Investigation of the Relationship Between Sensory Processing and Motor Development in Preterm Infants

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OBJECTIVE. The aim of this study was to analyze the correlation between sensory processing and motor development in preterm infants.

METHOD. We included 30 preterm and 30 term infants with corrected and chronological ages between 10 and 12 mo. We used the Test of Sensory Functions in Infants to evaluate sensory processing and the Alberta Infant Motor Scale to evaluate motor development.

RESULTS. The Spearman correlation test indicated a strong positive relationship between sensory processing and motor development in preterm infants ($r = .63$, $p < .001$).

CONCLUSION. Given the relationship between sensory processing and motor development in the preterm group, the evaluation of sensory processing and motor development in preterm infants was considered necessary for the effective implementation of physiotherapy assessment and interventions.

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Infants who are born preterm may have perinatal medical problems specific to prematurity and, thus, usually spend a long period of hospitalization in neonatal intensive care units (NICUs; Blencowe et al., 2013; Platt, 2014). Although the NICU is necessary to support vital functions, reduced spontaneous movements and excessive sensory stimuli exposure in the NICU may cause adverse consequences in the normal sensory and motor development of the infant. Infants staying in the NICU long term are deprived of a natural sensory environment and must cope with excessive sensory stimuli, painful invasive procedures, and life-supporting medical equipment (Kessenich, 2003; Royeen & Lane, 1991; Ullenhag, Persson, & Nyqvist, 2009). Incomplete sensory development due to preterm birth and NICU-related excessive sensory stimuli affect central nervous system (CNS) organization and may cause alterations in sensory processing functions (Mitchell, Moore, Roberts, Hachtel, & Brown, 2015).

The sensory environments of the NICU and uterus are substantially different. Infants in the NICU are exposed to many stimuli, a situation that would not occur in the uterus. Because the soft tissues around the uterus absorb sounds and light, they protect the fetus from light and high-frequency and -pitched sounds (Graven & Browne, 2008). Exposure to the intense, unusual, and timely inappropriate stimuli in the NICU may lead to significant changes in the normal sensory development pattern (Graven & Browne, 2008; Lickliter, 2000). For example, the more developed tactile and vestibular systems of the preterm infants in the NICU receive less stimulation, but the comparatively less developed auditory and visual systems receive much more stimulation

(Lickliter, 2011). This condition is not appropriate for the organization of the CNS and maturational level of the infant (White-Traut, Nelson, Burns, & Cunningham, 1994). This contradiction between the sensory needs of the infant and the sensory environment provided by the NICU may lead to an excessive sensory load, stress, and changes in neurosensory development (Als, 1986; Blackburn, 1998; Lickliter, 2011). As a result, oral defense, tactile defense, and general sensory processing disorders (SPDs) are more common in preterm infants than in their term peers (Kessenich, 2003).

The correct processing of sensory impulses is important in the normal neurodevelopmental period. In particular, disorders in the processing of the signals coming from the proximal sensory systems (vestibular, proprioceptive, tactile) lead to problems in the production of an adaptive response, the development of postural control and movement coordination, and the motor development and the arrangement of the awake-orientation status—all of which affect the development of play, social participation, education, and self-care occupations (Ayres & Robbins, 2005; Critz, Blake, & Nogueira, 2015; Mitchell et al., 2015). Therefore, the aim of this study was to investigate the relationship between the sensory processing skills and motor development in preterm infants and to compare these skills with those of their term peers.

Method

Research Design

We conducted this study using a cross-sectional design. Ethical approval for this study was obtained from the Gazi University Noninvasive Clinical Studies Ethical Committee (Protocol Number 25901600-G9) on August 2, 2016. Written consent was obtained from the families of the infants included in the study.

Patients

The infants included in the preterm group (1) were admitted to the Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation Pediatric Rehabilitation Unit between February and May 2016; (2) had gestational ages less than 37 wk, adjusted age 10–12 mo, without any congenital anomaly or systemic disease; and (3) spent at least 2 wk in the NICU. The infants who were under physiotherapy or sensory integration therapy in any center were excluded from the study. Healthy infants included in the term group (1) were between age 10 and 12 mo, (2) were followed up by the Department of Pediatrics in the Gazi University Faculty of Medicine Hospital as having normal development according to the Denver Developmental Screening Test—II (Yalaz & Epir, 1982), (3) carried no perinatal risk factors, and (4) had no history of postpartum NICU stay.

