Impact of selected risk factors on motor performance in the third month of life and motor development in the ninth month

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Background. Proper motor development can be influenced by a range of risk factors. The resulting motor performance can be assessed through quantitative and qualitative analysis of posture and movement patterns. **Methods.** This study was designed as the cohort follow-up of the motor assessment and aimed to demonstrate, in a mathematical way, the impact of particular risk factors on elements of motor performance in the 3rd month and the final motor performance in the 9th month of life. Four hundred nineteen children were assessed (236 male and 183 female), including 129 born preterm. Each child aged 3 month underwent a physiotherapeutic assessment of the quantitative and qualitative development, in the prone and supine positions. The neurologist examined each child aged 9 month, referring to Denver Development Screening Test II and assessing reflexes, muscle tone and symmetry. The following risk factors were analyzed after the neurological consultation: condition at birth (5th minute Apgar score), week of gestation at birth, intraventricular hemorrhage, respiratory distress syndrome, and the incidence of intrauterine hypotrophy and hyperbilirubinemia determined based on medical records. **Results.** A combination of several risk factors affected motor development stronger than any one of them solely, with Apgar score, hyperbilirubinemia, and intraventricular hemorrhage exhibiting the most significant impact. **Conclusions.** Premature birth on its own did not cause a substantial delay in motor development. Nonetheless, its co-occurrence with other risk factors, namely intraventricular hemorrhage, respiratory distress syndrome, and hyperbilirubinemia, notably worsened motor development prognosis. Moreover, improper position of the vertebral column, scapulae, shoulders, and pelvis in the third month of life may predict disturbances in further motor development.

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27 **Abstract**

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30 motor performance can be assessed through quantitative and qualitative analysis of posture and

31 movement patterns.

32 **Methods.** This study was designed as the cohort follow-up of the motor assessment and aimed to

33 demonstrate, in a mathematical way, the impact of particular risk factors on elements of motor

34 performance in the 3rd month and the final motor performance in the 9th month of life. Four hundred

35 nineteen children were assessed (236 male and 183 female), including 129 born preterm. Each

36 child aged 3 month underwent a physiotherapeutic assessment of the quantitative and qualitative

37 development, in the prone and supine positions. The neurologist examined each child aged 9

38 month, referring to Denver Development Screening Test II and assessing reflexes, muscle tone

39 and symmetry. The following risk factors were analyzed after the neurological consultation:

40 condition at birth (5th minute Apgar score), week of gestation at birth, intraventricular hemorrhage,

41 respiratory distress syndrome, and the incidence of intrauterine hypotrophy and

42 hyperbilirubinemia determined based on medical records.

43 **Results.** A combination of several risk factors affected motor development stronger than any one

44 of them solely, with Apgar score, hyperbilirubinemia, and intraventricular hemorrhage exhibiting

45 the most significant impact.

46 **Conclusions.** Premature birth on its own did not cause a substantial delay in motor development.

47 Nonetheless, its co-occurrence with other risk factors, namely intraventricular hemorrhage,

48 respiratory distress syndrome, and hyperbilirubinemia, notably worsened motor development

49 prognosis. Moreover, improper position of the vertebral column, scapulae, shoulders, and pelvis

50 in the third month of life may predict disturbances in further motor development.

51

52 Keywords: Infant; Motor development; Risk factors; Qualitative analysis; Cerebral palsy

53 **Introduction**

54

55 Certain conditions must be met for the motor development to proceed correctly, such as

56 correct genetic imprint and adequately functioning central nervous system, comprising normal

57 mental development, fully-working senses, and proper motor outcomes (Vojta & Peters, 2007;

58 Illingworth, 2012; Hadders-Algra, 2004). Even if in later months of life, the motor performance

59 differs due to environmental (familial, cultural, and socio-economic factors), early motor

60 performance seems to follow a very similar pattern in all regularly developing children (Hadders-

61 Algra, 2018)

62 Adequate cognitive development is essential in allowing the child to perform a given task or

63 function due to motivation: the natural desire to explore the world (Adolph & Hoch, 2019; Newell,

64 1986). Several authors previously discussed that various risk factors influence proper motor

65 development. The most crucial biological risk factors include the type of delivery (Lee, Han &

66 Lee, 2012), low 5th-minute Apgar scores (Bulbul et al., 2020), respiratory distress syndrome

67 (RDS) (Janssen et al., 2008), intrauterine hypotrophy, hyperbilirubinemia (Wusthoff & Loe, 2015),

68 and intraventricular haemorrhage (IVH) (Bulbul et al., 2020; Tatishvili et al., 2010; Wildin et al.,

69 1995).

70 Motor development follows a specific pattern, conserved across the human population,

71 permitting the development of homogeneous assessment methods. Such evaluation should be

72 based on quantitative and qualitative components appropriate for a given developmental stage

73 (Gajewska et al., 2013; Gajewska, Sobieska & Moczko, 2014). Furthermore, it should allow

74 detecting delays or abnormalities in motor skills provides a basis for therapy plan development

75 and makes it possible to predict further motor development. There is no consensus on a "gold

76 standard" on uniform functional assessment in pediatric physiotherapy in Poland. Similarly, there

77 currently needs to be a unified methodology for neurological evaluation. General movements

78 assessment (GMs) offers a notable degree of cerebral palsy predictability in Poland and worldwide.

79 Regrettably, defining therapeutic goals based on this method can be challenging. The Alberta

80 Infant Motor Scale (AIMS) is an excellent assessment tool but has yet to be validated in Poland.

81 However, it does not sufficiently capture the qualitative issues, which often tend to be crucial

82 during therapy (Boonzaaijer et al., 2021). Furthermore, the Test of Infant Motor Performance

83 (TIMP) was designed to detect developmental delays in children younger than four months

84 (Peyton, Schreiber & Msall, 2018). It is reported in the literature that a treatment plan can be

85 prepared based on this scale, but it does not allow to predict which child will develop cerebral

86 palsy accurately (Tripathi et al., 2022). However, after a thorough analysis of the test and an

87 attempt to use it, based on the experience of many physiotherapists, we believe that it does not

88 meet the standard requirements, as it is challenging to identify the main problem and assign an

89 appropriate therapy on its basis.

