International Journal of
Environmental Research and Public Health

MDPI

Article

Pelvic Symmetry Is Influenced by Asymmetrical Tonic Neck Reflex during Young Children's Gait

Ewa Gieysztor [1,*], Anna Pecuch [1], Mateusz Kowal [1], Wojciech Borowicz [2] and Małgorzata Paprocka-Borowicz [1]

1 Physiotherapy Department, Faculty of Health Sciences, Wroclaw Medical University, 50-355 Wroclaw, Poland; anna.pecuch@student.umed.wroc.pl (A.P.); mateusz.kowal@umed.wroc.pl (M.K.); malgorzata.paprocka-borowicz@umed.wroc.pl (M.P.-B.)

2 Department of Nervous System Diseases, Faculty of Health Sciences, Wroclaw Medical University, 50-367 Wroclaw, Poland; wojciech.borowicz@student.umed.wroc.pl

* Correspondence: ewa.gieysztor@umed.wroc.pl

Received: 4 June 2020; Accepted: 29 June 2020; Published: 2 July 2020

check for updates

Abstract: Gait is one of the examined functions in child development. It should be economical and symmetrical. One test increasingly used by physiotherapists and pediatricians is asymmetrical tonic neck reflex (ATNR). Physiologically, it is observed from in utero up to six postnatal months. This reaction is inhibited with the growing maturation of the central nervous system (CNS). In some children, when the natural process of development is incorrect, ATNR manifests later in life, when it is observed as an automatic response of muscle tension to head rotation. Analysis of pelvis symmetry in the gait of children with active ATNR is important for better understanding their specific movements. In the gait of children with persistent ATNR, some variations are observed. The aim of the study was to investigate the gait symmetry of preschool children and the influence of persistent ATNR. Fifty preschool children with a trace form of ATNR were examined. The distribution of the gait parameters was determined using a BTS G-SENSOR measurement instrument. ATNR negatively influences pelvic obliquity and pelvic rotation ($p < 0.01$). Younger children have a statistically higher symmetry index of pelvis obliquity in the examined group ($p = 0.015$). Boys obtain a higher result of symmetry in pelvic tilt than girls in the group ($p = 0.027$). ATNR affects walking symmetry in preschool children, thus evaluation of the reflex activity and then proper therapy is required to support proper development.

Keywords: gait symmetry; pelvic symmetry; preschool children; neurodevelopment; asymmetrical tonic neck reflex

1. Introduction

Gait symmetry is one of the determinants of proper child development. Some asymmetries are normal for human movement, however some can be impacted for various reasons. For parents and pediatricians as well as physiotherapists, the wide spectrum of factors influencing child development should be known for proper movement analysis [1]. Persistent asymmetrical tonic neck reflex (ATNR) is one of the factors that can impact child development. It has been found very commonly in healthy preschool children. The most frequent type is the left side form of this reflex [2–5]. The activity of the reflex during the motion gives some additional muscle tension response, which involves the central nervous system (CNS) after reception of additional stimuli. The movement of the head, in people with active ATNR, induces movement or muscle contraction in the limbs and trunk. This is especially visible in closed-chain tasks. The head rotation provokes extension activity in the muscles of the limbs and trunk at the face side and flexion muscle activity at the occipital side of the body. The grade of the response depends on the degree of primitive reflex (PR) activity. The more vital the reflex, the more active the response, which is visible as increased muscle tone, even causing motion in the limbs and the trunk [3,4].

The most studied symptoms connected with ATNR activity refer to learning difficulties such as visual disturbances, poor stability of posture during sitting and writing, and large and small motor skill delays or inadequacies [4,6–8]. Difficulties in riding a bicycle are also observed in children with ATNR.

The impact of ATNR on gait symmetry has not yet been studied, as far as the authors could determine. Noticing the wide range of child developmental fields impacted by primitive reflexes (PRs), the authors investigated if the walking pattern is also regulated by and dependent on the degree of PR activity. Because gait is a complex motion, which involves the whole body, dependence on the reflex reaction through muscle tension may influence gait parameters [1,3,9,10]. Thus, the aim of the study was to find if there is an ATNR impact on the symmetry parameters of the gait. Moreover, we wanted to check if there is a difference between two types of ATNR testing (in closed- and open-chain) taking into consideration the correlation with pelvic symmetry index parameters.

2. Materials and Methods

The study was approved by the Wroclaw Medical University Ethical Committee and conducted in accordance with the Declaration of Helsinki. All the parents of the subjects were kept informed of the purpose and process of examination and subsequently gave their written consent prior to the study.

2.1. Participants

In the study, fifty children (30 girls and 20 boys) were examined. The mean age of the group was 5.5 (±0.5) years. The mean height of the participants was 100 cm (±10), and the mean weight was 17 kg (±3.4). The group had ATNR at different levels, from none to extreme activity, according to the Goddard scale [11]. Parents reported neither pathological lower limb abnormalities at the time of testing nor other musculoskeletal/neurological and/or cardiopulmonary conditions likely to influence walking level.

2.2. Measurement of Asymmetrical Tonic Neck Reflex

The examination of ATNR was conducted in two different ways. The first test was executed in quadruple position according to the Ayres recommendation, and the second in standing position, using the Schilder test [12]. The Ayres test is taken in closed-chain, and the Schilder test is performed in open-chain.

In the Ayres test, the child was asked to stay in quadruple position. The researcher turned his or her head to the left and then to the right side. After turning the child's head, the researcher observed whether there was any change in upper limb position. The five-degree scale of reflex activity is: 0 for full integration to 4 for maximum activity. The child with ATNR shows occipital-side elbow banding from the mildest form, to elbow banding and shoulder banding with trunk rotation in the maximum form of activity.

In the Schilder test, the child was recommended to stand straight, feet close together, arms flexed to 90 degrees, hands facing down. The researcher turned the child's head to both sides slowly. During the test, the arms follow the head if active ATNR is observed. Maximum points are given for turning the whole body while the head is changing position.

2.3. Pelvis Symmetry Gait Parameters Measurement

The acquisition of the pelvis symmetry gait parameters was performed using a BTS G-SENSOR measurement instrument (BTS Bioengineering Corp., Quincy, MA, USA). The device was equipped with a Triaxial Accelerometer 16bit/axis with multiple sensitivity (±2, ±4, ±8, ±16 g), a Triaxial Gyroscope 16bit/axis with multiple sensitivity (±250, ±500, ±1000, ±2000 °/s), as well as a Triaxial Magnetometer 13bit (±1200 uT). An inter-instrument correlation coefficient between 0.90 and 0.99

and an intra-instrument coefficient of variation of ≤2.5% proved the G-Sensor to be suitable for the assessment of physical activity [12–14].

The measurement of gait was conducted with the protocol for the walking test. Children were asked to walk in their natural way four times over a distance of five meters. Children were walking barefoot. The pelvis symmetry parameters that were analyzed were: pelvic tilt (S), pelvic obliquity (F), and pelvic rotation (T).

2.4. Statistics

Statistical analysis was performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA). Arithmetic means and standard deviations were calculated for continuous variables. In order to determine the relationship between quantitative variables, Spearman's rho correlation analysis was used. Mann–Whitney U test was used to compare two groups in terms of quantitative variables. The chi-square test of independence was used to compare groups in terms of nominal/categorical variables. The level $\alpha = 0.05$ or $\alpha = 0.01$ was used for comparisons.

3. Results

3.1. Profile of Asymmetrical Tonic Neck Reflex in Examined Group

Using the Ayres test to examine the activity of asymmetrical tonic neck reflex, the results show that nearly 15% of examined children had no activity of the ATNR. In the Schilder test it was under 5% of examined preschoolers. The biggest group of children in both tests had ATNR R pointed at 2 in Ayres and 1 in the Schilder test. The results indicate that about 20% of the preschool children show the maximum intensity of ATNR, in both tests. The results of asymmetrical tonic neck reflex tests in the examined group of preschoolers are shown in Figures 1 and 2.

The correlation between the results of the Ayres test and the Schilder test was significant ($p < 0.01$). Moreover, the correlation between gender and ATNR measured in quadruple position was significant. Boys had higher results for ATNR than girls.

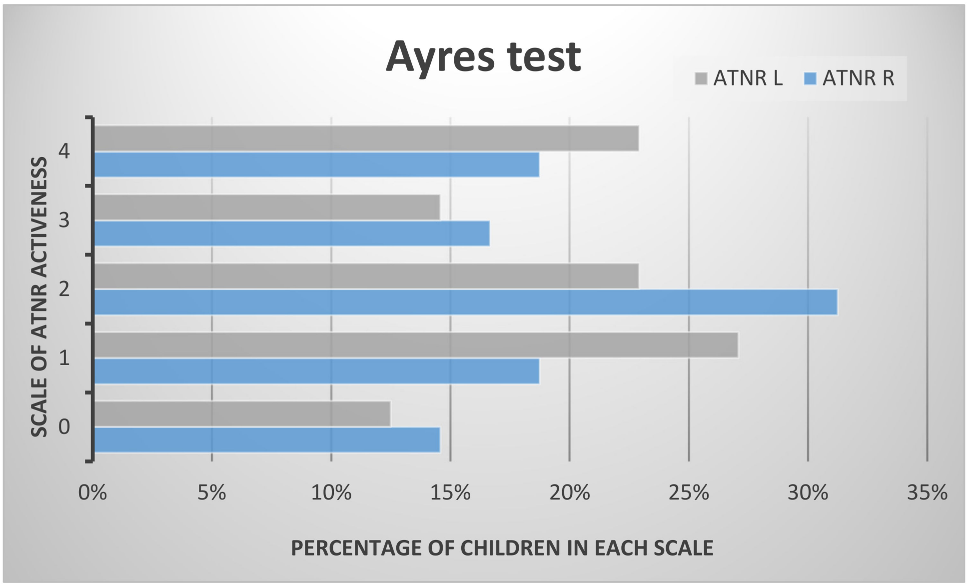


Figure 1. The results of asymmetrical tonic neck reflex (ATNR) in the examined group in the Ayres test.

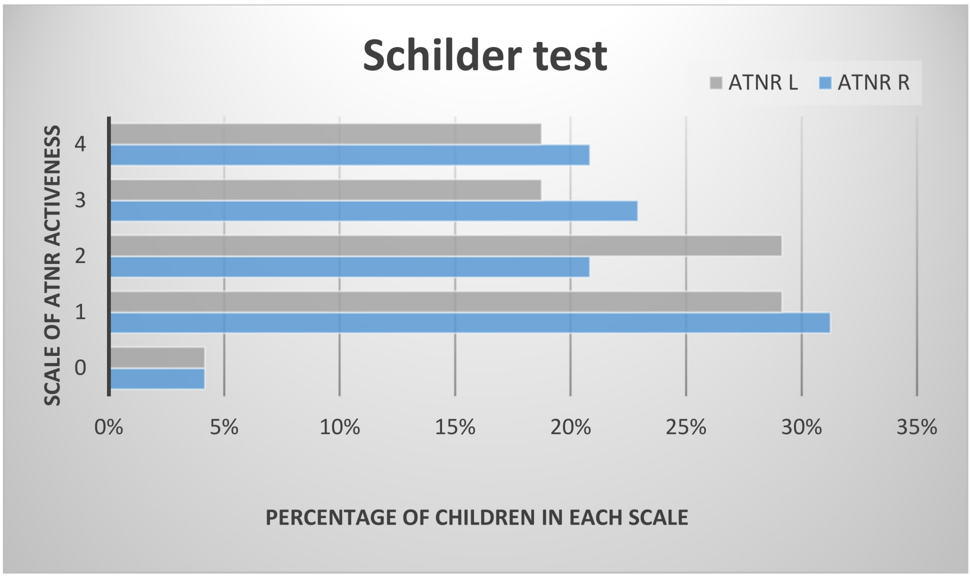


Figure 2. The results of ATNR in the examined group in the Schilder test.

3.2. Pelvic Motion during Gait

The results of pelvic symmetry in means, maximum, minimum, and standard deviation of the examined children are shown in Table 1.

Table 1. Range of motion, symmetry index and descriptive statistics of pelvic motion.

Pelvic Tilt (S)							
	L Side			**R Side**			
	Back Tilt	**Front Tilt**	**Range**	**Back Tilt**	**Front Tilt**	**Range**	**Symmetry Index**
MEAN	1.8	0.9	2.8	1.9	0.9	2.8	55.2
MAX	3.3	3.3	5.1	3.3	3.8	6.5	99.3
MIN	0.6	0.1	1.1	0.4	0	0.7	5.2
SD	0.7	0.7	1.1	0.7	0.7	1.2	25.3
Pelvic Obliquity (F)							
	L Side			**R Side**			
	Low	**Up**	**Range**	**Low**	**Up**	**Range**	**Symmetry Index**
MEAN	2.9	2.9	5.8	2.8	2.9	5.8	95.1
MAX	9	8.3	17.3	7.8	9.2	17	99.5
MIN	0.7	0.6	1.6	0.7	0.4	1.7	55.4
SD	1.6	1.5	3.0	1.4	1.7	3.0	8.4
Pelvic Rotation (T)							
	L Side			**R Side**			
	External	**Internal**	**Range**	**External**	**Internal**	**Range**	**Symmetry Index**
MEAN	7.7	7.7	15.4	7.1	8.0	14.8	93.2
MAX	14.7	16.7	31.4	14.8	14.1	26.1	99.5
MIN	1.9	2.6	5.6	1.5	1.8	3.4	40.3
SD	2.7	3.0	5.3	3.2	2.9	6.1	10.5

Moreover, the mean maximum and minimum range of the pelvic movement on the left and the right sides is shown in Figures 3–5. The pelvic rotation had the highest mean range of movement and the least had pelvic tilt. The least symmetry in the mean range of two sides movement of the pelvis was observed in frontal plane. Clear difference is between maximum of high position of the pelvis in the left and the right side.

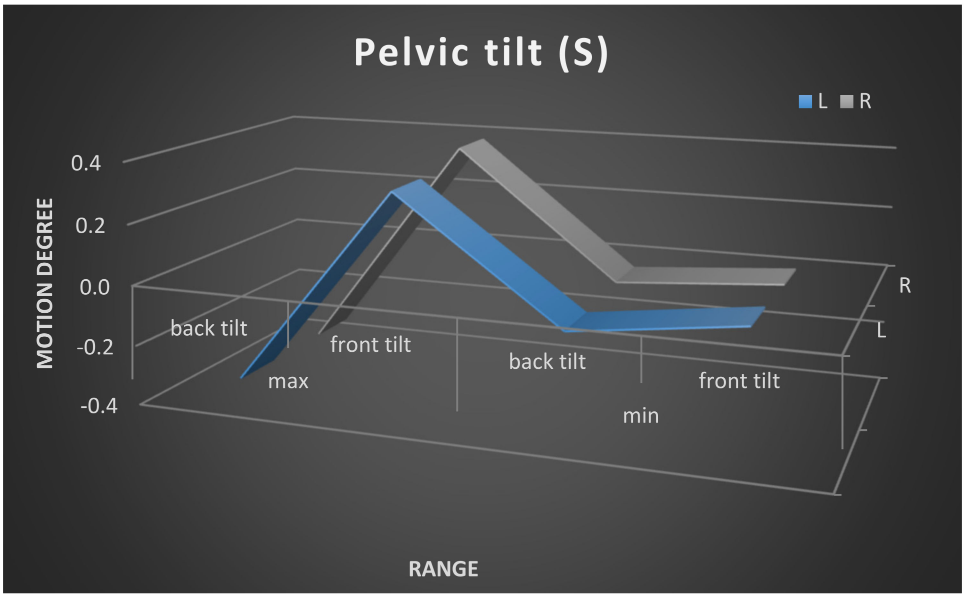


Figure 3. Pelvic tilt maximum and minimum range of movement. Left and right side comparison.

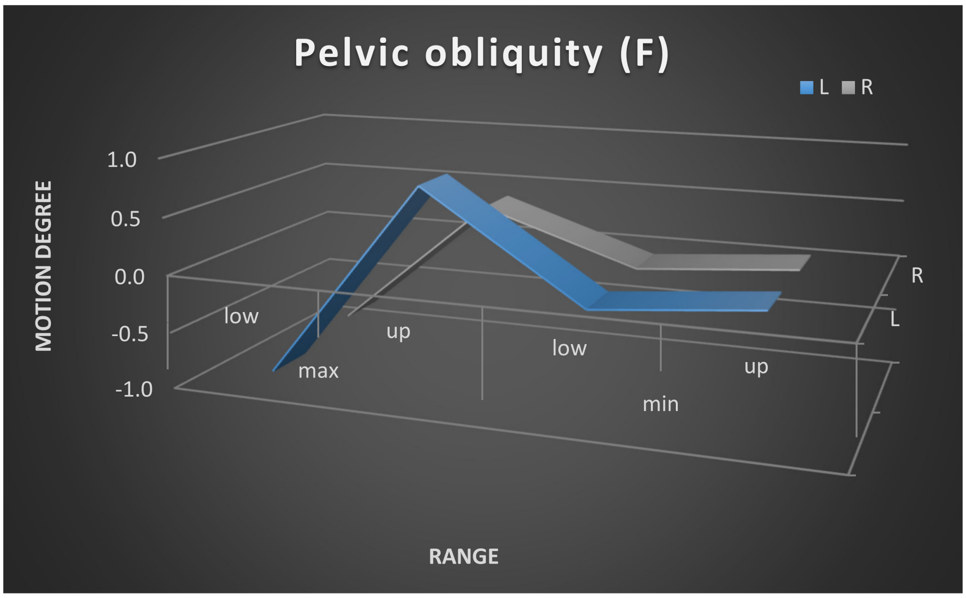


Figure 4. Pelvic obliquity maximum and minimum range of movement. Left and right side comparison.

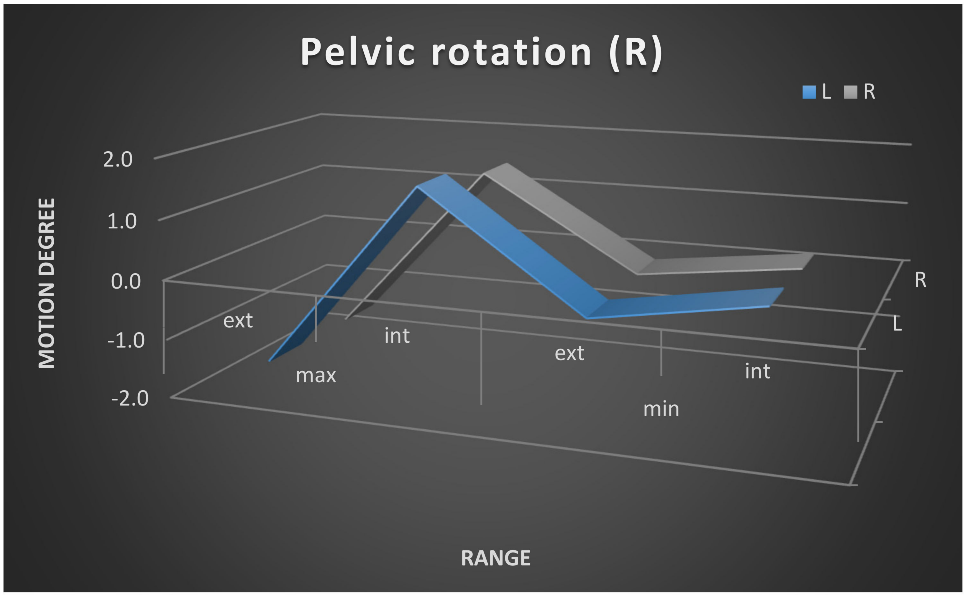


Figure 5. Pelvic rotation maximum and minimum range of movement. Left and right side comparison.

