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ORIGINAL RESEARCH

Evaluation of motor development and effect of physical therapy intervention in surgical neonates in a Neonatal Intensive Care Unit

Avaliação do desenvolvimento motor e do efeito da intervenção fisioterapêutica em recém-nascidos cirúrgicos em Unidade de Terapia Intensiva Neonatal

Evaluación del desarrollo motor y del efecto de la intervención de la fisioterapia en recién nacidos quirúrgicos en una Unidad de Cuidados Intensivos Neonatal

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ABSTRACT | This study aimed to verify the applicability of the Test of Infant Motor Performance (TIMP) in surgical neonates as a tool for evaluating motor performance and to evaluate the benefit of physical therapy. Surgical neonates, divided into group without physical therapy (n=38) and group with motor physical therapy (n=38), were evaluated by TIMP and reasssment two weeks later. The physical therapy group performed standardized exercises for motor sensory stimulation once a day, whereas the other group received the usual care from the Neonatal Intensive Care Unit. The predominant surgical diagnosis in both groups was gastroschisis, followed by congenital diaphragmatic hernia. In the initial evaluation, motor performance was equal between the groups, classified as "below average" for age, with z-score=−1.28 (p=0.992). In the reassessment, the physical therapy group presented better scores (p<0.001) and a higher difference in z-score (p<0.001), higher percentage of neonates classified as "within average" (44% in the physical therapy group and 2.6% in the no physical therapy group), as well as a higher weight gain percentage (p=0.038). We found a worsening of motor performance in 10.5% of the no physical therapy group (p<0.001) in the reassment. Motor performance improved in 81.6% of the physical therapy group and in only 13.2% of the no physical therapy group individuals (p<0.001). Conclusion: TIMP was safely and effectively applied to newborns; notably, the test must be performed by professionals experienced in care of neonates. Motor intervention was beneficial, significantly improving motor performance, and if applied early, it may adequate the motor development of these neonates, even before hospital discharge.

Keywords | Child Development; Congenital Abnormalities; Surgical Procedures Operative; Physical Therapy.

RESUMO | O objetivo do estudo foi verificar a aplicabilidade do *Test of Infant Motor Performance* (TIMP) em recém-nascidos (RN) cirúrgicos como ferramenta para avaliação do desempenho motor; e avaliar o benefício da fisioterapia. RN cirúrgicos, divididos em grupo sem fisioterapia motora (n=38) e com fisioterapia motora (n=38), foram avaliados pelo TIMP e reavaliados duas semanas depois. O grupo com

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fisioterapia realizou exercícios para estimulação sensório-motora uma vez ao dia, enquanto o grupo sem fisioterapia recebeu os cuidados habituais da Unidade de Terapia Intensiva Neonatal (UTIN). O diagnóstico cirúrgico predominante nos dois grupos foi de gastrosquise, seguido de hérnia diafragmática congênita. Na avaliação, não houve diferença no desempenho motor entre os grupos, classificados como "abaixo da média" para a idade, com escore-z=−1,28 (p=0,992). Na reavaliação, o grupo com fisioterapia apresentou melhor pontuação (p<0,001) e maior diferença de escore (p<0,001), com uma porcentagem maior de RN classificados como "dentro da média" em comparação ao grupo sem fisioterapia (44% e 2,6%, respectivamente); além de maior porcentagem de ganho de peso (p=0,038). Na reavaliação, verificou-se piora do desempenho motor em 10,5% do grupo sem fisioterapia (p<0,001), enquanto a melhora do desempenho motor foi observada em 81,6% do grupo com fisioterapia e em apenas 13,2% do grupo sem fisioterapia (p<0,001). Concluiu-se que o TIMP foi aplicado de forma segura e eficaz e necessita ser realizado por profissionais experientes na abordagem dessa população. A fisioterapia motora melhorou significativamente o desempenho motor, e, se iniciada precocemente, pode ser capaz de adequar o desenvolvimento motor desses RN, antes mesmo da alta hospitalar.