90 Previous publications have shown that the most appropriate moment for the assessment to

91 predict further motor development in the third month of life (Vojta & Peters, 2007; Hadders-Algra,

92 2004; Gajewska et al., 2013; Gajewska, Sobieska & Moczko, 2014). In line with this idea, a

93 quantitative and qualitative evaluation scale for motor development in the third month of life was

94 presented and validated through inter and intraobserver reliability analysis. Furthermore, it was

95 compared with a neurological evaluation method based on the Denver Developmental Screening

96 Test II, commonly used in Poland, supplemented with reflexes, muscle tone, and

97 symmetry/asymmetry testing. The results regarding its usefulness were published in several

98 scientific publications (Gajewska et al., 2013; Gajewska, Sobieska & Moczko, 2014; Gajewska et

99 al., 2015a). The assessment of spontaneous motor activity involves a thorough analysis of posture

100 and movement patterns. The quantitative evaluation determines the global pattern: a child's most

101 advanced function (a milestone). While the movement does not need to be performed flawlessly,

102 it is sufficient for the child to manifest it in any way or at least strive to achieve it (Vojta & Peters,

103 2007). The qualitative assessment focuses on the elements that make up one global movement

104 pattern, accurately analyzing its kinesiological content (Vojta & Peters, 2007). This assessment

105 method allows for planning the therapy aimed at individual deficits and makes it possible to predict

106 further motor development (Gajewska, Sobieska & Moczko, 2014; Gajewska et al., 2015). Earlier

107 publications mainly intended to demonstrate a proper analysis of the qualitative assessment of

108 motor development and determine predictors of further motor development, for example,

109 satisfactory quality in the 3rd month, which is necessary to achieve high support in the 6th month

110 (Gajewska, Sobieska & Moczko, 2014) independent sitting and crawling in the 9th month

111 (Gajewska et al., 2015b); the position of the pelvis in the 3rd month which is crucial for the

112 reaching of the crawl position in the 7th month (Gajewska et al., 2021b). However, we know that

113 many risk factors can affect motor development and decided to evaluate them using a qualitative

114 assessment-based scale. We decided to limit our analysis to the known biological risk factors

115 which are supposed to have the most substantial impact on motor development. Many other factors

116 may influence motor performance and need further analysis. Risk factors that affect motor

117 development: maternal gestational and obstetric history (planned pregnancy, type of delivery; the

118 number of prenatal consultations; use of medication and gestational intercurrence); features and

119 biological risk of the baby: (sex, mechanical ventilation, feeding difficulty, socio-demographic

120 factors), carrier and level of maternal schooling, number of children and people in the house,

121 psycho-social issues (the family regular participation and presence of psychic risk) (Crow, Deakin

122 & Longden, 1975). Out of those factors, the biological ones are regarded as the most crucial for

123 motor development.

124 Hence, this study aims to statistically determine the impact of particular risk factors on elements

125 of motor performance in the three- month-old infants, as well as final motor performance in the

126 9th month of life.

127

128 **Material and methods**

129 **Participants**

130 The study group consisted of children with no symptoms of impaired motor development, born at

131 term or preterm (between weeks 28 and 37 of gestation), and children referred to the Clinic of

132 Neurology for a periodic development assessment by a general practitioner, a pediatrician, or due

133 to parents' concerns (weak head control during traction response or suspicion of delayed

134 development). Data were collected as previously described (Gajewska et al., 2021).

135 The entire study population included 419 children: 236 boys and 183 girls, with 290 of them born

136 at term and 129 preterms. The average birth week of the included infants was 38±3 (born at term

137 40±1 weeks; preterm 34±3 weeks), and the mean body weight was 3100±814 g (born at term

138 3462±505 g; preterm 2282±788 g). Preterm children were assessed at the corrected age (Pin et al.,

139 2009).

140 Exclusion criteria comprised genetic or metabolic disorders, severe congenital disabilities, or

141 extreme preterm birth (below the 28th week of gestation). Moreover, no children with microcephaly

142 or macrocephaly were included in the study.

143 **Procedure**

144 The study was designed as a cohort follow-up of the motor assessment. The examination was

145   performed at the clinic of the Greater Poland Center for Child and Adolescent Neurology and the

146   child clinic in the years 2018–2021. The calculation of the sample size, regarding the number of

147   newborns per year in the area, showed the required sample size of 383. We decided to gather even

148   more population. The calculation was done using the Statistica.pl software;–assuming the

149   population of the region, where the study was performed, and the expected percentage of children

150   affected with motor disturbances. Children whose parents/guardians asked for a screening test to

151   exclude or confirm developmental abnormalities were recruited in the Western part of Poland.

152   Children referred for functional assessment by pediatricians or neurologists were also included.

153   All consecutive children aged 12-16 weeks, who presented at the Clinic were included if they did

154   not meet the exclusion criteria. Exclusion criteria were genetic or metabolic disorders, severe birth

155   defects, or extreme preterm birth (below 28 gestation week, microcephaly or macrocephaly.

156   Demographics related to a child's health are taken from a medical record book or discharge

157   summaries.

158   Altogether 450 were assessed and 21 were excluded due to: genetic disease (13); spina bifida (2),

159   brachial plexus (2); metabolic disease (1); hydrocephalus (3).

160   The prospective statistical analysis aimed to depict the risk factors that at most influenced the

161   motor performance in three-month-old infants, expressed as sum of properly performed elements

162   in the prone and supine positions, and affected at most the achieving of the proper motor

163   development at the age of nine months. As second step in the statistical analysis, the association

164   of the particular risk factors with the particular elements of the motor performance assessed in the

165   prone and supine positions was measured, as well as the association of the particular elements with

166   the achieving of the proper motor performance in the 9th months of life was measured.

167   In all children, a physiotherapeutic qualitative assessment of motor performance at three months

168   (completed three months but before completing four months) was performed in the prone and

169   supine positions, as presented in previous publications (Gajewska et al., 2013; Gajewska, Sobieska

170   & Moczko, 2014; Gajewska et al., 2021). During the assessment, a child was placed on the

171   rehabilitation table, without clothes (so that the qualitative features could be accurately assessed),

172   in a warm room (temperature 21-22º C), full-fed and well-rested (child in a state of vigilance,

173   active, non-sleepy, non-hungry (one hour after feeding). The examination lasted 10 to 15 minutes

174   (Gajewska et al., 2013; Gajewska, Sobieska & Moczko, 2014).

175   In the prone position, the assessment involved: isolated head rotation; arm in front; forearm in an

176   intermediate position; elbow outside of the line of the shoulder; palm loosely open; thumb outside,

177   spine in segmental extension; scapula situated in medial position; pelvis in an intermediate

178   position; lower limbs situated loosely on the rehabilitation table; foot in an intermediate position.

179   In the supine position, the assessment involved: head symmetry; spine in extension; shoulder in a

180   balance between external and internal rotation; wrist in an intermediate position; thumb outside;

181   palm in an intermediate position; pelvis extended; lower limb situated in moderate external rotation

182   and lower limb bent at the right angle at hip and knee joints; foot in an intermediate position –

183   lifted above the rehabilitation table. Both sides were assessed for symmetrical parts of the body to

184   exclude asymmetry. Each element was evaluated as 0 - performed only partially or entirely

185   incorrectly, 1 - performed correctly. Each assessed element had to be observed at least three to

186   four times during the test. The result was expressed as a sum of points (0-15 for prone and 0-15

187   for the supine position), and it is presented in the Table 1.

188   The qualitative assessment included 15 elements in prone and supine positions (Tables 2 and 3,

189   respectively).

190   A neurologist examined the infants at nine months of age. The evaluation was based on the Denver

191   Development Screening Test II (DDST II), the assessment of reflexes, muscle tone (hypotonia or

192   hypertonia), and symmetry (Touwen BCL, 1976; Ślenzak J, Michałowicz R, 1973). The proper

193   performance was the basis to qualify a child as adequately developed for the 9th month of life. In

194   case of irregularities, the neurologist indicated the maximum level of motor development achieved

195   by a child. In the case of children in which cerebral palsy (CP) was suspected, the final diagnosis

196   could be confirmed at 18 months of age (Figure 1). Two neurologists participated in the study,

197   their conformity reached very high level (Cohen's *kappa* = 1) (Gajewska, Sobieska & Moczko,

198   2014).

