

# The importance of assessing general motor activity in premature infants for predicting neurological outcomes

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## Abstract

**Introduction:** Conventional methods of neurological assessment of infants can detect nervous system damage, but also have a weakness, i.e., the inability to make predictions for neurological deficits. Prechtl's general movement assessment is a diagnostic tool for the functional assessment of young nervous system. The aim of the study was to assess the quality of spontaneous motor activity in preterm newborns as well as to determine the neurological outcome at the age of 24 months. After that, the predictive value of spontaneous motor activity for neuro-developmental outcome at the age of 24 months was determined.

**Material and methods:** The study included 160 pre-terms children, and designed as a prospective clinical study. Observation of spontaneous motor activity was performed according to the principles of Prechtl's method.

**Results:** Spontaneous motor activity was observed in three periods for each newborn: within 5 days of birth, in the period of 44-46 gestation weeks, and in the period of 50-54 gestation weeks of post-menstrual age. Neurological outcome was assessed at the age of 24 months, and was classified as: normal finding, minimal neurological dysfunction, and cerebral palsy. All preterms, who presented normal patterns of spontaneous movements in neonatal and infant periods had a normal neurological functional outcomes at the age of 24 months. Newborns with pathological patterns of movement (cramped synchronized and absence of fidgety movements) in neonate and infant periods in the final outcomes had minimal neurological dysfunction or cerebral palsy.

**Conclusions:** Assessment of general movement in preterms is a valuable method in prediction of dysfunctions in later neurological development. Early detection of symptoms of minimal neurological deficit and cerebral palsy is of crucial importance since it enables timely inclusion of children into neuro-developmental treatment.

**Key words:** preterm infants, general movements, Prechtl's method, neuro-developmental outcome.

## Introduction

According to the definition of the International Organization for the Registration and Monitoring of Cerebral Palsy in Europe, Surveillance of Cerebral Palsy in Europe (SCPE), cerebral palsy (CP) or childhood cerebral palsy is a group of non-progressive but often variable symptoms of motor impairment, movement,

posture, and other damage, resulting from abnormalities or lesions of the brain in early stages of development [13]. A definition proposed by Rosenbaum (2007) is: CP includes a group of developmental disorders of movement and posture, which cause limited activity, and are caused by a non-progressive brain lesion in the development of the fetus or newborn. Consensus was reached at a scientific conference held the same

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year in Bethesda, USA, and this definition was accepted. In addition to motor disorders that are dominant, CP is often associated with other associated disorders, including epilepsy, sensory, cognitive, intellectual, emotional, and behavioral communication and disorders, etc. [40].

Early detection of minimal neurological dysfunction (MND) and CP symptoms allows for timely inclusion of children into treatments, which may affect functional motor status at a later age, taking into account biological phenomenon of brain plasticity [12].

Most of the described quantitative tests and scales do not give enough importance to the acquisition of motor skills as basic for the development of other functions. Most of these scales practically cannot predict in which direction the child's development would go until 6<sup>th</sup> month of life [2,8,11,23,26,27,36,44].

Additional diagnostic methods used in clinical practice in order to detect neurological abnormalities in newborns and infants are ultrasound and MR of the endocranium as well as heart rate variability [15].

Prechtl believed that motor activity of a newborn is rhythmic and cyclical, both the one that occur in the intra-uterine period and the one that is observed after birth, which he confirmed in later research. Also, he concluded that rhythmic pattern of locomotion is generated in the lower center of central nervous system (CNS), such as bipolar cells at the level of spinal cord, called 'central pattern generator' (CPG) [20]. Activation of CPG results in rhythmic motor patterns, without the need of sensory stimulation or descending stimulation from higher centers [24].

General movements (GMs) involve the whole body in a different range of motion of all segments of the upper and lower extremities, head, neck, and torso. Intensity, strength, and speed decrease and increase, and have a gradual beginning and end. Changes in the direction of movement make them variable, complex, and elegant. GMs before the term of childbirth are called 'fetal' or 'preterm movements'. In the term, after the term, and in the period of up to 6<sup>th</sup> (sometimes up to 9<sup>th</sup>) week after the term, appearing GMs Prechtl called 'writhing' movements (Wr GMs). In the period from the 6<sup>th</sup> to 9<sup>th</sup> week after the term, Wr GMs gradually disappear, and new GMs movements appear, which Prechtl called 'fidgety movements' (F GMs). F GMs cease to manifest between 5-6<sup>th</sup> months after term [14,20]. After that, voluntary and antigravity movements appear and dominate.

