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Influence of Gestational Diabetes on Motor Development

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A B S T R A C T

Research shows that metabolically impaired intrauterine environment causes mild long-term neuromotor deviations that are more pronounced in younger children. The goal of this study was to examine possible long-term consequences of gestational diabetes on motor development. Maximal strength and the ability of precisely modulate strength and position in the wrist joint as well as visual-motor integration of 10 years old children born to mother with gestational diabetes and matched controls born from regular pregnancies were measured. Ten years ago, fetal behaviour of both, control and experimental group was recorded and general movements, mouth movements, hand movements and movements of fist/fingers of the experimental group was worse than in the control group. The obtained results showed no intergroup differences in maximal force production and in the ability to precisely modulate force and position in the wrist joint. However, the visual-motor integration of the dominant side resulted significantly better in the control group. The result indicates a possible greater negative impact of gestational diabetes on the graphomotor skills of school-aged children rather than on their maximal strength and ability to precisely modulate force and movement in the wrist joint.

Key words: *pregnancy, hyperglycemia, development, child, motor control*

Introduction

Uncontrolled diabetes during pregnancy can cause a whole range of neurological disorders, from the mildest to the most complicated pathologies. Even controlled gestational diabetes can cause certain neurological damage and have a significant impact on the child's neuromotor development[1,2]. Initial effects of gestational diabetes on neuromotor development can be studied intrauterine, thanks to the standardized assessment of fetal behaviour[3–5]. Changes in general spontaneous movements and different patterns of fetal behaviour have been described and observed in various pathological and high-risk pregnancies, including pregnancies of women with different type of diabetes[5,6]. Vasilj (2014) observed impaired motor behaviour of fetuses from mothers with gestational diabetes. In the same study, the association of glycosylated hemoglobin with altered fetal behaviour was proven. Intrauterine exposure to a metabolically disturbed environment may affect the development of the fetus central nervous system, which can manifest as developmental delay of the child later in life[7–9]. Several studies have proven the connection between children's developmental disorders and the level of maternal glycemia during pregnancy, as well as the long-term consequences on the child`s memory, expressive speech, attention and some forms of motor behaviour[1,7,8,10]. Slow motor development, as well as impairment of fine and gross motor function may be a consequence of diabetes during pregnancy[1,7,9,11–14]. Research confirms a positive correlation between the level of glycosylated hemoglobin and impairment of fine and gross motor function[7,11,12]. A meta-analysis confirmed the association of mothers pregestational and gestational diabetes with slower motor development in children[14]. Differences in motor disorders are more pronounced in children of younger age groups, while differences in older age groups are less pronounced[12,15]. This underlies the possibility of equating the motor abilities of children born to mother with gestational diabetes with those of their peers born to mother without gestational diabetes in later childhood[14]. However, it is not known whether this equalization is realized in all aspects of motor behaviour. An assessment of the neuropsychological abilities of children born from pregnancies with gestational diabetes at school age revealed milder deviations in

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graphomotor skills and fine motor skills[16], as well as weaker academic achievements[10].In a recent meta-analysis lower motor performances of 0–12 years old children born to mothers with gestational and pregestational diabetes were confirmed[14]. However, the number of studies is small and their conclusions are mainly based on cross-sectional methodology. Also, the existing research is quite heterogeneous (combining type 1, 2 and gestational diabetes), which makes it difficult to draw final conclusions about the outcomes on the motor development of children of mothers with gestational diabetes.

The main goal of this research was to examine the influence of gestational diabetes on children`s motor development later in life. Particularly, the difference in maximal strength, fine motor control, and visual-motor integration between 10-year-olds born to mothers with gestational diabetes (in which disturbed fetal behaviour was already recorded intrauterine) and their peers born to mothers without gestational diabetes (who were part of the control group in the same previous study comparing fetal behaviour) was verified. Defining the impact of gestational diabetes on children`s motor development later in life through a long-term study could contribute to a better understanding of the consequences that gestational diabetes may have on the child's development with regard to his age.