199   *Figure 1 near here*

200   Previously, this type of examination was used in the assessment of children aged three months and

201   the comparison between physiotherapeutic and neurological assessment showed high agreement,

202   with high conformity coefficients ($z = -5.72483$, $p < 0.001$) (Gajewska, Sobieska & Moczko,

203   2014).

204   The following risk factors were analyzed after the neurological consultation: condition at birth (5-

205   minute Apgar score) Apgar in the 5th minute is commonly regarded as the most predictive

206   value (Lai, Flatley & Kumar, 2017), week of gestation at birth, intraventricular hemorrhage (IVH)

207   (in some children, brain sonography was performed after birth, while all infants were subjected to

208   this examination at the second month of corrected age; intraventricular hemorrhages (IVH) were

209   classified into four grades of severity, as indicated by Papile (1978), respiratory distress syndrome

210   (RDS), and the incidence of intrauterine hypotrophy and hyperbilirubinemia determined based on

211   medical records.

212   The study was approved by the Research Ethics Committee of Poznan University of Medical

213   Sciences and registered under no. 22/10 (07-01-2010). Children recruited for the study were

214   patients/clients of the Child Neurology Center. All parents/caregivers written agreed to participate

215   in the study, as apart from routine assessment and therapy, no extra visit was necessary.

216

217   Statistics

218   Due to the nature of the variables, the results were presented as median with quartiles (Me, Q25-

219   Q75), with an assumed level of significance $p<0.05$, two-tailed test. To compare two groups, the

220   Mann-Whitney U test was used, to compare more than two groups: Kruskal-Wallis ANOVA and

221   post hoc Dunn's test). To estimate the effect size the Hodges-Lehman estimation of the Wilcoxon-

222   Mann-Whitney test from StatXact-11 Cytel Studio v.11.1.0 was used.

223   The assumed statistical significance level was $p<0.05$.

224   The association between pairs of nominal categorical variables was tested using the

225   following tests:

226   1) To measure the magnitude of the association between two nominal variables without regard to

227   the dimensions of the r x c contingency table – Cramer's V coefficient was used in place of

228   Pearson's chi-square statistics; the higher the coefficient, the stronger the association.

229   2) To measure the proportion of variation between interrelated nominal variables - the Goodman-

230   Kruskal's Tau test was used; the higher the result - the more substantial the influence of one

231   variable on another.

232   3) To estimate the best predictors of the impact of particular risk factors on the final assessment in

233   the 9th month of life, the ordered logit analysis was performed. The dependent variable was

234   measured on the ordinal scale, while all other predictors were expressed on the binary scale.

235   For the whole model, the pseudo R^2 value and likelihood ratio was given and $P>[z]$ value was

236   shown for each element.

237 For both the association tests and ordered logit test exact probability values of the two-sided *p*

238 (instead of asymptotic *p*-values) were calculated using StatXact-11 Cytel Studio v.11.1.0

239 The assumed statistical significance level was *p*<0.05.

240 **Results**

241 In our previous studies sex differences were never present (Gajewska et al., 2013; Gajewska,

242 Sobieska & Moczko, 2014). Also in this study, the difference between boys and girls was not

243 statistically significant (see Table 1). When children were divided according to prematurity and

244 then according to sex, following results were obtained: boys premature, n=71, prone 13 (5-15);

245 supine 15 (6-15); girls premature, n=58, prone 15 (8-15); supine 15 (6-15); boys born at term,

246 n=165, prone 15 (10-15), supine 15 (13-15); girls born at term, n=125, prone 15 (9-15), supine

247 15 (12-15). Any difference was statistically significant.

248

249 **Qualitative assessment at the age of 3 months**

250 The assessment at the age of 3 months is expressed as the sum of elements, in the prone and supine

251 positions (enumerated in Tables 2 and 3, respectively), with a maximum value of 15 points. Exact

252 data for the sum in the prone and supine positions are given in Table 1. For each subset of the

253 investigated group, divided according to various criteria, the median with quartiles for the sum in

254 prone position and sum in supine position is given, as assessed by the physiotherapist in the 3rd

255 month of life. Next, each subset of the investigated group the number of children is divided

256 according to the maximal level of development they achieved in the 9th month of life, as assessed

257 by the neurologist. The particular subsets are compared and the statistical results are depicted for

258 each comparison. The sum in both positions decreased with the increasing number of risk factors

259 and was always lower in preterm infants burdened with risk factors. Additionally, the sum in the

260 prone position was usually lower than in the supine position.

261 **Impact of particular risk factors on motor performance at the age of 9 months**

262 First, the impact of individual risk factors or their combination on the qualitative assessment of

263 motor skills in the 3rd month of life and the maximum skill level achieved at nine months were

264 investigated. The details of this analysis are presented in Table 1. However, it should be noted

265 that there were no children with three or four risk factors that were not born prematurely.

266 When children were divided according to the fifth-minute-Apgar category, the sum in the prone

267 position and the sum in the supine position were significantly different. For the prone position,

268   KW ANOVA showed high significance of the difference (H=14.19 p =0.001; post hoc

269   test: Apgar 4-7 vs Apgar 8-10, z=2.88; p=0.012; Apgar 0-3 vs Apgar 4-7, z=0.58; p=1.000;

270   Apgar 0-3 vs Apgar 8-10, z=1.73, p=0.252). For the supine position, there was also a significant

271   difference between the three groups (H=12.46; p=0.002). However, the post hoc test did not

272   point at any significant difference (Apgar 4-7 vs Apgar 8-10, z=1.09; p=0.830; Apgar 0-3 vs

273   Apgar 4-7, z=2.02; p=0.129; Apgar 0-3 vs Apgar 8-10, z=2.25, p=0.074).

274   As the strength of the test was very low when all three Apgar categories were compared, with the

275   smallest group (Apgar 0-3, n=2), the exact comparison was made for between the categories

276   Apgar 4-7 versus Apgar 8-10 and it showed a statistically significant difference (see Table 1).

277   There were altogether 38 children with hyperbilirubinemia but only in ten born at term and in ten

278   preterm infants it was a single risk factor. The difference between children born at term without

279   any risk factors versus those born at term with hyperbilirubinemia was statistically significant, the

280   difference between children born preterm with versus without hyperbilirubinemia was significant

281   only in the prone position. The difference between children born with hyperbilirubinemia at term

282   versus preterm was not significant.

283   There were altogether 18 children born with hypotrophy but only in ten born at term it was a single

284   risk factor. The difference between children born at term without any risk factors versus those born

285   at term with hypotrophy was not significant (see Table 1).