3.3. Correlation Between Asymmetrical Tonic Neck Reflex and Gait Parameters

Correlation analysis using Spearman's rho coefficient was carried out to check the relationship between gait parameters and persistent asymmetrical tonic neck reflex. Table 2 contains the results of the analyses carried out. Statistically significant correlations are observed for ATNR and pelvic obliquity as well as pelvic rotation. For ATNR Left Side measured both in closed- and open-chain, the results are nearly statistically significant for pelvic rotation. ATNR R and ATNR L in all the other results are strongly and moderately negatively correlated with pelvic obliquity and rotation. The results show no correlation between ATNR and pelvic tilt.

Table 2. Spearman correlation between asymmetrical tonic neck reflex and gait symmetry index.

Gait Parameters	Gait Symmetry Index		
	Pelvic Tilt (S)	**Pelvic Obliquity (F)**	**Pelvic Rotation (T)**
ATNR R	0.048	−0.407 **	−0.307 *
ATNR L	0.056	−0.430 **	−0.249
ATNR in standing R	0.053	−0.387 **	−0.384 **
ATNR in standing L	0.041	−0.341 *	−0.260

* $p < 0.05$; ** $p < 0.01$.

3.4. Correlation between Age and Gait Parameters

To check whether age was related to gait parameters, a correlation analysis was performed taking into account Spearman's rho coefficient. The analysis shows that the pelvis symmetry parameters did not correlate with age in the examined group.

Additionally, the respondents were divided into two age groups: children under 5 years of age ($n = 23$) and above 5 years of age ($n = 27$). The results for gait parameters in both groups were compared using the Mann–Whitney U test. Differences were observed between the two groups of younger and older children in the parameter of pelvic obliquity (PO). Children under 5 years old have a statistically higher symmetry index of PO in the examined group; Figure 6 and Table 3 displays the results.

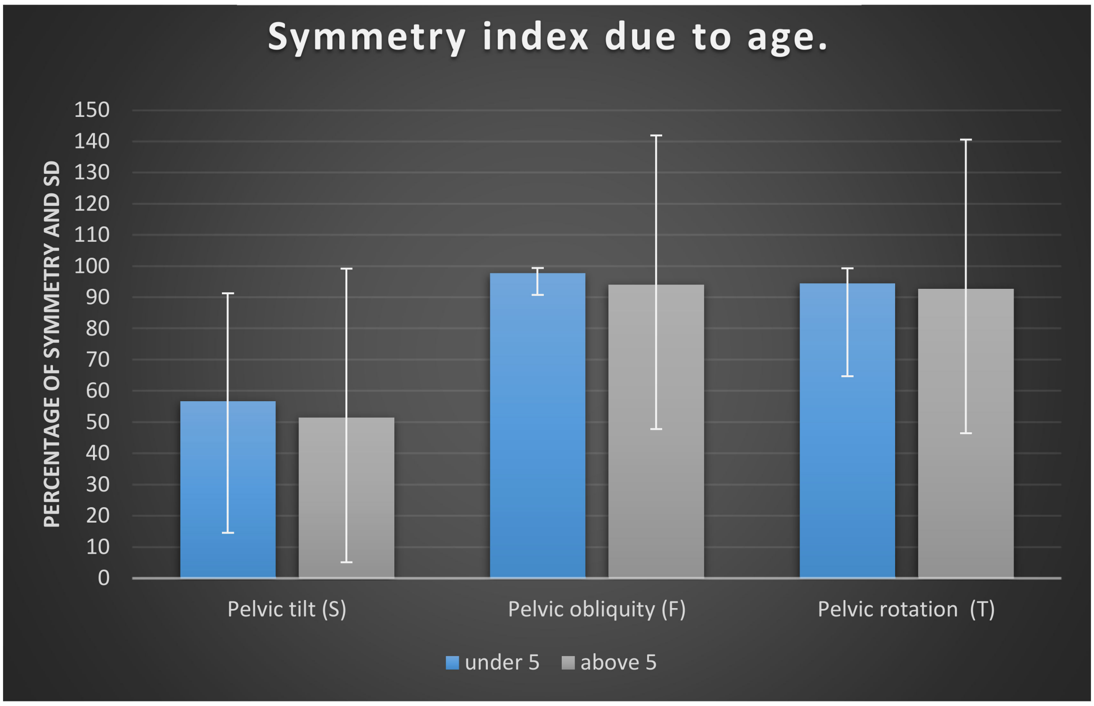


Figure 6. Symmetry index of pelvic tilt, pelvic obliquity, and pelvic rotation in examined children, shown as mean according to age.

Table 3. Gait parameters comparison between the two groups of younger and older children.

Symmetry	Under 5 Years Old			Above 5 Years Old			U	p	η^2
	M	**Me**	**SD**	**M**	**Me**	**SD**			
Pelvic tilt (S)	56.75	56.80	22.72	51.53	59.20	27.25	267.50	0.528	0.01
Pelvic obliquity (F)	97.82	98.70	2.16	94.18	97.60	9.24	178.00	0.015 *	0.12
Pelvic rotation (T)	94.60	97.80	8.03	92.83	97.30	12.17	272.50	0.595	0.01

M—mean; Me—median; SD—standard deviation; U—Mann–Whitney test results; p—level of significance; η^2—effect size; * $p < 0.05$.

3.5. Differences between Girls and Boys in Pelvis Symmetry Parameters

To determine whether girls and boys differed in terms of gait parameters, an analysis was carried out using the Mann–Whitney U test. A graphic representation of the results for girls and boys is shown in Figure 7. The most different results in these two groups are observed in the sagittal plane. In addition, the standard deviations of the results are higher in girls. SD results in boys more closely correspond to the mean in all pelvic movements.

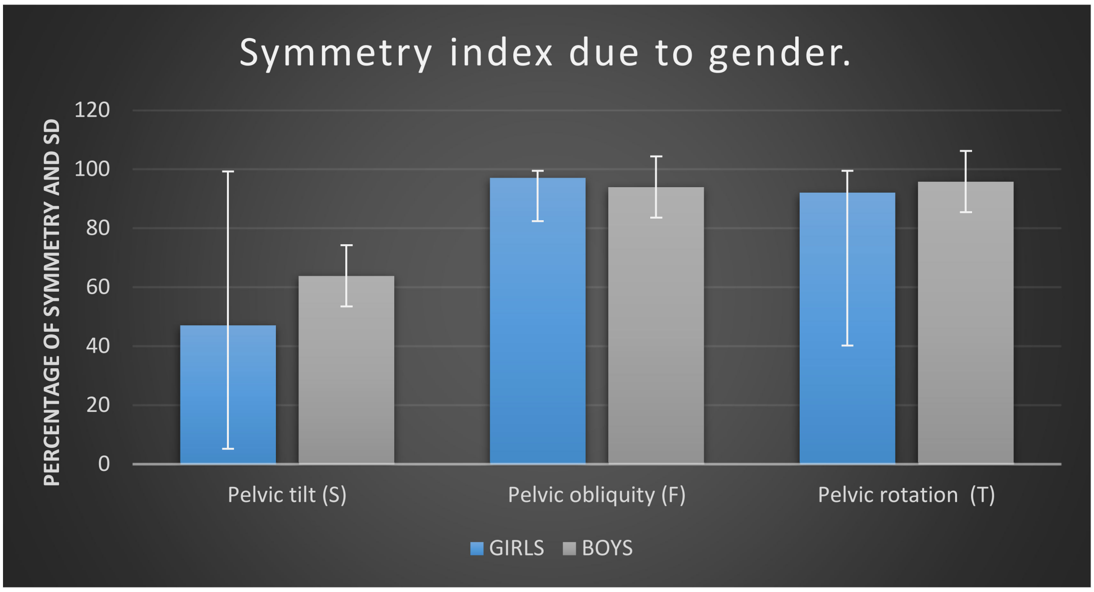


Figure 7. Symmetry index of pelvic tilt, pelvic obliquity, and pelvic rotation in examined children, shown as mean according to gender

Detailed analysis of the results is presented in Table 4.

Table 4. Gait symmetry parameters due to gender of examined children.

Gait Parameters	Girls (n = 30)			Boys (n = 20)			U	p	η^2
	M	Me	SD	M	Me	SD			
Pelvic tilt (S)	47.15	37.70	27.49	63.89	69.30	17.42	181.50	0.027 *	0.10
Pelvic obliquity (F)	97.17	98.50	3.53	94.03	97.60	10.09	201.50	0.072	0.06
Pelvic rotation (T)	92.13	97.30	12.88	95.87	97.60	4.29	286.00	0.935	0.00

M—mean; Me—median; SD—standard deviation; U—Mann–Whitney test results; p—level of significance; η^2—effect size; * $p < 0.05$.

The analysis showed one significant difference between the girls and boys examined. This difference relates to symmetry in pelvic tilt (S). Boys obtain a significantly higher result for this parameter than tested girls.

4. Discussion

Persistent primitive reflexes (PPR) co-exist with disturbances in child motor and posture development [4,15]. Their activity indicates the level of neuromotor immaturity in children [6,16–18]. Some children with PPR are observed to move in a specific way during spontaneous play as well as during gait. They have no neurological or musculoskeletal orthopedic impairments, but their movement schema differs. The question is if their movement can be indicated just by muscle tension caused by reflex response? Is the specific way that children with primitive reflexes perform walking visible in the gait parameters?

The results of our research show that primitive reflexes, such as ATNR, if they persist, have a significant impact on symmetry parameters in pelvis kinematics during gait. It seems that gait is another field of child development which is impacted by ATNR. Previously, learning skills have been studied, as well as eye–hand coordination and motor skills [2–4,19–23]. The kind of measurement that we proposed was conducted for the first time, so there is no strict comparison with other research. The most common gait analysis is conducted in children with scoliosis or cerebral palsy (CP) or in adults with hemiplegia [24–30]. We have tried to compare some of the results, while keeping cautions.

The most important correlation we have found was the dependence between asymmetrical tonic neck reflex and pelvic kinematics. We have found that pelvic obliquity symmetry depended on levels of ATNR activity. The children with a higher index of ATNR had a lower index of symmetry pelvic obliquity. There was a significant correlation for all of the tests done. Both the standing test and the quadruple test results correlated with symmetry pelvic obliquity. This means that checking ATNR in open- and in closed-chain gives comparable results. Moreover, both the right and the left form of ATNR have an impact on symmetry in the frontal plane of the pelvic kinematics during gait. We have observed similar results for pelvic rotation symmetry. All results have a negative correlation to ATNR level. The results for the right side of the ATNR were significant. We have found no correlation of ATNR level with pelvic tilt. The explanation for these results can be based on the mechanical pattern of the reflex. To describe it closer, we analyzed the movement of the body during the reflex response in parts. During the head's turn to the right, the right leg and arm moved to extension and at the same time the left arm and leg moved to flexion. This kind of movement or muscle tenseness must impact pelvic motion. Pelvic motion can be visible in various forms. A high level of reflex activity gives a more obvious response in the form of body movement, especially in the limbs. A low level of reflex activity leads to muscle tension, sometimes even invisible. The change in tension in some parts of the body, in the example stated above, may determine the pelvic kinematics in terms of both the obliquity and rotation. The pelvic kinematics are changed by additional movements of the limbs and trunk in the response of the reflex reaction. This is obviously a model of pelvic behavior as an effect in the case of persistent reflex. We know that more specific movement analysis is needed. Our observation is described first and should lead to deeper analysis with different research devices. We can see the need for wider analysis of the body's reaction in the ATNR response in spontaneous child movement as well as movement with a given task. For such observation, a tool for in-depth motion analysis is necessary.

Pelvis symmetry index in children is not evaluated as often. In the literature, we can find absolute symmetry index (ASI) calculated, which is based commonly on foot loading [31]. As this is a different method of checking symmetry in gait, it does not directly indicate pelvis symmetry. Asymmetry in pelvic obliquity is very common in spastic cerebral palsy and scoliosis [24,32]. It is a parameter observed in static position. The results are obvious, taking into consideration the severity of the illnesses. In our study, children were symmetrical in clinical images but the asymmetries became visible during movement. Manicolo et al. and Papadopoulos et al. conducted analyses of gait symmetries in children with ADHD and developmental coordination disorders [31,33–37]. The authors show many gait variables in these groups. Some of the spatiotemporal gait variables in ADHD children were not different than in the control group [34]. These results show the disturbances in gait in such illnesses.

Performing further analyses in our research, we also divided children into two sub-groups by age. The only statistically important difference we found between these groups was pelvic obliquity (F). The symmetry in this parameter was higher in the younger group (under 5 years old) than in the group above 5 years old. Smith et al. [38] also checked the gait parameters of normally developed children. This work was conducted in South Africa. The children's range of pelvis tilt was around 18 degrees, and pelvis obliquity was around 6 degrees as well as pelvis rotation. In our group, we observed a range of motion for pelvic tilt around 2.8 degrees, for pelvic obliquity 5.8 degrees, and for pelvis rotation around 15 degrees. A very big difference in the results was found in pelvic tilt and pelvic rotation. Can it be the result of ATNR activity? It is not so obvious. The differences may be rather enlarged by the different races of examined children and are very intriguing for future investigation. The authors, like us, compared gait parameters in two groups of children, in this case aged 6–8 years old and 9–10 years old. Smith at al.'s research shows minimum variation in the kinematic patterns of the pelvis between the two age groups. There was no statistical difference in the results between the two groups. As the authors took into consideration older children than in our research, the comparison cannot be literal and this may be the next reason for such discrepancies.

In the sub-groups dependent on gender, we found a statistical difference in pelvic tilt (S) symmetry. Boys obtain a significantly higher result for this parameter than tested girls. The differentiation in pelvic tilt symmetry between genders may also be connected with a difference in sagittal standing posture between genders, such as pelvic tilt which is higher in girls than in boys [39]. The higher range of motion makes the system more unstable, thus the results showing higher asymmetrical pelvic tilt in girls is the consequence.

As there is little research connected with the gait symmetry index in normally developing children, a wider comparison is not possible. Most of the studies focus on spatio-temporal gait parameters, which is not the field of our study. Even if kinematic parameters are explored in some studies, the symmetry index of pelvis motion has not been found by authors so far. The impact of primitive reflexes on a child's life is still being checked by different kinds of researchers in different disciplines such as psychology, pedagogy, and physiotherapy, where some interventions are being undertaken [38–43]. This demonstrates the importance of cooperation for child integral understanding and support. The differentiation in gait patterns completes the child picture with primitive reflexes in clinical images. This kind of child movement is usually described as clumsy. Our study may introduce a reason for a specific way of moving. Movement in which the child cannot control the movement of his or her limbs causes many problems. The child's physically awkward behavior can be incomprehensible for his or her entourage. Such analysis as that which we have conducted may explain the child's unwitting behavior as well as remind and emphasize how important it is to work on the integration of primitive reflexes for a well-balanced child.

5. Conclusions

This research can bring important information for physicians, physiotherapists, and parents taking care of children with certain developmental disturbances. The awareness of active primitive reflexes contributing to misbalancing so many spheres of child development may be essential in the decision-making process regarding the facilitation, management, modification, or elimination of each sign of developmental delays.

Author Contributions: Conceptualization, E.G.; methodology, E.G.; software, M.K.; validation, M.P.-B.; formal analysis, E.G.; investigation, E.G., A.P.; resources, M.K., W.B.; data curation, A.P.; writing—original draft preparation, E.G.; writing—review and editing, E.G., A.P., M.K., W.B., M.P-B.; visualization, W.B.; supervision, M.P.-B.; project administration, E.G., M.K., M.P.-B.; funding acquisition, M.P.-B. All authors have read and agreed to the published version of the manuscript

Funding: This research received no external funding The APC was funded by MINISTRY OF SCIENCE AND HIGHER EDUCATION IN POLAND grant number SUB.E.060.19.001.

Acknowledgments: The authors gratefully acknowledge the teachers, parents and children who participate in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Valentín-Gudiol, M.; Mattern-Baxter, K.; Girabent-Farrés, M.; Bagur-Calafat, C.; Hadders-Algra, M.; Angulo-Barroso, R.M. Treadmill interventions in children under six years of age at risk of neuromotor delay. *Cochrane Database Syst. Rev.* **2017**, *7*, CD009242. [CrossRef] [PubMed]
2. Montgomery, R.; Nichols, C.; Ornburn, C.; Rudd, A.; Williams, L. The Effects of Persistent Asymmetrical Tonic Neck Reflex (ATNR) on Reading Scores in First and Second Grade Children. Available online: http://soar.wichita.edu/handle/10057/11429 (accessed on 16 April 2017).
3. Zemke, R. Application of an ATNR rating scale to normal preschool children. *Am. J. Occup. Ther. Off.* **1985**, *39*, 178–180. [CrossRef]
4. Gieysztor, E.Z.; Choińska, A.M.; Paprocka-Borowicz, M. Persistence of primitive reflexes and associated motor problems in healthy preschool children. *Arch. Med. Sci.* **2018**, *14*, 167–173. [CrossRef] [PubMed]
5. Madejewska, M.; Choińska, A.M.; Gieysztor, E.Z.; Trafalska, A. Neuromotorical Assessment of Children Aged 4–7 from the Kamienna Góra District Based on Sally Goddard Tests. *Pielęgniarstwo Zdr. Publiczne Nurs. Publ. Health* **2016**, *6*, 179–186. [CrossRef]