In this cross-sectional, comparative study, the 30 infants (17 girls, 13 boys) in the preterm group had (1) a mean gestational age of 31.8 wk (±2.3); (2) a mean birth weight of 1,812 g (±603); (3) a mean Apgar score of 7 (±2) and 9 (±2) in the 1st and 5th min, respectively; (4) a mean NICU stay of 33.9 days (±19.8); and (5) a mean age of 10.7 mo (±0.69) at the time of assessment. The control group of 30 term infants (15 girls, 15 boys) had (1) a mean gestational age of 39.2 wk (±1.2); (2) a mean birth weight of 3,224.3 g (±419.4); (3) a mean Apgar score of 8 (±1) and 9 (±1) in the 1st and 5th min, respectively; and (4) a mean age of 11.1 mo (±0.9) at the time of assessment.

Instruments

Two standardized assessments were used. We assessed sensory processing using the Test of Sensory Functions in Infants (TSFI; DeGangi & Greenspan, 1989), and we assessed motor development using the Alberta Infant Motor Scale (AIMS; Piper, Pinnell, Darrah, Maguire, & Byrne, 1991).

Test of Sensory Functions in Infants. The TSFI is used in 4- to 18-mo-old infants primarily to evaluate sensory defensive behaviors. Although it can be used after 4 mo, the most valid and reliable results are obtained between 7 and 18 mo (DeGangi & Greenspan, 1989). However, in infants with developmental delay (motor, language, or cognitive delay), use before 10 mo is not advised (DeGangi & Greenspan, 1989; Jirikowic, Engel, & Deitz, 1997). TSFI consists of 5 subdomains and 24 items. Although the total score ranges between 0 and 49, higher scores indicate better sensory processing. The test has different age group cutoff values for both the total score and the subdomains. On the basis of the cutoff values, the sensory processing skill is evaluated as normal, risky, or abnormal (DeGangi & Greenspan, 1989).

Alberta Infant Motor Scale. The AIMS is a norm-referenced test that gives information about the gross motor development of 0- to 18-mo-old infants (Piper et al., 1991). However, the AIMS gives the most sensitive results between 0 and 12 mo. The ceiling effects observed after age 12 mo adversely affect its discriminative characteristics (Fleuren, Smit, Stijnen, & Hartman, 2007). The test is composed of 58 items with 4 subsection domains: prone, supine, sitting, and standing. At the end of the assessment, the scores of the four subdomains are added to obtain a total score, and this score is converted

into percentile scores showing the infant's condition compared with that of his or her peers (Piper & Darrah, 1994). To identify abnormal motor development, one should use 10% and 5% cutoff scores for 4- and 8-mo-old infants, respectively. Using 5% cutoff scores is suggested for other age groups to maintain the high specificity of the test (Fleuren et al., 2007).

Assessment Procedures

The sociodemographic and birth data were obtained from the infants included in the study. The behavioral and emotional statuses of the infant were extremely important during the evaluations. Because the TSFI was scored according to the behavioral responses of the infants, attention was paid to their emotional status during the evaluation (DeGangi & Greenspan, 1989). The conditions that negatively affected the evaluations, such as hunger, sleepiness, and sickness of the infants, were taken into consideration. The evaluations were conducted by an experienced physiotherapist at least 2 hr after feeding in a quiet, illuminated, and warm room and, when possible, while the infant was naked. Additionally, the evaluations were done while the infant was not crying, awake, active, and with his or her parents (Piper & Darrah, 1994). If the infant cried and could not be calmed, the evaluations were interrupted and repeated at another suitable time convenient for the infant. The total evaluation time lasted approximately 40 min. The sensory processing and motor development evaluations were done by different and independent researchers. The results for the preterm infants were interpreted according to the adjusted age.

Statistical Analysis

The analysis of the data was conducted with IBM SPSS Statistics (Version 21.0; IBM Corp., Armonk, NY). We performed the normal distribution analysis of the data using a histogram, a variation coefficient rate, skewness–kurtosis, and Kolmogorov–Smirnov tests. As a result, the data obtained from the assessments were not found to be suitable for a normal distribution. The Mann–Whitney U test for nonparametric conditions was performed to analyze the differences in the assessment results between the preterm and term groups. We calculated the relationship between the variables using the Spearman's correlation coefficient ($\rho = r$). The levels of significance according to the Spearman's correlation coefficient were determined as $r = .75$–1.00, excellent; $r = .70$–$.75$, very strong; $r = .60$–$.70$, strong; $r = .40$–$.60$, moderate; $r = .30$–$.40$, lower moderate; and $r = .05$–$.30$, weak or an insignificant relationship. A p value of $\leq .05$ was considered statistically significant.

Results

Sensory Processing Assessment

There were significant differences in the TSFI total scores between the preterm and term infants ($p < .001$). Additionally, when the TSFI score distributions were studied, there was a significant difference between the groups ($p < .001$). Of the preterm infants, 11 (36.7%) had abnormal sensory processing scores, and 7 (23.3%) had risky sensory processing scores, whereas of the term infants, 3 (10%) had risky sensory processing scores.