Premature children have the same characteristics of GMs as fetuses. They can differ only in higher amplitude and/or velocity relative to the term newborn GMs.

Preterms are more likely to have deviations in neuro-motor development, and identifying predispositions is a major challenge [17,38,41,42].

The aim of the study was to assess the quality of spontaneous motor activity in newborns and infants as well as to determine the neurological outcome and motor functional status at the age of 24 months. After that, the predictive value of spontaneous motor activity for neurological and functional outcome at the age of 24 months was determined.

## Material and methods

This prospective clinical study included preterm infants (gestational age  $\leq$  37 weeks), born between 2012 and 2014 in the Gynecology and Obstetrics Clinic of the University Clinical Center Niš.

Criteria for exclusion from the study were: parents' refusal to participate in the study, the presence of congenital anomalies, deformities, and genetic syndromes of a newborn, invalid video, non-attendance in the follow-up (incomplete research). In total, the study included 160 newborns.

For each newborn included in the study, anamnestic data were taken, such as gender, gestational age, body weight and length at birth, head circumference, Apgar score at 1 and 5 minutes, data on multiple (twin) pregnancies, and data on the mode of delivery.

Observation of spontaneous motor activity was performed according to the basic principles of Prechtl's method. Assessment of spontaneous motor activity was done by an educated person, who has a valid license for expertise of spontaneous motor activity, based on video analysis.

Necessary conditions for an adequate video recording included a relaxed awake state of newborn, so-called 'State 4': absence of crying, open eyes, irregular breathing, and the presence of movement. Since the behavioral condition was not established before 36<sup>th</sup> week of post-menstrual age, preterm's data below 36 gestational weeks (GW) were recorded during the onset of movement, regardless of whether the newborn was awake or asleep. During filming, newborns were in a supine position, on a flat surface (bed, mat), in diapers or scanty clothes, so that the movements were unhindered, with a constantly visible face, without a pacifier. During making of the video, all objects from the environment that would draw attention of both the subject and observer were removed, such as noise, the presence of parents and other persons, toys as well as colorful blankets, mirrors, and similar objects. Room temperature was appropriate for the age and clothes of a newborn.

Spontaneous motor activity was recorded with a camera, 3 times for each child: within 5 days of birth,

in the period from 44 to 46 weeks (writhing period), and in the period from 50 to 54 GW (fidgety period). In the writhing period, the recording lasted for 9-25 minutes. In the fidgety period, the recording lasted for 8-18 minutes.

In the writhing period, GMs were classified as:

1. Normal writhing movements (N) characterized by low to moderate amplitude and slow to moderate speed. The shape of the movement is ellipsoidal, creating the impression of twisting.
2. Poor repertoire (PR) defined poor spontaneous motor skills. These included abnormal patterns of writhing movement described as a meager repertoire. This model of writhing movement is characterized by less variability and the appearance of successive components of movement that are uniform and do not give the impression of complex movements, as is the case with the presentation of normal writhing movements. The newborn starts the movement, but does not finish it, which gives an impression of broken sequence.
3. Cramped synchronized movements (CS) are abnormal patterns of writhing movements. They occur from the preterm period onwards. This type of pathological writhing movement is characterized by simultaneous contraction of the musculature of the trunk and upper and/ or lower extremities, which also relax at the same time.
4. Chaotic movements (CH) belong to the group of pathological writhing movements. They are characterized by movements of the upper and lower extremities of extremely large amplitude and occur chaotically, without any order or fluency. They appear as sudden movements. CH can be observed in the preterm, term, and early post-term periods.

In the fidgety period, GMs were classified as:

1. Fidgety movements (F) are movements of small amplitudes, moderate speed, and variable acceleration, on the head, neck, torso, and extremities, primarily on the distal parts (radio-carpal and talocrural joint). They are manifested continuously in the awake infant, except during crying. They can be noticed as early as in 6<sup>th</sup> week, after the term, but they usually appear around 9<sup>th</sup> week, and remain present until 20<sup>th</sup> week or even a few weeks longer.
2. Absence of fidgety movements (F-), is a motor activity, in which the described fidgety movements are not registered.
3. Abnormal fidgety movements (AbF) look like normal fidgety movements, but their amplitude and speed are moderately or markedly higher.

