system or more than one [9].

Sensory discrimination disorder implies the inability to interpret the quality of sensory stimuli, such as

identification, location, similarities or differences between stimuli [10]. It can refer to the visual, auditory, tactile, proprioceptive, vestibular or olfactory system or more simultaneously [9].

Motor disturbance due to sensory processing disorders will result in postural instability or movement deficits. Thus, the two subtypes of this disorder are dyspraxia and postural disorder [9].

## SENSORY PROCESSING IN PREMATURE INFANTS

While some brain development processes take place automatically at the molecular level, other aspects of brain development depend on activity, relying on sensory exposure in the newborn environment [11]. Although relatively insufficiently studied, premature birth poses specific risks to the maturation of the child's sensory systems due to interruptions in critical periods of sensory development in the uterus [12]. Sensory processing disorders affect 39% to 52% of preterm infants, with some evidence to suggest that infants born 32 weeks ago are most at risk [13, 14].

In 2013, Wickremasing [13] and associates found in their study that 39% of children born prematurely (at 32 weeks of gestation) had an atypical overall sensory profile. The sensory parts most likely to be affected were auditory, tactile, and vestibular processing. Besides, in this study, preterm infants had atypical performance in all four quadrants of the sensory profile [13].

The literature to date has consistently reported difficulties in sensory modulation of preterm infants within the tactile, vestibular, auditory, oral, and visual domains [12]. Links have also been found between sensory modulation abnormalities, gestational age, and length of stay in the neonatal unit, suggesting that preterm infants with sensory modulation difficulties are more likely to have a lower gestational age at birth and a longer length of stay in the neonatal unit [15].

Sensory processing disorders in preterm infants appear to occur as a result of their immature neurological and biological system and living in a neonatal intensive care unit that is unable to meet the sensory needs of preterm infants [16]. Sensory disturbances in newborns can be characterized as hyper or hyposensitivity. Wickremasing and associates found that behaviors such as hyposensitivity, sensory search, sensory sensitivity, and sensory avoidance can be observed in preterm infants, 39% had at least one atypical response, and the hyposensitivity rate to sensory stimuli was 24% [13].

The organization of the CNS is important for the development of autonomic stability, motor maturity, organization, attention, interaction and self-regulation. Changes can result in hypersensitivity, poorly modulated behavior, and responses to all or nothing [3]. For example, a hypersensitive newborn will be frightened at the slightest level of noise and tremble and cry, or, on the other hand, will not react to this stimulation at all. All of these behaviors have been seen in preterm infants and later in development [17]. The organization is also important for processing sensory information. Sensory organs develop in a certain order that begins with tactile, and then smell, taste, hearing and sight [3].

It remains unclear whether sensory processing disorder is evident at an early age. Although sensory development begins early in the womb and continues over time, the early sensory development of preterm infants occurs primarily in the external environment with sensory stimuli that the child is not yet ready to integrate [18].

## INFLUENCE OF NEONATAL UNIT ENVIRONMENT ON SENSOR PROCESSING

Babies born prematurely have immature organs and organ systems, which are not able to maintain basic physiological needs, but they need additional help to survive. This additional help is provided to them in modern neonatal intensive care units. The environment of an early neonatal intensive care unit could play a role in the development of sensory processing disorders in premature infants, since the environment has external stimuli that it would not normally experience in utero [19]. These sensory exposures occur during a critical period of brain development, which can interfere with motor, neurological, and sensory development. Sources of stress in the neonatal unit are medical procedures, interventions, pain, and especially sound and light [3].

Negative outcomes of the sensory environment of the neonatal intensive care unit indicate that (1) exposure to strong light may have a detrimental effect on some aspects of later motor development; (2) exposure to alarm sounds may disrupt the functional use of the tactile system; (3) exposure to painful procedures has a negative relationship with cognitive and motor development [12].

Graven and Brownie especially emphasize the importance of sleep, as the basis for the development of the sensory system. The environment of the neonatal unit threatens the REM phase of sleep, due to excessive stimuli. First of all, higher sound levels are the ones that increase the probability of sleep interruption [20].

Also, it is believed that the environment of the neonatal unit can represent an overload of sensory stimuli to premature babies, which can change physiological reactions and lead to changes in behavior. They are at special risk of negative sensory developmental outcomes due to the mismatch of the intensity of sensory stimuli in the environment and insufficient maturation of the neurological sensory system of the newborn [8]. These altered sensory experiences, during periods of neurodevelopmental vulnerability and fragility, may result in sensory processing disturbances, which may include enhanced responses or less response to stimuli [18].

