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Original Article

Timing of Elective Cesarean Section and Growth and Psychomotor Developmental Indices in 6-Month-Old Infants

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Abstract

Background: In the present study, we evaluated post-natal growth and psychomotor development status of infants at 6 months of age based on their gestational age at elective cesarean sections.

Methods: This is a prospective cohort study performed in 2014-2015 in Iran. The study population consisted of 6-month-old infants with gestational ages of 38–40 weeks delivered by elective cesarean section. The subjects were divided into 3 groups: Group A (neonates with gestational age of $38^{0/7}$ weeks), group B (neonates with gestational age of $39^{0/7}$ weeks), and group C (neonates with gestational age of $40^{6/7}$ weeks). At the infant age of 6 months, the mothers were called for follow-up visits. Growth and psychomotor status of all subjects were assessed by expert pediatricians based on the Age and Stage Questionnaires. Recorded data related to outcomes in neonatal period and 6 months later were analyzed to determine associations between groups' variables.

Results: A total of 952 subjects were found eligible for study participation. The mean birth weight, length and head circumference were significantly higher in group C compared with the other groups ($P=0.005$). Regarding growth parameters, a significant association was found between gestational age at birth and all other growth indices at 6 months of age ($P=0.005$). The mean weight at 6 months of age was higher in group B in comparison with group A ($P=0.001$) and C ($P=0.007$). Infants born at $38^{0/7}$ weeks were shorter in comparison with those born at $39^{0/7}$ ($P=0.002$) and $40^{6/7}$ weeks ($P=0.005$). Head circumference was significantly lower in group A than group B ($P=0.02$) and C ($P=0.05$). Regarding psychomotor indices at 6 months, a significant association was found between gestational age at birth and problem-solving skills ($P=0.003$). Delays in problem-solving skills were more frequent in neonates born at $38^{0/7}$ weeks compared with those born at $39^{0/7}$ ($P=0.005$) or $40^{6/7}$ weeks ($P=0.003$). This difference was also significant between the two groups who were born at $39^{0/7}$ and $40^{6/7}$ weeks ($P=0.01$).

Conclusion: The results from this study demonstrated that postponing the time of planned elective cesareans beyond 39 weeks of gestation may improve infant's growth and psychomotor outcomes.

Keywords: Elective cesarean, Gestational age, Growth and psychomotor development status, Infants, Timing of delivery

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Introduction

Cesarean section (CS) delivery is the most common obstetric surgery. The rate of CS is rising worldwide to improve perinatal and neonatal outcomes.[1] Elective or planned CS refers to a scheduled delivery based on maternal request or physician's recommendation. It may be performed based on the patient's right for selection of type of delivery or due to certain fetal-maternal indications such as chorioamnionitis, pelvic deformity resulting in cephalo-pelvic disproportion, life-threatening conditions (such as mother's heart disease or preeclampsia), abnormal placental location, fetal malpresentation or malposition and so on.[2] On the other hand, several studies have demonstrated that elective CS, similar to emergency caesarean sections, may increase the rate of maternal and neonatal morbidities.[3] Long recovery time and post-operative maternal complications, increased risk of neonatal respiratory distress even after 37 weeks of gestation, risk of hospitalization in the neonatal intensive care unit (NICU) for more than 7 days, unexplained stillbirth in following pregnancies, etc. have been shown among neonates born by elective caesarean section.[4-11]

Few studies have assessed the influence of different gestational ages at planned CS on infant's health outcome, growth status, and psychomotor developmental scores. Pirjani et al showed a positive relationship between elective CS at early-term gestation age and the risk of NICU admission.[12] Other investigations also revealed that infantile growth parameters, mental, psychomotor, and cognitive development indices might improve

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parallel to each additional week of gestation.[13,14] An inverse association has been reported between gestational age at planned delivery and risk of poor psychomotor development among children at school age.[15]

Correct timing of the elective CS is of importance to prevent neonatal, infantile and childhood morbidities. Although some studies within the past few years have examined the frequency of neonatal-maternal morbidities and mortalities, little information is available regarding the infantile growth and development. Considering the growing rate of CS in Iran during the past 30 years,[16] this study aimed to evaluate the post-natal growth and psychomotor development status in six-month-old infants with regard to their gestational age at time of elective CS (38–40 weeks). Such investigations may provide a more realistic picture regarding the risks and benefits associated with planned elective cesarean at different gestational ages.