Descritores | Desenvolvimento Infantil; Anormalidades Congênitas; Procedimentos Cirúrgicos Operatórios; Fisioterapia.

RESUMEN | El objetivo de este estudio fue verificar la aplicabilidad del *Test of Infant Motor Performance* (TIMP) en recién nacidos quirúrgicos (RN) como una herramienta de evaluación del desempeño motor, y analizar el beneficio de la fisioterapia. Los RN quirúrgicos, divididos en los grupos sin fisioterapia motora (n=38) y con fisioterapia (n=38), fueron evaluados por el TIMP y reevaluados dos semanas después. El grupo con fisioterapia realizó ejercicios de estimulación sensoriomotora una vez al día, mientras que el grupo sin fisioterapia recibió la atención habitual de la Unidad de Cuidados Intensivos Neonatal (UCIN). El diagnóstico quirúrgico predominante en ambos grupos fue el de la gastrosquisis, seguido de hernia diafragmática congénita. En la evaluación, no hubo diferencia en el desempeño motor entre los grupos, clasificados como "por debajo del promedio" para la edad, con puntaje -z=−1,28 (p=0,992). En la reevaluación, el grupo con fisioterapia tuvo mejor puntuación (p<0,001) y mayor diferencia de puntaje (p<0,001), con mayor porcentaje de RN clasificados como "dentro de la media" en comparación con el grupo sin fisioterapia (44% y 2,6%, respectivamente); además de un mayor porcentaje de ganancia de peso (p=0,038). En la reevaluación hubo un empeoramiento del desempeño motor en el 10,5% del grupo sin fisioterapia (p<0,001), mientras que se observó una mejora en el desempeño motor en el 81,6% del grupo con fisioterapia y solo en el 13,2% del grupo sin fisioterapia (p<0,001). Se concluyó que el TIMP se aplicó con seguridad y eficacia y que este debe ser realizado por profesionales con experiencia con esta población. La fisioterapia motora mejoró significativamente el rendimiento motor y, si se inicia precozmente, puede ser capaz de adaptar el desarrollo motor de estos RN, incluso antes del alta hospitalaria.

Palabras clave | Desarrollo Infantil; Anomalías Congénitas; Procedimientos Quirúrgicos Operativos; Fisioterapia.

INTRODUCTION

The advances in neonatal and pediatric care, as well as in surgical procedures, improved the survival of neonates with congenital malformations and requiring surgery. However, such advances increased the concerns of multidisciplinary team with quality of life, reduction of complications, and neuropsychomotor development (NPMD) of neonates since the effects of morbidities can extend to adulthood[1].

Neonates requiring surgical treatment need intensive care and are exposed to several risks to their NPMD[2]. These neonates are exposed to pain, general anesthesia, prolonged sedoanalgesia, bed restriction, need for mechanical pulmonary ventilation, difficulty in diet progression, low weight gain, and longer hospital stay, besides being more susceptible to infections[3].

To minimize the deleterious effects of hospitalization in the Neonatal Intensive Care Unit (NICU) and to identify neonates at risk of developmental delay, validated and standardized tools should be used for evaluation[4], such as the Test of Infant Motor Performance (TIMP)[5]. Interventions that stimulate the somatosensory and kinesthetic system can be performed in neonates to reduce the adverse effects of hospitalization and facilitate motor and behavioral organization[6]. The literature lacks studies evaluating the motor performance of non-cardiac surgical neonates by the TIMP and the effect of sensorimotor intervention in this population still during hospitalization in the NICU. The TIMP allows for evaluating motor development and the effect of physical therapy intervention, from preterm neonates to infants, being the tool analyzed in this study since it

allows for early evaluation of neonates and follow-up in cases of prolonged hospitalization time in NICU until the four months of age.

METHODOLOGY

The guardians of the children signed the informed consent form.