6. Goddard-Blythe, S. The role of primitive survival reflexes in the development of the visual system. *J. Behav. Optom.* **1995**, *6*, 31–36.
7. Andrich, P.; Shihada, M.; Vinci, M.; Wrenhaven, S.; Goodman, G. Statistical Relationships Between Visual Skill Deficits and Retained Primitive Reflexes in Children. *Optom. Vis. Perf.* **2018**, *3*, 106–111.
8. Goddard-Blythe, S. *Attention, Balance and Coordination: The A.B.C. of Learning Success*; Wiley: Hoboken, NJ, USA, 2009.
9. Bruijn, S.M.; Massaad, F.; Maclellan, M.J.; Van Gestel, L.; Ivanenko, Y.P.; Duysens, J. Are effects of the symmetric and asymmetric tonic neck reflexes still visible in healthy adults? *Neurosci. Lett.* **2013**, *556*, 89–92. [CrossRef]
10. Jacobs, L.; Gossman, M.D. Three primitive reflexes in normal adults. *Neurology* **1980**, *30*, 184. [CrossRef]
11. Blythe, S.G. *Neuromotor Immaturity in Children and Adults: The INPP Screening Test for Clinicians and Health Practitioners*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
12. Blythe, S.G. INPP Screening Test for Signs of Neuromotor Immaturity in Adults. In *Neuromotor Immaturity in Children and Adults*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2014; pp. 83–110.
13. Sankarpandi, S.K.; Baldwin, A.J.; Ray, J.; Mazzà, C. Reliability of inertial sensors in the assessment of patients with vestibular disorders: A feasibility study. *BMC Ear Nose Throat Disord.* **2017**, *17*, 1. [CrossRef]
14. Del Din, S.; Godfrey, A.; Rochester, L. Validation of an Accelerometer to Quantify a Comprehensive Battery of Gait Characteristics in Healthy Older Adults and Parkinson's Disease: Toward Clinical and at Home Use. *IEEE J. Biomed. Health Inform.* **2016**, *20*, 838–847. [CrossRef] [PubMed]
15. Gieysztor, E.; Sadowska, L.; Choińska, A.; Paprocka-Borowicz, M. Trunk rotation due to persistence of primitive reflexes in early school-age children. *Adv. Clin. Exp. Med.* **2018**, *27*, 363–366. [CrossRef] [PubMed]
16. Goddard-Blythe, S. Movement a child's first A, B, C. In *Early Childhood Education Redefined*; Routledge: Abingdon, UK, 2018; pp. 44–63.
17. Goddard-Blythe, S. *The Well Balanced Child: Movement and Early Learning*, 2nd ed.; Hawthorn Press: Stroud, UK, 2005.
18. Zemke, R. Incidence of ATNR Response in Normal Preschool Children. *Phys. Occup. Ther. Pediatr.* **1981**, *1*, 31–38. [CrossRef]
19. Gieysztor, E.Z.; Sadowska, L.; Choińska, A.M. The degree of primitive reflexes integration as a diagnostic tool to assess the neurological maturity of healthy preschool and early school age children. *Pielęgniarstwo Zdr. Publiczne Nurs. Publ. Health* **2017**, *7*, 5–11. [CrossRef]
20. Alibakhshi, H.; Salmani, M.; Ahmadizadeh, Z.; Siminghalam, M. Relationship between primitive reflexes and fine motor skills in children with specific learning disorders. *Koomesh* **2018**, *20*, 478–483.
21. Thelen, E.; Fisher, D.M.; Ridley-Johnson, R. The relationship between physical growth and a newborn reflex. *Infant Behav. Dev.* **1984**, *7*, 479–493. [CrossRef]
22. McPhillips, M.; Sheehy, N. Prevalence of persistent primary reflexes and motor problems in children with reading difficulties. *Dyslexia Chichester Engl.* **2004**, *10*, 316–338. [CrossRef]
23. Mok, M.M.C.; Chin, M.-K.; Korcz, A.; Popeska, B.; Edginton, C.R.; Uzunoz, F.S.; Podnar, H.; Coetzee, D.; Georgescu, L.; Emeljanovas, A.; et al. Brain Breaks® Physical Activity Solutions in the Classroom and on Attitudes toward Physical Activity: A Randomized Controlled Trial among Primary Students from Eight Countries. *Int. J. Environ. Res. Public. Health* **2020**, *17*. [CrossRef]
24. Domagalska-Szopa, M.; Szopa, A. Gait Pattern Differences between Children with Mild Scoliosis and Children with Unilateral Cerebral Palsy. *PLoS ONE* **2014**, *9*. [CrossRef]
25. Grivas, T.B.; Angouris, K.; Chandrinos, M.; Kechagias, V. Truncal changes in children with mild limb length inequality: A surface topography study. *Scoliosis Spinal Disord.* **2018**, *13*, 27. [CrossRef]
26. Pulido-Valdeolivas, I.; Gómez-Andrés, D.; Martín-Gonzalo, J.A.; Rodríguez-Andonaegui, I.; López-López, J.; Pascual-Pascual, S.I.; Rausell, E. Gait phenotypes in paediatric hereditary spastic paraplegia revealed by dynamic time warping analysis and random forests. *PLoS ONE* **2018**, *13*. [CrossRef]
27. Kim, C.-H.; Chu, H.; Park, C.; Kang, G.-H.; Seo, J.; Sung, K.-K.; Lee, S. Comparison of recovery patterns of gait patterns according to the paralyzed side in Korean stroke patients. *Medicine* **2018**, *97*. [CrossRef] [PubMed]
28. Winiarski, S.; Rutkowska-Kucharska, A.; Pozowski, A.; Aleksandrowicz, K. A New Method of Evaluating the Symmetry of Movement Used to Assess the Gait of Patients after Unilateral Total Hip Replacement. *Appl. Bionics Biomech.* **2019**, *2019*, 1–11. [CrossRef]

29. Assaiante, C.; Mallau, S.; Viel, S.; Jover, M.; Schmitz, C. Development of Postural Control in Healthy Children: A Functional Approach. *Neural Plast.* **2005**, *12*, 109–118. [CrossRef]
30. Keci, A.; Tani, K.; Xhema, J. Role of Rehabilitation in Neural Plasticity. *Open Access Maced. J. Med. Sci.* **2019**, *7*, 1540–1547. [CrossRef] [PubMed]
31. Bosch, K.; Rosenbaum, D. Gait symmetry improves in childhood-A 4-year follow-up of foot loading data. *Gait Posture* **2010**, *32*, 464–468. [CrossRef] [PubMed]
32. Domagalska-Szopa, M.; Szopa, A. Body Posture Asymmetry Differences between Children with Mild Scoliosis and Children with Unilateral Cerebral Palsy. *BioMed Res. Int.* **2013**, *2013*. [CrossRef] [PubMed]
33. Manicolo, O.; Grob, A.; Lemola, S.; Hagmann-von Arx, P. Age-related decline of gait variability in children with attention-deficit/hyperactivity disorder: Support for the maturational delay hypothesis in gait. *Gait Posture* **2016**, *44*, 245–249. [CrossRef]
34. Papadopoulos, N.; McGinley, J.L.; Bradshaw, J.L.; Rinehart, N.J. An investigation of gait in children with Attention Deficit Hyperactivity Disorder: A case controlled study. *Psychiatry Res.* **2014**, *218*, 319–323. [CrossRef]
35. Eggleston, J.D.; Harry, J.R.; Hickman, R.A.; Dufek, J.S. Analysis of gait symmetry during over-ground walking in children with autism spectrum disorder. *Gait Posture* **2017**, *55*, 162–166. [CrossRef]
36. Axeti, G.; Gissis, I.; Vrabas, I.; Grouios, G.; Komsis, G.; Komsis, S. Assessment of kinematic characteristics of preschoolers' gait during the implementation of an intervention training program. *J. Hum. Sport Exerc.* **2017**, *12*, 1298–1309. [CrossRef]
37. Lythgo, N.; Wilson, C.; Galea, M. Basic gait and symmetry measures for primary school-aged children and young adults whilst walking barefoot and with shoes. *Gait Posture* **2009**, *30*, 502–506. [CrossRef] [PubMed]
38. Smith, Y.; Louw, Q.; Brink, Y. The three-dimensional kinematics and spatiotemporal parameters of gait in 6–10 year old typically developed children in the Cape Metropole of South Africa–a pilot study. *BMC Pediatr.* **2016**, *16*. [CrossRef] [PubMed]
39. Araújo, F.A.; Simões, D.; Silva, P.; Alegrete, N.; Lucas, R. Sagittal standing posture and relationships with anthropometrics and body composition during childhood. *Gait Posture* **2019**, *73*, 45–51. [CrossRef] [PubMed]
40. McPhillips, M.; Hepper, P.G.; Mulhern, G. Effects of replicating primary-reflex movements on specific reading difficulties in children: A randomised, double-blind, controlled trial. *Lancet* **2000**, *355*, 537. [CrossRef]
41. Grigg, T.M.; Fox-Turnbull, W.; Culpan, I. Retained primitive reflexes: Perceptions of parents who have used Rhythmic Movement Training with their children. *J. Child. Health Care* **2018**, 406–418. [CrossRef]
42. Grzywniak, C. Integration exercise programme for children with learning difficulties who have preserved vestigial primitive reflexes. *Acta Neuropsychol.* **2017**, *15*, 241–256. [CrossRef]
43. Bowden, A. *Primitive Reflex Integration in Intensive Physical Therapy and Gross Motor Function in Children with Cerebral Palsy: A Case Report*; University of Iowa: Iowa City, IA, USA, 2019; p. 9.

International Journal of
Environmental Research and Public Health

MDPI

Article

Primitive Reflex Factors Influence Walking Gait in Young Children: An Observational Study

Ewa Gieysztor *, Mateusz Kowal and Małgorzata Paprocka-Borowicz

Department of Physiotherapy, Faculty of Health Sciences, Wroclaw Medical University, 50-367 Wrocław, Poland; mateusz.kowal@umw.edu.pl (M.K.); malgorzata.paprocka-borowicz@umw.edu.pl (M.P.-B.)
* Correspondence: ewa.gieysztor@umw.edu.pl

Abstract: Background: Primitive reflexes (PRs) are observed as an automatic response to a specific stimulus. They are vivid from intrauterine life to 6 months postnatal. The reactions are inhibited with the growing maturation of the central nervous system (CNS). In some cases, when the natural process of development is incorrect, PRs manifest later. The analysis of differentiation in gait parameters in children with persistent PRs is important for better understanding their specific behaviour and movement. This study's aim was to investigate the influence of active PRs on the gait parameters of preschool children. Methods: There were 50 children examined, 30 girls and 20 boys. They were 3.5–6 years old. The children had persistent PRs in the trace form. Each child was examined by S. Goddard's Battery Test. The acquisition of the spatial-temporal gait parameters was performed using a BTS G-SENSOR measurement instrument. Participants walked barefoot, in the most natural way for them, at a self-selected speed on a 5 m walkway, then turned around and went back. They performed this twice. Results: The reflex activity influences gait cycle duration (p = 0.0099), the left step length (p = 0.0002), the left double support phase (p = 0.0024), the right double support phase (p = 0.0258) and the right single phase. Difficulties in recreating the crawling pattern and GRASP reflex influence gait cadence ($p < 0.05$). The left GRASP reflex corresponds to step length ($p < 0.05$). The activeness of the symmetrical tonic neck reflex correlates with the right single support ($p < 0.05$). Conclusion: The presence of PRs affect walking gait in preschool children.

Keywords: primitive reflexes; children; spatio-temporal parameters; gait

check for updates

Citation: Gieysztor, E.; Kowal, M.; Paprocka-Borowicz, M. Primitive Reflex Factors Influence Walking Gait in Young Children: An Observational Study. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4070. https://doi.org/10.3390/ijerph19074070

Academic Editor: Paul B. Tchounwou

Received: 21 January 2022
Accepted: 23 March 2022
Published: 29 March 2022

1. Introduction

The phenomenon of an immature central nervous system (CNS) can be observed in some preschool children. This is especially noticeable in the activeness of primitive reflexes (PRs). PRs are an automatic response to a specific stimulus. They manifest in utero and should have desisted by the sixth month of life. No activity of the reflexes is expected. The reflexes are restrained due to the growing maturation of the central nervous system. In some cases, when the natural process of development is incorrect, PRs can manifest later in life. PR activeness is increasingly observed, even in groups of neurologically healthy children [1–4]. In subjects with CNS injuries, such as cerebral palsy (CP), the full range of PR reactions is visible. The trace form of PRs is observed in children, later in life, usually of preschool or school-age and diagnosed, for example, as ADHD or specific learning difficulties [1]. Primitive reflexes indicate the level of neuromotor immaturity in children [5–7]. Some studies show the association of motor developmental delays with the activeness of primitive reflexes (APR), along with posture development [4,8]. Children with APR move in a specific way during spontaneous play and walking (gait). They have no neurological and musculoskeletal impairments, but their movement patterns may be affected by muscle tension caused by the reflex's response [9]. The gait may be influenced by many factors. The most obvious are injuries of the lower limbs or brain injuries, but the subtle changes in the gait smoothness may also be noticed in children with gentle disturbances in brain activity, which may be observed in the activeness of primitive reflexes. There are no previous studies of gait parameters in children with APR; however, gait analyses in children with ADHD or CP are common and they are similar for comparison purposes because it is proven that some PRs are also active in children with ADHD [10–12].

Gait factors such as duration (s), cadence (steps/min), velocity (m/s), step length (m) and step length to height component, as well as gait cycle duration (s), step length (%), support phase duration (%), swing phase (%), double support duration (%) and single support duration (%) are usually analysed [13–16]. The surveying of the differentiation in gait parameters in children with APR is important for better understanding their specific behaviour and movement in preschool diagnoses and specialist medical diagnoses, but also in the natural environment of the child. The patterns of the gait and spontaneous movement of the child with APR are often described using qualitative and subjective methods (e.g., descriptive method) [17–19]. Unfortunately, such a process does not allow for detailed knowledge of the spatio-temporal variables in the gait cycle, so more precise analyses cannot be performed without specific human movement analysis and the application of devices.

Taking the above into consideration, the basic aim of the study was to investigate the impact of primitive reflexes on walking gait.

2. Materials and Methods

2.1. Study Design

The observational study is part of the PRACS (Primitive Reflexes and All Children Sphere) project. The project investigates primitive reflexes and their impact on the motor, sensory, and cognitive development in preschool and school-age children. There are four articles published from the project so far [20–22].

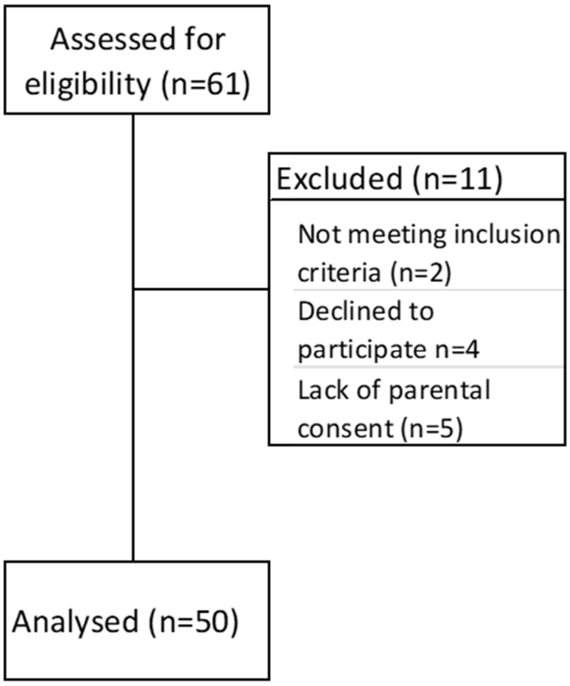
The research related to human use has complied with all relevant national regulations and institutional policies, following the tenets of the Declaration of Helsinki. The study was approved by the Wroclaw Medical University's Ethical Committee KB-116/2019. All parents of the subjects were kept informed of the purpose and process of examination and had given their written consent prior to the study.

2.2. Definitions

Crawling—crawling pattern
PR—primitive reflexes
ATNR R and L—asymmetrical tonic neck reflex, right and left sides
ATNR in standing—ATNR examined by Schilder test
STNR FLX and EXT symmetrical tonic neck reflex in flexion and in extension
GALANT R and L—Galant reflex
TLR FLX and EXT—tonic labyrinthine reflex in flexion and in extension
MORO—Moro reflex
GRASP P and L—Grasp reflex, right and left side

2.3. Participants

Preschool children whose parents/guardians consented to the study were included in the study. The inclusion criteria were communicativeness at the level of command understanding and proper motor and intellectual development of the child. The examination took place in the preschool of the child in a known environment. The flow chart of participation is shown in Scheme 1.



Scheme 1. Flow chart of participation.

Fifty children aged 3.5–6 years old were examined, 30 girls and 20 boys. The mean age of the group was 5.5 (±0.5) years. The mean height of the children was 100 cm (±10) and the mean weight was 17 kg (±3.4). The children had APR in trace form covering the entire spectrum of intensity–from none to alarming, according to the S. Goddard scale [6]. The specific characteristics of the degree of PR activity, divided by gender, are presented in Figures 1 and 2.

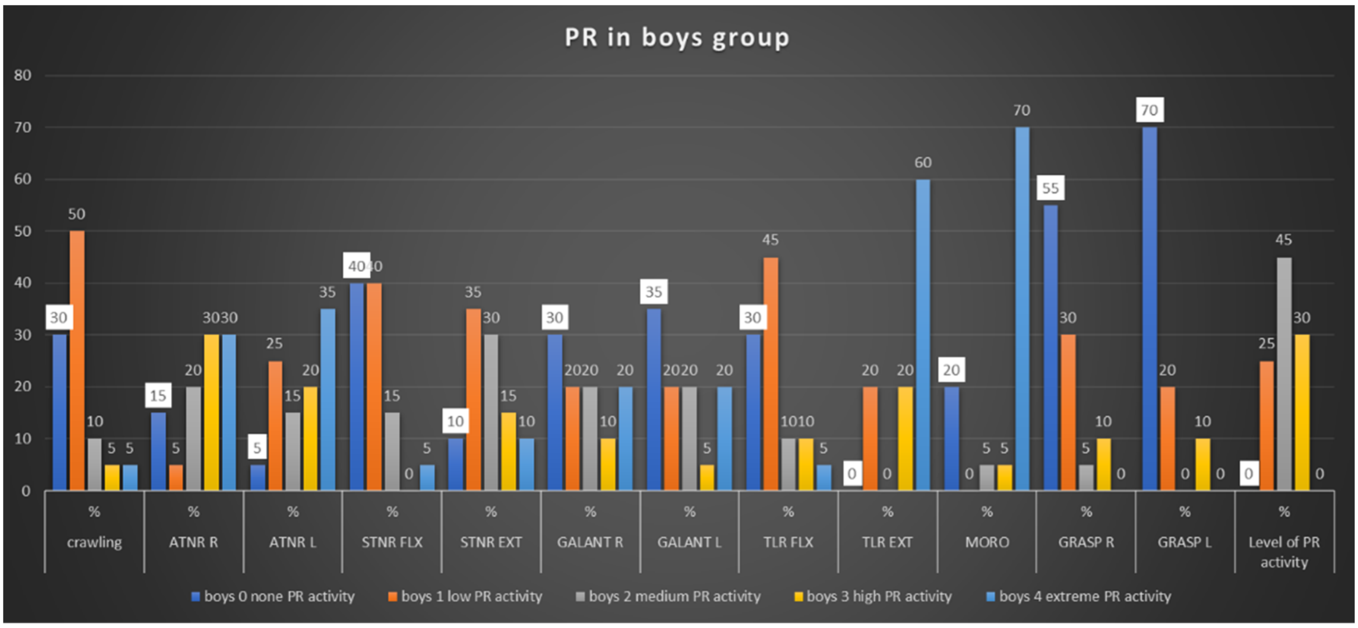


Figure 1. The scale of primitive reflexes (PRs) activity in boys. Percentage of crawling pattern performance and the reflexes activity.

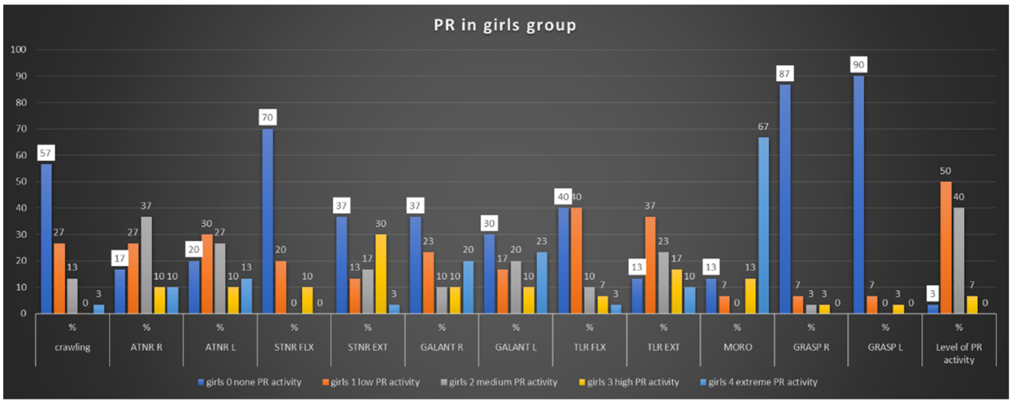


Figure 2. The scale of primitive reflexes (PRs) activity in girls. Percentage of crawling pattern performance and the reflexes activity.

Moreover, the characteristics of the children due to age are presented in Figures 3 and 4.

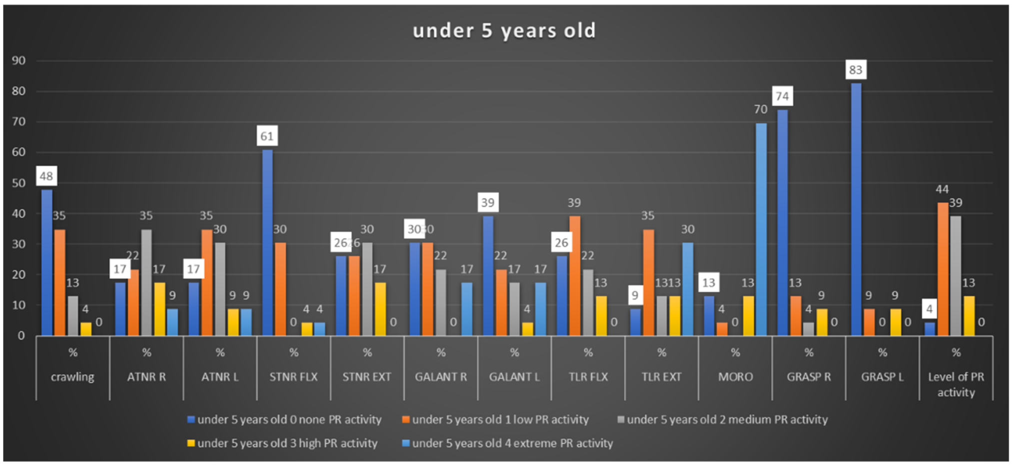


Figure 3. The scale of primitive reflexes (PRs) activity in younger children. Percentage of crawling pattern performance and the reflexes activity.

