RĪGA STRADIŅŠ UNIVERSITY

LATVIAN ACADEMY OF SPORT EDUCATION

Irina Bogdanoviča

ORCID 0009-0006-1832-8284

Optimisation Model for Teaching Swimming Strokes to 6–7-Year-Old Children with Residual Primitive Reflexes

Summary of the Doctoral Thesis for obtaining the scientific degree "Doctor of Science (*PhD*)"

Sector group – Medical and Health Sciences

Sector – Health and Sports Sciences

Sub-Sector – Sports Pedagogy

Riga, 2025

The Doctoral Thesis was developed at the Rīga Stradiņš University Latvian Academy of Sport Education from 2017–2024.

Supervisor of the Doctoral Thesis:

Dr. med., Professor **Viesturs Lāriņš**,
Rīga Stradiņš University, Latvia

Scientific advisor:

Dr. paed., Professor **Andra Fernāte**,
Rīga Stradiņš University, Latvia

Official Reviewers:

Dr. paed., Professor **Juris Grants**,
Rīga Stradiņš University, Latvia

Dr. med., Professor **Gundega Knipše**,
University of Latvia

Dr. biol., Associate Professor **Ruta Dadeliene**,
Vilnius University, Lithuania

Defence of the Doctoral Thesis will take place at the public session of the Promotion Council of Health and Sports Sciences on 3 December 2025 at 16.30 in the Hippocrates Lecture Theatre, 16 Dzirciema Street, Rīga Stradiņš University.

The Doctoral Thesis is available in RSU Library and on RSU website:
https://www.rsu.lv/en/dissertations

Secretary of the Promotion Council:

Dr. paed., Associate Professor **Inta Bula-Biteniece**

Table of Contents

Abbreviations used in the Thesis

ANOVA	Analysis of variance
ANS	Autonomic nervous system
ATNR L	Asymmetrical tonic neck reflex for the left side
ATNR R	Asymmetrical tonic neck reflex for the right side
BMI	Body mass index
CNS	Central nervous system
CV	Coefficient of variation
EXT	Extension
FLX	Flexion
HF	High-frequency band
HR	Heart rate
HRV	Heart rate variability
LF	Low-frequency band
LF/HF	Low-frequency band / high-frequency band ratio
M	Mean
n	Number
NN50	Number of differences between adjacent normal R-R intervals longer than 50 ms
PhIL	Physical intensity level
pNN50	Percentage of differences between adjacent normal R-R intervals more than 50 ms
PNS	Parasympathetic nervous system
PR	Pulse rate
RF	Relative phase
RMSSD	Square root of mean of sum of squared differences between adjacent normal R-R intervals
RPAP	Regulation processes adequacy parameter

RRNN	Mean intervals RR
RVF	Rhythm vegetative factor
SD	Simple standard deviation
SDNN	Standard deviation of the normal-to-normal interval
SNS	Sympathetic nervous system
SPSS	Statistical Package for the Social Sciences
STNR	Symmetrical tonic neck reflex
TLR	Tonic labyrinthine reflex
TP	Stress index / Tension parameter
TP1	Total power
VBP	Vegetative balance parameter
VLF	Very low frequency band

Introduction

Swimming is an important life skill that can affect a child's health and even life. Latvia is a country with many lakes and rivers, as well as a long along the Baltic Sea and its bays, providing many opportunities for swimming and relaxing by the water. Unfortunately, an average of 10 children and young people under the age of 19 die every year in Latvia due to insufficient swimming skills. Implementing the "Safety on Water" programme is one of the priorities set out in the Sport Policy Guidelines for 2022–2027. Teaching swimming strokes is the main task of the swimming education programme (Solovjova, 2017). Effective acquisition of swimming skills is important in preventing accidents in the water. A child's ability to learn these new skills affects their performance in the basic tasks of the learn-to-swim programme.

In the scientific literature, there are different opinions about which stroke of swimming to start learning to swim with (Langendorfer, 2013), however, learning the movements of swimming strokes typically begins with the backstroke and front crawl (Donaldson et al., 2010, Oh et al., 2011). A prerequisite for learning a rational swimming technique is the initial teaching stage, in which the first swimming skills are formed (Solovjova, 2017). Of the four main swimming strokes, the front crawl and backstroke are the most economical swimming styles from the point of view of energy consumption, followed by the butterfly stroke and breaststroke (Barbosa et al., 2006). Efficient swimming has an impact on the ability to swim longer and to increase the distance swum. Learning rational swimming techniques gives children the opportunity for further self-improvement and allows them to develop their skills in sports swimming (Virag et al., 2014).