Definitive neurological outcome was assessed on the basis of a detailed neurological examination at the age of 24 months (corrected calendar age). Examina-

tion was performed by a well-educated and experienced neurologist, who specializes in pediatric neurology. The examination included a detailed assessment of muscle tone, reflexes, posture, and movement. Neurological outcomes were classified as:

1. Normal finding: completely normal neurological outcome.
2. MND: according to TINE criteria (Touwen infant neurological examination) or non-specific signs without clear and definite signs of CP [1,41].
3. CP: according to SCPE criteria [28,42]. In subjects with motor deficit corresponding to CP at the age of 2 years, a neurological examination is repeated and a definitive diagnosis is made at the age of four, according to already described SCPE criteria [28].

Statistical analysis of the data was conducted using SPSS v. 20.0 software. Continuous parameters were represented by medians and interquartile ranges, and normality of distribution of continuous variables was determined. Comparison of the values of continuous variables between groups was defined by Mann-Whitney or Kruskal-Wallis tests. Pearson's  $\chi^2$  test compared representation of modalities of qualitative variables between the groups. Proportions of category variables between groups were compared with Pearson  $\chi^2$  or Fisher-exact tests.

In order to evaluate diagnostic value of the assessment of spontaneous motor activity of newborns and infants in the prediction of outcomes after 24 months, the following were used: sensitivity, specificity, prevalence, positive predictive value, negative predictive value, and 95% confidence interval. Statistical significance was defined as  $p$ -value < 0.05.

## Results

Table I shows clinical characteristics of the respondents and their relationship to the final neurological outcome at the age of 24 months of the corrected calendar age. The largest number of respondents ( $n = 126$ ) was in the group of late premature newborns. In the group of moderately prematurely born newborns, there were a total of 14 respondents, while in the group very prematurely born newborns, there were 16 respondents, and in the group of extremely prematurely born newborns, 4 respondents. The median gestational age of all subjects was 35 GW, with an interquartile range between 34 and 36 GW. Gender structure of the subjects, the presence of twin pregnancies, and the presence of caesarean section at birth did not differ statistically significantly between the groups that had a normal findings in the final neurological outcomes, MND, and CP.

Subjects with a final neurological outcome of CP belong to the group of prematures born under 30 years of age could be grouped into the group of very prema-

**Table I.** Characteristics of subjects according to outcome after 24 months

Clinical characteristics	Outcome after 24 months				
	Normal	MND	CP	Summarized	p-value
Gestational age (GW)	35 (35-36)	35 (33-35)	29 (27-29)	35 (34-36)	< 0.05
< 30 weeks (%)	1.61	–	100.00	10.00	< 0.001
≥ 30 weeks (%)	98.39	100.00	–	90.00	
Gender (%)					
Female	48.39	45.45	57.14	48.75	N.S.
Male	51.61	54.55	42.86	51.25	
Twins (%)					
No	74.19	81.82	100.00	77.50	N.S.
Yes	25.81	18.18	–	22.50	
Caesarean section (%)					
No	64.52	54.55	42.86	61.25	N.S.
Yes	35.48	45.45	57.14	38.75	
Birth weight (g)	2,150 (2,000-2,350)	1,750 (1,350-2,400)	1,320 (1,250-1,350)	2,125 (1,800-2,350)	< 0.01
Birth body length (cm)	45 (42-47)	44 (43-45)	39 (35-40)	44 (42-47)	< 0.05
Head circumference (cm)	30 (29-32)	30 (28-32)	28 (26-29)	30 (28.5-31)	N.S.
Apgar score (1 <sup>st</sup> minute)	8 (8-9)	8 (8-8)	6 (1-7)	8 (8-9)	< 0.001
Apgar score (5 <sup>th</sup> minute)	9 (8-9)	8 (8-8)	7 (5-8)	9 (8-9)	< 0.001

MND – minimal neurological dysfunction, CP – cerebral palsy, N.S. – not significant

turely born newborns, as well as the group of extremely prematurely born newborns. Subjects with a final normal neurological outcome and MND, predominantly belong to the group of prematures born over 34 GW, could be classified into the group of late premature newborns as well as the group of moderately premature newborns. A statistically significant difference was found between the gestational age of subjects and final neurological finding (normal, MND, CP). There was a statistically significant difference in gestational age of the groups of subjects ( $p < 0.001$ ) who had any of the three listed outcomes (normal, MND, or CP) at the age of 24 months of the corrected calendar age.