Patients and Methods

Study Population and Study Design

A prospective cohort study was carried out at Arash hospital (Tehran, Iran) from April 2014 to April 2015. The study population consisted of 6-month-old infants with gestational ages of 38–40 weeks delivered by elective CS. The subjects were divided into 3 groups based on their gestational age at birth:

Group A involved neonates with gestational age of 38 $^{0/7}$ weeks.

Group B involved neonates with gestational age of 39 $^{0/7}$ weeks.

Group C included neonates with gestational age of 40 $^{6/7}$ weeks.

The inclusion criteria were singleton births at planned times ranging 38 to 40 weeks. Emergency CS before the determined deadline (due to irregularity in fetal heart rate, non-reactive non-stress test, chorioamnionitis, prolonged rupture of membrane and placental abruption), multiple gestation, congenital anomalies or infant's death, mentally ill parents and lack of parental consent were considered as exclusion criteria.

Parental data including mother and father's age, education, occupation, economic status, gravidity, parity, abortion, interval between pregnancies, underlying maternal disease and obstetrical complications, gestational age at time of CS (based on last menstrual period, and ultrasound examination at 11–13 weeks of pregnancy), causes of caesarean and postpartum complications (postpartum hemorrhage, infection, thromboembolism, hematoma at incision site, repeated hospitalization, blood transfusion and maternal death) were gathered from medical records.

Neonatal demographic information such as postnatal Ballard score, birth weight, length, head circumference, first and fifth minute Apgar scores, history of NICU hospitalization, duration of hospitalization, neonatal complications (still birth, neonatal mortality, Erb's palsy, respiratory distress syndrome, apnea, asphyxia, hypoglycemia; blood sugar <45 mg/dL, sepsis, hypothermia [rectal temperature <36.5°C], bradycardia [heart rate <100 beat/minute], presence of jaundice leading to phototherapy or blood exchange) and type of feeding (breastfeeding or formula) were also gathered and recorded.

Prior to the study, parents of the participating neonates were invited and briefed about the purpose of the study. The related questionnaires were also presented to them. Moreover, they were assured that they had the right to decline to take part in the research and to withdraw at any time. All participants signed an informed consent. The collected data were considered confidential and no extra cost was imposed on the participants.

In the appointed times, (when infants were 6 months old), the mothers were called for their infants' follow-up visits. Growth and psychomotor status of all subjects were assessed by expert pediatricians (who were blinded to the mode of delivery and the gestational age at birth) on the basis of Age and Stage Questionnaires® (ASQ-3). The ASQ was translated into Persian. In addition, in order to be administered among Iranian children, it was validated by the Children's Bureau of Ministry of Health and Medical Education in Iran. Its sensitivity and specificity were determined at 90% and 81–91%, respectively. The results and scores of the questionnaire were reported as normal or abnormal according to cutoff point for each domain written in the guideline (the cutoff was 29 for communication, 19 for gross motor, 27.5 for fine movement, 37 for problem solving, and 27.5 for social domain). The ASQ consists of 30 items (six questions in each of the five domains) to assess communication, personal-social, problem-solving ability, fine and gross motor control. Scores of 10, 5 and 0 are assigned to answers 'yes', 'sometimes' and 'not yet', respectively. Age-specific norms of < 2 standard deviations (SDs) were considered as ASQ fail for each domain.[17,18] Moreover, parents were asked to determine the time of parental-infant relationship (hours per day). The scores and gathered data were recorded in checklists. The main objective of our study was to determine the association between infants' growth and psychomotor development status of neonates at 6 months of age on the basis of their gestational age at birth. Some related factors like maternal complications were also compared between the three groups as secondary outcomes.

Data Analysis

The Statistical Package for Social Sciences (SPSS) version 23 was used for statistical analysis. Quantitative and qualitative data were reported as means ± standard deviations and frequency, respectively. Non-parametric Kolmogorov-Smirnov test (for non-normal distribution), ANOVA test (for normal distribution), as well as T and Chi-square tests were applied to analyze the associations between the groups' variables.