Although there was no relationship among the TSFI total scores and gestational age, birth weight, ventilator need, perinatal morbidities, and duration of stay in the NICU ($p > .05$), there was a significant relationship between the 5th-min Apgar score and TSFI total score in the preterm group ($r = .68$, $p < .05$).

Motor Development Assessment

Because age was not normally distributed, AIMS percentile scores were used to compare the motor development between groups, which revealed a significant difference ($p = .03$). Additionally, 6 of the preterm infants had abnormal motor development (AIMS percentile score <5%), whereas all the term infants showed normal motor development.

Relationship Between Sensory Processing and Motor Development

The AIMS percentile scores and TSFI total and subdomain scores were included in the correlation analysis to study the relationship between sensory processing and motor development in the preterm infants. Although there was a positive, strong correlation between the AIMS percentile score and the TSFI total score, there was a moderate correlation between the AIMS percentile scores and the vestibular stimuli response and visual–tactile integration scores; there were also lower moderate correlations in the response to the tactile deep pressure scores ($p < .05$; Table 1).

Discussion

In this study, the preterm infants were found to be behind their term peers with respect to sensory processing and motor development. Additionally, there was a strong positive correlation between sensory processing and motor development in the preterm infants. Because the AIMS has a ceiling effect after 12 mo (Fleuren et al., 2007) and the TSFI is used in infants with a developmental delay after

Table 1. Relationship Between the AIMS Percentile Scores and the TSFI Total and Subdomain Scores

	AIMS Percentile Score	
TSFI Total Score and Subdomains	*r*	*p*
TSFI total score	**.630**	**< .001**
Response to tactile deep pressure	**.389**	**.034**
Adaptive motor functions	.308	.098
Visual–tactile integration	**.480**	**< .01**
Oculomotor control	.038	.852
Response to vestibular stimuli	**.595**	**< .001**

Note. Values in **bold** indicate statistically significant results. AIMS = Alberta Infant Motor Scale; TSFI = Test of Sensory Functions in Infants.

10 mo (Jirikowic et al., 1997), infants ages 10–12 mo were included in the study. Because we selected the most sensitive age group (10–12 mo) for both the sensory processing and the motor development tests, and because the evaluations were made by different and independent researchers, the reliability of this study has been improved.

Sensory Processing

It is remarkable that there is no epidemiological study in the literature about SPD prevalence in preterm infants. The SPD ratio differs in the available studies (Bart, Shayevits, Gabis, & Morag, 2011; Cabral, Pereira da Silva, Tudella, & Simões Martinez, 2014; Chorna, Solomon, Slaughter, Stark, & Maitre, 2014). Chorna et al. (2014) used the TSFI to evaluate preterm infants with gestational ages less than 30 wk and birth weights less than 1,500 g, and they reported an 82% SPD ratio in these infants. Bart et al. (2011) evaluated sensory processing skills of late preterm and healthy term infants using the TSFI and the Sensory Profile (Dunn, 2002), and they found a 47% SPD ratio in the preterm infants.

In our study, the SPD ratio in preterm infants was 60%. The different SPD ratios in the studies performed with preterm infants could be attributed to the difficulty in establishing standard study groups in terms of sociodemographic and clinical characteristics. In the study by Chorna et al. (2014), having lower inclusion criteria with regard to gestational age and birth weight may have led to an increased exposure to perinatal risk factors and, thus, may have resulted in excessive sensory stimulation in these infants. Decreased perinatal morbidity and consequently decreased days spent in the NICU with an increased gestational age can explain the reason why the SPD ratio was low (47%) in the study by Bart et al. (2011; gestational age = 34–36 wk). When considering the substantial ratio of preterm infants with SPD—and the effects that motor, emotional, and cognitive development have on social and play participation—sensory processing functions should be evaluated as early as possible; if necessary, it may also be useful to include sensory-based approaches in the intervention programs.

In their study conducted with preterm children, Crozier et al. (2016) demonstrated that the 5th-min Apgar score was related to the differences in sensory processing. Having found a relationship between sensory processing and the Apgar score at the 5th min, Crozier et al. demonstrated that the Apgar score, which is used to obtain information concerning the infant's neurological condition, can reveal the differences in sensory processing.