Hearing and sight are especially immature in premature babies. On the other hand, these two systems have the largest sensory input of information in the neonatology unit, which will affect their degree of maturation and organization [3]. It has been well established in the literature that the noise level in modern neonatology units is above the recommended guidelines [4]. Concerns about the effects of the sound environment in the neonatal unit go in three directions: (a) high-intensity sound can cause damage that will lead to hearing loss; (b) repeated arousal to sounds in the neonatal unit may deplete the child's physiological resources and energy reserves, interfere with sleep and lead to fatigue and irritability; and (c) noise may interact with ototoxic drugs to effect on hearing loss [3].

The levels of illumination in the neonatology unit are very variable, and often very high. Concerns about lighting

include exposure of infants to continuous exposure to high-intensity light, lack of systematic, rhythmic daily patterns, and potential interaction between lighting and retinopathy of prematurity [3].

Tactile receptors are located in our skin. Each receptor is specific for a certain sensory input, touch, pain, temperature. The skin of the premature is sensitive and vulnerable. Early repeated exposure to pain and stress in the neonatology unit may alter the neurological substrate associated with pain processing and consequently lead to changes in somatosensory pain processing and altered neurobehavioral pain response. Repeated experiences of early developmental pain may have consequences such as reduced pain threshold, hyperalgesia, and allodynia [21]. The cumulative experience of pain affects somatosensory perception and sensitivity to pain at later ages.

The traditional environment of the neonatal unit is task-oriented and protocol-oriented and represents complete separation from parents, sensory overload, and at the same time a frequent experience of invasive and painful events. The stimuli to which a premature baby is exposed depend on the type of equipment present in the neonatal unit. Monitoring equipment usually records vital signs such as heart and respiratory rhythm, blood pressure, oxygen levels, and infant temperature. Alarms will often sound in response to unusual changes in these vital signs [12]. Therefore, admission to a neonatology unit after preterm birth can lead to prolonged and excessive auditory, visual, and tactile stimulation during critical brain periods that can disrupt the development of specific sensory systems, potentially affecting the development of sensory modulation difficulties [8].

On the other hand, (1) exposure to the parental voice during a stay in the neonatology unit may result in improved sensory and motor activity; (2) environments that support reduced sound exposure, but provide typical ambient sound, can have a positive effect on motor and language outcomes; and (3) filling the "stimulation" of medical care with controlled auditory, tactile-kinesthetic / vestibular and multimodal stimulation can result in improvements in developmental outcomes [12]. Clinical studies on early parent-child interactions have also shown positive effects of parental interactions on neonatal motor and attention responses [22].

## POSSIBLE OVERCOMING OF HARMFUL INFLUENCES

In the medical literature, there are data on the possible harmful effects of continuous light, noise, inappropriate positioning, frequent harassment, repeated pain due to the necessary diagnostic and therapeutic procedures, the absence of the mother, family. According to the NIDCAP® care system (The Newborn Individualized Developmental Care and Assessment Program), all these negative environmental factors are eliminated or reduced [23]. Continuous lighting in hospital wards is abolished and a day-night regime is introduced: lights are turned off when the baby's clinical condition allows, incubators are covered with special blankets to allow longer periods of peaceful sleep and rest, and immature eyes are dosed with the optimal amount of light concerning the development phase. Noise is minimized by eliminating sounds coming from outside, silencing alarm beeps, quiet conversation, and controlling noise levels with decibelmeters. Examinations, diagnostic and therapeutic procedures are planned in such a way as to avoid frequent harassment of the newborn and to allow him as long periods of peaceful sleep and rest as possible. Special attention is paid to positioning [24]. The baby should always be in a slightly bent (flexion) position, with the head in the axis of the body, and the arms and legs slightly bent.

A SENSE program (Supporting and Enhancing NICU Sensory Experience) has also been developed with the aim of maximally engaging parents. It consists of educational materials for parents, weekly guides on appropriate sensory exposure, which was approached systematically and scientifically, assessment of newborns to determine the need for changes in programs and diaries for parents and health professionals to monitor sensory exposure [25].

## CONCLUSION

Premature birth is a dramatic event for the child, but also the parents. There is a need to pay more attention to sensory processing disorders in premature babies. Premature babies are at increased risk for developing sensory processing disorders. More research in this area could help identify early and identify the need for targeted interventions to optimize outcomes. Based on these findings, it is clear that the impact of the sensory environment of the neonatal unit on short-term and long-term outcomes in the sensory development of preterm infants should be further considered.

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