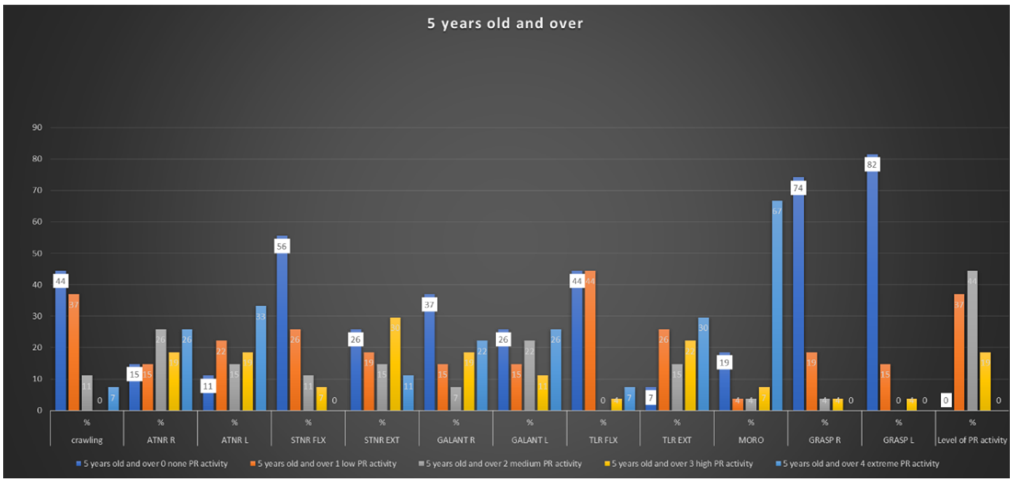


Figure 4. The scale of primitive reflexes (PRs) activity in older children. Percentage of crawling pattern performance and the reflexes activity.

The percentage of PR occurrence in groups of girls and boys is presented in Figures 1 and 2. Of the boys, 75% achieved a higher score of PR activity. In the group of girls, this was under 50%. The least integrated were the Galant Reflex (GR) and Moro Reflex (MR) in the group of younger children, and Tonic Labyrinthine Reflex (TLR) and MR in the group of older children.

There were two significant differences in the group of examined children. Boys had higher scores in TLR in extension (EXT) than girls (p = 0.028), which means a higher level of TLR activity, while younger children had Romberg with eyes closed at a higher activity level (p = 0.038).

2.4. Measurement

INPP Battery Test by S. Goddard [6].

Each child was examined by S. Goddard's Battery Test. The tests covered: Crawling, Romberg test, Asymmetrical Tonic Neck Reflex (ATNR), Symmetrical Tonic Neck Reflex (STNR), Tonic Labyrinthine Reflex (TLR), Galant Reflex (GR), Moro Reflex (MORO), Grasp reflex (GRASP).

For establishing the primitive reflexes profile, the points of ATNR left and right, STNR in flexion and extension, TLR in flexion and extension, GR left and right and MR were summed up. The results were then divided into the activity of the reflexes in five levels:

0—no reflex activity;
1—low reflex activity;
2—medium reflex activity;
3—high reflex activity;
4—alarming reflex activity.

The testing protocol used followed Gieysztor et al. [4].

2.5. Spatio-Temporal Gait Parameters

For the acquisition of the spatial-temporal gait parameters, a BTS G-SENSOR (BTS Bioengineering Corp., Quincy, MA, USA) was used. The instrument was equipped with Triaxial Accelerometer 16 bit/axes with multiple sensitivity (±2, ±4, ±8, ±16 g), Triaxial Gyroscope 16 bit/axes with multiple sensitivity (±250, ±500, ±1000, ±2000 °/s), as well as Triaxial Magnetometer, 13 bit: (±1200 μT). The G-sensor is suitable for assessing physical activity, as shown by analyses of the inter-instrument correlation coefficient from 0.90 to 0.99 and the coefficient of variation between instruments ≤2.5% [16,23].

Before the measurement, each child performed the same exercises (warm-up) in order to prepare better for the test. The measurement was performed in an environment known to children. Body height and leg length (from the greater trochanter to the floor) were measured prior to gait measurement which was performed by placing a wireless inertia sensor on the lower lumbar region. The gauge was centred on the L4–L5 intervertebral disc. Participants walked barefoot, in the most natural way for them, at a speed of their choice along a five-meter pavement, turning and back twice. The raw data was then processed using the Smart Analyser G-Walk (BTS Bioengineering, Quincy, MA, USA), devoted software to calculate spatio-temporal parameters such as: cadence (steps/min), velocity (m/s), step length (m), swing and double support phase duration (calculated as a percentage of the gait cycle).

2.6. Sample Size Calculation

The study sample size (n = 50) was sufficient to achieve 80% power assuming the correlation coefficient threshold being equal to 0.4, and the two-tailed alpha level-0.05 (calculation performed with the use of the G * Power 3.1.9.7.).

2.7. Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 25. For continuous variables, arithmetic means and standard deviations were calculated. Moreover, Spearman's rho correlation analysis was used in order to determine the relationship between quantitative variables. To compare two groups in terms of quantitative/ordinal variables Mann–Whitney's U test was used. The analysis of the results for the right and left side gait parameters was made with the Wilcoxon labelled rank test. The chi-square test of independence was used to compare groups in terms of nominal/categorical variables. The level $\alpha = 0.05$ was used for all comparisons. The power of the test was estimated using the G * Power 3.1.9.4 program. for the analysis of correlation, with the assumed sample N = 50 and $\alpha = 0.05$. The test power was 0.57. For the comparison of age groups, the power of the test was 0.73.

3. Results

The gait results, such as means, standard deviations and medians of spatio-temporal parameters of gait in the group were collected in Table 1.

Table 1. Spatio-temporal parameters of gait in children with APR.

Parameter	Mean	SD	Median	95% CI
analysis duration (s)	44.8	10.6	43.7	41.7–4.7
cadence (steps/min)	136.6	20.7	132.8	130.7–142.6
velocity (m/s)	0.8	0.3	0.8	0.7–0.9
step length (m)	0.7	0.2	0.8	0.6.–0.9
% step length/height	65.8	21.3	69.3	60–72
gait cycle duration (s)				
left	1.0	0.3	0.9	0.9–1.1
right	1.0	0.4	0.9	0.9–1.1
step length (%)				
left	51.7	7.9	50.5	49.4–54.0
right	48.3	7.9	49.5	46.0–50.6
support phase duration (%)				
left	66.7	4.1	66.4	65.5–67.9
right	65.6	4.4	65.4	64.3–66.9
swing phase (%)				
left	33.3	4.1	33.6	32.1
right	34.4	4.4	34.6	34.5
double support duration (%)				
left	19.4	21.7	15.7	33.1
right	15.4	3.3	15.8	35.6
single support duration (%)				
left	34.4	3.9	34.0	33.3–35.5
right	33.9	4.1	33.7	32.7–35.1
steps analysed				
left	9.1	5.1	8.5	7.6–10.5
right	9.5	5.5	9.0	8.0–11.1

CI—Confidence Interval; m—metre; m/s—metre per second; steps/min—steps per minute.

3.1. Gait Parameters and Retained Primitive Reflexes Correlations

Some of the reflexes influence most gait parameters. The coefficient of determination R^2 was calculated for the model with one variable, in turn for each of the variables. The percentage distribution is shown in Table 2. This summary shows that STNR FLX and ATNR R in standing affect almost all of the spatio-temporal gait parameters.

In order to check the relationship between retained reflexes and gait parameters, an analysis of Spearman's rho was carried out.

The analysis showed a positive relationship between the duration of the gait and Tonic Labyrinthine Reflex FLX. Cadence is negatively correlated with the level of reflex activity, crawling and the GRASP reflex of the right hand. Children with higher levels of reflex activity took longer steps during gait analysis. A longer step was observed in children who had difficulty recreating the crawling pattern, while the right GRASP reflex increased.

Table 2. Distribution of frequency in the influence of gait parameters by some of the examined reflex factors.

Reflex Parameter	Value of Influence	Gait Parameter
STNR FLX	78%	all gait parameters
ATNR R in standing	78%	
MORO	67%	
PR activity	67%	
ROMBERG open	56%	
crawling	44%	
GALANT L	39%	

STNR FLX–Symmetrical Tonic Neck Reflex in flexion; ATNR R in standing—asymmetrical tonic neck reflex (right side) examined by Schilder test; MORO—Moro reflex; PR activity—Primitive Reflex activity as the sum of the reflexes; ROMBERG open—Romberg test with eyes open; crawling—performance of crawling pattern; GALANT L—Galant reflex left side.

The presence of the right GRASP reflex positively correlates with the duration of the gait analysis. There is also a positive correlation between the left GRASP reflex and step length, and a negative correlation between the left GRASP reflex and the right step length. In children with left GRASP reflex, the left step is extended, while the right step is shortened.

The duration of the single right support phase correlates positively with the STNR in extension. Children with a higher Symmetrical Tonic Neck Reflex EXT indicator have a longer phase of single support on the right leg.

Tables 3 and 4 show the results.

Table 3. Spearman's correlations between selected reflexes and gait parameters such as duration, cadence, velocity, step length and proportion of step length and height.

Kind of Reflex/Test	Analysis Duration	Cadence	Velocity	Step Length	% Step Length/Height
crawling	0.140	−0.318 *	−0.120	0.020	0.062
TLR FLX	0.297 *	−0.236	0.059	0.181	0.210
GRASP R	0.195	−0.300 *	−0.147	−0.033	0.045
Level of PR activity	0.052	−0.291 *	−0.009	0.158	0.122

* $p < 0.05$; crawling—performance of crawling pattern; TLR FLX—Symmetrical Tonic Neck Reflex in flexion; GRASP R—Grasp reflex right side; Level of PR activity—Primitive Reflex activity as the sum of the reflexes.

Table 4. Spearman's correlations between selected reflexes and gait parameters are mostly divided into left and right side. Gait time, step length, stance and swing phase time, double and single support phase time, along with some of the primitive reflexes' correlations are shown.

Gait Parameter/Kind of Reflex	STNR EXT	GALANT R	GRASP R	GRASP L
Gait time				
left	0.130	−0.018	0.286 *	0.087
right	0.137	0.014	0.238	0.071
Step length				
left	0.203	−0.218	0.245	0.325 *
right	−0.138	0.218	−0.245	−0.325 *
Stance phase time				
left	−0.138	−0.094	−0.167	−0.166
right	−0.093	−0.024	−0.187	−0.094
Swing phase time				
left	0.138	0.094	0.167	0.166
right	0.093	0.024	0.187	0.094
Double support phase time	−0.262	0.172	−0.148	0.006
Single support phase time				
left	0.162	−0.136	0.156	0.065
right	0.289 *	−0.097	0.083	<0.001

STNR EXT—Symmetrical Tonic Neck Reflex in extension; GALANT R—Galant reflex right side; GRASP R and L—Grasp reflex right and left sides; * $p < 0.05$.

3.2. Gait Parameters Divided into Two Groups Due to Age and Gender

An analysis of the correlation between age and gait parameters in the examined children was performed. It showed significant relationships between the age and duration of the double support phase ($p = 0.005$), the duration of the single support phase (right) ($p = 0.025$), and the developed steps for the left and right legs ($p < 0.03$). In older children, the duration of the double support phase is shorter and the number of steps smaller, while the duration of the single support phase (right) is longer.

Gait parameters were also compared according to age. Children under 5 years of age obtained a higher statistically significant result for cadence ($p = 0.017$), duration of the double support phase ($p = 0.005$) and number of steps ($p = 0.002$). Older children were statistically significant for a longer duration of the single support phase (right side) ($p = 0.011$) and gait duration for the right side ($p = 0.031$). The differences in gait parameters between boys and girls were also calculated. The Mann–Whitney U test shows no statistically significant differences between genders in the examined group.

4. Discussion

Searching new aspects of child development, working in new fields and using new tools to understand children in the process of growing up is one of the goals of the PRACS project. We analysed the neuromotor development of the children in the aspects of physical, social and educational status [8,20–22,24]. The presented article shows the results of the research connected with spatio-temporal gait parameters. The children with APR are often perceived as those who cannot remain in one place for a long time. Their gestures are chaotic, and often uncoordinated. Functionally they are still in the norm, but the manner of execution is a bit different than typical. It seems this is because children with neuromotor delay have central muscle stability impairment, which causes higher peripheral muscle tension [21].

In this research, we evaluated the gait parameters in a group of typically developed children within neuro-maturity disturbance cases, manifested in the persistence of primitive reflexes. The gait analysis shows the next aspect of child functioning.

Symmetrical Tonic Neck Reflex FLX and Asymmetrical Tonic Neck Reflex R are very common reflexes observed in the examined group. In the study, we found that the activity of these two reflexes influenced almost all of the studied gait parameters (78% of all analysed). This means that the persistence even of a single reflex can modulate the parameters of walking gait in children. STNR is frequently observed in children with ADHD symptoms [9]. It is known that these children have a specific way of moving, i.e., 'they usually are everywhere'. Their specific walk is sometimes described as uncoordinated or clumsy. This effect may be explained by the results of our study. Moreover, seeing the power of the cumulative effect of the reflexes on child functioning, we could predict larger gait abnormalities when reflexes overlap each other, even if they are of very low intensity. As such, our study covered many more PRs.

As mentioned above, the gait analysis of ADHD children can function as a measure of comparison to our findings. This is because in the group of children with ADHD we have found some variability of gait connected with the degree of PR activity, especially in terms of step length or single support phase time. In children with neuro-maturity disorders, the gait variability was observed by Manicolo et al. [25]. Their study exhibits irregular gait patterns and greater variability in the timing of steps in children with ADHD. In addition, the authors emphasize that the results may indicate a delay in puberty rather than a permanent deviation from gait. They show that gait patterns tend to become more regular with age. Referring to this statement, we would expect better regularity in gaits of children with APR with age caused by growing maturation, as shown by Gieysztor et al. [26]. The variability of gait is commonly observed in children with APR, as well as ADHD, and are both popularly referred to as clumsiness. Some authors analysed the gait symmetries in children with ADHD and developmental coordination disorders. Many gait variables in these groups were observed by the authors, but some of the spatio-temporal gait variables did not differ from the control group [27–29]. These abnormalities are approximated in this study, where we tried to indicate and name some differences in the movement patterns of children with APR. More objective research is, however, necessary to describe variability in clumsy behaviour. At the same time, we expect that our research will constitute a springboard for the wider investigation of the neuro-maturity disorders manifested, for example, in APR.

In our study, cadence was negatively correlated with the level of PR activity. Children with a higher level of PR activity had lower cadence. Longer walking steps in those children may be seen as clumsy, but this form of gait coexisted with difficulty in recreating the crawling pattern. Papadopoulos et al. [28], who studied the gait of ADHD children during self-selected fast speed, show that they had higher cadence and walked faster than the control group. The examination shows some change in gait pattern, which corresponds to a timing deficit. Dziuba et al. [15] conducted gait analysis in children with cerebral palsy (CP), who usually exhibit PR at a higher level than children with neuromotor delays [30]. The results showed that the speed of the gait in some groups of children with CP does not differ from healthy children, with some moving even faster. Then, there were the results of children with mild CP and good overall functional status. This study underlines the difficulty in comparing results, caused by the different forms of CNS damage. Another research study conducted by Deconinck et al. [14] compared 10 subjects of Developmental Coordination Disorder (DCD) to 10 typically developed (TD) children. They showed shorter strides in both time and space during stepping. This gait pattern was characterised by a higher frequency than their TD peers. In our study, the distance of the gait took more time for children with higher TLR FLX. For this particular reflex activity, the result was different than in the above-mentioned study.

Furthermore, in our study, we found that asymmetry in gait patterns is linked with the occurrence of reflexes on one side. The results show that in children with the left GRASP reflex, the left step is extended, and the right step is shortened. The muscle arousal in the region of the upper limb can transfer tension in the region of the lower extremities. Another difference in the results was the longer single support phase on the right lower limb in children with a higher STNR EXT indicator.

ADHD-participants, in the study of Buderath et al. [23,31], presented gait and balance abnormalities and deficient coordination of postural adjustments during tasks.

In our study, the analysis of spatio-temporal gait parameters due to the age of the examined group shows the correlation resulting from the growth of children. In older children, the duration of the double support phase was shorter, the number of steps smaller, and the longer step and duration of the single support phase (right) longer. Comparing children under and over 5 years of age shows significant differences in some spatio-temporal gait parameters. The cadence and double support phase time, as well as the number of steps, had higher values in the younger group. Moreover, gait duration time and single support phase on the right foot had lower values in this group. Similar results describing an older group of participants (5 to 13 years old) were obtained by Lythgo et al. [29]. They assessed the gait in three different speeds and indicated the significant speed differentiation between slow, free and fast conditions. The examined pupils walked 24% slower and 30% faster than the free speed condition. The Lythgo et al. results encouraged us to conduct the gait study in the group of children with APR in various conditions such as: speed, environment, footwear. In this context, Moreno-Hernandez et al. [32] also provided some suggestions. They argue that the variation in gait patterns may depend on the footwear. The use of footwear resulted in an increase in speed, cadence, stride and stride length, while the percentage of the support phase decreased. The authors also found no significant differences between gender. The same results were found in our study.

All of the above-mentioned measurements were performed using various motion analysis software. The available literature does not allow for a strict comparison of the results due to the different methods of data collection; however, it paints a concrete picture of the subject. The lack of studies analysing detailed primitive reflexes is the reason why it is difficult to compare the results. All studies used for discussion can only point to similarities in the gait, but in spite of different points of view, the comparison cannot be strict. Moreover, it is obvious that there are many more items that should be taken into consideration in gait analysis [33].

Our study presents the significant influence of reflexes on walking gait in preschool children. The findings can explain some abnormalities in the group of children with neurodevelopmental delays. They are the first reports on the subject, which refer to primitive reflexes. As PR can be observed in paediatrics, the findings can be important for paediatricians and physical therapists working with developmentally delayed children, as well as teachers and parents, and highlight a reason for the abnormal movements of children. Knowing the cause of the walking abnormality, there is scope to expand the treatment on primitive reflexes therapy with complex results. The study shows that PR activity is worth examining, as it is much more meaningful than previously acknowledged.

Limitations of the study:

Gait analysis was based on time–space measurements of gait variables only. Such analysis does not provide a complete picture of movement in children with active PR. Future research is essential to assess changes in the pelvis, torso and skull during gait movement, and ground responses due to reflex evaluation concerning Asymmetrical Tonic Neck Reflex, Symmetrical Tonic Neck Reflex, Tonic Labyrinthine Reflex, Galant Reflex and Moro Reflex. Such tests, however, provide clinical guidelines and extend the biomechanical knowledge necessary to assess a child's development and work on supporting its development. The advantage of such an examination may be clinically viable and tangible.

5. Conclusions

The presence of primitive reflexes affects the spontaneous motion of children, as expressed in their gait. Symmetrical and Asymmetrical Tonic Neck Reflex are the most frequent reflexes whose activeness correlates with gait parameters. Taking into account the impact of primary reflexes on a child's motor skills suggests difficulties in neuromotor maturation and may clarify the 'bit weird' way of movement in children with neuromotor disturbances. For practitioners, this may be valuable information for the diagnosis and treatment of children with neurodevelopmental immaturity.