As our study was a prospective cohort study, 952 neonates (born by elective CS at 38 to 40 weeks of gestation from April 2014 to April 2015) entered the study. Based on an investigation by Rose et al (Santiago, Chile, 2013), Psychomotor Development Index (PDI) was related to GA (PDI in 38 weeks = 94.4 ± 14.6 and PDI in 40 weeks = 98.5 ± 15).[19] According to these parameters, the estimated sample size was determined to be 190 in each group; however, there was some missing data. Our study (952 cases totally) had a power of 80% and an alpha error of 0.05.

Results

In the beginning of the study, 1500 medical records of mothers with elective CS were registered. Of all records, 490 subjects were excluded due to parental dissatisfaction and incomplete information. A total of 952 infants were eligible for this study. Gestational ages of 551 (54.55%), 295 (29.21%) and 164 (16.4%) infants at birth were $38^{0/7}$, $39^{0/7}$ and $40^{6/7}$ weeks, respectively. The mean birth weight was 3241.21 ± 431.41 grams. Of these 952 infants, 523 (55.34%) were female. First minute Apgar score in 928 (91.88%) neonates was 9 and fifth minute Apgar score in 950 subjects (94.06%) was 10.

The mean age of infants' fathers was 32.91 ± 5.5 years. In terms of educational level, 35% of these fathers were below high school diploma. One hundred and eighty-eight fathers (18.6%) were workers whereas 43 fathers (4.2%) were unemployed. The mean age of mothers was 29 ± 5.35 years and 27.13% of mothers were below high school diploma. Regarding economic status, 917 (90.8%) of parents were home renters while 93 (9.2%) were homeowners.

Descriptive data related to maternal demographic and obstetric history is presented in Table 1. Characteristic data related to neonates are shown in Table 2.

Regarding postpartum complications, there was a significant association between postpartum hemorrhage and gestational age at CS (P = 0.02). Postpartum hemorrhage was more frequent in group B compared with the other groups (5.7% vs. 4.9% in group A and 0.6% in group C). Drop of hemoglobin level was more common in mothers in group B and C in comparison with group A (P = 0.005, P = 0.003, respectively). A significant positive association was observed between occurrence of postpartum infection and gestational age at birth (P = 0.01); nobody in group A, 0.3% in group B, and 2.4% in group C had postpartum infection. Postpartum hospitalization was longer in group A than the other groups (1.7 vs. 1.5 and 1.4 days; P = 0.0001).

Mean birth weight, length and head circumference were significantly higher in group C than groups A and B (P = 0.005). The differences were not significantly different between groups A and B (P = 0.9). There was a significant

Table 1. Demographic Data of Mothers

Variables	No. (%)
Gravidity	
1	258 (25.54)
2	432 (42.77)
3	222 (21.98)
Others	98 (9.40)
Parity	
0	352 (34.85)
1	510 (50.50)
2	132 (13.07)
3	16 (1.58)
History of stillbirth	30 (2.97)
History of abortion	261 (25.84)
Median interval between pregnancies (months)	66
History of underlying maternal complications	
No complications	864 (83.76)
Hypertensive disorder	26 (2.57)
Diabetes	15 (1.39)
Hypothyroidism	124 (12.28)
History of prenatal complications	
No complications	862 (85.35)
Thyroid complication	49 (4.85)
Gestational diabetes	80 (7.92)
Gestational hypertensive disorders	6 (59)
First trimester spotting	2 (0.20)
Others	19 (2.08)
Mean height (Cm)	162.23 ± 5.66
Mean weight (Kg)	78.65 ± 9.4
Mean BMI	29.9 ± 3.3
Cause of CS	
Repeat	510 (50.50)
Malpresentation (breech and transverse)	127 (12.57)
macrosomia	79 (7.02)
Postpartum complication	
Re-hospitalization	14 (1.39)
Postpartum hemorrhage	45 (4.46)
Hematoma at incision site	56 (5.54)
Infection of incision site	68 (6.73)
PID	5 (0.50)
Blood transfusion	9 (0. 89)

association between low first-minute Apgar score and low gestational age at CS (P = 0.026). No neonate in group B, 1.6% of neonates in group A and 0.6% of neonates in group C had Apgar scores <7. Regarding low first-minute Apgar score, a significant difference was observed between groups A and B (P = 0.009); however, this difference was not significant between groups A and C or groups B and C (P = 0.1 and P = 0.3). Also, there was no significant association between low fifth-minute Apgar score and gestational age at delivery (P = 0.142).