The largest number of respondents with the final neurological outcome of CP belonged to the group of prematures with very low birth weight (1,000-1,500 g). Subjects with the final neurological outcome of MND and normal neurological finding predominantly belonged to the group of low birth weight prematures (1,500-2,500 g). There was a statistically significant difference when it comes to the relationship between final neurological outcome (normal, MND, and CP) and birth weight ( $p < 0.001$ ). Body weight was highest in subjects with normal finding and lowest in subjects with CP in the final neurological outcome. Post-hoc analysis found that birth weight in the group with normal outcome was statistically significantly higher compared to subjects with MND ( $p < 0.05$ ) and CP neurological

outcome ( $p < 0.001$ ), and it was statistically higher in subjects with MND in relation to CP neurological outcome ( $p < 0.05$ ).

There was a statistically significant difference ( $p < 0.001$ ) between the groups of subjects who had a normal neurological outcome, MND, or CP, and Apgar scores. The lowest value of Apgar score was found in the group of subjects with CP in the final neurological outcome, and the highest in those with a normal finding in the final neurological outcome. A statistically significant difference in Apgar score was found between the groups in the 1<sup>st</sup> and 5<sup>th</sup> minute ( $p < 0.001$ ), with the lowest value of Apgar score in both cases in the group with subjects with CP as the final neurological outcome.

The prevalence of GMs in the three observation periods (up to 5 days, between 44 and 46 GW, and between 50 and 54 GW) differed statistically significantly between the three examined groups ( $p < 0.001$ ) (Table II). Normal movements in all three periods were represented only in the group with normal neurological outcome at the age of 24 months of the corrected calendar age. In the group with CP in the observation period of 50-54 GW, there were no respondents with a normal presentation of the fidgety movement. In the period of the newborn, i.e., in the period of 44-46 GW, CS GMs were registered in all the subjects, while in the period of up to 5 days, all but one of the subjects were

**Table II.** Neurological outcomes of subjects in relation to observed quality of general movements (GMs)

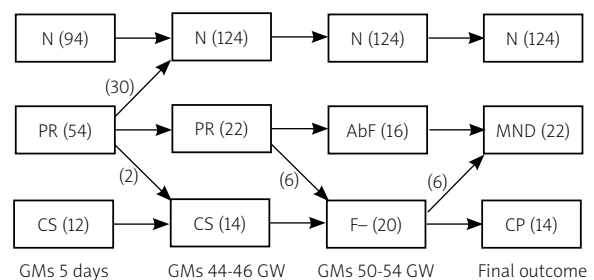
GMs	Final outcome after 24 months				p-value
	Normal (n = 124)	MND (n = 22)	CP (n = 14)	Summarized (n = 160)	
GMs within 5 days, n (%)					
N	94 (75.81)	–	–	94 (58.75)	< 0.001
PR	30 (24.19)	22 (100.00)	2 (14.29)	54 (33.75)	
CS	–	–	12 (85.71)	12 (7.50)	
GMs 44-46 GW, n (%)					
N	124 (100.00)	–	–	124 (77.50)	< 0.001
PR	–	22 (100.00)	–	22 (13.75)	
CS	–	–	14 (100.00)	14 (8.75)	
GMs 50-54 GW, n (%)					
F	124 (100.00)	–	–	124 (72.50)	< 0.001
AbF	–	16 (72.73)	–	16 (10.00)	
F–	–	6 (27.27)	14 (100.00)	20 (12.50)	

MND – minimal neurological dysfunction, CP – cerebral palsy, GW – gestational weeks, N.S. – not significant

registered with CS GMs. In subjects with a final neurological outcome of MND at the age of 24 months of the corrected calendar age, in the observation period up to 5 days and in the period between 44 and 46 GW PR, GMs were registered in all the subjects.

All subjects with normal movements in the writing period developed fidgety movements in the period of infancy. All subjects with normal writhing movements during the neonatal period and normal fidgety movements in the infant period had a normal neurological functional outcomes at 24 months of age. No subject with registered CS-type GMs in the GMs period of up to 5 days developed fidgety movements during infancy. All subjects with CS GMs in the neonatal period and no fidgety movement in the infant period had a neuro-motor discrepancies of the MND or CP type at the age of 24 months of the corrected calendar age. More precisely, all children with CS GMs in the neonatal period developed CP, while those with no fidgety movement in infancy, developed CP or MND, i.e., none had an outcome of normal motor activity at the age of 24 months of the corrected calendar age (Fig. 1).