Author Contributions: Conceptualization, E.G.; methodology, E.G.; software, E.G., M.K. and M.P.-B.; validation, E.G., M.P.-B. and M.K.; formal analysis, E.G.; investigation, E.G.; resources, E.G.; data curation, E.G.; writing—original draft preparation, E.G.; writing—review and editing, M.K. and M.P.-B.; visualization, E.G.; supervision, M.P.-B.; project administration, E.G.; funding acquisition, M.P.-B. All authors have read and agreed to the published version of the manuscript.

Funding: The presented research results, carried out within the subject, according to the records in the Simple system with the number SUB2.E060.22.099.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and or Ethics Committee of Wroclaw Medical University KB-116/2019.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors gratefully acknowledge the teachers, parents and children who participated in the study.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Leonard, H.C.; Hill, E. Review: The impact of motor development on typical and atypical social cognition and language: A systematic review. *Child Adolesc. Ment. Health* **2014**, *19*, 163–170. [CrossRef] [PubMed]
2. Grzywniak, C. Role of early-childhood reflexes in the psychomotor development of a child, and in learning. *Acta Neuropsychol.* **2016**, *14*, 113–129.
3. Goddard Blythe, S.; Duncombe, R.; Preedy, P.; Gorely, T. Neuromotor readiness for school: The primitive reflex status of young children at the start and end of their first year at school in the United Kingdom. *Education 3–13* **2021**, 1–14. [CrossRef]
4. Gieysztor, E.Z.; Choińska, A.M.; Paprocka-Borowicz, M. Persistence of primitive reflexes and associated motor problems in healthy preschool children. *Arch. Med. Sci.* **2018**, *14*, 167–173. [CrossRef] [PubMed]
5. Blythe, S.G. *Movement a Child's First, A.B.C. Early Childhood Education Redefined*; Routledge: London, UK, 2018.
6. Goddard, S. *Neuromotor Immaturity in Children and Adults: The INPP Screening Test for Clinicians and Health Practitioners*; John Wiley Sons: Hoboken, NJ, USA, 2015.
7. Goddard-Blythe, S. The role of primitive survival reflexes in the development of the visual system. *J. Behav. Optom.* **1995**, *6*, 31–36.
8. Gieysztor, E.Z.; Sadowska, L.; Choińska, A.M.; Paprocka-Borowicz, M. Trunk rotation due to persistence of primitive reflexes in early school-age children. *Adv. Clin. Exp. Med.* **2018**, *27*, 363–366. [CrossRef]
9. O'Dell, N.E.; Cook, P. *Stopping ADD/ADHD and Learning Disabilities: A Unique and Proven Treatment without Drugs for Eliminating ADD/ADHD and Learning Disabilities in Children and Adults*; Stopping Hyperactivity LLC: Indianapolis, IN, USA, 2004.
10. Konicarova, J.; Bob, P.; Raboch, J. Persisting primitive reflexes in medication-naïve girls with attention-deficit and hyperactivity disorder. *Neuropsychiatr. Dis. Treat.* **2013**, *9*, 1457–1461. [PubMed]
11. Blythe, S.G. Releasing Educational Potential Through Movement: A Summary of Individual Studies Carried Out Using the INPP Test Battery and Developmental Exercise Programme for use in Schools with Children with Special Needs. *Child Care Pract.* **2006**, *11*, 415–432. [CrossRef]
12. Blythe, S.G. *Attention, Balance and Coordination: The A.B.C. of Learning Success*; Wiley: Hoboken, NJ, USA, 2017; 429p.
13. Bruening, D.A.; Baird, A.R.; Weaver, K.J.; Rasmussen, A.T. Whole body kinematic sex differences persist across non-dimensional gait speeds. *PLoS ONE* **2020**, *15*, e0237449.
14. Deconinck, F.J.A.; De Clercq, D.; Savelsbergh, G.J.P.; Van Coster, R.; Oostra, A.; Dewitte, G.; Lenoir, M. Differences in Gait between Children with and Without Developmental Coordination Disorder. *Mot. Control* **2006**, *10*, 125–142. [CrossRef]
15. Dziuba, A.K.; Tylkowska, M.; Jaroszczuk, S. Index of mechanical work in gait of children with cerebral palsy. *Acta Bioeng. Biomech.* **2014**, *16*, 77–87.
16. Din Del, S.; Godfrey, A.; Rochester, L. Validation of an Accelerometer to Quantify a Comprehensive Battery of Gait Characteristics in Healthy Older Adults and Parkinson's Disease: Toward Clinical and at Home Use. *IEEE J. Biomed. Health Inform.* **2016**, *20*, 838–847. [CrossRef]
17. Oudenhoven, L.M.; Booth, A.T.C.; Buizer, A.I.; Harlaar, J.; van der Krogt, M.M. How normal is normal: Consequences of stride to stride variability, treadmill walking and age when using normative paediatric gait data. *Gait Posture* **2019**, *70*, 289–297. [CrossRef] [PubMed]
18. Kolb, B.; Gibb, R. Brain plasticity and behaviour in the developing brain. *J. Can. Acad. Child Adolesc. Psychiatry* **2011**, *20*, 265–276.
19. Cinelli, H. Les réflexes archaïques. *Sages-Femmes* **2021**, *20*, 43–46.
20. Demiy, A.; Kalemba, A.; Lorent, M.; Pecuch, A.; Wolańska, E.; Telenga, M.; Gieysztor, E.Z. A child's perception of their developmental diffi-culties in relation to their adult assessment. Analysis of the inpp questionnaire. *J. Pers. Med.* **2020**, *10*, 156. [CrossRef] [PubMed]
21. Gieysztor, E.; Pecuch, A.; Kowal, M.; Borowicz, W.; Paprocka-Borowicz, M. Pelvic Symmetry Is Influenced by Asymmetrical Tonic Neck Reflex during Young Children's Gait. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4759. [CrossRef]
22. Pecuch, A.; Gieysztor, E.; Telenga, M.; Wolańska, E.; Kowal, M.; Paprocka-Borowicz, M. Primitive Reflex Activity in Relation to the Sensory Profile in Healthy Preschool Children. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8210. [CrossRef]
23. SankarPandi, S.K.; Baldwin, A.J.; Ray, J.; Mazzà, C. Reliability of inertial sensors in the assessment of patients with vestibular disorders: A feasibility study. *BMC Ear Nose Throat Disord.* **2017**, *17*, 1–9. [CrossRef]
24. Gieysztor, E.; Kurzaj, P.; Choińska, A.; Kowal, M.; Pecuch, A.M.; Borowicz, W.; Paprocka-Borowicz, M. Perception of sensory impressions in children from music classes and their peers from general classes in Poland—A comparison. *Physiother. Q.* **2019**, *27*, 26–30. [CrossRef]
25. Manicolo, O.; Grob, A.; Lemola, S.; von Arx, P.H. Age-related decline of gait variability in children with attention-deficit/hyperactivity disorder: Support for the maturational delay hypothesis in gait. *Gait Posture* **2016**, *44*, 245–249. [CrossRef] [PubMed]
26. Gieysztor, E.Z.; Sadowska, L.; Choińska, A.M. The degree of primitive reflexes integration as a diagnostic tool to assess the neurological maturity of healthy preschool and early school age children. *Nurs. Public Health* **2017**, *7*, 5–11. [CrossRef]
27. Willson, J.D.; Dougherty, C.P.; Ireland, M.L.; Davis, I.M.C. Core Stability and Its Relationship to Lower Extremity Function and Injury. *J. Am. Acad. Orthop. Surg.* **2005**, *13*, 316–325. [CrossRef] [PubMed]
28. Papadopoulos, N.; McGinley, J.L.; Bradshaw, J.L.; Rinehart, N.J. An investigation of gait in children with Attention Deficit Hyper-activity Disorder: A case controlled study. *Psychiatry Res.* **2014**, *218*, 319–323. [CrossRef] [PubMed]

29. Lythgo, N.; Wilson, C.; Galea, M. Basic gait and symmetry measures for primary school-aged children and young adults whilst walking barefoot and with shoes. *Gait Posture* **2009**, *30*, 502–506. [CrossRef]
30. Pavão, S.L.; dos Santos, A.N.; Woollacott, M.H.; Rocha, N.A.C.F. Assessment of postural control in children with cerebral palsy: A review. *Res. Dev. Disabil.* **2013**, *34*, 1367–1375. [CrossRef] [PubMed]
31. Buderath, P.; Gärtner, K.; Frings, M.; Christiansen, H.; Schoch, B.; Konczak, J.; Gizewski, E.R.; Hebebrand, J.; Timmann, D. Postural and gait performance in children with attention deficit/hyperactivity disorder. *Gait Posture* **2009**, *29*, 249–254. [CrossRef]
32. Moreno-Hernández, A.; Rodríguez-Reyes, G.; Quiñones-Urióstegui, I.; Núñez-Carrera, L.; Pérez-SanPablo, A.I. Temporal and spatial gait parameters analysis in non-pathological Mexican children. *Gait Posture* **2010**, *32*, 78–81. [CrossRef] [PubMed]
33. Brady, K.; Kiernan, D. Centre of pressure error with increasing gait velocity: The clinical impact on predicted inverse dynamics during gait in children with typical development. *Gait Posture* **2020**, *82*, 96–99. [CrossRef] [PubMed]

Journal of
Personalized Medicine

Article

A Child's Perception of Their Developmental Difficulties in Relation to Their Adult Assessment. Analysis of the INPP Questionnaire

Alina Demiy [1], Agata Kalemba [1,*], Maria Lorent [1], Anna Pecuch [1,3], Ewelina Wolańska [1,2], Marlena Telenga [1] and Ewa Z. Gieysztor [1,3]

1 Student Research Group of the Developmental Disorders of Children and Youth, Department of Physiotherapy, Faculty of Health Sciences, Medical University, 50-367 Wroclaw, Poland; alina.demiy@student.umed.wroc.pl (A.D.); maria.lorent@student.umed.wroc.pl (M.L.); anna.pecuch@student.umed.wroc.pl (A.P.); ewelina.wolanska@student.umed.wroc.pl (E.W.); marlena.telenga@student.umed.wroc.pl (M.T.); ewa.gieysztor@umed.wroc.pl (E.Z.G.)

2 Division Pediatric Propedeutics and Rare Disorders, Department of Pediatrics, Faculty of Health Sciences, Medical University, 50-367 Wroclaw, Poland

3 Laboratory of Clinical Bases of Physiotherapy, Department of Physiotherapy, Faculty of Health Sciences, Medical University, 50-367 Wroclaw, Poland

* Correspondence: agata.kalemba@student.umed.wroc.pl

Received: 5 August 2020; Accepted: 5 September 2020; Published: 5 October 2020

Abstract: This study involved a comparison of the perception of developmental difficulties in a child by the parents, the teacher, and through the child's self-assessment. Based on the Institute for Neuro-Psychological Psychology (INPP) questionnaire according to S. Goddard Blythe, three groups were examined: schoolchildren, parents, and teachers. Each of them answered a set of 21 questions and assessed the degree of occurrence of a given difficulty for the child on a scale from 0 to 4. The questions concerned psychomotor problems related to balance, motor coordination and concentration, as well as school skills. In total, 49 questionnaires from children and parents and 46 from teachers were used for the study. The mean answer to each question was calculated within the following groups: child–parent, child–teacher, and parent–teacher. The sum of the children's answer points was significantly higher than the sum of the parents' answer points ($p = 0.037$). Children assessed their developmental difficulties more strongly than teachers, but this difference was not statistically significant. The individual difficulties of the children were assessed significantly more seriously or more gently than by the National Scientific Conference "Human health problems—causes, present state, ways for the future" speeches by 44 teacher participants on 5 June 2020. Parents and teachers also assessed the children's difficulties significantly differently ($p = 0.044$). The biggest difference in answers concerned the question of maintaining attention. The obtained results indicate a significant difference in the perception of difficulties occurring in the same child by the teacher and the parent. The child's behavior in school and home environments may be different and, depending on the requirements, assessed differently. Children perceive their difficulties much more seriously than adults. Talking and the support of adults can make it easier for a child to overcome developmental difficulties.

Keywords: children; adult; difficulties; disorders; coordination; focus

1. Introduction

The appearance of symptoms such as problems with maintaining balance; coordination problems; difficulty with jointing together elements of running, jumping, throwing, and catching a ball; time–space orientation disorder; deep sensibility or kinesthesia (awareness of the arrangement of the body in space and ability to repeat a set motor pattern) in a schoolchild is a clear sign of developmental difficulties that should be considered by parents or legal guardians. Other indications include issues with reading, writing, and mathematical abilities, such as counting and understanding of instructions [1]. All of the aforementioned symptoms increase the risk of dyslexia and can be the reason for psychomotor and social problems in adult life [2,3]. There are preliminary screening tests that enable early detection of problems connected to learning and behavioral or emotional disorders in schoolchildren. These include, among others, the Institute for Neuro-Psychological Psychology (INPP) questionnaire by Goddard Blythe, which allows a profound examination of children in terms of the presence of psychomotor disorders, which, in turn, can be a sign of neuromotor immaturity [4,5]. The use of a questionnaire allows the selection of children who have trouble at school and children who have motoric problems, which indicate disintegrated primitive reflexes [6]. Research with the use of the aforementioned questionnaire was conducted by Grzywniak. According to the author, a child aged 6 or 7 years old gains the neuropsychological maturity for school learning through a correct development and the integration of the primary reflex within the central nervous system [2,4]. The methods of evaluation of retained reflexes became the research objects of not only Goddard Blythe but also of Masgutova who developed a rehabilitative and therapeutic system, Masgutova neurosensorimotor reflex integration (MNRI), with a view to helping patients with neurological and cognitional disorders [5]. Both authors in their methods acknowledge the importance of the incorrect work of structures responsible for the equilibrium and coordinative abilities of the child (cerebellum and central nervous system) in contrast with neonatal reflex [1].

The use of the INPP questionnaire can determine which children have school and motor problems, indicating disintegrated primary reflexes.

Research concerning the perception of difficulties in children is extremely important for both the parent and teacher perspective, and most importantly the children themselves. An adult becomes a witness of the everchanging influence of the environment, that is the school or home, on the behavior of a schoolchild. The foregoing problem arises because of many factors, e.g., the parental attitude, overprotectiveness of the parents or a liberal upbringing style, peer contact, emotional experiences, teacher competences, and the methods of knowledge transfer. Different attitudes will be observed by a parent in a house where the child feels much more at ease and has a greater sense of security and acceptance and a possibility to release emotions in contrast with teacher observations in the school environment where there are top-down rules and time frames regarding the length of the lessons or breaks. With the use of the screening test and observation, the teacher is able to recognize the children with psychomotor disorders [1]. The early pedagogical diagnosis gives the opportunity to take further educational and, if there is such a need, therapeutic steps [4].

The aim of this study was to compare the perception of a child's developmental difficulties by the parents, a teacher, and through the child's self-assessment based on an analysis of the INPP questionnaire.

2. Materials and Methods

2.1. Examined Group

A total of 68 children took part in the research. For comparison, a number of questionnaires were completed; 49 were filled out by children, 49 by parents (72%), and 44 by teachers (74%). A greater number of questionnaires was taken into consideration for the possibility of comparison depending on the analyzed group. Each pupil was rated thrice—by a parent, a teacher, and through the pupil's self-assessment.

The first treatment group counted 49 children (21 girls and 28 boys). The average age was 8 years. The youngest pupil was 6 years old, and the oldest was 12 years old (SD = 1.63; MED = 8.0; MOD = 6).

All of the participants were elementary students. The second group was formed of parents, and the third of teachers.

2.2. Questionnaire

The research was conducted with the use of the INPP screening test by S. Goddard Blythe. It comprises 21 questions for which the answers are given on a 5-grade scale (0–4) where 4 means that the disorder is present to a great extent and 0 means a lack of the disorder [7–9].

In the questionnaire, each of the groups had to determine on a scale from 0 to 4 the degree of difficulty with which the child copes in day-to-day life. Among them, concentration problems; problems with sitting still, writing, or reading; easy distraction; and motor problems such as swimming, bike riding, or coordination can be distinguished.

Moreover, every child's result was summed up and categorized into levels, where the larger the sum of the point, the greater the disorder. The aforementioned scale can be seen in Table 1.

Table 1. The scale of disorder assessment.

Sum	Level	Degree of Disorder
0	0	no disorder
1–21	1	present to a minimum degree
22–42	2	present to a moderate degree
43–63	3	present to a great degree
64–84	4	present at a very high intensity

2.3. Statistical Methods

Statistical analysis was performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA). Means, standard deviation, and medians were calculated. The Mann–Whitney U test was used to compare the two groups in terms of quantitative/ordinal variables. The level $\alpha = 0.05$ or $\alpha = 0.01$ was used for comparisons. The effect size was calculated using eta-squared for the Mann–Whitney U test.

3. Results

The results were analyzed in three subgroups: child–parent (Table 2), child–teacher (Table 3), and parent–teacher (Table 4). Tables 2–4 show the distribution of the average of particular answers to questions between the groups. Statistically significant differences are highlighted in red. In the child–teacher comparison, 10 of the answers show this feature. Similarly, in the parent–teacher group, the answers vary significantly in 10 cases. In the last child–parent column, there are six differences in grading particular difficulties that are statistically significant

Table 5 shows a comparison between the average sums of results and the sum of levels, and the calculated average score in the subgroups. The number of given answers differs significantly. It is the most noticeable in the parent–teacher subgroup where the averages and the division into levels are substantially apart. The parents often assessed the children's troubles at the first level. Eight pupils more were classified as that level by the parents than those classified as that level by the teachers. The teachers scored the children's troubles higher, and the children were classified as the second level more by the teachers than by the parents. The difference in the sum of the points is 6.16 (0.57 for the child–teacher subgroup; 5.32 for child–parent). In this group, there is also the greatest difference between the levels, that being 0.38 (child–teacher 0.08; child–parent 0.26). In the remaining groups, the answers are the same or differ insignificantly in at least two aspects.

Table 2. The distribution of responses in the child–parent group.

Questionnaire	Children (n = 40) M	Me	SD	Parents (n = 40) M	Me	SD	U	p	η^2
1.Inability to sit still	1.2	1	1.2	1.1	1	1.2	786	0.45	0.00
2.Attention problems	1.3	1	1.3	1.1	1	1.1	753	0.33	0.00
3.Easy to distract	1.6	1	1.4	1.4	1	1.1	740	0.28	0.00
4.Coordination problems	1.0	0	1.4	0.8	0	1.1	780	0.35	0.00
5.Incorrect grip	0.9	0	1.3	0.7	0	1.1	744	0.30	0.00
6.Incorrect sitting posture	1.0	1	1.2	1.1	1	1.1	739	0.28	0.00
7.Difficulty catching the ball	1.2	1	1.2	0.8	0	1.2	660	0.09	0.02
8. Difficulty learning to swim	1.4	1	1.5	0.8	0	1.1	642	0.06	0.03
9.Diffiiculty riding a bike	0.5	0	1.2	0.2	0	0.8	701	0.17	0.01
10.Travel sickness	1.1	0	1.5	0.5	0	1.0	638	0.06	0.03
11.Reading problems	1.4	1	1.4	0.8	0	1.1	589	0.02	0.05
12.Writing problems	1.2	1	1.2	0.9	0.5	1.1	697	0.16	0.01
13.Rewriting problems	0.9	0.5	1.2	0.7	0	1.1	718	0.22	0.01
14.Math problems	1.1	1	1.2	0.5	0	1.0	546	0.00	0.08
15.Spelling problems	1.4	1	1.4	1.1	1	1.2	713	0.16	0.01
16.Rearranging numbers or letters	0.7	0	1.0	1.0	1	1.2	692	0.15	0.01
17.Difficulty reading the time	1.5	1	1.6	1.1	0	1.4	669	0.08	0.02
18.Difficulty multi-tasking	0.9	0.55	1.0	0.9	0	1.2	818	0.49	0.00
19.Recurring headaches	1.0	1	1.1	0.2	0	0.7	437	0.00	0.15
20.Frequent fatigue	1.1	1	1.1	0.6	0	1.0	570	0.01	0.06
21.Clear agitation	1.2	1	1.3	1.0	1	1.1	767	0.37	0.00
Sum	23.3	23	13.2	17.3	16	12.1	681	0.05	0.02
Level	1.6	2	0.6	1.4	1	0.7	616	0.04	0.04

* Statistically significant values are marked in red.