Growth Indices at 6 Months of Neonatal Age

Regarding growth parameters at 6 months, there was a significant relationship between gestational age at birth and growth indices at 6 months of age (P = 0.005). Detailed

Table 2. Infants' Demographic Data at Birth and 6 Months Later

Variables	Mean ± SD
Growth indices at birth	
Group A	3189.26 ± 421.24
Group B	3194.42 ± 406.88
Group C	3339.38 ± 464.07
Mean length (cm)	
Group A	48.68 ± 7.63
Group B	49.18 ± 5.29
Group C	49.61 ± 6.97
Mean HC (cm)	
Group A	34.64 ± 1.09
Group B	34.69 ± 1.06
Group C	35.00 ± 1.05
Growth indices at 6 months	
Group A	7076 ± 824
Group B	7241 ± 525
Group C	7238 ± 232
Height (cm)	
Group A	67.19 ± 0.118
Group B	67.89 ± 0.158
Group C	68.49 ± 0.238
HC (cm)	
Group A	43.46 ± 0.041
Group B	43.64 ± 0.054
Group C	43.79 ± 0.082
Developmental indices at 6 months of age	
Mean ASQ for communication	44.48 ± 6.72
- Normal ASQ, No. (%)	991(98.12)
Mean ASQ for gross motor	41.19 ± 9.71
- Normal ASQ, No. (%)	982(97.23)
Mean ASQ for fine movement	42.22 ± 8.05
- Normal ASQ, No. (%)	967(95.74)
Mean ASQ for problem solving	44.78 ± 6.25
- Normal ASQ, No. (%)	940(93.07)
Mean ASQ for social domain	41.96 ± 7.28
- Normal ASQ, No. (%)	984(97.43)

data are shown in Table 3. The mean weight at 6 months of age was higher in group B in comparison with group A (P = 0.001) and C (P = 0.007). However, the difference between groups A and C was not significant (P = 0.4). A significant association was observed between infant's weight gain during 6 months and underlying maternal complications (P = 0.005); Infants of mothers with a history of hypertensive disorders before pregnancy had the highest level of weight gain at 6 months of age (4371.53 ± 523.39 g) compared with those born to mothers with a history of other complications like maternal diabetes (4256.429 ± 512.4843 g) and thyroid complication (4009.435 ± 601.9282 g) or no complications (3875.29 ± 649.47 g). No associations were observed between infant's weight gain and prenatal complications (P = 0.1), parent's economic status (P = 0.08) or occupation (P = 0.9).

A significant relationship was found between height of infant at 6 months of age and gestational age at birth (P = 0.001). Infants who were born at 38 weeks of gestation were shorter in comparison with infants who were born at 39 (P = 0.002) and 40 weeks (P = 0.005). This association, however, was not significant between the ones born at 39 and 40 weeks of gestation (P = 0.08). Moreover, the mean increase in height at 6 months of age was significantly greater in group B compared to groups A and C (P = 0.002 and 0.005, respectively). A significant difference was observed between the increase in height and prenatal complications (P = 0.006); the mean increase in height in infants whose mothers had no complication, gestational diabetes, hypertensive disorders, thyroid complication or spotting in the first trimester was 17.63 ± 2.63, 17.80 ± 3.17, 16.87 ± 2.62, 19.66 ± 2.06, and 15 cm, respectively. Infants of mothers with a history of thyroid complication had the greatest increase in their height measures. No associations were observed between infant's height and underlying maternal complications (P = 0.4), parent's economic status (P = 0.06), or occupation (P = 0.1).