286   All children with a suspicion of CP in the 9th month of life did not perform correctly in the 3rd

287   month. This diagnosis was confirmed at 18 months (nine participants were diagnosed with

288   tetraplegia and one with diplegia). Children with tetraplegia failed to perform any of the evaluated

289   elements in the prone and supine positions (scored 0 points), and only one child finally diagnosed

290   with diplegia (weight 3210g; born on the 40th week of gestation) scored 6/15 points in the supine

291   position (hands, thumbs, external rotation of the lower limbs). Out of 10 children with suspicion

292   of CP, four were affected by grade I IVH, one with grade II IVH, five with RDS, one with

293   hyperbilirubinemia, and one with hypotrophy. When the total number of risk factors was taken

294   into account, four children finally diagnosed with CP were not affected by any risk factor, one

295   suffered from hypotrophy, four were affected by two risk factors (IVH + RDS), and one was

296   affected by three (IVH + RDS + hyperbilirubinemia) (see Table 1).

297   The type of delivery (vaginally, $n = 224$; Caesarean section, $n = 158$; forceps delivery, $n = 23$;

298   vacuum, $n = 14$) did not entail significant differences in the 3rd month of life or the maximum

299 development at nine months of age (KW ANOVA, H=2.54; p=0.468 for prone position and
300 H=7.19; p=0.066 for the supine position).

301 Children born prematurely and at term, without risk factors, achieved a similar maximum
302 development level. Almost half of the children born prematurely and with additional risk factors
303 showed delayed motor development and CP in extreme cases. In contrast, most children born at
304 term but affected by risk factors still achieved the proper level of motor development (see Table
305 1).

306 It seems that prematurity does not cause a significant delay in motor development. Still, in
307 combination with risk factors, IVH, RDS, and hyperbilirubinemia, it results in a notably worse
308 motor development prognosis (see Table 1).

309 Proper development manifests in achieving all the postural and motor characteristics listed in the
310 scale, i.e., the maximum sum of points. Its reduction indicates deficits/abnormalities and may
311 herald/predict developmental delay. Therefore we have evaluated whether risk factors in infants
312 could coincide with reduced assessment scores. The effect of risk factors on the total qualitative
313 assessment in the prone and supine positions was analyzed.

314 The result of the detailed qualitative assessment of motor performance was first presented in the
315 form of a sum of points obtained to demonstrate to what extent individual risk factors or their
316 combination reduces the level of functioning. The results of this analysis are presented in Table 1.
317 The final development level of children with a given risk factor or their combinations in the 9th
318 month of life was also indicated. Then, we investigated which risk factors influenced specific
319 motor components assessed in pronation and supination. The results of this analysis are presented
320 in Tables 2 and 3, respectively.

321 The last column of these tables indicates which motor element assessed in the 3rd month of life
322 was critical (had a significant effect) to the child's achievement of the maximum level of motor
323 development assessed at nine months of age. Statistical significance suggests that given risk factors
324 disturbed the correct position or function in the examined children at the third month of life.

325 The differences of the "sum in the prone position" ($H = 49.08$, $p = 0.000$) and "sum in supine
326 position" ($H = 47.69$, $p = 0.000$)   variables depending on the number of risk factors were
327 statistically significant, while the difference investigated using the post hoc test was as followed:
328 without risk factors / two risk factors $p = 0.002$; without risk factors / three risk factors $p = 0.003$.
329 Depending on the type of risk factors in the studied children, it was also possible to demonstrate

330   the differences in the "sum in the prone position" ($H = 52.81$, $p = 0.004$) and "sum in supine

331   position" ($H = 13.21$, $p = 0.022$) variables were significant, but detailed comparisons failed to

332   achieve significance.

333   *Table 1 near here*

334   Next, the influence of particular risk factors on motor elements, investigated in the prone and

335   supine positions, was studied. Six risk factors were included in the analysis: prematurity, 5th

336   minute-Apgar score 4-7, the presence of IVH, RDS, hyperbilirubinemia, and hypotrophy. Only

337   reduced 5th minute Apgar score, IVH and hyperbilirubinemia were repeatedly significant and were

338   presented in Tables 2 and 3.

339   Subsequently, we analyzed which elements of motor skills, assessed qualitatively in the prone and

340   supine positions in the 3rd month of life, had the most significant impact on the maximal level of

341   motor performance, evaluated by the neurologist at the age of nine months. The axial features,

342   namely the spine, scapulae, and pelvis, showed the highest impact. The results of this analysis are

343   listed in detail in Tables 2 and 3.

344   *Table 2, and Table 3 near here*

345   The elements in the prone position which best determined the proper prognosis of motor

346   development included: correct curvatures of the vertebral column, scapula situated in the medial

347   position, pelvis in the intermediate position, lower limbs situated loosely on the rehabilitation

348   table, while in the supine position these comprised: proper curvatures of the vertebral column,

349   shoulder in a balance between external and internal rotation, pelvis extended, lower limbs bent at

350   a right angle at hip and knee joints, foot in the intermediate position - lifted above the rehabilitation

351   table. The ologit analysis showed the pseudo R^2 value of 0,4023 and the likelihood ratio of 267,02.

352   Only for few elements the model showed significant *P>(z)*. The results are presented in the Tables

353   2 and 3, last column.

354

355   **Discussion**

356   Some authors point out that the early detection of motor abnormalities is relatively difficult

357   (Crnković et al., 2011). Thus, it seems advisable to examine diagnostic methods that would make

358   it possible to detect children at risk of abnormal development at the earliest possible time,

359   irrespective of the risk factors involved. We present an assessment method that was validated in

360   comparison to neurologic check, it is short, relatively easy to follow and allows to depict particular

361 elements of motor performance at the crucial age of three months (Gajewska et al., 2013;

362 Gajewska, Sobieska & Moczko, 2014; Gajewska et al., 2021).

363 The primary finding is that none of the singular risk factors universally recognized as the most

364 dangerous (prematurity, IVH, RDS, hyperbilirubinemia) is responsible for severe motor

365 development impairment. However, the higher the number of coinciding risk factors, the worse

366 the prognosis for motor development.

367 The percentage of premature births is 7.1% in Europe (Caring for tomorrow– EFCNI) and

368 approximately 6.5% in Poland ("GUS Roczniki demograficzne," 2011). It was shown that RDS,

369 IVH and sepsis, hypoglycemia, hypernatremia, and hypothermia are the factors causing

370 developmental delay and potentially leading to unfavorable long-term neurodevelopmental

371 consequences (Khan et al., 2012; Stephens & Vohr, 2009).

372 One risk factor did not worsen the quality in the children born at term. Preterm delivery as a single

373 risk factor significantly affected motor performance, though the median quality did not differ. Yet,

374 the relative risk of CP was higher in those children (3/68 = 4,4% vs 1/211 = 0,5% in born at term).

375 The more risk factors, the lower the quality. The difference was significant for three versus fewer

376 risk factors in the supine position. However, it should be noted that there were no children with an

377 extremely low gestational age in the investigated group who could exhibit a delay despite being

378 examined at the corrected age.

379 Many authors report that the CP diagnosis is often made too late, and rehabilitation, which could

380 help improve the affected children's condition, is implemented with a significant delay (Morgan

381 et al., 2015). Novak et al. (2017) identified two diagnostic pathways for infants at risk of

382 developing CP. About 50% are infants from the risk group with certain factors, such as

383 prematurity, fetal growth disorders, encephalopathy, genetic defects, and convulsions, and are

384 diagnosed under five months of age (corrected age). Infants with no such medical/ clinical history

385 are diagnosed later in life, based on the second pathway. The first disturbing symptoms in such

386 infants include a delay in motor development (e.g., lack of sitting ability at nine months of age, or

387 a clear one-sided preference, visible only when performing more complex actions (e.g., griping)

388 (Novak et al., 2017).