This is a prospective study, with a sample randomly distributed in two groups (group with motor physical therapy and group without physical therapy). Premature and term neonates admitted from August 2017 to February 2020 at the Neonatal Intensive Care Unit 2 (NICU-2) of the Institute of the Child and Adolescent of the School of Medicine of the Universidade de São Paulo, subjected to surgical procedures (major thoracoabdominal) and who had: corrected gestational age at the time of motor evaluation from 34 weeks to 4 months post-term; minimum of 3 days of life; and spontaneous breathing in room air or in a low-flow oxygen nasal catheter (less than 1L/min).

Neonates or infants who presented restriction for evaluation in ventral decubitus; malformations of the central nervous system; hemodynamic instability; orthopedic restrictions; complex congenital heart disease with hemodynamic repercussion; thrombosis; peri-intraventricular hemorrhages (PIVH) grades III and IV; hypoxic-ischemic encephalopathy; severe asphyxia; genetic syndromes; short intestine with dependence on parenteral nutrition; and incomplete medical records were excluded. Neonates who died or who were transferred or discharged before the study period were also excluded.

The TIMP motor evaluation was performed by the responsible researcher, trained and certified for applying the test. Both groups were evaluated after clinical stability in the postoperative period, provided that the state of alertness necessary for evaluation was respected (state 3, 4, or 5, according to the Brazelton scale), and the neonates where not vigorous crying for 15 seconds. Applying the test can take 30–40 minutes on average and comprises 42 items (consisting of 13 observable and 29 testable items), totaling 142 points at maximum. Based on the sum of the points (gross score), the z-score is calculated using a normative table. Motor performance is then classified as "within average" for age, "low average," "below average," or "far below average," according to test standards[7].

The neonates were reassment two weeks after the initial evaluation, in which information on birth, hospitalization, surgical diagnosis, and motor evaluation data were recorded for analysis.

Neonates in the motor physical therapy group were observed after the first evaluation and remained in care once a day. During the stimulation period, the neonate's weight and vital signs (heart rate, respiratory rate, and peripheral oxygen saturation) were collected daily immediately before and after the intervention. Motor stimulation was performed via two protocols, according to corrected age: (1) protocol starting from 34 weeks to 39 weeks and 6 days of corrected age; and (2) protocol starting from 40 weeks of corrected age.

The first protocol is based on the multisensory intervention ATVV (Auditory, Tactile, Visual, and Vestibular stimulation)[8] and consists of: hearing stimulation with soft voice of the therapist for 30 seconds; tactile stimulation added to the auditory (respecting the sequence: scalp, posterior trunk, neck, upper limbs, abdomen, alba line, lower limbs, and face) for 10 minutes; and, finally, vestibular stimulation in the therapist's lap for five minutes, maintaining auditory and visual stimulation with eye to eye contact[8].

The second protocol was based on studies by Lee and Galloway[9], directed to term neonates and infants. Exercises appropriate to the NICU environment and that were easily replicable were selected, plus handling methods already performed in physical therapy care at NICU-2. This protocol consists of: auditory stimulation with the therapist's voice for one minute; tactile stimulation (upper and lower limbs in supine position, posterior trunk in sitting position with support of cervical, scalp, and face) for three minutes; midline stimulation (hand-to-hand movement) for two minutes; cervical and postural control training (in elevated prone position or in the lap associated with visual and auditory stimulation with voice, the therapist's face, and a toy) for six minutes; pull-to-sit training for three minutes; and, at the end, vestibular stimulation in the lap for three minutes.

The group without physical therapy received the usual care of the NICU by the multidisciplinary team.

Statistical analysis

The sample was not calculated, and therefore a convenience sample was used. The results were obtained by the IBM SPSS Statistics version 20.0 and Statistica version 12.0 software programs. The comparison between the groups—considering the primary outcome of the z-score of the evaluation test (TIMP), the socioeconomic variables, and the secondary outcomes of clinical data—was performed by comparing

means (Student's t-test), form quantitative variables, and distributions (Fisher's exact test), for qualitative variables. The z-score of the TIMP and the secondary outcomes (heart rate, respiratory rate, and peripheral oxygen saturation of neonates with motor physical therapy, to measure their improvement) was compared by using the paired Student's t-test. For all analyses, $p<0.05$ was considered significant.