With regard to head circumference, this parameter was significantly lower in group A than groups B (P = 0.02) and C (P = 0.05). This difference was not significant between groups B and C (P = 0.3). The increase in head circumference during 6 months was not significantly different between the three groups (P = 0.09). A significant association was found between the mean increase in head circumference at 6 months of age and prenatal complications (P = 0.02); the mean increase in head circumference at 6 months of age among infants whose mothers had no prenatal complication, suffered from diabetes, hypertensive disorders, thyroid problems or spotting in the first trimester was 8.85 ± 0.97, 8.72 ± 0.80, 9.01 ± 0.69, 8.33 ± 0.51 and 9.00 cm, respectively. Infants

Table 3. Comparison of Neonatal Growth and Psychomotor Indices Between Groups at 6 Months of Age

Variables	Group A, n = 551	Group B, n = 295	Group C, n = 164	*P* Value
Growth indices (mean ± SD)				
Weight (g)	7076.82 ± 35.40	7241.52 ± 40.65	7238.23 ± 66.04	0.005
Length (cm)	67.19 ± 0.11	67.89 ± 0.15	68.49 ± 0.23	0.001
Head circumference	43.46 ± 0.41	43.46 ± 0.05	43.79 ±0.08	0.001
Abnormal psychomotor indices, No. (%)				
Communication	14 (2.54)	2 (0.68)	3 (1.83)	0.16
Gross motor	21 (3.81)	4 (1.36)	3 (1.83)	0.08
Fine movement	23 (4.17)	15 (5.08)	5 (3.05)	0.57
Problem-solving	52 (9.44)	12 (4.07)	6 (3.66)	0.003
Social domain	14 (2.54)	4 (1.36)	8 (4.88)	0.07

of mothers with a history of gestational hypertensive disorders had the highest increase in head circumference. A significant positive association was also observed between the mean increase in HC and parents' economic status ($P = 0.01$), while no association was observed between infant's HC, maternal underlying diseases ($P = 0.5$), or parent's occupation ($P = 0.5$).

Psychomotor Indices at 6 Months of Neonate's Age

Regarding psychomotor indices at 6 months, there was a significant association between gestational age at birth and problem-solving skills ($P = 0.003$). Delay in problem-solving skills (at 6 months) was more common among infants who were born at $38^{0/7}$ weeks compared with those born at $39^{0/7}$ (9.44% vs. 4.07%; $P = 0.005$) or $40^{6/7}$ weeks (9.44% vs. 3.66%; $P = 0.003$). The frequency of delay in problem-solving skills was also significant in groups who were born at $39^{0/7}$ and $40^{6/7}$ weeks (4.07% vs. 3.66%; $P = 0.01$). As detailed data show in Table 3, no significant difference was observed between groups regarding the frequency of abnormality in other psychomotor domains including communication ($P = 0.16$), gross motor ($P = 0.08$), fine motor ($P = 0.57$) or personal-social ($P = 0.07$).

Delay in psychomotor domains was significantly correlated with mother's education ($P = 0.009$). The results showed that 30% of infants with illiterate mothers had psychomotor delay in at least one domain while this rate was 17% among infants with highly educated mothers. Infant's gross motor and problem-solving skills were also significantly associated with father's education ($P = 0.005$, $P = 0.005$). We also found that paternal age was a significant influencing factor for infant's psychomotor abilities ($P = 0.005$); psychomotor delay in at least one domain was more frequent among infants of older mothers (with mean age = 31.2 years) or older fathers (with mean age = 34.7 years). A positive association was observed between parents' economic status and infant's psychomotor delay (32.3% of infants in homeowner families and 13.7% of infants in families living in rented homes showed delay in at least one domain; $P = 0.005$). In addition, infant's psychomotor delay was positively associated with the mother's gravidity ($P = 0.005$). This significant relationship was also found between infant's psychomotor delay and mother's underlying medical complications ($P = 0.05$); impaired psychomotor developmental status was more frequent among infants of mothers with a history of thyroid disorders. However, no significant association was observed between prenatal complication and psychomotor delay ($P = 0.3$). Our results indicated an inverse relationship between time of mother-infant relationship and psychomotor delay. The mean time was 4.7 hours for infants with delay in at least one psychomotor domain, while it was 5 hours among their healthy counterparts ($P = 0.04$).