Materials and Methods

Participants

The sample consisted of 25 children born to mothers with gestational diabetes (7 males and 18 females; experimental group) and 24 children born to mothers without gestational diabetes or any other pregnancy complication (14 males and 10 females – control group). The mean age of the subjects at the time of testing was 10.05 ± 0.07 years. The exclusion criteria were perinatal or postnatal complications, genetic syndromes or acquired impairments. The children included in this research were previously monitored. Their fetal behaviour was recorded during pregnancy, and back then, an intergroup difference was established between the experimental (then fetuses of mothers with gestational diabetes) and control (then fetuses of mothers without gestational diabetes) group. Specifically, four studied forms of fetal behaviour: general movements, mouth movements, hand movements and movements of fist/fingers were significantly better in fetuses of mother without gestational diabetes (Vasilj, 2014). All participants and their parents were informed about the protocol, research goals and potential risks. The participation was voluntary with a signed consent for participation by the parents. The study was conducted in accordance with the requirements of the Ethics Committee of the Faculty of Kinesiology of the University of Zagreb. The measurement was performed by two examiners who were not aware of which group the children belonged to.

Measurement

Maximal force production was assessed by the Hand Motor Control Diagnostic measurement system (HAMOCODI System, S2P Ltd, Ljubljana, Slovenia). The device consists of a hardware part to which a dynamometer and an electronic goniometer are attached. This enables the assessment of both force and range of motion during flexion and extension in the wrist joint. The maximal voluntary isometric contraction of the hand flexor`s muscles was assessed. Participants performed three maximal voluntary isometric contractions. The arithmetic mean of three repetitions was calculated for further processing.

Fine motor control was also assessed using the HAMOCODI System. The ability to precisely modulate force and position in the wrist joint were tested as fine motor control indicators. To assess the ability to precisely modulate force in the wrist joint, first maximal strength of the hand flexor`s muscles was assessed through the task of a maximal voluntary isometric contraction. The software than generated a random sinusoidal curve within an amplitude of 10 to 60% of the examinee's maximal strength. The curve was generated on the screen positioned in front of the participants. The subjects tried to follow the randomly generated sinusoidal curve as precisely as possible by modulating the force of their hand flexor muscles. The task lasted 45 seconds. The subjects performed the task three times, and the arithmetic mean of the three repetitions was used for further analysis. The root mean square deviation of the produced curve from the one generated by the computer in % was the variable of interest.

Similarly, to assess the ability to precisely modulate the position in the wrist joint, first maximal range of motion (for wrist flexion and extension) was assessed. The software than generated a random sinusoidal curve within an amplitude of 10 to 90% of the examinee's maximal wrist range of motion. The curve was generated on the screen positioned in front of the participants. The subjects tried to follow the randomly generated sinusoidal curve as accurately as possible by modulating their hand position through movements of wrist flexion and extension. The task lasted 45 seconds. The subjects performed the task three times, and the arithmetic mean of the three repetitions was used for further analysis. The root mean square deviation of the produced curve from the one generated by the computer in % was the variable of interest.

The visual motor integration test by Bavčević & Bavčević (VMI)[17] was used to assess the extent to which the participants were able to integrate their visual and motor abilities. The test consists of two parallel lines which connect the starting and ending dots. The distance between them was 178.5 cm. The participant's task was to connect the initial and the final dot by drawing a line with a pencil. The line had to be drawn without touching the border lines and without interruption. The examiner measured the time needed to perform the task in seconds. After finishing the task, the examiner counted the errors.

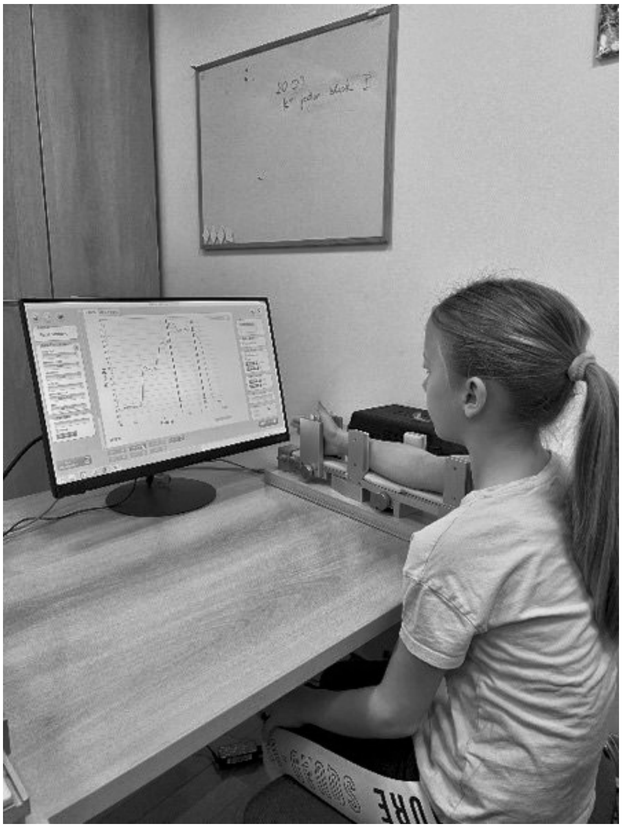

Fig. 1. Maximal force production assessed by HAMOCODI system.