Evaluation of the diagnostic value of the assessment of spontaneous motor activity of newborns and infants in the prediction of CP (as binary variables: yes/no) in the final neurological outcome is presented in Table III. Probability of developing CP in the final neurological outcome depending on the different results of GMs at different time intervals is shown in Table IV. Normal motor findings had the best diagnostic value, because at any time to determine, it indicated normal development after 24 months of birth. CS GMs indicated the development of CP at the age of 24 months of



**Fig. 1.** Development of subjects with general movements (GMs) findings and neurological outcomes.

the corrected calendar age. For PR in the neonatal period, it was not possible to be sure what the outcome would be in the later period, especially regarding the distinction between the normal outcome and MND.

### Discussion

By analyzing the results, it was noticed that all pre-matures with normal movements in the writhing period developed fidgety movements in the period of infancy. Prematures with N GMs in the first observation period maintained normal movement patterns in the second and third observation periods, and had a normal neurological findings in the final outcomes. This certainly proves the great predictive value of N GMs. There is no available published study, which described that normal GMs in the writhing and fidgety period have CP as the final outcome (providing that there were no serious interval complications), so there are no cases of false negative finding [6,9,25,43]. The probability that CP would develop from

**Table III.** Evaluation of diagnostic value of the assessment of spontaneous motor activity of newborns and infants in the prediction of cerebral palsy (CP) (as binary variables: yes/no) in the final neurological outcome

	Sn, % (95% CI)	Sp, % (95% CI)	PREV, % (95% CI)	PPV, % (95% CI)	PNV, % (95% CI)
N GMs within 5 days	0.00 (0.00-41.07)	35.62 (24.75-47.69)	8.75 (3.61-17.21)	0.00 (0.00-7.62)	78.79 (61.08-90.98)
PR GMs within 5 days	14.29 (2.37-57.77)	64.38 (52.31-75.25)	8.75 (3.61-17.21)	3.70 (0.62-19.03)	88.68 (76.96-95.70)
CS GMs within 5 days	85.71 (42.23-97.63)	100.00 (95.02-100.00)	8.75 (3.61-7.21)	100.00 (54.05-100.00)	98.65 (92.67-99.77)
N GMs 44-46 GW	0.00 (0.00-41.07)	15.07 (7.78-25.37)	8.75 (3.61-17.21)	0.00 (0.00-5.83)	61.11 (35.77-82.64)
PR GMs 44-46 GW	0.00 (0.00-41.07)	84.93 (74.63-92.22)	8.75 (3.61-17.21)	0.00 (0.00-28.67)	89.86 (80.20-95.8)
CS GMs 44-46 GW	100.00 (58.93-100.00)	100.00 (95.02-100.00)	8.75 (3.61-17.21)	100.00 (58.93-100.00)	100.00 (95.02-100.00)
N GMs 50-54 GW	0.00 (0.00-41.07)	15.07 (7.78-25.37)	8.75 (3.61-17.21)	0.00 (0.00-5.83)	61.11 (35.77-82.64)
AbF GMs 50-54 GW	0.00 (0.00-41.07)	89.04 (79.54-95.13)	8.75 (3.61-17.21)	0.00 (0.00-37.09)	90.28 (80.98-95.98)
F- GMs 50-54 GW	100.00 (58.93-100.00)	95.89 (88.44-99.10)	8.75 (3.61-17.21)	70.00 (34.84-92.97)	100.00 (94.82-100.00)

Sn – sensitivity; Sp – specificity; PREV – prevalence; PPV – positive predictive value; PNV – negative predictive value; GMs – general movements, GW – gestational weeks

**Table IV.** Probability of developing cerebral palsy (CP) in the final neurological outcome depending on different results of general movements (GMs) at different time intervals

Pre-test probability % (95% CI)	GMs within 5 days % (95% CI)	GMs 44-46 GW % (95% CI)	GMs 50-54 GW % (95% CI)
8.75 (3.61-17.21)	Normal 0.00 (0.00-7.62)	Normal 0.00 (0.00-5.83)	Normal 0.00 (0.00-5.83)
	PR 3.70 (0.62-19.03)	PR 0.00 (0.00-41.07)	AbF 0.00 (0.00-37.09)
	CS 100.00 (54.05-100.00)	CS 100.00 (58.93-100.00)	F- 70.00 (34.84-92.97)

GW – gestational weeks

N GMs in the final neurological outcome is 0% in the sample of this study, which corresponds to the high predictive value of N GMs in the literature [5,35,45]. Prechtl's general movement assessment method is more sensitive in prematures compared to term newborns [45].