389 It is worth noting that Novak et al. (2017) suggest diagnostics only after the age of 5 months, while

390 in our studies (repeatedly), children who were diagnosed with CP at the age of 18 months showed

391 large motor deficits at 3 months of age (they did not perform any, or only performed 2-3 activities

392   of the assessed 15 in pronation and supination) (Gajewska et al., 2013; Gajewska, Sobieska &

393   Moczko, 2014; Gajewska et al., 2015a).

394   However, early detection of motor deficits may support therapy for children at risk of CP and those

395   who will eventually only develop a developmental delay. Moreover, in the third month of life, it

396   could be noticed that they did not perform all of the observed functions correctly, or at least did

397   not achieve the maximum score. Hence, we suggest that diagnostics should be performed very

398   early, already at three months. Even if the diagnosis of CP may be delayed until 18 months,

399   rehabilitation should be implemented as early as any worrying symptoms are noticed.

400   The most crucial aim of the study was to demonstrate whether it is possible to associate specific

401   risk factors with a motor delay up to the occurrence of CP.

402   As for particular risk factors, an Apgar score lower than eight significantly worsened both the

403   quality in children aged three months and the prognosis of further motor development and the

404   relative risk of CP ($3/12 = 25\%$ vs $7/394 = 1,8\%$). IHV I^{o} was not a thread, and the number of

405   children with higher grades was too low to perform the analysis. Hyperbilirubinemia significantly

406   affected motor performance in 3-month-old children, and in half of them caused a delay in motor

407   development, and it affected equally children born at term and preterm. It should be regarded as a

408   potential threat to further motor development even in children without any other risk factors and

409   these children should be followed, carefully supervised by a physiotherapist, and subjected to

410   proper therapy if necessary. In contrast, hypotrophy did not cause any delay in motor development

411   if present as a single risk factor. Other investigated risk factors were present in too few children

412   for exact analysis. However, an individual motor performance at three months was low, and motor

413   development was delayed.

414   It is also worth emphasizing that these factors, acting not individually but in combination, had the

415   most significant effect on motor development delay.

416   Apart from the statement that children with particular risk factors developed more slowly, it was

417   shown that their performance in the 3rd month was worse. Only a detailed qualitative assessment

418   can detect these minor deviations from normal development that affect motor progress. At the

419   same time, detection of disorders in the 3rd month of life allows for the implementation of early

420   physiotherapy, following commonly accepted canons.

421   The pronation score seems to reflect better the discrete deficits seen in children born with a poorer

422   5th minute Apgar score. The ability to overcome the forces of gravity is probably a good indicator

423   of both the proper development of muscle strength and the maturity of the nervous system.

424   The predictive value of the commonly used Bayley scale is being undermined (highly unstable

425   delay classifications, low sensitivities, and poor positive predictive values), and the need for a new,

426   more effective tool used to predict motor development and allow early therapeutic intervention is

427   emphasized (Lobo et al., 2014).

428   Since there is no globally recognized "gold standard" method of functional assessment, it was

429   impossible to compare the results of this study with such a standard or to calculate the confidence

430   intervals or odds ratio. The only point of reference was the neurological examination, and more

431   specifically – the level of motor development assessed at the age of 9 months. This age was chosen

432   as this is the usual time for assuming the standing position (Vojta & Peters, 2007; Gajewska,

433   Sobieska & Moczko, 2014). Achieving this milestone (with the support of furniture or an adult)

434   reflects the achievement of complete motor control and guarantees further proper motor

435   development (including walking) (Adolph & Hoch, 2019).

436   Another important risk factor for developmental disorders and CP is the increasing severity of IVH

437   (Fily et al., 2006; Spittle et al., 2009). Measures of brain structure and function are by far the most

438   predictive of neurodevelopmental outcomes. Preterm infants with ventricular dilatation and IVH

439   showed worse motor test results than those without IVH (Vollmer et al., 2006). IVH in children

440   born prematurely leads to worse psycho-motor assessment outcomes and more frequent CP

441   occurrence (Klebermass-Schrehof et al., 2012). In our study, in the group of children who obtained

442   bad scores, IVH was much more frequent. In the studies by Sherlock et al. 2005, patients with IVH

443   grade IV showed up to four times higher percentages of abnormal results than grade I patients.

444   However, we could not confirm this finding due to the small number of children with higher grades

445   of IVH included in our study.

446   The risk of the RDS occurrence is inversely proportional to the newborn's gestational age- occurs

447   in 1% of all newborns and nearly 70% of infants born before the 28th week of gestation (Shonkoff

448   & Meisels, 2000). In our study, RDS occurred mainly in children whose motor development was

449   assessed as inferior. However, it should be stressed that these children were not born extremely

450   premature.

451   The analysis of risk factors and their impact on motor development in the investigated group was

452   similar to that of other authors. Some papers put more attention to socio-economic risk factors
453   (Sania et al., 2019) other relate to the combination of social and biologic risk factors, but
454   investigate gross motor function and cognitive functions, whereas we decided to focus on
455   biological factors only and investigate fine motor skills in details (Tian et al., 2018).   It is
456   believed that there is a critical need for collaboration among experts to determine early predictive
457   factors and neuroprotective therapies (Khan et al., 2012). Furthermore, while hyperbilirubinemia
458   proved to be a highly burdening factor, even children who suffered from many complications of
459   similar severity occasionally showed proper development and reached maximal performance at
460   nine months.

461   The qualitative assessment conducted at the age of 3 months is a reliable prognosis of motor
462   development at 9 months of age, with a crucial role played by proximal characteristics related to
463   the axial skeleton (spine-scapulae-shoulders-pelvis). Ologit analysis implies the independent
464   predictors that affect the prognosed variable. It should be noticed that the particular elements of
465   the motor performance in the third month are in fact related to each other. That is probably why
466   the whole model testing the impact of those elements on the level of the motor development
467   achieved in the ninth month showed relatively high likelihood, though particular elements did not
468   show the statistically significant relation. In other words, all elements in the third month are
469   necessary for the perfect motor performance in the ninth month, and the more central elements are
470   disturbed, the more delay one can expect.

471   One can notice that the values of Cramer's V coefficient were not high (the highest value observed
472   was 0,2856); the same can be seen for the Goodman and Kruskal Tau coefficient (the highest value
473   was 0,0972). The highest values were observed for hyperbilirubinemia.

474   Thus, the presence of risk factors affects motor performance as a whole, but some elements seem
475   more critical. The axial elements (spine-scapulae-pelvis-lower limbs) showed more pronounced
476   dependence - particularly for hyperbilirubinemia. The precise determination of which motor
477   development elements are impaired also allows for the implementation of appropriate therapy.