General Linear Multivariate test was also undertaken to adjust for confounding factors (Table 4). Birth weight was an influencing factor for problem-solving and gross motor abilities ($P = 0.001$ and $P = 0.044$). The first- and fifth-minute Apgar scores also significantly affected communication ($P < 0.001$; $\beta = 0.193$, 95% CI: 1.23, 4.50 and $P = 0.040$; $\beta = -0.113$, 95% CI: -5.60, -0.08), gross movement ($P < 0.001$; $\beta = 0.252$, 95% CI: 3.08, 7.66 and $P = 0.024$; $\beta = -0.119$, 95% CI: -8.16, -0.40) and problem-solving domains ($P < 0.001$; $\beta = 0.305$, 95% CI: 2.706, 5.653 and $P < 0.001$; $\beta = -0.205$, 95% CI: -7.248, -2.257). As detailed data show in Tables 4 and 5, problem-solving and gross motor were independently correlated

Table 4. Associations Between Variables and Psychomotor Domains (General Linear Model)

Source	Dependent Variable	B	*P*-Value	95% CI
First-minute Apgar score	Communication	0.193	< 0.001	1.23–4.50
	Gross motor	0.252	< 0.001	3.08–7.66
	Fine motor	0.049	0.424	-1.07–2.81
	Problem-solving	0.305	< 0.001	2.706–5.653
Fifth-minute Apgar score	Communication	-0.113	0.040	-5.60–-0.08
	Gross motor	-0.119	0.024	-8.16–-0.40
	Fine motor	-.014	0.995	-3.701–2.896
	Problem-solving	-0.205	< 0.001	-7.248–-2.257
Birth weight	Communication	0.041	0.682	0.000–0.002
	Gross motor	0.080	0.044	0.000–0.003
	Fine motor	0.061	0.118	0.000–0.002
	Problem-solving	0.092	0.001	0.000–0.002
Gestational age	Communication	0.043	0.163	-0.15–0.81
	Gross motor	0.099	< 0.001	0.42–1.77
	Fine motor	0.19	0.681	-0.40–-0.74
	Problem-solving	0.096	0.039	0.247–1.119

Table 5. The Mean Differences Scores for Each Domain in Each Gestational Age (Post Hoc Analysis)

Dependent Variable	Gestational age	Mean Difference		*P*-Value	95% Confidence Interval	
					Lower Bound	Upper Bound
Communication	38	39	-0.7259	0.457	-1.9409	0.4891
		40	-1.0535	0.219	-2.4607	0.3537
	39	38	0.7259	0.457	-0.4891	1.9409
		40	-0.3276	1.000	-1.6641	1.0089
	40	38	1.0535	0.219	-.3537	2.4607
		39	0.3276	1.000	-1.0089	1.6641
Gross motor	38	39	-2.8847*	<0.001	-4.6267	-1.1427
		40	-3.2765*	<0.001	-5.2940	-1.2589
	39	38	2.8847*	<0.001	1.1427	4.6267
		40	-0.3918	1.000	-2.3080	1.5244
	40	38	3.2765*	<0.001	1.2589	5.2940
		39	0.3918	1.000	-1.5244	2.3080
Fine motor	38	39	-0.3423	1.000	-1.7935	1.1090
		40	-0.6029	1.000	-2.2838	1.0779
	39	38	.3423	1.000	-1.1090	1.7935
		40	-0.2607	1.000	-1.8570	1.3357
	40	38	0.6029	1.000	-1.0779	2.2838
		39	0.2607	1.000	-1.3357	1.8570
Problem-solving	38	39	-0.8348	0.227	-1.9612	0.2915
		40	-1.3412*	0.042	-2.6457	-0.0367
	39	38	0.8348	0.227	-0.2915	1.9612
		40	-0.5063	0.982	-1.7453	0.7326
	40	38	1.3412*	0.042	0.0367	2.6457
		39	0.5063	0.982	-0.7326	1.7453

with gestational age. According to post-hoc test, the mean score related to problem-solving in the $38^{0/7}$ weeks group was significantly lower than the $40^{6/7}$ weeks group (Mean Difference; -1.34; $P = 0.042$, 95% CI: -2.64, -0.03). In addition, gross motor scores in group A were significantly lower than both group B (Mean Difference; -2.8847; $P < 0.001$, 95% CI: -4.6267, -1.1427) and group C (Mean Difference; -3.2765; $P < 0.001$, 95% CI: -5.2940, -1.2589).

Discussion

Adverse neonatal outcomes related to preterm and postterm births are well documented by previous studies; however, timing of termination of a term pregnancy requires more investigation. In the present study, we assessed the association between different gestational ages at CS ($38^{0/7}$, $39^{0/7}$ and $40^{6/7}$ weeks) and infants' growth-psychomotor outcomes. The results of such studies can provide comparative information that guide continuing the pregnancy to potentially optimized risks of maternal and infantile morbidities.