The first described pathological pattern of movement in the writhing period is PR motor activity. It can often be seen in prematurity. These movements can be followed by both orderly and pathological patterns of spontaneous movements. There are studies that have failed to prove an association between PR and minimal neurological impairment, coordination problems, and fine motor skills in school-age and puberty [7,18].

The results of this study indicate that the presentation of PR GMs should certainly not be viewed as a mild abnormality. In separate studies, Kodrić *et al.* and Beccaria *et al.* found that subjects with registered PR movements in the final neurological outcome had neurological deviations of MND type, inadequate function of the upper extremities, vision, hearing, and speech [3,30]. These studies concluded PR GMs showing that the CNS was not in optimal condition, and represented a pathological finding. For that reason, it can be considered that it is necessary to pay attention when observing the subject and not to qualify motor activity casually as PR.

The probability that prematures would develop CP at 24 months if PR GMs are recorded in the first observation

period is very low. Among the total number of pretermatures, in the first period of GMs observation, PR GMs were recorded in 54 subjects. This can be explained by the fact that behavioral condition of prematurity has not yet been determined in the first days after birth.

In the second period of observation (44-46 GW), there was a change in the patterns of motor activities. N GMs were recorded in 30 pretermatures, PR GMs persisted in 22, and CS GMs were seen in two newborns. Such a trajectory shows that PR GMs do not have a high predictive value for the neurological outcome of the subjects. Research by other authors confirmed that PR is a pathological finding of spontaneous motor activity, but its' predictive value for later neurological abnormalities and CP is small [33].

In all subjects in whom CS GMs were registered in the first period of observation, the recorded movements persisted in the second period of observation. The same number of respondents with CS GMs in the third period of observation had no fidgety movements. In all mentioned subjects, the final neurological outcome was CP. It can be concluded that none of the subjects with registered CS GMs in the neonatal period developed F GMs in the infant period. This result correlates with the research of other authors [15]. Also, all subjects who had CS GMs in the neonatal period and F- GMs in the infant period had a neuro-motor deficits of MND or CP types in the final neurological outcome. Ferrari *et al.* emphasized that the time of the beginning of manifestation of the CS movement predicts the degree of later functional damage [22]. The earlier the manifestation of CS GMs, the greater the functional impairment.

The question is whether newborns and infants with normal presentation of spontaneous movements can have a pathological neuro-developmental outcome. Previous studies indicated its' rare occurrence [14,21]. The pathological outcome ranged from mild forms of CP, to attention deficit hyperactivity disorder syndrome in high-risk infants with normal fidgety movement. However, this was not the case in the present study. The evaluation of diagnostic value in this research led to a conclusion that if the finding is normal (i.e., if there is a presentation of FGMs), the probability that the final neurological outcome would be CP is 0%. This data confirms the high predictive value of F GMs, which was reported in a research with experts in the field of GMs [19].

Fidgety movements also have their pathological forms. One of them is AbF GMs. The results of this study indicate that AbF GMs have little predictive value for CP development. All subjects in this study, in whom AbF GMs were registered, developed MND in the final neurological outcome. Einspieler *et al.* reported AbF GMs as an early marker for MND, and concluded that AbF GMs do not have great predictive value for the development of CP and for the development of a complex form of MND [18]. This

manifestation of movement has a good predictive value for a simple form of MND, which implies a lack of fine motor skills.

In this study, all twenty subjects with F- GMs registered in the third observation period had a neurological deficit as the final neurological outcome (14 CP subjects and 6 MND subjects). All previous studies exploring GMs have confirmed the high predictive value of F- GMs. They showed that infants who do not register F GMs in the period when their manifestation is expected, have a high-risk of developing neurological deficits at a later age [46]. In a study conducted in Australia among 259 respondents, 48 F- GMs were registered. Of the 48 subjects, 39 developed CP in the final neurological outcome, and the remaining 9 also did not have a normal neurological finding in the final outcome, but a neurological deficit (MND type) [32]. Burger *et al.* performed systematic analysis of 17 studies on the predictive value of fidgety movement, mainly the absence of presentation of fidgety movement. A total of 1,926 subjects were observed, of which 90% belonged to prematurity group. Follow-up period was 12-24 months, and high sensitivity (98%) and specificity (94%) for fidgety movements were concluded [10]. Romeo *et al.* have published similar results in a study of 900 newborns [39].