478   Four children whose diagnosis of tetraplegia was ultimately confirmed at the age of 18 months
479   were not affected by any risk factors but scored zero during the quantitative assessment in the 3rd
480   month, both in prone and supine positions. Qualitative and quantitative evaluation makes it
481   possible to focus on motor delays or disorders as early as in the 3rd month of life. According to

482   McIntyre et al. (2011), 50% of CP cases are diagnosed in infants born at term in whom no risk

483   factor has been identified.

484   **Strengths and limitations**

485   The greatest limitation is that no extrinsic constraints were evaluated. We also confirm statistical

486   limitations due to the number of cases or absence of cases in some cells. Also, the problem of the

487   absence of a gold standard instrument is an external limitation.

488   The presented paper is based on a large and homogenous study group, and the implemented

489   statistical analysis, not commonly used in similar research, is accordingly adjusted to the

490   hypothesis. Qualitative analysis was performed in the third month of life, regarded as a crucial

491   time point to predict further development, allowing to plan therapy or social support in cases of

492   expected disability.

493   A relatively short follow-up (up to nine months) is the only limitation of the study.

494   **Conclusions**

495   It was not prematurity itself but its combination with risk factors (IVH, RDS, hyperbilirubinemia)

496   that made the prognosis of proper motor development worse. Children with a motor delay at nine

497   months of age demonstrated a lower quality of movement as early as in the 3rd month of life.

498   Furthermore, qualitative assessment allowed to identify high-risk children and predict the degree

499   of delay.

500   Axial skeleton characteristics (vertebral column, scapulae, shoulders, pelvis) were the best

501   determinants of the proper prognosis of motor development.

502

503   **Ethics approval and consent to participate**

504   The study was conducted at the Center for Child and Adolescent Neurology Clinic between 2018

505   and 2021, following the ethical guidelines of the 1964 Helsinki declaration and its later

506   amendments.

507

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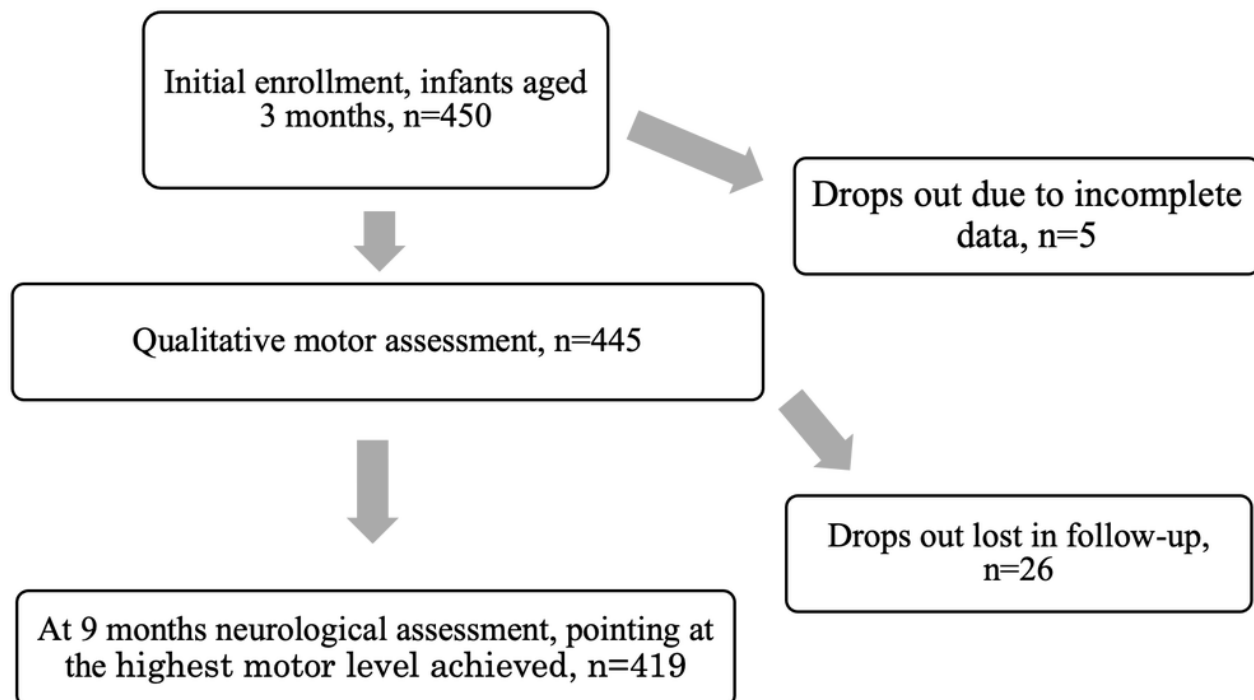
638

Figure 1

The process of the study

Risk factors, motor performance at 3rd month and final motor performance at 9th month. Qualitative assessment was expressed as the sum of particular elements in the prone and supine positions (median and quartiles; max= 15). The final

CP- cerebral palsy, IVH- intraventricular hemorrhages, RDS- respiratory distress syndrome

2 Table 1. Risk factors, motor performance at 3rd month and final motor performance at 9th month.
3 Qualitative assessment was expressed as the sum of particular elements in the prone and supine
4 positions (median and quartiles; max= 15). The final assessment was performed by the
5 neurologist at the age of 9 months and is expressed as a number of children who reached the
6 given level of motor performance. If the number of children in a group was lower than seven,
7 particular values instead of median and quartiles were given. The statistical difference is for ech
8 comparison expressed as follows: Mann-Whitney U test ($z=$; $p=$); Hodges-Lehman test (two-
9 sided exact p); theta value with confidence intervals. Statistically significant differences are
10 marked by bold

The risk factors	Quality in the prone position Median (Q25-Q75)	Quality in the supine position Median (Q25-Q75)	Final assessment at the age of 9 months				
			Suspected CP	6th month	7th month	8th month	9th month
Sex: girls; n=183 boys; n=236	15 (8-15) 15 (9-15)	15 (9-15) 15 (11-15)	7 3	7 12	17 26	10 8	142 187
Significance of the difference, boys versus girls	0,65; 0.509 0.5095 0,0000 (0-0)	0,98; 0,324 0.3247 0,0000 (0-0)					
no risk factors, n=254 gestation age 39.5 ± 1.1	15 (10-15)	15 (13-15)	1	9	24	8	212
1 risk factor, n=33 gestation age 36.7 ± 2.6	15 (9-15)	15 (8-15)	0	1	3	3	26
Significance of the difference, born at term, no risk factors versus one risk factor	0,99; 0,318 0.3199 0,0000 (0-0)	0,79; 0,42 0.4262 0,0000 (0-0)					
Preterm, no other risk factors, n=80 gestation age 35.4 ± 1.8	15 (10-15)	15 (11-15)	3	1	5	3	68
Significance of the difference, no risk factors, born at term versus preterm	3,15; 0,002 0.9750 0,0000 (0-0)	3,54; 0,004 0.5081 0,0000 (0-0)					
preterm+1 risk factor, n=25 gestation age 33.5 ± 2.4	8 (2-15)	11 (6-15)	1	4	3	3	14