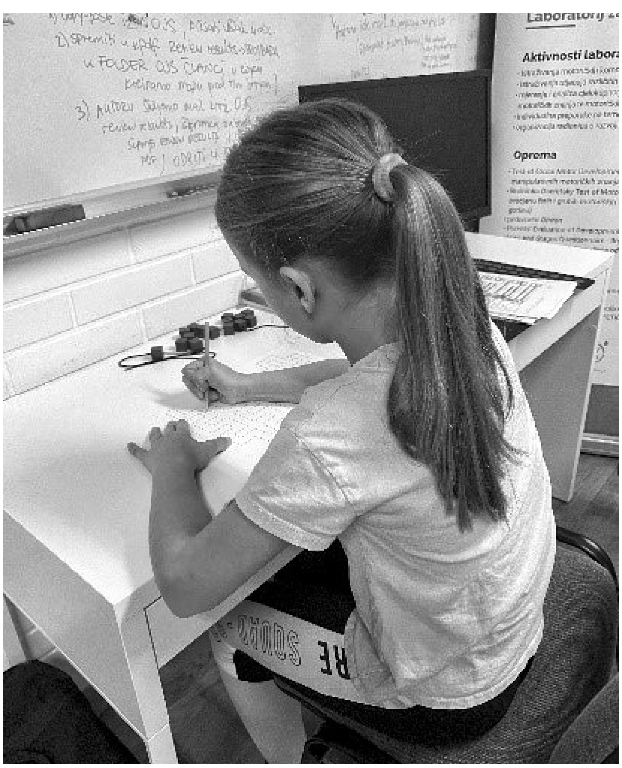

Fig. 2. Visual Motor Integration by Bavčević and Bavčević[17].

The result of the test represents the sum of the time required to perform the task and all errors multiplied by two. The test was performed only once according to previous guidelines[17].

All tests except the VMI (that was performed only with the dominant side) were performed with the dominant and non-dominant hand.

Statistical analysis

Data analyses were performed using the Statistica 13.5 program. Basic central and dispersive parameters were calculated for all variables. T-tests for independent samples were used to check the differences between groups in the monitored variables. The level of statistical significance was set at $p<0.05$.

Results

Basic central and dispersive parameters for maximal strength, force tracking and position tracking of both, dominant and non-dominant hand, as well as the values for visual-motor integration are presented in Table 1 (for the experimental group) and Table 2 (for the control group).

T-test for independent samples did not show a statistically significant intergroup difference between maximal voluntary contraction of the wrist flexors muscles, and the ability to precisely modulate force and position of both hands (Table 3 and 4). A statistically significant difference in favor of subjects born to mothers without gestational diabetes was found only for visual-motor integration of the dominant side (Table 3).

Discussion

The goal of this study was to examine possible long-term consequences of gestational diabetes on motor development. For that purpose, the motor abilities of ten-year-olds born to mother with gestational diabetes and control peers born to mother without gestational diabetes were measured. It is important to note that ten years ago, fetal behaviour (general movements, mouth movements, hand movements and movements of fist/fingers) of the experimental group was worse than that of the control group[5]. The obtained results showed no intergroup differences in maximal force production and in the ability to precisely modulate force and position in the wrist joint. However, the visual-motor integration of the dominant side resulted significantly better in the control group.

The fact that the maximal strength and fine motor control of the wrist joint of ten-year-olds born to mother with gestational diabetes resulted similar like those born to mother without gestational diabetes, regardless the fact that certain aspects of their fetal behaviour were worse[5], supports the assumption of a possible equalization of certain motor abilities later in life. This assump-

TABLE 1

BASIC CENTRAL AND DISPERSIVE PARAMETERS FOR THE MONITORED VARIABLES OF THE DOMINANT AND NON-DOMINANT HAND OF THE EXPERIMENTAL GROUP