RESULTS

During the study, 245 neonates with surgical diagnoses were admitted. Out of these, 169 were removed by exclusion criteria (death, hospital discharge, transfer to another inpatient unit, or to the hospital of origin), totaling 76 neonates for the final analysis, with 38 in the group without physical therapy and 38 in the group with motor physical therapy.

Table 1 shows birth, surgical, and hospitalization data, with no statistical differences between groups. In the sample analyzed, seven neonates were clinically diagnosed with convulsion, with five undergoing electroencephalogram tests. Only three neonates presented alterations in the electroencephalogram, but all presented cranial ultrasound within the normal range.

Table 1. Birth, surgical, and hospitalization data

Birth, surgical, and hospitalization data	Without physical therapy n=38	With motor physical therapy n=38	p-value
Sex – n (%)			0.647*
Female	21 (55.3)	18 (47.4)	
Male	17 (44.7)	20 (52.6)	
Gestational Age at Birth (weeks)			0.403**
Mean (SD)	37.1 (2.32)	36.6 (2.12)	
Birth weight (g) – Mean (SD)	2,600 (592.02)	2,365 (504.49)	0.14**
Surgical diagnosis – n (%)			0.103*
Gastroschisis	15 (39.5)	20 (52.6)	
Congenital diaphragmatic hernia	10 (26.3)	9 (23.7)	
Esophageal atresia	5 (13.2)	6 (15.8)	
Gastrointestinal issues	8 (21)	1 (2.6)	
Omphalocele	0 (0)	1 (2.6)	
Others	0 (0)	1 (2.6)	
Use of sedoanalgesia – n (%)	37 (97.4)	37 (97.4)	1.000**
Median (min-max)	10.5 (0–154)	10 (0–103)	
TI length (days)			0.926**
Median (min-max)	5 (1–73)	4.5 (1–83)	
Complications – n (%)			0.587*
Sepsis	24 (32.9)	18 (32.1)	
Pulmonary complications	23 (31.5)	17 (30.4)	
Gastrointestinal complications	6 (8.2)	3 (5.4)	
Surgical complications.	4 (5.5)	5 (8.9)	
Neurological complications	9 (12.3)	10 (17.9)	
Shock	6 (8.2)	1 (1.8)	
Cardiorespiratory arrest	1 (1.4)	2 (3.6)	
Transfontanellar ultrasound – n (%)			0.597*
Not performed	2 (5.3)	6 (15.8)	
Normal	28 (73.7)	26 (68.4)	
PIVH grade I	6 (15.8)	5 (13.2)	
Periventricular leukomalacia	1 (2.6)	0 (0)	
Discrete ventricular dilation	1 (2.6)	1 (2.6)	
Electroencephalogram – n (%)			0.240*
Not performed	37 (97.4)	34 (89.5)	
Normal	1 (2.6)	1 (2.6)	
Altered	0 (0)	3 (7.9)	
Length of hospitalization (days)			0.914**
Median (min-max)	36 (14–154)	33 (16–146%)	

SD=standard deviation; g=grams; min-max=minimum-maximum; TI=tracheal intubation; PIVH=peri-intraventricular hemorrhage; *Fisher's exact test; **Student's t-test.

Table 2 shows the data collected on the day of TIMP motor evaluation and reassment. The difference in the z-score of the evaluation and reassessment was greater in the motor physical therapy group, indicating greater evolution in this group.