According to the obtained results, the majority of elective CSs in our study were performed at $38^{0/7}$ weeks (54.55%) compared with delivery at $39^{0/7}$ (29.21%) and $40^{6/7}$ weeks (16.4%). Similarly, Wilmink et al showed that more than half of 20973 planned CSs were carried out before 39 weeks.[20] However, several investigations indicated the necessity of avoiding non-indicated C/S before 39 weeks to decrease the risk of morbidities.[21,22] Wilmink et al also demonstrated that although the trend of elective CS before 39 weeks was decreasing from 56% to 43% (from 2000 to 2010 in the Netherlands), more elective CSs were performed before 39 weeks of gestation in peripheral hospitals (not academic hospitals).[18]

Based on the results, the mean values of growth parameters (birth weight, length, and head circumference) in newborns born at 40 weeks were significantly higher than the other groups. Our results are in line with the findings of a study by Korzhynskyy et al who demonstrated an increasing trend in birth weight according to gestational age of 366 607 full term boy and girl newborns; the median ranges of birth weight were 3160 g (at 38 weeks) to 3500 g (at 40 weeks) for boys and 3060 g (at 38 weeks) to 3360 g (at 40 weeks) for girls (23). Rose et al have also shown a significant positive association between birth weight and increased gestational age from 38 to 40 weeks ($P = 0.03$).[19]

According to the results, there was a significant positive association between first-minute Apgar score and gestational age at CS. It is clear that gestational age and its influence on birth weight could affect first-minute Apgar score and its related neonatal adverse outcomes. Another study also reported that postponing a planned CS beyond 39 weeks can decrease 48% of adverse neonatal outcomes including Apgar scores of 3 or below. Although, we did not find any difference between groups B and C regarding first-minute Agar score in our study, Tita et al indicated that delaying delivery beyond 40 weeks increases the risks of neonatal complication compared with delivery at 39 weeks.[24] Another study by Vidic et al showed a significant association between low gestational age and high rate of Apgar scores <7 among 7364 neonates born at 37, 38, 39, 40, and 41 weeks ($P = 0.013$).[25]

We found that gestational age at birth, even in term newborns, could significantly influence anthropometric values of neonates at 6 months of age. Weight and height of 6-month-old infants born at 39 weeks were significantly higher than those born at 38 and 40 weeks. Moreover, head circumferences of infants born at 38 weeks were significantly lower than the other groups. McCowan et al reported that neonates' weight, length and HC at 6 months could be predicted by these measures at birth. They showed that failure of catch-up growth was remarkable among infants with lower birth weight, length, and HC measures during the first 6 months. They also indicated that sex of an infant can influence these parameters. In our study, however, we did not assess this association between growth indices at 6 months and sex of infant.[26]

According to the results of the present study, the range of weight gain and increase in length and HC parameters within the first 6 months were more notable among infants born to women with some prenatal or underlying complications compared with those of uncomplicated mothers. Of all infants, those born to mothers with a history of hypertensive disorders before pregnancy, thyroid complication and history of gestation-related hypertensive disorders had the highest increase in weight, height, and head circumference dimensions. Other investigations have also underpinned the remarkable postnatal growth as compensatory or catch-up growth in infants with growth restriction due to maternal complications. In addition, some studies have reported that the greatest postnatal catch-up growth occurs in the first year, particularly within in the first 6 months of life. Some hormones and growth regulatory mechanisms including IGF-1, IGF-2 and Ghrelin are involved in such compensatory responses.[24,25] Consistent with our finding, Pizzi et al have indicated that infantile growth parameters of size are under influence of some prenatal and maternal characteristics like maternal hypertension, smoking, pre-pregnancy weight, etc.[27]