preterm+2 risk factors, n=18 gestation age 31.7 ± 3.1	5 (0-12)	6 (0-15)	3	2	6	1	6
preterm+3 risk factors, n=6 gestation age 31.7 ± 3.1	0 (0-5)	0 (0-4)	1	1	2	-	2
Significance of the difference, preterm, one risk factor versus two risk factors	1,42; 0,156 0.1554 2,0000 (0-8)	1,26; 0,208 0.2079 2,0000 (0-8)					
Significance of the difference, preterm, one risk factor versus three risk factors	1,92; 0,055 0.3164 0,0000 (0-9)	**2,69; 0,007** 0.0724 0,0000 (0-13)					
Significance of the difference, preterm, two risk factors versus three risk factors	1,02; 0,307 0.2786 0,0000 (0-0)	1,80; 0,072 0.0754 0,0000 (0-0)					
Particular risk factors, as single or in combinations							
Apgar 5th minute 0-3, n=2 4-7, n=22 8-10, n=394	7;4 8 (0-11) 15 (9-15)	4;4 12 (0-15) 15 (11-15)	1 2 7	- 1 17	- - 43	- 2 16	1 9 320
Significance of the difference: Apgar 5th minute 4-7 versus 8-10	**3,28; 0,001** **0.0009** **-4,0000 (-7-0)**	**3,00; 0,003** **0.003** **-2,000 (-3-0)**					
IVH, n=9 I° n=7 II° n=1 III° n=1	11 (9-15) 15 (11-15) 7 15	15 (5-15) 15 (15-15) 15 15	- - - -	1 1 - -	1 1 - -	- - - -	7 5 1 1
Significance of the difference: no IVH versus all IVH cases	1,03; 0,304 0.3515 0,0000 (0-4)	0,52; 0,602 0.9334 0,0000 (0-0)					
Hyperbilirubinemia, n=14	11 (6-15)	9 (4-15)	-	1	3	3	7
Significance of the difference: born at term with or without hyperbilirubinemia	**2,88; 0,004** 0.0521 0.000 (0-4)	**2,88; 0,004** 0.0059 3.000 (0-7)					
Hypotrophy, n=10	15 (15-15)	15 (15-15)	-	-	1	1	8
Significance of the difference: born at term	0,11; 0,914 0.1744	0,32; 0,752 0.3151					

with versus without hypotrophy	0.000 (0-0)	0.000 (0-0)					
preterm+ hyperbilirubinemia, n=10	10 (1-15)	10 (9-15)	-	1	2	1	6
Significance of the difference: born preterm with versus without hyperbilirubinemia	**2,36; 0,018** **0.0191** *2*.000 (0-8)	1,48; 0,138 0.1805 0.000 (-6-0)					
Significance of the difference: born at term with hyperbilirubinemia versus born preterm with hyperbilirubinemia	0,39; 0,694 0.6809 0.000 (0-0)	0,53; 0,598 0.6012 0.000 (0-0)					
preterm+IVH+RDS, n=10	5 (0-15)	10 (0-15)	3	1	2	-	4
preterm+RDS, n= 6	4;8;8;15;15;15	4;12;12;15;15;15	-	1	-	1	4
preterm+IVH, n= 6	6;7;9;11;15;15	6;6;9;11;15;15	-	1	1	1	3
preterm+IVH+ hyperbilirubinemia, n=5	0;0;2;12;15	0;2;7;15;15	-	-	3	-	2
preterm+IVH+RDS+ hyperbilirubinemia, n=4	0;0;0;15	0;0;0;11	1	-	1	-	2
preterm+hypotrophy, n=3	2;0;0	0;6;6	1	-	-	1	1
preterm+IVH+hypotrophy n= 2	7;7	6;6	-	1	-	1	-
RDS+hyperbilirubinemia, n=2	7;15	4;15	-	-	-	-	2
IVH+RDS, n=1	0	0	-	-	-	-	1
preterm+hypotrophy+ hyperbilirubinemia, n=1	0	0	-	-	1	-	-
preterm+IVH+hypotrophy+ hyperbilirubinemia, n=1	5	4	-	-	1	-	-
preterm+RDS+hypotrophy +hyperbilirubinemia, n=1	0	0	-	1	-	-	-

13   Abbreviations: CP- cerebral palsy, IVH- intraventricular hemorrhages, RDS- respiratory
14   distress syndrome

The impact of risk factors on individual elements of motor performance, was studied in the 3rd month in the prone position. For each pair of variables, the values of Cramer's V coefficient, confidence interval, and Goodman and Kruskal Tau coefficient are

1   Table 2: The impact of risk factors on individual elements of motor performance, was studied in
2   the 3rd month in the prone position. For each pair of variables, the values of Cramer's V coefficient,
3   confidence interval, and Goodman and Kruskal Tau coefficient are given, along with the exact *p*-
4   value. The ordered log it analysis was used to assess the particular elements' impact on the motor
5   performance in the ninth month. The dependent variable was measured in the ordinal scale, while
6   all other predictors were expressed in the nominal (binary) scale. For the significant models
7   (*p*<0.05), the pseudo R^2 value along with *P*>[z] was given. Only significant value are shown

Qualitative characteristics in the prone position:	Side of the body; right=R, left=L	Cramer's V, G-K-Tau, *p*=			ologit
		Apgar 5th minute lower than 8	IVH	hyperbilirubinemia	The impact on the motor performance in the ninth month, *P*>[z]
Isolated head rotation		0,1782 (0,0718-0,2846); 0,0318; *p*=0,0070	0,1984 (0,0917-0,3952); 0,0394; *p*=0,0001	0,1676 (0,0610-0,2742); 0,0281; *p*=0,0010	0,231
Arm in front, forearm in an intermediate position, elbow outside of the line of the shoulder	R	0,2101 (,01220-0,2981); 0,0189; *p*<0,0001	0,1792 (0,0804-0,2779); 0,0321; *p*=0,0004	0,1202 (0,0279-0,2285); 0,0164; *p*=0,0123	0,153
	L	0,2170 (0,1278-0,3062); 0,0471; *p*<0,0001	0,2248 (0,1274-0,3222); 0,0505; *p*<0,0001	0,1371 (0,0360-0,2383); 0,0188; *p*=0,0069	0,269
Palm loosely open	R	0,1988 (0,0726-0,3250); 0,0395; *p*=0,0003	0,2590 (0,1364-0,3816); 0,0671; *p*<0,0001	0,2090 (0,0888-0,3292); 0,0437; *p*=0,0001	0,992
	L	0,1687 (0,0434-0,2948); 0,0285; *p*=0,0018	0,2813 (0,1587-0,4040); 0,0791; *p*<0,0001	0,2090 (0,0888-0,3292); 0,0437; *p*=0,0001	0,992
Thumb outside	R	0,0707 (0,0231-0,3002); *p*=0,0261	0,2210 (0,0873-0,3546); 0,0488; *p*=0,0010	0,2710 (0,1368-0,4052); 0,0734; *p*<0,0001	0,990
	L	0,1243 (-0,0080-0,2567); 0,0155; *p*=0,0224	0,2429 (0,1084-0,3773); 0,0833; *p*<0,0001	0,2667 (0,1333-0,4002); 0,0711; *p*<0,0001	0,991
Spine segmentally in extension		0,1244 (0,0222-0,2267); 0,01550; *p*=0,0187	0,1972 (0,0965-0,2979); 0,0389; *p*=0,0001	0,1992 (0,0982-0,3001); 0,0397; *p*=0,0001	0,407