Table 3. The distribution of responses in the child–teacher group.

Questionnaire	Children (n = 44) M	Me	SD	Teachers (n = 44) M	Me	SD	U	p	η^2
1.Inability to sit still	1.18	1	1.17	1.52	1	1.62	909	0.31	0.00
2.Attention problems	1.34	1	1.22	2.57	3	1.44	506	0.00	0.15
3.Easy to distract	1.66	1	1.41	2.57	3	1.44	637	0.00	0.09
4.Coordination problems	0.78	0	1.19	0.25	0	0.94	725	0.02	0.05
5.Incorrect grip	0.75	0	1.14	1.34	1	1.24	680	0.01	0.07
6.Incorrect sitting posture	1.07	1	1.25	1.43	1	1.42	836	0.14	0.01
7.Difficulty catching the ball	1.18	1	1.23	0.80	0	1.19	854	0.05	0.01
8.Difficulty learning to swim	1.43	1	1.55	0.09	0	0.60	471	0.00	0.20
9.Diffiiculty riding a bike	0.57	0	1.23	0.09	0	0.60	795	0.07	0.02
10.Travel sickness	1.23	0	1.57	0.32	0	1.03	610	0.00	0.10
11.Reading problems	1.25	1	1.28	1.43	2	1.39	905	0.30	0.00
12.Writing problems	1.05	1	1.16	1.45	1	1.25	782	0.06	0.03
13.Rewriting problems	0.89	1	1.19	1.30	1	1.19	745	0.03	0.04
14.Math problems	1.12	1	1.19	1.20	1	1.11	945	0.36	0.00
15.Spelling problems	1.46	1	1.28	1.32	1	1.20	945	0.36	0.00
16.Rearranging numbers or letters	0.68	0	0.93	0.64	1	0.81	958	0.47	0.00
17.Difficulty reading the time	1.46	1	1.53	0.25	0	0.89	514	0.00	0.16
18.Difficulty multi-tasking	0.82	1	0.99	1.50	1	1.34	868	0.04	0.01
19.Recurring headaches	0.87	1	1.05	0.09	0	0.60	474	0.00	0.19
20.Frequent fatigue	1.14	1	1.12	0.98	0	1.21	861	0.15	0.01
21.Clear agitation	1.18	1	1.30	1.52	1	1.70	926	0.36	0.00
Sum	23.1	23	12.6	22.70	22	13.30	1003	0.27	0.00
Level	1.61	2	0.65	1.90	2	0.73	794	0.07	0.02

* Statistically significant values are marked in red.

Table 4. The distribution of responses in the parent–teacher group.

Questionnaire	Parents (n = 38)			Teachers (n = 38)					
	M	Me	SD	M	Me	SD	U	p	η^2
1.Inability to sit still	1.13	1	1.23	1.66	1	1.60	591	0.09	0.03
2.Attention problems	1.11	1	1.03	2.68	3	1.42	284	0.00	0.27
3.Easy to distract	1.32	1	1.09	2.68	3	1.42	329	0.00	0.22
4.Coordination problems	0.76	0	1.08	0.29	0	1.01	496	0.01	0.07
5.Incorrect grip	0.61	0	1.00	1.40	1	1.31	462	0.00	0.10
6.Incorrect sitting posture	1.08	1	1.12	1.40	1	1.37	640	0.20	0.01
7.Difficulty catching the ball	0.84	0	1.15	0.87	0	1.26	715	0.47	0.00
8. Difficulty learning to swim	0.79	0	1.14	0.11	0	0.65	463	0.00	0.10
9.Diffiiculty riding a bike	0.21	0	0.81	0.11	0	0.65	685	0.35	0.00
10.Travel sickness	0.51	0	1.02	0.37	0	1.10	602	0.14	0.02
11.Reading problems	0.79	0	1.04	1.55	2	1.45	517	0.02	0.06
12.Writing problems	1.00	1	1.16	1.53	2	1.31	557	0.04	0.04
13.Rewriting problems	0.76	0	1.15	1.37	1	1.26	504	0.01	0.07
14.Math problems	0.58	0	1.08	1.32	1	1.14	431	0.00	0.12
15.Spelling problems	1.21	1	1.28	1.29	1.5	1.29	697	0.40	0.00
16.Rearranging numbers or letters	1.05	1	1.18	0.66	1	0.85	604	0.11	0.02
17.Difficulty reading the time	1.11	0	1.45	0.26	0	0.95	485	0.01	0.08
18.Difficulty multi-tasking	0.90	0	1.25	1.66	1	1.36	462	0.00	0.10
19.Recurring headaches	0.24	0	0.68	0.11	0	0.65	649	0.22	0.01
20.Frequent fatigue	0.55	0	0.95	0.92	0	1.22	613	0.13	0.02
21.Clear agitation	1.00	1	1.09	1.45	1	1.64	648	0.22	0.01
Sum	17.53	16.5	12.17	23.66	22	13.91	503	0.01	0.07
Level	1.29	1	0.65	1.71	2	0.73	489	0.01	0.08

* Statistically significant values are marked in red.

Table 5. The average sum of results and levels.

	Child	Teacher	Parent	Teacher	Child	Parent
Average sum of results	23.3	22.73	17.5	23.66	20.16	14.84
Level 0 *	0	0	2	0	6	10
Level 1	22	19	25	17	22	26
Level 2	19	23	9	19	18	11
Level 3	3	0	2	0	3	2
Level 4	0	2	0	2	0	0
Average levels	1.57	1.65	1.32	1.70	1.36	1.1

* Degrees of disorders are described as "levels".

3.1. Child–Teacher Subgroup

In order to compare the answers in the child–teacher group in detail, 44 questionnaires were analyzed. The results are presented in Figures 1 and 2.

The charts show the layout of the children's and teachers' answers. There are clear differences between the perception of the problems that the child struggles with (Figure 1), especially in questions 1, 2, and 3. They touch upon the abilities concerning difficulties with sitting still and keeping attention and the child's ability to stay focused.

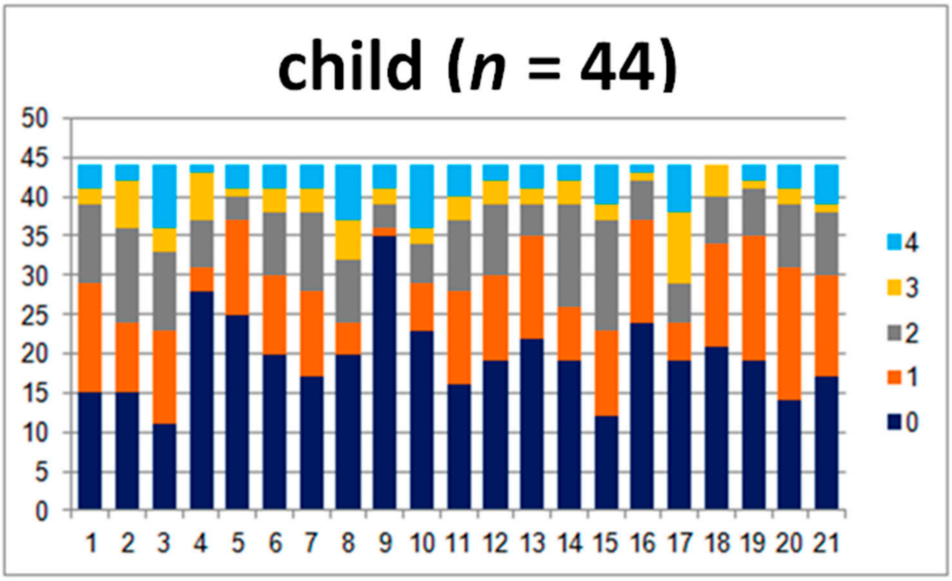


Figure 1. Answers given by the examined children.

The teachers marked levels 3 and 4, which are "present to a great degree" and "present at a very high intensity", more frequently, while the children were more likely to give 0, 1, or 2 points (Figure 2). The opposite was observed for questions 4, 5, 8, 9 10, 17, 18, and 19, where teachers marked 0. The questions concerned motor abilities, coordination, motion sickness, the ability to read the analogue clock, and headaches. All of the aforementioned differences are statistically significant ($p \leq 0.02$). Differences in answers to question 1 are not statistically significant. Moreover, the comparison of the sum of the points and levels is also not significant ($p \geq 0.05$).

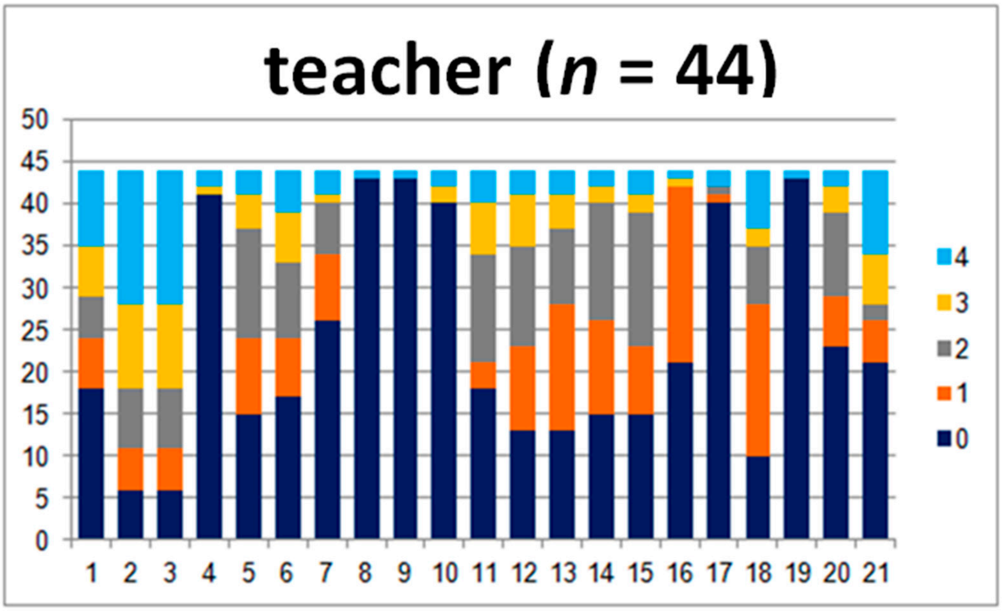


Figure 2. Answers given by the teachers.

3.2. Parent–Teacher Subgroup

In this group, there were 37 analyzed questionnaires.

In the comparison of the parent–teacher group's answers, there are differences between the answers to questions 2, 3, 4, and 8, where the teachers marked many more 4s than the parents (Figure 3). Those questions were related to motor coordination.

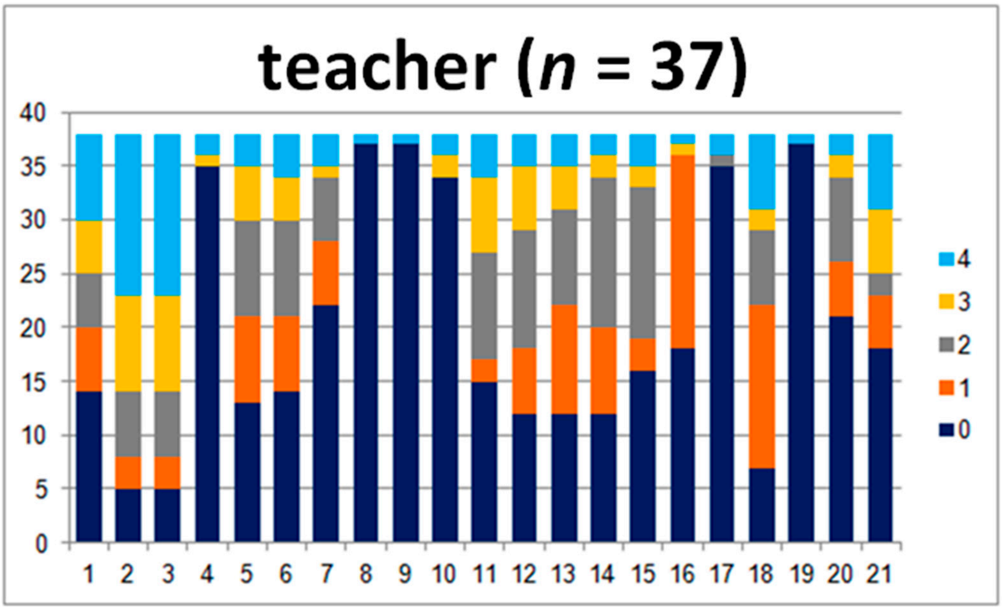


Figure 3. Answers given by the teachers.

For the question concerning reading the time, the teachers marked 0 most of the time, in contrast to parents who marked the 0–3 answers (Figure 4). In questions 11, 13, 14, and 18, the parents marked lower answers (0 and 1) much more frequently than the teachers. These questions concerned the issues of writing, rewriting, and mathematical abilities. Question number 18 touched upon headaches. All of the parameters and the comparison of the sum of points and levels show great statistical importance.

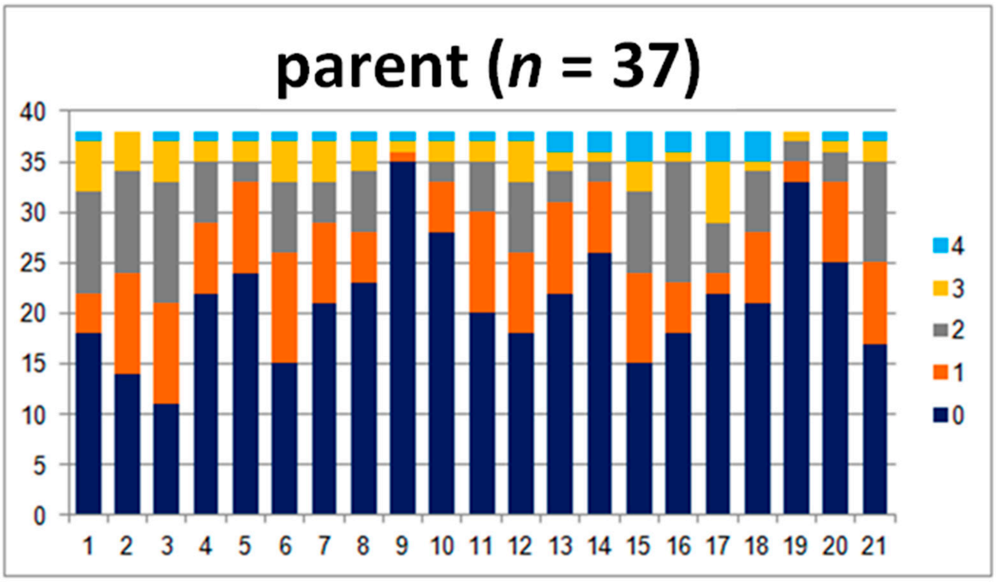


Figure 4. Answers given by parents of examined children.

3.3. Child–Parent Subgroup

In this group, there were 49 analyzed questionnaires.

In the child–parent group, the answers differ the most for questions 17, 18, 19, and 20 (19 and 20, $p < 0.05$), where the parents more commonly gave answers of 0 (Figure 5). The questions concerned reading the time, maintaining attention, headaches, and fatigue. Parents seldomly marked 4 (present at a very high intensity). Furthermore, there are statistically important differences when it comes to questions 8, 10, 11, and 14. These questions touched upon swimming, motion sickness, reading, and mathematical abilities, respectively.

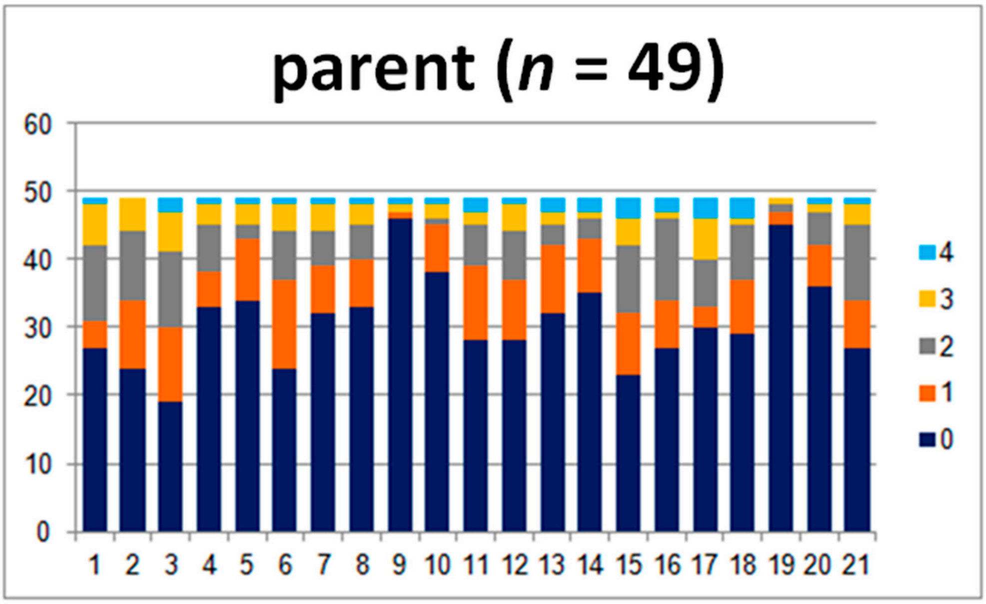


Figure 5. Answers given by parents of examined children.

The children's answers indicated that they have more difficulties with the aforementioned areas than their parents acknowledge (Figure 6). The comparison between the average sums of the points and levels shows great statistical significance (p = 0.04 and p = 0.03).

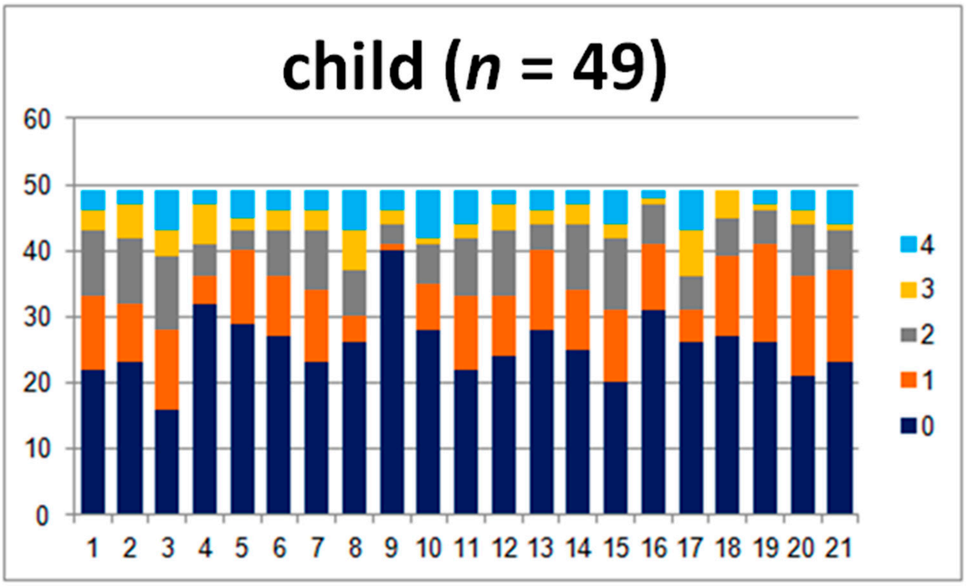


Figure 6. Answers given by examined children.