Table 2. Data on motor evaluation and reassessment by the Test of Infant Motor Performance

Motor Assessment Data (TIMP)	Without physical therapy n=38	With motor physical therapy n=38	P-value*
CGA in the initial evaluation (weeks) – Mean (SD)	40.0 (3.37)	38.8 (2.84)	0.118
Days of life in the initial evaluation			0.237
Median (min-max)	16 (4-84)	9 (4-94)	
Weight in the initial evaluation (g) – Mean (SD)	2,946.1 (856.73)	2,571.1 (551.36)	0.026
Weight in the reassessment (g) – Mean (SD)	3,185.7 (790.25)	2,886.8 (516.96)	0.055
Weight variation per day (%) – Mean (SD)	0.68 (0.51)	0.95 (0.62)	0.038
Z-score in the evaluation – Mean (SD)	−1.28 (0.46)	−1.28 (0.42)	0.992
Z-score in the reassessment – Mean (SD)	−1.26 (0.42)	−0.55 (0.51)	<0.001
Difference in the z-score of the evaluation and reassessment			
Mean (SD)	0.05 (0.318)	0.74 (0.331)	<0.001
Median (min-max)	0.04 (−0.68–0.53)	0.46 (0.11–1.40)	

CGA=corrected gestational age; SD=standard deviation; min-max=minimum-maximum; g=grams; *Student's t-test.

Regarding the comparison of the classification of the evaluation and reassessment, according to the TIMP, adjusting the motor development for the corrected age was possible in 44.7% of the neonates in the group with motor physical therapy. Table 3 shows that the comparison between the groups was statistically significant, with p<0.001.

Table 4 shows vital signs collected immediately before and after the intervention.

Table 3. Comparison of motor performance classification according to the Test of Infant Motor Performance between the evaluation and the reassessment

Comparison of evaluation × reassessment classification – n (%)	Without physical therapy n=38	With motor physical therapy n=38	P-value*
Worse score	4 (10.5)	0 (0)	
No score change	29 (76.3)	7 (18.4)	
Better score	5 (13.2)	31 (81.6)	<0.001
"Within average" evaluation	1 (2.6)	1 (2.6)	
"Within average" reassessment	1 (2.6)	31 (44.7)	

*Student's t-test

Table 4. Vital signs before and after motor intervention of neonates in the group with motor physical therapy

Vital Signs Motor physical therapy n=38	Pre-Physical therapy	Post-Physical therapy	Difference in vital signs	% Change	P-value*
HR (bpm)					
Mean (SD)	160.2 (15.54)	152.1 (13.93)	−8.2 (14.44)	−0.046 (−8.99)	<0.001
Median (min-max)	160 (109-199)	152 (112–192)	−7 (−67–49)	−4.6 (−33.8–41.2)	
RR (bpm)					
Mean (SD)	55.5 (9.30)	50.7 (8.62)	−4.8 (7.35)	−0.079 (12.65)	<0.001
Median (min-max)	56 (25–86)	50 (22–78)	−5 (−30–20)	−8.6 (−46.7–42.6)	
SpO2 (%)					
Mean (SD)	96.3 (2.56)	98 (1.92)	1.8 (2.11)	0.019 (2.26)	<0.001

HR=heart rate; bpm=beats per minute; SD=standard deviation; min-max=minimum-maximum; RR=respiratory rate; bpm=breaths per minute; SpO_2=peripheral oxygen saturation; *Paired Student's t-test.

Of the 76 neonates included in the study: 94.7% (n=36) of the group without motor physical therapy were discharged from the hospital and 5.3% (n=2) were transferred to the hospital of origin; of the group with motor physical therapy, 89.5% (n=34) were discharged from the hospital, 7.9% (n=3) were transferred to the hospital of origin after the study period, and 2.6% (n=1) were transferred to another inpatient unit (infirmary) of the Institute of the Child and Adolescent.

DISCUSSION

Early evaluation and identification of developmental changes are important for making appropriate interventions. During neonatal period, the brain plasticity occurs more intensely and, therefore, strategies to calm and to organize neonates should be performed, stimulating typical patterns, midline movements, and spontaneous activity[10].