Recent study indicate that there is an association between gestational age of newborns and later development of CP. In the group with MND, there were subjects born after or in the 30<sup>th</sup> week of gestation, while all subjects in the group that eventually developed CP, also developed a neurological outcome and were born before 30 GW, which correlates with similar studies [29].

Determining the body weight of newborns is an important prognostic factor, which relates to gestational age. In this study, all subjects who had CP as the final neurological outcome were in the group of pretermatures, whose body weight at birth was between 1,250-1,350 g. Subjects with MND as the final neurological outcome had a body weight below 2,500 g at birth. Such research results are in accordance with data from the literature [37].

A large number of studies that used Prechtl's method to predict the neurological outcome indicated great sensitivity and specificity of the method. In a study by Bosanquet *et al.* [4] and a study conducted by Noble and Boyd [34], the results were obtained on specificity of 98% and sensitivity of 94% using Prechtl's method in CP prediction. Sensitivity index is the percentage of cases marked as high-risk for later neurological damage. Most studies resulted in an overall sensitivity between 90% and 94%. The specificity index is the percentage of cases that are correctly identified as normal. The specificity index is lower during the writhing movement and in the preterm period (range, 46-93%). The reason for this is the num-

ber of children with abnormal GMs (mostly PR GMs) at an early age, who normalized before or during the period of fidgety movement, and in whom the neurological outcome was normal. As newborns grow, the specificity index visibly increases to 82–100% during third month, when normal fidgety movements indicate a normal neurological outcome. Kwong *et al.* suggested a high predictive value of Prechtl's method for developing CP, as they reported results of 47 studies. The sensitivity of Prechtl's method found during the fidgety period in this study was 97%, and the specificity of 89% for the later development of CP was found [31]. Analyzing the research of the past 20 years, the high connection and great positive predictive value of the fidgety movement and the neurological outcome can be concluded. The use value of Prechtl's method is proven by the fact that no previous studies reported normal GMs as ultimately accompanied by CP, provided that there were no serious interval complications. There are no cases with false negative findings. Scarce spontaneous motor activity, in the second act of assessment, as is the case in this study, can be normalized, and with the later appearance of fidgety movement, provide a normal neuro-motor outcome. However, as clinically as a minor deviation from normal may appear, PR may indicate later development of both MND and CP, according to a study, in which spontaneous motor activity in children with Rett syndrome was observed [16]. The appearance of CS writhing movements during the preterm and early post-term periods as well as the absence of fidgety movements, indicate spastic CP. Abnormal fidgety movements do not have a predictive value for CP, as there is an absence of fidgety movements, but they can indicate later development of MND, which was reported by Kodrić *et al.* [30].

A limitation of this study can be considered the fact that the first observations of the writhing movement were within 5 days of birth. Prechtl believed that it is not desirable to record spontaneous motor activity during the first three days after birth. During these days, there is an initial instability of behavioral state, changing abruptly from sleeping to crying, which interferes with observation of GMs. The reason for the recording in this period was the possibility of dismissing the examinees from maternity hospital, and the impossibility of coming to the examination again quickly. Confirmation of this shortcoming is the fact that in the first period of observation, there were 94 subjects with N Wr, 54 with PR, and 12 with CS, and in the following period (44–46 GW), there were 124 subject with N Wr, 22 with PR, and 12 with CS presentation of the movement, where a large deviation in N Wr observation and PR presentation of the movement were noted.

This research was based on the qualitative segment of Prechtl's method, and therefore Prechtl's optimal score was not used, which can be done in some of the future research.

Based on the obtained results of this research, it can be concluded that due to Prechtl's general movement assessment method, observation, and detection of normal patterns of spontaneous motor activity, it is possible to predict a normal neuro-developmental outcome with high probability. Also, by observing and detecting pathological patterns of movement, it is possible to recognize specific neurological symptoms in preterm (and/or term) newborns, which are excellent indicators of later neurological development of the child. Early detection of symptoms of minimal neurological deficit and cerebral palsy is of great clinical importance, since it enables timely inclusion of children into neuro-developmental treatment, which contributes to improving functional motor status at a later age, counting on the biological phenomenon of brain plasticity.

## Disclosure

The authors report no conflict of interest.

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