4. Discussion

The results of our research show that the answers in the parent–teacher group differed substantially in many aspects. The biggest difference was found for the answers given to the question concerning keeping attention, where the provided scales differ by 2 degrees. The results present a significant difference in the way that parents and teachers perceive a child's abilities. The difference of the teacher's and the parent's assessment where the child's answer is similar to the teacher's answer might be a result of a parent's limited awareness concerning the child, who is in a situation that demands focused attention during the class. However, the similarity between the child's and the parent's answers and substantially different teacher's answers might suggest that the teacher perceives the child to be in a difficult situation in the school environment. Different scores in the answers may also reflect the different expectations of the teacher, the child, and the parent. The difference might moreover suggest that the child behaves differently at school than he/she behaves at home. Significant differences appeared in the answers to the questions concerning the child's ability to catch a ball and the frequency of headaches. There was an incompatibility between the child's answer and the parent's answer concerning this issue. The children more often graded themselves higher in the answer to the question about catching the ball and lower when it comes to the answer concerning headaches. This might indicate the children's understated self-esteem and concealment of experiencing pain such as headaches, or it might suggest a lack of knowledge about how to qualify the frequency of their condition.

Similar research was previously conducted involving parent–teacher groups. There were also studies conducted with the use of other tests in a form of the questionnaires SRD-6, SPE_R, and the SPE IBE scale. The results of our study, however, showed that the teachers' observations are far more adequate than the data obtained by the use of the questionnaires mentioned above [1]. However, the INPP questionnaire focuses in particular on the children's difficulties, and it is proven to be an accurate and precise research tool [6]. Furthermore, there are studies that compare groups of children with groups of adults in general, for instance, children who are hospitalized, the nurses who are taking care of them, and the children's parents. These studies show that the children, though being under their parents' custody by law, should have the possibility to be consulted about and take an active part in adjusting the treatment they are undergoing, and they should be allowed to receive the information concerning their medical condition [10,11].

The differences in the perception of children's problems can lead to misunderstanding and create a stressful situation between parents and teachers. However, it could be reduced by analyzing the results of the research conducted with the use of the INPP questionnaire [4]. This allows us to initially discover the children's difficulties. With the use of the questionnaire, both the parents and the teachers are able to check which aspects of their children's life they should focus on more and whether the child is in a need of deeper analyses and further diagnosis. This tool can easily limit the problems that the child deals with and suggest therapeutic steps that will inhibit the progress of the problem in the future. The therapeutic activity and further diagnosis can show the child's autism disorders, which also are the cause of a child's problems at school and at home [12]. The observation and the reduction of a risk of further progress of dyslexia, problems reading and writing, and other symptoms of language disorders, at an early stage, can eliminate negative consequences that would appear later on [1]. The difficulties might be caused by the survival of the primitive reflexes [6]. They might indicate that the child suffers from mental problems [13]. They could also be an effect of the collision between home and school environment [14]. The atmosphere of home and the atmosphere of school differ substantially. They consist of different components, such as peers, teachers, parents, siblings who simultaneously influence the child's behavior [15]. To engage in a dialogue about the differences in perceiving children's difficulties enables us to make better decisions concerning the form of help that the child should receive.

Moreover, other factors that influence the rate of a child's difficulties should be taken into consideration too. Some other decisive factors that influence the child's difficulties include financial situation; parents' educational background; living conditions; access to knowledge, science, and information; and state of health [16]. All of them should be analyzed in a dialogue between the teacher, the parent, and possibly the child [10,11].

The main limitation of this study is that small groups were used for the INPP test. Future work could involve a larger group of children with neurological disorders, thus providing information about the children's and adults' perception of the children's developmental difficulties [1]. Future study could also include a sociological interview to determine the parents' wealth and education.

The conversation about developmental problems between children and the people who support their development should lead to developing the best tactic on how to act in school and home environments. The cooperation between parents and teachers is necessary in order to achieve maximum results while taking into account the child's individual needs too. This also enables objective comparison of information provided by both of these sources.

5. Conclusions

The presented research concerning parents' and teachers' perceptions of children and the children's self-assessment enabled us to draw the following conclusions:

1. Teachers notice children's problems with concentration and distraction during the classes substantially more often than the children themselves.

2. Teachers notice writing and copying problems and issues with math skills more often than parents.

3. Children notice their own physical coordination problems and trouble with concentration more often than parents do.

4. Children are perceived differently by their parents, their teachers, and by themselves. Something that is perceived as troublesome by children is not always perceived as problematic by parents or teachers.

The presented conclusions might provide an important reference both for parents and teachers. The integration and support for both of these communities is the key to success in the proper perception of a child in daily life [17].

Author Contributions: Concept and study design, A.P., E.W., M.T., E.Z.G.; data collection and compilation, A.D., A.G., M.L., A.P., E.W., M.T., E.Z.G.; data analysis and interpretation, A.D., A.K., M.L., E.Z.G.; writing the article, A.K., M.L.; critically reviewing the article, E.Z.G.; approval of the final version of the article, A.D., A.K., M.L., A.P., E.W., M.T., E.Z.G. All authors have read and agreed to the published version of the manuscript.

Funding: The publication was prepared under the project financed from the funds granted by the Ministry of Science and Higher Education in the "Regional Initiative of Excellence" program for the years 2019–2022, project number 016/RID/2018/19 and amount of funding 11 998 121.30 PLN.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wiejak, K.; Krasowicz-Kupis, G.; Awramiuk, E. Linguistic determinants of early reading and writing skills based on the teacher's assessment using the IBE Educational Forecasting Scale. *Educ. Psychol.* **2017**, *11*, 41–63.
2. Bogdanowicz, M. Specific difficulties in reading and writing—Developmental dyslexia. In *Speech Therapy: Questions and Answers*; Gałkowski, T., Jastrzębowska, G., Eds.; University of Opole: Opole, Poland, 1999; pp. 815–859.
3. Bogdanowicz, M. *Risk of Dyslexia. Problem and Diagnosis*; Harmonia Publishing House: Gdańsk, Poland, 2002.
4. Grzywniak, C. Research on neuropsychological maturity for school learning. *Rep. Own Res. Men Disabil. Soc.* **2015**, *2*, 67–83.
5. Pecuch, A.; Kołcz-Trzęsicka, A.; Żurowska, A.; Paprocka-Borowicz, M. Psychomotor disorders assessment in 4–6 year-old children with INPP test battery. *Nurs. Public Health* **2018**, *8*, 11–20. [CrossRef]
6. Gieysztor, E.; Sadowska, L.; Choińska, A. The degree of primitive reflexes integration as a diagnostic tool to assess the neurological maturity of healthy preschool and early school age children. *Nurs. Public Health* **2017**, *7*, 5–11. [CrossRef]
7. Goddart-Blythe, S. The role of primitive survival reflexes in the development of the visual system. *J. Beh. Opt.* **1995**, *6*, 31–35.
8. Goddard-Blythe, S. *Reflexes, Learning and Behavior: A Window into the Child's Mind*; Fern Ridge Press: Eugene, OR, USA, 2005.

9. Goddard-Blythe, S. *Attention, Balance and Coordination: The A.B.C. of Learning Success*; Wiley: Hoboken, NJ, USA, 2009.
10. Coyne, I. Consultation with children in hospital: Children, parents' and nurses' perspectives. *J. Clin. Nurs.* **2006**, *15*, 61–71. [CrossRef] [PubMed]
11. Coyne, I. Children's participation in consultations and decision-making at health service level: A review of the literature. *Int. J. Nurs. Stud.* **2008**, *45*, 1682–1689. [CrossRef] [PubMed]
12. Crane, L.; Batty, R.; Adeyinka, H.; Goddard, L.; Henry, L.A.; Hill, E.L. Autism Diagnosis in the United Kingdom: Perspectives of Autistic Adults, Parents and Professionals. *J. Autism. Dev. Disord.* **2018**, *48*, 3761–3772. [CrossRef] [PubMed]
13. Soneson, E.; Childs-Fegredo, J.; Anderson, J.K.; Stochl, J.; Fazel, M.; Ford, T.; Humphrey, A.; Jones, P.B.; Howarth, E. Acceptability of screening for mental health difficulties in primary schools: A survey of UK parents. *BMC Public Health* **2018**, *18*, 1404. [CrossRef] [PubMed]
14. Trusz, S. *Cognitive and Social Development of a Child in the Light of Interpersonal Expectations of Parents and Teachers*; Institute of Educational Sciences, Pedagogical University of Cracow: Cracow, Poland, 2011.
15. Sikorska, I. *"The Diversity of Contexts of the Social Development of a Child" Department of Developmental and Educational Psychology Im. Stefan Szuman*; Jagiellonian University Cracow, Developmental Psychology: Cracow, Poland, 2005.
16. Frydrychowicz, A.; Misiorna, E.; Kozłowska, E.; Pietrzak-Kurzac, M.; Rusiak, P.; Szczepkowska-Szcześniak, K. Teacher's advisor for six-year-olds: Methodological materials for teachers developed as a result of the project "Study of school readiness of six-year-olds" implemented at the Methodological Center of Psychological and Pedagogical Assistance. In *Development and Assessment of Reading Skills of Six-Year-Old Children*; Methodological Center for Psychological and Pedagogical Assistance: Warsaw, Poland, 2006.
17. Peterson, J.; Bruce, J.; Patel, N.; Chamberlain, L.J. Parental Attitudes, Behaviors, and Barriers to School Readiness among Parents of Low-Income Latino Children. *Int. J. Env. Res. Public Health* **2018**, *15*, 188. [CrossRef] [PubMed]

International Journal of
Environmental Research and Public Health

Article

The Correlation between Residual Primitive Reflexes and Clock Reading Difficulties in School-Aged Children—A Pilot Study

Agata Kalemba [1], Maria Lorent [1], Sally Goddard Blythe [2] and Ewa Gieysztor [1,3,*]

1 Student Research Group of the Developmental Disorders of Children and Youth, Department of Physiotherapy, Faculty of Health Sciences, Wroclaw Medical University, 50-367 Wroclaw, Poland
2 The Institute for Neuro-Physiological Psychology, Chester CH4 9BR, UK
3 Laboratory of Clinical Bases of Physiotherapy, Department of Physiotherapy, Faculty of Health Sciences, Wroclaw Medical University, 50-367 Wroclaw, Poland
* Correspondence: ewa.gieysztor@umw.edu.pl

Abstract: The aim of the pilot project was to research relationships between the occurrence and level of intensity of primitive reflexes in primary school children, the ability to read an analogue clock and to tell the time. A group of 28 children (14 girls and 14 boys) who attended Montessori Primary School was examined. In the first stage, participants were assessed for the presence of five primitive reflexes (PR): the asymmetrical tonic neck reflex (ATNR), symmetrical tonic neck reflex (STNR), spinal Galant reflex, tonic labyrinthine reflex (TLR) and Palmar grasp reflex. Romberg's test was employed to identify signs of difficulties with control of balance and/or proprioception. In the second stage, pupils underwent tests that challenged their ability to read a clock and calculate passing time. After summing up points obtained for all tests, a correlation coefficient was made from which the results were derived. There is a negative correlation between the ability to read an analogue clock and the continued presence of some primitive reflexes. Lower neuromotor maturity (higher points of PR) correlates with lower ability to read a clock. The highest correlations between difficulty with telling the time were found with persistence of the STNR, ATNR and Romberg's test.

Keywords: children; primitive reflexes; clock; dyscalculia; developmental disorders; neuromotor development

check for updates

Citation: Kalemba, A.; Lorent, M.; Blythe, S.G.; Gieysztor, E. The Correlation between Residual Primitive Reflexes and Clock Reading Difficulties in School-Aged Children—A Pilot Study. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2322. https://doi.org/10.3390/ijerph20032322

Academic Editor: Paul B. Tchounwou

Received: 13 October 2022
Revised: 24 January 2023
Accepted: 25 January 2023
Published: 28 January 2023

1. Introduction

Primitive reflexes (PR) are an important index of children's neuromotor maturity. They are examined after birth when their relative strength indicates normal development of the central nervous system (CNS). The reflex reactions are linked to early spontaneous movements and children's psychomotor development is closely linked to the sequenced time of activity, inhibition and integration of individual reflexes. Brain stimulation from sensors and movement activity combined with the normal process of maturation facilitates the appropriate development of different stages of growth [1].

Primitive reflexes emerge from 9–12 weeks after conception and are observed in babies born at full term (40 weeks) [1–4]. They are mediated in the brain stem. Between the 6th and 12th month as a result of maturation of the central nervous system, their activity gradually recedes as postural reflexes emerge alongside the development of more advanced motor activities [1]. Postural reflexes provide a foundation for further psychomotor development of the child. They support subconscious control of posture and balance [2], taking up to three years of age to be fully developed. A delay in occurrence of a particular reflex reflects immaturity in the functioning of the CNS and can interfere with the child's psycho-motor development. The activity of primitive reflexes is closely linked to the later emergence of postural reflexes and vice-versa, which in turn can interfere with a child's ability to interact physically with the environment [5].

Gradually, as primitive reflex response is superseded by postural reflexes and increased voluntary control of posture, balance and coordination, psycho-social, motoric, educational skills and aspects of emotional development, which depend on postural control to provide a secure physical reference point in space, should be observed. The research on primitive reflexes shows that, in preschool or school-age children, they may still persist, especially in children in whom some spheres of development are disturbed [6–11]. Children with persistent PR are seen to have lower motor, cognitive, visual and learning achievements [12–14]. Some of the research shows specific difficulties in reading [15–18] or language disorder [8] in relation to PR activity. Moreover, primitive reflexes have been shown to persist in children of school-age who have specific learning difficulties [19,20], with the asymmetrical tonic neck reflex (ATNR) and symmetrical tonic neck reflex (STNR) being particularly prevalent amongst this group, followed by the Palmar grasp reflex and tonic labyrinthine reflex (TLR). Difficulty performing the Romberg test is also of significance.

The ability to tell the time develops in preschool (in countries where formal schooling starts from 6 years of age) and this skill is used throughout the whole of life [21], so being able to read a clock or estimate time is an important goal in primary school [22]. The ability to perceive time is a complex cognitive competence based on literacy, memory, arithmetic and spatial skills [23].

PRs under examination in this project are those which have been shown to be linked to other aspects of child development and to specific learning difficulties. The ATNR and STNR, for example, are elicited as a result of lateral rotation of the head (ATNR) or flexion and extension of the head (STNR). Both head movements provide stimulation to the vestibular system, but the reflex response allows only a limited and stereotyped reaction in terms of adjustment of muscle tone and its effect upon posture. Signs of difficulty in performing Romberg's test may be secondary to an underlying conflict between vestibular function, muscular reaction and proprioceptive feedback, affecting physical stability and realisation of position in space. A secure reference point in space is an important precursor to being able to orientate in space and understand directional and spatial relationships and is fundamental to some of the spatial cognitive processes involved in reading an analogue clock or many other mathematical competencies (e.g., arithmetic abilities).

Levinson suggested that underlying directional disturbances are a functional problem of the "inner ear's compass" [24]. Vertical stability in space, of which postural control is both instrumental and an outcome, is essential for being able to understand spatial relationships such as the ability to differentiate left from right, up from down, etc., abilities that are basic to being able to understand the meaning of the upper and lower sections of a clock face and that left and right sides of a clock indicating before and after. Spatial deficits, which may be a secondary consequence of immature postural control, can potentially affect higher cognitive abilities such as directional awareness, misinterpretation of numbers, meaning derived from which hand is pointing at the numbers and understanding of clockwise movements.

Analogical reasoning in humans plays a prominent role in problem solving and involves application of past experience to new but similar experience based on physical knowledge of the world. Retained or residual primitive reflexes in school-aged children may contribute to, or be a reflection of, disassociation in the functional relationship between the vestibular and proprioceptive systems affecting equilibrium, which is chiefly related to space and supports cognitive understanding of spatial relationships.

The sense of physical stability in space involves both corporal space—that which is sensed as a result of information to and inside the body—and outside space, from which the basic notion of body schema (the body's representation at the level of the cortex) is obtained through the experience of movement and the motoric adaptations to outside space. Partial retention of primitive reflexes in children of school age signifies immaturity in the acquisition of vertical stability in space, of which difficulty in performing the Romberg test is only one sign.

Furthermore, the ATNR divides the body into two parts, left and right, and similarly the STNR into upper and lower. The clock must be interpreted by a child in terms of sections describing halves, quarters and minutes as well as the understanding of clockwise motion.

Observing that the occurrence of persistent primitive reflexes has a direct connection to learning disorders we would like to answer two questions:

1. Is there a connection between persistence of primitive reflexes and the ability to read the time from an analogue clock or to calculate passing time?
2. Which of the reflexes have the most significant impact on the ability to read a clock?

2. Materials and Methods

This study is a part of the *Primitive Reflexes and All Children Sphere (PRACS) Project*, the aim of which was to determine researching reflexes and their influence on motor, sensory and cognitive development in preschool and school-aged children. The research has been certified by the Bioethical Committee of the Wrocław Medical University, no. of permit: KB-626/2018.

In a group of primary school children, the incidence of selected primitive reflexes was tested. Every parent signed a consent form for their child to take part in the research. They were also informed about the aim and the non-invasive character of the research.

2.1. Group Characteristics

Twenty-eight children took part in the research: 14 boys (50%) and 14 girls (50%) who attended the Montessori Primary School. The average age of the group was 8.14 (Me = 8).

2.2. Testing the Activity of Primitive Reflexes

The children were tested for the following reflexes: ATNR quadruped test (Ayres), ATNR Hoff-Schilder test, STNR, Spinal Galant, TLR and Palmar grasp reflex. They also undertook Romberg's test. Points were given depending on the level of activity of a reflex. The tests were administered as in the INPP screening test [25], where a score of 0 described no reflex (no abnormality detected) and 4 meant that the reflex was fully retained. The scores have been averaged for each reflex, which were tested in two positions, e.g., left and right, or flexion and extension.

Tests for the ATNR using the Hoff-Schilder test and TLR were carried out with the participant's eyes closed. Romberg's test was administered first with the eyes open, then with the eyes closed. ATNR Ayres, STNR and GALANT reflexes were carried out with the test subject in the quadruped position with the eyes open. ATNR Hoff-Schilder, TLR, Palmar grasp reflex and Romberg's test were conducted in the erect position.

The Asymmetrical Tonic Neck Reflex (ATNR) was assessed in two ways. Firstly, it was observed whether passive lateral rotation of the head to either side in the quadruped position was accompanied by involuntary flexion in the upper occipital limb (bending of the cubital and glenohumeral joints), movement of the torso, or pelvis. Secondly (ATNR Hoff-Schilder test), each child was asked to stand with their feet together, arms extended to the front and wrists floppy. The researcher turned the child's head in both directions. The test was deemed positive when one or both of the arms followed the movement of the head and there was no isolation of head movement from the rest of the body.

For the STNR, the researcher instructed the child in the quadruped position to: "extend your head as if looking towards the ceiling" and then, "flex your head as if looking between your knees". During the extension phase, the focus was on any increase in extensor tone in the arms and flexion in the lower body such as tendency to sit on the heels. During the flexion phase, a positive score was recorded if there was increased flexor tone in the arms and extensor tone in the lower body.

Assessment of the TLR involved the child actively flexing and extending the head while in the erect position with the feet together. During the flexion phase, any increase in flexor tone throughout the length of the body was observed. During the extension phase, compensations such as increased extensor tone in the legs or other forms of upper limb movement, standing on tip-toes, or loss of balance indicated that the reflex is active.

The Palmar Grasp reflex (GRASP) and spinal Galant reflex are skin reflexes. Assessment of the Palmar reflex was made by applying gentle stimulation to the palm of the hand administered by the researcher. This was applied using the blunt end of a pencil as the stimulus. A positive response was detected when the child flexed finger II–V or there was adduction of the thumb. The test was repeated on both sides while simultaneously observing the symmetry of the reaction.