Motor Development

When we reviewed studies comparing motor developments in preterm and term infants, the motor development of the preterm infants was found to be delayed, similar to the current study (Guimarães, Reinaux, Botelho, Lima, & Cabral Filho, 2011; Maia, Silva, Oliveira, & Cardoso, 2011; Pin, Eldridge, & Galea, 2010; Prins, von Lindern, van Dijk, & Versteegh, 2010; Syrengelas et al., 2016; van Haastert, de Vries, Helders, & Jongmans, 2006). Syrengelas et al. (2016) evaluated the motor developments of 1- to 19-mo-old preterm infants without major morbidity and healthy term infants using the AIMS. They reported delayed motor developments in the preterm infants compared with their term peers in all the studied age groups. Guimarães et al. (2011) evaluated the motor development of 9.5- to 10-mo-old preterm and healthy term infants using the Test of Infant Motor Performance (TIMP; Campbell et al., 2008), and they reported lower TIMP scores for the preterm infants compared with the term infants. Pin et al. (2010) evaluated the motor developments of 4- to 18-mo-old infants at 4, 8, 12, and 18 mo using the AIMS, and they reported a delayed motor development in the preterm group in all the evaluations.

It is evident from the studies investigating preterm infants in different age groups, from the perspective of motor development, that these infants fail to catch up with the term infants in the early stages of their lives. Therefore, the evaluation of motor development in preterm infants should not be overlooked in early follow-up clinics. It should be kept in mind that they may have a delay in their motor development.

The number of studies reporting abnormal motor development proportions among preterm infants is insufficient. Guimarães et al. (2011) reported that 26% of the preterm infants in their study had an abnormal motor development in contrast to a normal motor development in all term infants. However, in a study by Maia et al. (2011), 8% of the preterm infants were reported to have an abnormal motor development compared with a normal motor development in all the term infants. In the current

study, 20% of the preterm infants had an abnormal motor development, whereas all the term infants had a normal motor development. In Maia et al.'s study, the small sample size ($n = 24$) and exclusion of infants with serious perinatal risk factors may have contributed to the smaller number of preterm infants with an abnormal motor development.

Relationship Between Motor Development and Sensory Processing

The number of studies in the literature investigating the relationship between sensory processing and motor development among preterm infants is limited (Cabral et al., 2014; Case-Smith, Butcher, & Reed, 1998). In their study on preterm infants ages 10–15 mo who stayed at least 14 days in the NICU, Case-Smith et al. (1998) evaluated psychomotor development using the Bayley–II (Bayley, 1993) and sensory processing using the Sensory Rating Scale (SRS; Provost & Oetter, 1994), and they reported no relationship between sensory processing and motor development.

In this study, the study outcomes may have been affected because (1) there were no serious sensory processing problems in the infants; (2) the validity and reliability of the SRS have not been extensively studied; and (3) the SRS is applied by the caregiver and is, thus, subject to sociocultural differences. Cabral et al. (2014) reported no relationship between motor development and sensory processing in 15 preterm infants ages 4–6 mo who stayed at least 1 day in the NICU. Limitations such as a small sample size, the definition of the NICU stay being at least 1 day, and the TSFI not being advised for use in infants with a developmental delay risk before 10 mo may have affected their study outcomes. In this study, we included 30 infants with at least 14 days of NICU stay. The significant relationship between the AIMS percentile scores and the total TSFI score, the response to the vestibular stimuli, the visual–tactile integration, and the tactile deep pressure response subdomain scores demonstrate that sensory processing may affect motor development in preterm infants. Therefore, we consider it to be necessary to evaluate sensory processing function and motor development in preterm infants and to take sensory-based approaches into account when planning intervention programs for more effective neurodevelopmental outcomes.

Recommendations for Future Research

In this study, we found no relationship between the duration of NICU stay and sensory processing. Future studies investigating the effect of NICU stay on sensory development, taking into account the intenseness of exposure to sensory stimuli in addition to the days spent in the NICU, will provide more effective results in defining exposure to sensory stimuli. Further research is also needed to investigate the short- and long-term effects of sensory processing problems on language, cognitive, emotional, and social development in addition to motor development encountered in the early developmental periods of preterm infants.

Implications for Occupational Therapy Practice

The findings of this study have the following implications for occupational therapy practice:

- There was a significant relationship between sensory processing and motor development in the preterm group. Therefore, the sensory processing problems encountered in the early developmental period may have adversely affected their motor development.
- Additionally, the evaluation of the sensory processing skills and the standard assessments in early follow-up clinics will contribute to the development of preterm infants.
- Informing pediatricians and neonatologists about SPDs through seminars, lectures, and workshops is important for screening preterm infants for SPDs, follow-up, and guidance for early intervention programs.
- Additionally, informing families with preterm infants about SPDs will be beneficial for the identification of sensory signs and symptoms in the early stages of the infants' lives.

Conclusion

It was determined that SPD was encountered at a high rate and that there were relationships between sensory processing and motor development in preterm infants. When the relationship between sensory processing and motor development in the preterm group was considered, evaluating sensory processing skills in addition to motor development in preterm infants was considered necessary for more effective physiotherapeutic evaluations and interventions. ▲

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