Scapula situated in the medial position:	R	0,2114 (0,1232-0,2997); 0,0447; *p*<0,0001	0,1992 (0,1013-0,2971); 0,0379; *p*=0,0001	0,2168 (0,1194-0,3142); 0,0470; *p*<0,0001	0,354
	L	0,2199 (0,1301-0,3096); 0,0483; *p*<0,0001	0,1916 (0,0916-0,2917); 0,0367; *p*=0,0001	0,1408 (0,0393-0,2423); 0,0198; *p*=0,0047	0,086
Pelvis in the intermediate position		0,1235 (0,0106-0,2364); 0,0153; *p*=0,0163	0,1732 (0,0617-0,2847); 0,0300; *p*=0,0008	0,2610 (01500-0,3720); 0,0681; *p*<0,0001	0,446
Lower limbs situated loosely on the substrate	R	0,1239 (-0,0012-0,2490); 0,0154; *p*=0,0200	0,1919 (0,0681-0,3158); 0,0368; *p*=0,0040	0,2340 (0,1094-0,3585); 0,0547; *p*<0,0001	0,138
	L	0,1239 (-0,0012-0,2490); 0,0154; *p*=0,0200	0,1919 (0,0681-0,3158); 0,0368; *p*=0,0040	0,2561 (0,1309-0,3813); 0,0656; *p*<0,0001	0,245
Foot in intermediate position	R	0,1515 (0,0117-0,3039); 0,0249; *p*=0,0067	0,1752 (0,0408-0,3097); 0,0307; *p*=0,0017	0,2613 (0,1219-0,4007); 0,683; *p*<0,0001	0,126
	L	0,1578 (0,0081-0,2950); 0,0230; *p*=0,0085	0,1833 (0,046-0,3199); 0336; *p*=0,0012	0,2714 (0,1301-0,4126); 0,0736; *p*<0,0001	0,599

The impact of risk factors on individual elements of motor performance, was studied in the 3rd month in the supine position. For each pair of variables, the values of Cramer's V coefficient and confidence interval and Goodman and Kruskal Tau coefficient a

1 Table 3: The impact of risk factors on individual elements of motor performance, was studied in
2 the 3rd month in the supine position. For each pair of variables, the values of Cramer's V coefficient
3 and confidence interval and Goodman and Kruskal Tau coefficient are given, along with the exact
4 p-value. The ordered log it analysis was used to assess the particular elements' impact on the motor
5 performance in the ninth month. The dependent variable was measured in the ordinal scale, while
6 all other predictors were expressed in the nominal (binary) scale. For the significant models
7 ($p<0.05$), the pseudo R^2 value along with $P>[z]$. Only significant value are shown.

Qualitative characteristics in supine position:	Side of the body, right= R, left=L	Cramer's V, G-K-Tau, $p=$			ologit
		Apgar 5th minute lower than 8	IVH	hyperbilirubinemia	The impact on the motor performance in the ninth month, $P>[z]$
Head symmetry		0,1380 (0,0274-0,02486); 0,0190; $p=0,0077$	0,1958 (0,0865-0,3051); 0,0383; $p=0,0002$	0,1473 (0,0392-0,2554); 0,0217; $p=0,0039$	0,134
Spine in extension		0,1244 (0,0222-0,2267); 0,0155; $p=0,0187$	0,1972 90,0965-0,2979); 0,0389; $p=0,0001$	0,1992 (0,0982-0,3001); 0,0397; $p=0,0001$	0,633
Shoulder in balance between external and internal rotation	R	0,2196 (0,1122-0,3269); 0,0482; $p=0,0000$	0,1979 (0,0883-0,3075); 0,0392; $p=0,0001$	0,2059 (0,0967-0,3152); 0,0424; $p=0,0001$	0,014
	L	0,0214 (0,1081-0,3205); 0,0459; $p=0,0001$	0,2111 (0,1026-0,3196); 0,0446; $p=0,0001$	0,2364 (0,1286-0,3443); 0,0559; $p=0,0000$	0,168
Wrist in intermediate position	R	0,2194 (0,0693-0,3696); 0,0482; $p=0,0003$	0,2499 (0,1099-0,3998); 0,0624; $p<0,0010$	0,2517 (0,1142-0,3893); 0,0634; $p<0,0001$	0,310
	L	0,1762 (0,0332-0,3202); 0,0310; $p=0,0026$	0,2590 (0,1544-0,4358); 0,0870; $p<0,001$	0,2427 (0,1069-0,3784); 0,0589; $p<0, 0001$	0,238
Thumb outside	R	0,1516 (0,0081-0,2958); 0,0230; $p=0,0085$	0,1473 (0,0165-0,2780); 0,0217; $p=0,0067$	0,2347 (0,0970-0,3724); 0,0551; $p<0,0001$	0,792
	L	0,147 (0,0029-0,2825); 0,0204; $p=0,0117$	0,2182 (0,0812-0,3552); 0,0476; $p=0,0001$	0,2730 (0,1350-0,4110); 0,0745; $p<0,0001$	0,034

Palm in intermediate position	R	0,1086 (-0,0251-0,2422); 0,0118; $p=0,0423$	0,2224 (0,0845-0,3604); 0,0495; $p=0,0001$	0,2256 (0,0898-0,3614); 0509; $p=0,0001$	0,955
	L	0,1036 (-0,0279-0,2350); 0,0107; $p=0,0507$	0,2681 (0,1285-0,4076); 0,0719; $p<0,0010$	0,2427 (0,1069-0,3784); 0,0589; $p<0,0001$	0,221
Pelvis extended (no anteversion, no retroversion)		0,1542 (0,0396-0,2686); 0,0237; $p=0,0036$	0,1777 (0,0654-0,2899); 0,0316; $p=0,0006$	0,2856 (0,1745-0,3968); 0,0816; $p=0,0000$	0,165
Lower limb situated in moderate external rotation	R	0,2233 (0,0901-0,3546); 0,0499; $p=0,0001$	0,1980 (0,0728-0,3231); 0,0392; $p=0,0001$	0,1959(0,0724-0,3194); 0,0384; $p=0,0003$	0,083
	L	0,2181 (0,0864-0,3497); 0,0475; $p=0,0000$	0,1919 (0,0681-0,3158); 0,0368; $p=0,0004$	0,2118 (0,0883-0,3354); 0,0449; $p=0,0001$	0,115
Lower limb bent at a right angle at hip and knee joints, foot in intermediate position – lifting above the substrate	R	0,2009 (0,0740-0,3278); 0,0404; $p=0,0004$	0,2196 (0,0947-0,3391); 0,0470; $p=0,0001$	0,3185 (0,1965-0,4404); 0,1014; $p=0,0000$	0,328
	L	0,1966 (0,0709-0,3222); 0,0386; $p=0,0005$	0,2114 (0,0903-0,3326); 0,0447; $p=0,0001$	0,3118 (0,1908-0,4327); 0,0972; $p=0,0000$	0,311