EKSPERIMENTAL GROUP							
Variable	Unit of measure	Hand	Arithmetic mean	Standard deviation	Max	Min	Mode
MVC	Nm	Dominant	19.96	7.94	40.9	10.09	15.3
		Non-dominant	17.1	7.28	38.5	5.7	12.2
PTR	%	Dominant	0.23	0.08	0.51	0.13	
		Non-dominant	0.23	0.09	0.54	0.12	0.14
TRA	%	Dominant	0.3	0.11	0.69	0.17	
		Non-dominant	0.28	0.08	0.47	0.18	0.24
VMI	Arbitrary number	Dominant	28.89	7	44.78	17.19	

MVC – maximal voluntary contraction; PTR – position tracking; FTR – force tracking; VMI – visual-motor integration (only dominant side); Arbitrary number obtained by summing the time required to perform the task and all errors and multiplying it by two; Nm – newton meter

TABLE 2

BASIC CENTRAL AND DISPERSIVE PARAMETERS FOR THE MONITORED VARIABLES OF THE DOMINANT AND NON-DOMINANT HAND OF THE CONTROL GROUP

CONTROL GROUP							
Variable	Unit of measure	Hand	Arithmetic mean	Standard deviation	Max	Min	Mode
MVC	Nm	Dominant	22.44	7.78	36.33	7.55	
		Non-dominant	17.5	7.28	26.2	7.6	22.2
PTR	%	Dominant	0.21	0.08	0.37	0.12	
		Non-dominant	0.22	0.06	0.36	0.16	0.18
TRA	%	Dominant	0.3	0.06	0.45	0.2	
		Non-dominant	0.28	0.08	0.48	0.21	0.25
VMI	Arbitrary number	Dominant	25.22	6.34	44.21	15.01	

MVC – maximal voluntary contraction; PTR – position tracking; FTR – force tracking; VMI – visual-motor integration (only dominant side); Arbitrary number obtained by summing the time required to perform the task and all errors and multiplying it by two; Nm – newton meter

TABLE 3

BETWEEN GROUPS DIFFERENCES FOR THE VALUES OF THE DOMINANT HAND CHECKED BY T-TEST FOR INDEPENDENT SAMPLES

Variable	Unit of measure	Experimental group	Control group	p-value
MVC	Nm	19.96 ± 7.94	22.43 ± 7.78	0.139
PTR	%	0.23 ± 0.08	0.21 ± 0.08	0.175
TRA	%	0.30 ± 0.11	0.30 ± 0.06	0.396
VMI	Arbitrary number	28.89 ± 7.00	25.22 ± 6.34	0.031

MVC – maximal voluntary contraction; PTR – position tracking; FTR – force tracking; VMI – visual-motor integration; Arbitrary number obtained by summing the time required to perform the task and all errors and multiplying it by two; Nm – newton meter

TABLE 4

BETWEEN GROUPS DIFFERENCES FOR THE VALUES OF THE NON-DOMINANT HAND CHECKED BY T-TEST FOR INDEPENDENT SAMPLES

Variable	Unit of measure	Experimental group	Control group	p-value
MVC	Nm	17.10 ± 7.28	17.50 ± 5.57	0.42
PTR	%	0.23 ± 0.09	0.22 ± 0.06	0.32
TRA	%	0.28 ± 0.08	0.31 ± 0.08	0.095

MVC – maximal voluntary contraction; PTR – position tracking; FTR – force tracking; Nm – newton meter tion was made by Ornoy et. al.[12,15] based on a cross-sectional study conducted on 5 to 12 years old children in which significantly better gross and fine motor achievements (measured by means of The Touwen–Prechtl neurological examination, Bender Visual Gestalt test, Bruininks–Oseretsky Motor Development test, Southern California Integration Test, Conners Abbreviated Parents–Teachers and The Pollack tapper test) were found in children born to nondiabetic mothers compared to those born to mothers with diabetes, which was less pronounced in the subgroup of subjects from 9 to 12 year. The results of this study give a firmer support to the fact that children born from gestational diabetes can really have the opportunity to equalize the ability to produce maximal strength as well as their ability to control strength and movement in the wrist joint.

The significantly better visual-motor integration of the dominant side in the control group is supported by previous knowledge about school-aged children (8 years old) born to mothers with gestational diabetes who had lower results in manual dexterity as well as in graphic and spatial abilities measured by means of the Purdue Pegboard Dexterity Test[16]. Previously, also lower eye-hand coordination was found in school-age children measured by specific tasks of the Bruininks–Oseretsky Motor Development test[12].