Tactile stimulation was also used to test the spinal Galant reflex. The researcher made a vertical movement with their thumb along the erector spinae muscle of the child on each side. When the reflex was active, a torso bending movement away from the stimulated side could be observed.

During the Romberg test, the children were asked to keep their feet together while standing with the arms at the sides and to stand still with the eyes open. The test was then repeated with the eyes closed.

All the tests were completed by the clinicians with proper preparing and with 8 years of practice of examination and therapy of children with neuromotor immaturity. The results of the two independent clinicians were compared. The detailed form of the examination is described in Gieysztor et al. [9].

2.3. The Clock Test

The second part of the examination required participants to complete the clock test on their own. This part was administered by the teacher of the child. The test comprised seven tasks, four of which were open questions and three were choice tests. Each child could obtain a maximum of 23 points (100% correct answers). The questions assessed the ability to read the time on a clock shown in pictures and count the differences between hours.

2.4. Statistical Analysis

Test results of all the primitive reflexes assessed were tallied and, by summing up the results, an index of neuromotor status was obtained. The results of the clock test were summated and shown as a percentage. Statistical analysis was conducted using the IBM SPSS Statistics 25 version (IBM Corp., Armonk, NY, USA). The Pearson's correlation coefficient was calculated. The established level of importance for analysis interpretation is $p < 0.05$.

3. Results

3.1. Descriptive Indices of the Activity Level of Reflexes and the Clock Test

An analysis of the level of activity of each reflex was conducted. The highest level of activity was observed in the ATNR (M = 1.8 points; SD = 1.06) and TLR (M = 1.1 p.; SD = 0.70).

Calculating the CT points children obtained, the descriptive results shown average results of nearly half of the maximum points (M = 46%; SD = 0.35; Me = 29%). The descriptive statistics are shown in Table 1.

Table 1. Descriptive statistics obtained in the examination of the level of reflexes and clock test performance.

	CT	PR	ATNR	STNR	Galant	ATNR H-S	Romberg	TLR	Grasp
M	0.46	1.14	1.80	0.88	0.73	1.20	0.26	1.10	0.38
SD	0.36	0.46	1.06	0.56	0.92	0.63	0.32	0.70	0.64
Me	0.29	1.00	1.50	1.00	0.50	1.00	0.00	1.00	0.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	1.00	3.00	4.00	2.00	3.00	2.50	1.00	2.50	2.50

M—mean; level of reflexes–neuromotor status, CT—clock test; PR—level of primitive reflexes; ATNR measured by Ayres test; STNR—symmetrical tonic neck reflex; ATNR H-S—asymmetrical tonic neck reflex measured by Hoff-Schilder test; TLR—tonic labyrinthine reflex.

3.2. Correlation Analysis of the Clock Test Results and the Activity Level of Reflexes Results

An analysis of the correlation coefficient between the clock test (CT) results and the activity level of reflex test results was conducted. The results are shown in Table 2. There is a negative correlation between the results of the CT and the PR test (r = −0.34). That means that children with a lower score on the clock test had a higher incidence of persistent primitive reflexes (lower neuromaturation). Analyzing the correlation of the CT results with each reflex and looking for the answer to which have the most impact, we can see, that the STNR reflex shows a significant ($p < 0.01$) negative correlation with performance on the clock test. This means that the higher the level of activity in the STNR reflex observed in a child, the lower the results in the clock test. Tests for the ATNR, Palmar grasp reflex and Romberg's sign also showed a statistically significant negative correlation with performance on the clock test ($p < 0.05$). The spinal Galant reflex and TLR showed a low negative correlation with performance on the clock tests.

Table 2. The results of correlation analyses performed for clock test and the activity level of reflexes.

	CT	PR	ATNR	STNR	Galant	ATNR H-S	Romberg	TLR	Grasp
CT	–	−0.34	−0.30	−0.6	−0.18	−0.26	−0.30	−0.15	−0.31
PR	−0.34	–	0.64	0.63	0.61	0.63	0.49	0.61	0.30
ATNR	−0.30	0.64	–	0.52	0.48	0.64	0.40	0.34	0.10
STNR	−0.60	0.63	0.52	–	0.15	0.51	0.28	0.32	0.27
Galant	−0.18	0.61	0.48	0.15	–	0.31	0.44	0.37	0.10
ATNR H-S	−0.26	0.63	0.64	0.51	0.31	–	0.49	0.38	0.16
Romberg	−0.30	0.49	0.40	0.28	0.44	0.49	–	0.59	0.02
TLR	−0.15	0.61	0.34	0.32	0.37	0.38	0.59	–	0.03
grasp	−0.31	0.30	0.10	0.27	0.11	0.16	0.02	0.03	–

CT—clock test; reflexes–summed points for reflexes; PR—primitive reflexes as a sum; ATNR measured by Ayres test; STNR—symmetrical tonic neck reflex; ATNR H-S—asymmetrical tonic neck reflex measured by Hoff-Schilder test; TLR—tonic labyrinthine reflex.

3.3. Analysing the Specific Problems Observed in Children's Answers

Analysing consistent errors made by children, we have indicated:

- Low ability to differentiate the functions of the different hands of the clock
- Misunderstanding the instruction for the task
- Lack of counting ability
- Ignorance of the nomenclature used in the context of the clock, i.e., not understanding the word 'quarter'

- Lack of knowledge regarding reading full hours or difficulties in interpreting (answering 3:60 instead of 3:00, in case the short hand is located on 3 and long on 12)

4. Discussion

The aim of this study was to analyse the correlation between neuromotor development level, based on PR activity, and the ability to read a clock and to count passing time.

We have observed that children with lower neuromotor status had lower results in the clock test. Moreover, Pearson's correlation shows that the most implicated reflexes were the STNR, followed by the ATNR, and soft signs of difficulties with balance and/or proprioception as revealed by the Romberg test. This is the first study, known to the authors, to compare neuromaturation status with the ability to read a clock and the results of tests to assess the ability to count passing time.

However, the number of participants involved in the study was small. Although statistical analysis revealed trends in terms of higher incidence of PRs being associated with difficulty reading a clock or calculating passing time, further investigations are needed involving a larger numbers, which include control and comparison groups.

To date, immature neuromotor status as identified by persistent primitive reflexes in children of school age has been shown to be elevated in children presenting with emotional and behavioural issues [26], children diagnosed with attention deficit hyperactive disorder (ADHD) [27], visual processing difficulties [28], immature motor skills [29,30], relation to motor skills in pre-school children [10], motor skills in relation to school readiness [31], communication disorder [32], developmental language disorder [8], differences in school performance [13,33] and social disadvantage [34]. This broader spectrum of issues found to be present in conjunction with signs of neuromotor immaturity suggests that it may be a general underlying factor in a number of developmental disorders and specific learning difficulties. In other words, immature neuromotor status may undermine performance in a range of "higher" cognitive skills and emotional regulation.

Learning to read an analogue clock and count passing time involves multiple cognitive skills including, but not exclusive to: language, the ability to count from 1–12 (or 24) and understanding sequencing and spatial relationships. While several of these abilities may be involved in calculating time, the results of this study suggest that spatial problems linked to the retention of primitive reflexes, which can affect balance and postural control and therefore the physical basis for cognitive operations in space, may be of significance. These findings and the questions they raise could be used as a basis for a larger scale study to discover whether persistence of PRs is directly related to difficulty in learning to read an analogue clock and calculate passing time [2,25].

The results of our study confirm the hypothesis that some reflexes may play a special role in the ability to read an analogueclock. The highest coexistence of ATNR, STNR, or Romberg test with clock reading disturbances was the most important. Similarly, results suggest that subsequent areas of child development and related cognitive skills may be impacted by retention of primitive reflex activity, and point to potential areas of improvement after therapy for PR integration. Answering the question of why these particular reflexes have the most significant impact on the ability in reading the clock, we may think again about the function of underlying pathways that these reflexes and the Romberg test reflect. They are important for orientation in space and understanding directional and spatial relationships. Retained or residual primitive reflexes in school-aged children may lead to, or be a mirror of, inappropriate functional relationship between the vestibular and proprioceptive systems affecting equilibrium, which is particularly related to space and supports cognitive orientation of spatial relationships. Stability in space involves the stability of the body, based on the internal sensory information and environmental space, which is achievable through the experience of movement and the motoric adaptations to outside space.

So far, no study has been conducted, known to the authors, that proves the occurrence of persistent primitive reflexes in children who experience difficulties in reading the hour from a clock; however, some authors point to children who have problems with mathematics making numerous mistakes while trying to read the clock. Andersson et. al. and Burny et. al. suggest that difficulty in reading a clock can also be one of the first signals pointing to dyscalculia in early school-age children. They show that children who have mathematical difficulties also demonstrate increased challenges in clock reading [22,35,36]. Mutlu et al. show that the majority of children experience difficulty in not only reading the clock but also in correctly drawing the clock face and remembering the functions of the hands. The most common mistake shown in the research was paying attention to only one hand on the clock (minute or hour), which resulted in omitting the information about hour or minutes or incorrectly adding the missing element [37]. Similar problems were observed in our group of children with lower neuromotor maturation. We have observed a low ability to differentiate the functions of each hand of the clock, misunderstanding the instruction for the task, lack of counting ability, ignorance of the nomenclature used in the context of the clock, i.e., not understanding the word 'quarter', and lack of knowledge regarding reading full hours. Mutlu et al. claim that, while dyscalculia explains the cause of these difficulties in children at risk, no cause has been found for poor clock reading in children who have not been diagnosed with dyscalculia. Maybe in these cases lower neuro-maturity plays its role? To answer this question, wider research is necessary for investigating the abilities of clock reading in school-age children.

This pilot study presents neuromotor status as being a factor in being able to read a clock and calculate time; however, because of the small sample of participants, the claim should be treated as the very beginning. Looking at the limitations of the study, we have also found that it should be conducted with a larger population. It may also be expanded to investigate the role of lateralization as a foundation for being able to tell the time. Researchers may also look for other temporal aspects, using tests consisting of other spheres of time such as orientation, sequences, time units, clock reading, life span, birthday, or present time awareness.

5. Conclusions

1. Neuromotor maturity status may be related to the ability to read a clock and to count time.
2. There is a need to expand the research in this area on laterality and the research should be conducted with a bigger sample.
3. The recommendations to introduce reflex integration therapy to children with learning problems may also improve the ability to read a clock.

Author Contributions: Conceptualization, E.G.; methodology, E.G.; formal analysis, E.G. and S.G.B.; investigation, E.G.; resources, E.G.; data curation, E.G.; writing—original draft preparation, M.L., A.K., S.G.B. and E.G.; writing—review and editing, M.L., A.K., S.G.B. and E.G.; visualization, M.L., A.K. and E.G.; supervision, E.G.; project administration, E.G.; funding acquisition, E.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Wroclaw Medical University (KB-626/2018).

Informed Consent Statement: Informed consent was obtained from all subjects' parents or guardians involved in the study.

Data Availability Statement: Data can be provided upon request.

Acknowledgments: The authors gratefully acknowledge the teachers, parents, and children who participate in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zafeiriou, D.I. Primitive reflexes and postural reactions in the neurodevelopmental examination. *Pediatr. Neurol.* **2004**, *31*, 1–8. [CrossRef] [PubMed]
2. Goddard, S. *Reflexes, Learning and Behavior: A Window into the Child's Mind*; Fern Ridge Press: Eugene, OR, USA, 2005; p. 182.
3. Gardner, S.L.; Carter, B.S.; Hines, M.E.; Niermeyer, S. *Merenstein & Gardner's Handbook of Neonatal Intensive Care: An Interprofessional Approach*; Elsevier Health Sciences: Amsterdam, The Netherlands, 1238.
4. Sohn, M.; Ahn, Y.; Lee, S. Assessment of Primitive Refl exes in High-risk Newborns. *Orig. Artic. J. Clin. Med. Res.* **2011**, *3*, 285–290. [CrossRef]
5. Pecuch, A.; Kołcz-Trzęsicka, A.; Żurowska, A.; Paprocka-Borowicz, M. Psychomotor disorders assesment in 4–6 year-old children with INPP test battery. *Nurs. Public Health* **2018**, *8*, 11–20. [CrossRef]
6. Melillo, R. Persistent primitive reflexes and childhood neurobehavioral disorders. In *Neuroplasticity in Learning and Rehabilitation*; Nova Biomedical Books: Washington, DC, USA, 2016.
7. Bogdanoviča, I.; Lāriņš, V. Backstroke teaching methods in healthy children with residual primitive reflexes. *Soc. Intefration Educ. Proc. Int. Sci. Conf.* **2021**, *4*, 318–332. [CrossRef]
8. Matuszkiewicz, M.; Gałkowski, T. Developmental language disorder and uninhibited primitive reflexes in young children. *J. Speech Lang. Hear. Res.* **2021**, *64*, 935–948. [CrossRef]
9. Gieysztor, E.Z.; Choińska, A.M.; Paprocka-Borowicz, M. Persistence of primitive reflexes and associated motor problems in healthy preschool children. *Arch. Med. Sci.* **2018**, *14*, 167–173. [CrossRef]
10. Pecuch, A.; Gieysztor, E.; Wolańska, E.; Telenga, M.; Paprocka-Borowicz, M. Primitive Reflex Activity in Relation to Motor Skills in Healthy Preschool Children. *Brain Sci.* **2021**, *11*, 967. [CrossRef]
11. Goddard-Blythe, S. The role of primitive survival reflexes in the development of the visual system. *J. Behav. Optom.* **1995**, *6*, 31–36.
12. Grzywniak, C. Role of early-childhood reflexes in the psychomotor development of a child, and in learning. *Acta Neuropsychol.* **2016**, *14*, 113–129. [CrossRef]
13. Zielińska, M.; Goddard Blythe, S. School functioning of students with neuromotor immaturity. *Int. J. Pedagog. Innov. New Technol.* **2020**, *7*, 40–46. [CrossRef]
14. Gieysztor, E.; Pecuch, A.; Kowal, M.; Borowicz, W.; Paprocka-Borowicz, M. Pelvic symmetry is influenced by asymmetrical tonic neck reflex during young children's gait. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4759. [CrossRef]
15. McPhillips, M.; Jordan-Black, J.A. Primary reflex persistence in children with reading difficulties (dyslexia): A cross-sectional study. *Neuropsychologia* **2007**, *45*, 748–754. [CrossRef]
16. Montgomery, R.; Nichols, C.; Ornburn, C.; Rudd, A.; Williams, L.; Smith, B. The Effects of Persistent Asymmetrical Tonic Neck Reflex (ATNR) on Reading Scores in First and Second Grade Children. Published Online 2015. Available online: https://soar.wichita.edu/handle/10057/11429 (accessed on 20 October 2022).
17. González, S.R.; Ciuffreda, K.J.; Hernández, L.C.; Escalante, J.B. The Correlation between Primitive Reflexes and Saccadic Eye Movements in 5th Grade Children with Teacher-Reported Reading Problems. *Optom. Vis. Dev.* **2008**, *39*, 140–145.
18. McPhillips, M.; Hepper, P.G.; Mulhern, G. Effects of replicating primary-reflex movements on specific reading difficulties in children: A randomised, double-blind, controlled trial. *Lancet* **2000**, *355*, 537–541. [CrossRef]
19. Blythe, S.G.; Hyland, D. Screening for Neurological Dysfunction in the Specific Learning Difficulty Child Screening for Neurological Dysfunction in the Specific Learning Difficulty Child. *Br. J. Occup. Ther.* **1998**, *61*, 459–464. [CrossRef]
20. Goddard Blythe, S. *Assessing Neuromotor Readiness for Learning: The INPP Developmental Screening Test and School Intervention Programme*; Wiley-Blackwell: New York, NY, USA, 2012. [CrossRef]
21. Friedman, W.; Laycock, F. Children's Analog and Digital Clock Knowledge. *JSTOR*. Published Online 1989. Available online: https://www.jstor.org/stable/1130982 (accessed on 6 January 2023).
22. Burny, E.; Valcke, M.; Desoete, A. Clock Reading: An Underestimated Topic in Children With Mathematics Difficulties. *J. Learn Disabil.* **2012**, *45*, 351–360. [CrossRef]
23. Foreman, N.; Boyd-Davis, S.; Moar, M.; Korallo, L.; Chappell, E. Can virtual environments enhance the learning of historical chronology? *Instr. Sci.* **2008**, *36*, 155–173. [CrossRef]
24. Levinson, H.L. *Smart but Feeling Dumb*; Warner Books: Albertville, AL, USA, 1994.
25. Goddard, S. Neuro-motor Maturity as an Indicator of Developmental Readiness for Education. Report on the use of a Neuro-Motor Test Battery and Developmental Movement Programme in Schools in Northumberland and Berkshire Neuro-motor Maturity as an Indicator of Developm. In Proceedings of the Paper Presented at the Institute for Neuro-Physiological Psychology Conference, Miami, FL, USA, 11–12 April 2010.
26. Taylor, B.; Hanna, D.; McPhillips, M. Motor problems in children with severe emotional and behavioural difficulties. *Br. J. Educ. Psychol.* **2020**, *90*, 719–735. [CrossRef]
27. Bob, P.; Konicarova, J.; Raboch, J. Disinhibition of Primitive Reflexes in Attention Deficit and Hyperactivity Disorder: Insight Into Specific Mechanisms in Girls and Boys. *Front. Psychiatry* **2021**, *12*, 1992. [CrossRef]
28. Andrich, P.; Wrenhaven, S.L.; Glenn Goodman, O.D. Statistical Relationships Between Visual Skill Deficits and Retained Primitive Reflexes in Children. *Optom. Vis. Perform* **2018**, *3*, 106–111.
29. Pecuch, A.; Gieysztor, E.; Telenga, M.; Wolańska, E.; Kowal, M.; Paprocka-Borowicz, M. Primitive Reflex Activity in Relation to the Sensory Profile in Healthy Preschool Children. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8210. [CrossRef] [PubMed]

30. Duncombe, R.; Preedy, P. Physical development in the early years: Exploring its importance and the adequacy of current provision in the United Kingdom. *Education* **2020**, *49*, 920–934. [CrossRef]
31. Goddard Blythe, S.; Duncombe, R.; Preedy, P.; Gorely, T. Neuromotor readiness for school: The primitive reflex status of young children at the start and end of their first year at school in the United Kingdom. *Education* **2021**, *50*, 654–667. [CrossRef]
32. Mironova Tabachová, J.; Vitásková, K. Evaluation of primary reflexes in children with communication disorder aged 5–10 years in relation to pre-school competencies. In *The 13th Annual Conference of Education, Research and Innovation 9–10 November Online Conference*; IATED: Valencia, Spain, 2020; ISSN 2340–1095.
33. Ivanovic, L.; Ilic-Stosovic, D.; Nikolic, S.; Medenica, V. Does neuromotor immaturity represents a risk for acquiring basic academic skills in school-age children? *Vojn. Pregl.* **2019**, *76*, 1062–1070. [CrossRef]
34. McPhillips, M.; Jordan-Black, J.A. The effect of social disadvantage on motor development in young children: A comparative study. *J. Child Psychol. Psychiatry* **2007**, *48*, 1214–1222. [CrossRef]
35. Andersson, U. Mathematical Competencies in Children With Different Types of Learning Difficulties. *J. Educ. Psychol.* **2008**, *100*, 48–66. [CrossRef]
36. Andersson, U.; Östergren, R. Number magnitude processing and basic cognitive functions in children with mathematical learning disabilities. *Learn. Individ. Differ.* **2012**, *22*, 701–714. [CrossRef]
37. Mutlu, Y.; Korkmaz, E. Investigating Clock Reading Skills of Third Graders with and without Dyscalculia Risk. *Int. Online J. Prim. Educ.* **2020**, *9*, 97–110.