Our results also demonstrated a significant association between gestational age at birth and some psychomotor abilities at 6 months. Delay in problem-solving was more common among 6-month-old infants born at 38 weeks compared with those born at 39 and 40 weeks. In addition, this complication was less common in neonates born at 40 weeks in comparison with the other groups. Our finding confirms previous studies regarding the importance of longer gestation in full-term infants and its benefits for psychomotor development. Consistent with our results, Dueker et al pointed to lower gestational age (from 35–41 weeks) as a predictive risk factor for delay in problem-solving during the first two years of life.[28] Espel et al showed a significant association between longer gestations (37–41 weeks) and enhanced mental and motor development at 1, 3, 6, and 12 months of age.[29] Rose et al. demonstrated that each additional week of gestation could increase the mental and psychomotor indices by 0.8 (95% CI: 0.2–1.4) and 1.4 (95% CI: 0.6–2.1) in 1657 full term infants born at gestational age of 37–42 weeks. They also added that this association was more notable at gestational ages 39–41 weeks compared to others (37-38 weeks). These findings confirm the importance of intrauterine milieu for brain maturation.[23] Yang et al have also shown a significant positive association between the mean IQ of 6.5-year-old children and each completed week of gestation from 37 to 40 weeks at birth. They also indicated that the cognitive ability in children with gestational age of 37 and 38 weeks was lower compared to those born after 38 weeks of gestation.[30]

According to our results, the frequency of each psychomotor delay was significantly correlated with some factors like mother's education, paternal age, and parent's economic status, as well as the number of mother's gravidity, medical complications and quality of mother-infant relationship. Similar to our results, Lung et al indicated the influence of 12 factors on infant's developmental status at 6 months, including mother's education level, parental age, number of siblings, maternal health status, etc.[31,32]

In our study, a significant difference was found between the three groups regarding maternal postpartum complications. Postpartum hemorrhage, anemia, infection and prolonged hospitalization were significantly more frequent in group B, groups B and C, group C, and group A, respectively. It is supposed that some other factors like neonate's birth weight, duration of surgery, and type of anesthesia may be involved. This finding, however, is not supported by other studies; Glavind et al demonstrated no significant differences with respect to maternal postpartum adverse events in two groups with elective CS at 38 and 39 weeks.[33] In another investigation , they also demonstrated no significant difference regarding hysterectomy or serious thromboembolic complication between groups; however, postpartum hemorrhage >500 mL was significantly higher in mothers with CS delivery at 38 weeks compared with mothers with CS delivery at 39 weeks (21.7 vs. 17.1%).[34] Hu et al also showed no significant differences in maternal adverse outcomes including mild to severe postpartum hemorrhage, infection, hospitalization or embolism based on the timing of delivery from 37 to 41 weeks of gestation.[35]

Consistent with the study by Eickmann et al,[36] we also found that Apgar scores and birth weight could be significant factors for some psychomotor domains, like problem-solving and gross movement. They indicated that among 135 preterm and term infants aged 6 to 12 months, neuropsychomotor development was significantly influenced by both birth weight and Apgar scores.

Strengths and Limitations

The strengths of our study include assessment of the influence of gestational age at elective CS on infant's growth and neurodevelopmental outcomes. Our large sample size was composed of 952 full-term neonates which could provide valuable informative and comparative data for future studies. Regarding the limitations of the study, it should be noted that we did follow neurodevelopmental status after 6 months of age to determine whether or not psychomotor impairment persists into childhood. We ignored some factors and did not assess their associations with growth and neurodevelopment status, like type of infant's feeding, infant's sex, type of anesthesia, and duration of operation. Nor did we compare the obtained results with delaying delivery beyond 40 weeks. Such information may provide further reliable and helpful findings.

In conclusion, the results of the present study indicate that postponing the timing of planned elective CSs beyond 39 weeks of gestation might improve the infant's growth and psychomotor outcomes. On the other hand, it may not beneficial for mothers in terms of some maternal morbidity. Thus, more extensive investigations are strongly needed.

Authors' Contribution

MS and ME carried out the design and coordinated the study, participated in most of the experiments. MSh and ZKS, MZ and NH coordinated and carried out all the experiments, Analysis of data and participated in manuscript preparation. They also provided assistance for all experiments and prepared the manuscript. All authors have read and approved the content of the manuscript.

Conflict of Interest Disclosures

None to be declared.

Ethical Statement

Ethical approval for the study was obtained from the institutional review board of Tehran University of Medical Sciences according to Helsinki declaration (with ID 1395-22334).

Consent to Participate

At the beginning of the study, all participants signed an informed consent. Our paper does not include any details related to an individual person.

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