The here established better visual-motor integration of the control group, with simultaneously equal maximal strength and fine motor control as the experimental group, is possibly explainable with the earlier measured participant`s fetal behaviour and previous knowledge about significantly worse motor development of younger children born from mother with gestational diabetes. All together that could have interfered with the learning and retention of graphomotor skills. Specific fetal behaviour of the experimental group was statistically worse than those of the control group (established 10 years ago by Vasilj[5]). Along with that, a recent meta-analysis showed that children born to mothers with gestational and preexisting diabetes have significantly lower motor scores compared with children born to nondiabetic mothers[14]. Previous finding also shows that diabetes and preexisting diabetes are associated with worse offspring school entry assessment scores and IQ scores[10]. Furthermore, as stated before these differences are more visible in earlier stages of life. Based on the previously established worse fetal behaviour of the experimental group, and based on previous knowledge of mild long-term neuromotor deviations that are more pronounced in younger children[9,10,14–16] it is possible to assume that an intergroup difference in motor development was present at some earlier point in the subject`s life. Even though that moment was not captured by this research, previously measured fetal behaviour and findings support the assumption that early in life (for instance at the moment of learning the skills of handling a pen and writing) a mild motor development impairment led to a weaker establishment of visual-motor coordination in the experimental group, which lasted to the age of 10. However, this is only an assumption that should be investigated by planning longitudinal studies with a greater number of measurement points in time in order to capture the dynamics of change.

Recent research performed on young healthy individuals suggests that motor learning of dynamic balance tasks may depend on the physical capability to execute the correct movement, that is on muscle power[18]. Therefore, the performance of some motor tasks might depend on the physical capacity to adequately perform the movement[18]. Although these claims are based on motor tasks of the lower extremities, it is possible to assume a similar pattern for the upper extremities. Damage to the motor functions of the central nervous system caused by metabolically disturbed environment may affect later motor development[7–9] and later motor development may interfere with graphomotor skill acquisition[19]. A certain level of motor development is required for good acquisition of graphomotor skills and, potentially, higher levels of motor abilities represent~~s~~ a better basis for the acquisition and retention of graphomotor tasks.

Conclusion

Gestational diabetes, although controlled, can adversely affect fetal behaviour. A metabolically disturbed intrauterine environment can impair a child`s motor development in various ways. Children born from mother with gestational diabetes may have impaired motor behaviour early in life as well as later on. The exact dynamic of changes as well as the influence on different motor abilities is not fully known and has been mainly investigated through cross-sectional studies. The results obtained from this study indicate the possibility of a different effect of gestational diabetes on a ten-year-old child. In particular, usual level of strength and movement control was found with weaker visual-motor coordination. This suggests that the ability of maximal force production as well as the ability to modulate strength and position in the wrist joint of children born to mother with gestational diabetes may be aligned to those of children born to mother without gestational diabetes by the age of ten which seems not to be the case for graphomotorics. However, more studies are needed in order to better establish the potential different effects of gestational diabetes on initial and later motor development.

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UTJECAJ GESTACIJSKOG DIJABETESA NA MOTORIČKI RAZVOJ DJETETA

SAŽETAK

Istraživanja pokazuju da metabolički narušeno intrauterino okruženje uzrokuje blage dugotrajne neuromotorne devijacije koje su izraženije u mlađe djece. Cilj ove studije bio je ispitati moguće dugoročne posljedice gestacijskog dijabetesa na motorički razvoj djeteta. Mjerene su maksimalna jakost i sposobnost precizne modulacije sile i položaja u zglobu šake kao i vizualnomotorička integracija 10-godišnje djece rođene iz trudnoće s gestacijskim dijabetesom te kontrolne skupine vršnjaka rođenih iz urednih trudnoća. Prije deset godina procijenjeno je fetalno ponašanje i kontrolne i eksperimentalne skupine, a generalizirani pokreti, pokreti usta, šake i šake/prstiju eksperimentalne skupine bili su znatno lošiji nego u kontrolnoj skupini. Dobiveni rezultati nisu pokazali međugrupne razlike u maksimalnoj jakosti, sposobnosti precizne modulacije sile i položaja u zglobu šake. Međutim, vizuoalnomotorička integracija dominantne strane rezultirala je značajno boljom u kontrolnoj skupini. Rezultati ukazuju na mogući veći negativni utjecaj gestacijskog dijabetesa na grafomotoriku djece školske dobi nego u odnosu na njihovu maksimalnu jakost te sposobnosti precizne modulacije sile i pokreta u zglobu šake.