In 2016, Stolwijk et al.[11] conducted a systematic review that showed motor delay in about 25% of children—evaluated at 1 and 2 years of age by the Bayley Scale of Child Development—undergoing non-cardiac surgeries in the neonatal period with a variation of 0 to 77%. The meta-analysis comprised 511 children who had congenital diaphragmatic hernia, gastroschisis, and esophageal atresia as surgical diagnosis, without associated genetic syndromes. The authors observed mean scores of 0.5 (standard deviation) below the normative population without the anomalies.

This study could identify the delay in motor development of neonates who underwent non-cardiac surgeries in the first TIMP assessment in 97.3% of the group without physical therapy and in 97.4% of the group with motor physical therapy. In both groups, most of the sample was classified as "below average" for their age (78.9% and 73.7%, respectively), followed by "low average" (15.8% and 21.1%, respectively), and "far below average" (2.6% in both groups). Only one neonate from each group (2.6%) was classified, according to the TIMP, as "within average" for their age in the initial evaluation and the remainder was classified as atypical development. The most frequent surgical diagnoses were also gastroschisis, congenital diaphragmatic hernia, and esophageal atresia.

Assessment instruments that are validated and viable for NICU neonates should consider the fragility of this population and the complexity of handling. In 2017, Craciunoiu and Holsti[4] conducted a systematic review of the main evaluation tools used in NICU, showing that TIMP and General Movements had greater predictive validity and greater association with neurological outcomes. This study used the TIMP since motor evaluation of surgical neonates is only possible after clinical stability, good recovery, satisfactory postoperative evolution, and good tolerance to handling. We found no studies in the literature using TIMP in non-cardiac surgical neonates during NICU admission.

The TIMP can evaluate the effects of the sensory-motor intervention and help the physical therapy team to trace conducts directed to the needs of each patient. In 2016, Ustad et al.[12] conducted a multicenter, controlled, and randomized study involving 153 preterm neonates (PTN) and evaluated the effect of the sensory-motor intervention performed by parents, supervised and guided by physical therapists in the NICU with the TIMP. The group with motor physical therapy showed a significant improvement ($p=0.005$), with a mean z-score difference between the evaluation and the reassessment of 0.42, indicating improvement in the z-score after motor intervention. Although the populations studied are different, evaluating the effect of motor intervention was also possible in this study, with improvement of the z-score.

For three decades, methods and ways to reduce the pain and stress of neonates in the NICU have been investigated, such as the use of massage[13]. In 2019, Elsagh et al.[14] conducted a randomized controlled study with 75 PTN divided into a control group, intervention group (massage for 10–15 minutes), and positioning group (prone position) for five days. They verified that heart rate decreased in the intervention and positioning group ($p<0.001$), whereas oxygen saturation increased—which did not occur in the control group ($p<0.001$)—and may reflect the effect of massage due to greater relaxation and better response of the vagal system[14].

This study, although evaluating a distinct population with TIMP, also showed positive responses to the method, demonstrating greater relaxation during the physical therapy session, with consequent reduction in heart and respiratory rate and increased oxygen saturation. The improvement of vital signs indicates the benefits and safety of stimulation in surgical neonates.

The surgical neonates presented different severities and limitations for evaluation and beginning of sensorimotor stimulation, such as: pain; complications with the surgical wound; presence of drains; probes; central venous catheter; peripheral venous accesses; low acceptance of diet; and low weight gain. However, performing the TIMP in this population was possible, respecting the appropriate time for evaluation (which occurred between 15 and 20 days, on average). The intervention by physical therapy proved to be beneficial, with significant improvement in vital signs. In addition, the group with motor physical therapy had greater weight gain in percentage, which is beneficial for surgical patients, who mostly had gastrointestinal malformations.

CONCLUSION

TIMP can be applied in surgical neonates and should be performed by professionals experienced in handling this population. It proved a viable tool for evaluating neonates, from premature infants to infants, restricted to bed, with prolonged hospitalization time. The exercises were safe, improved vital signs and weight gain, significantly increased scores and favored the typical development for age in the reassessment. If the intervention is initiated early, it may adequate the motor development of these neonates even before hospital discharge.

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