The acquisition of swimming strokes is influenced by the remaining primitive reflexes (Blythe, 2011; Bilbilaj, Gjipali & Shkurti, 2017). Primitive reflexes are unconscious muscle responses caused by involuntary movements that occur in response to a specific stimuli (Sohn, Ahn & Lee, 2011). These reflexes influence a child's psychomotor development, which is determined by the development and maturation of the central nervous system (CNS) (Tierney & Nelson, 2009). Cerebral maturation is characterised by the transition from involuntary reflex responses of the spinal cord to responses controlled by the cerebral cortex (Desorbay, 2013; Zafeiriou, 2004).

As a result of CNS maturation, primitive reflexes should not be retained in children (Blythe, 2009), however studies show that residual primitive reflexes are observed in approximately 90 % of preschool children and over 50 % of elementary school children (Blythe, 2012; Gieysztor, Sadowska & Choińska, 2017; Gieysztor, Choińska & Paprocka-Borowicz, 2018a; Blythe, Duncombe, Preedy & Gorely, 2021). When testing primitive reflexes in children, three retained primitive reflexes are mainly evaluated – the asymmetrical tonic neck reflex (ATNR), the tonic labyrinthine reflex (TLR) and the symmetrical tonic neck reflex (STNR) (Gieysztor et al., 2018a, 2018b; Blythe et al., 2021). Research results show that up to three preserved primitive reflexes can be observed simultaneously in children (Blythe et al., 2021).

Head movements such as turning the head during inhalation, changes in body position such as swaying, and limb movements are necessary movements for swimming skills in the backstroke and front crawl (Donaldson et al.,, 2010; Oh et al., 2011). While learning swimming movements, head and body movements constantly cause the activation of primitive reflexes. Retained ATNR, STNR and TLR result in head and body movements that affect limb muscle tone, balance, and movement coordination (Blythe, 2011; Gieysztor, Choińska & Paprocka-Borowicz, 2018a; Zafar, Alghadir & Anwer, 2018).

Research shows that preserved primitive reflexes affect a child's cognitive and motor abilities, emotional and social status, and self-regulation skills (Gieysztor, Choińska & Paprocka-Borowicz, 2018a; Grigg, 2018; Rashikj-Canevska & Mihajlovska, 2019; Demiy et al., 2020; Pecuch et al., 2020;

Blythe, Duncombe, Preedy & Gorely, 2021). Scientific research databases (PubMed, EBSCO and ScienceDirect) did not identify any scientific or methodological recommendations for teaching swimming to children with residual primitive reflexes. Therefore, in order to start teaching swimming strokes, it is necessary to determine the presence of residual primitive reflexes in children and apply a theoretically based approach to teaching swimming strokes to children with residual primitive reflexes. This determined the choice of the topic for the Doctoral Thesis: "Optimisation Model for Teaching Swimming Strokes to 6–7-Year-Old Children with Residual Primitive Reflexes".

Object of the research: swimming strokes teaching to children with residual primitive reflexes at the age of 6–7 years.

Subject of the research/or limitations: swimming strokes teaching optimisation to children with residual primitive reflexes at the age of 6–7 years.

Research base: participants in individual or group swimming lessons at the sports complex "Ķeizarmežs": children aged 6–7 with residual primitive reflexes.

Aim of the Thesis

To develop/create and confirm the optimisation model for teaching swimming strokes to children with residual primitive reflexes at the age of 6–7 years and to develop recommendations for swimming coaches for teaching swimming strokes to children with residual primitive reflexes.

Hypotheses of the Thesis

The optimisation model for teaching swimming strokes will improve the learning of swimming strokes in children with retained primitive reflexes at the age of 6–7 years. If children with residual primitive reflexes aged 6–7 years are targeted in the process of learning swimming strokes to coordinate bilateral upper and lower limb diagonal movements within the same movement cycle, their acquisition of swimming strokes will be improved.

Tasks of the Thesis

1. To theoretically investigate the basis of teaching swimming strokes to 6–7-year-old children with residual primitive reflexes.
2. To determine/assess the primitive reflexes and their level of activity before teaching swimming to children aged 6–7 years.
3. To develop a theoretically based model for optimising the teaching of swimming strokes to children with residual primitive reflexes at the age of 6–7 years.
4. To apply an optimisation model developed for teaching swimming strokes and to determine its impact on the acquisition of swimming stroke skills in 6–7–year-old children with retained/residual primitive reflexes.
5. To develop practical recommendations for teaching swimming to children with retained/residual primitive reflexes aged 6–7 years.

Methods of the Thesis

1. Reviewing, summarising and analysing scientific literature.
2. Assessment/testing of primitive reflexes.
3. Pedagogical observation.
4. Pulsometry.
5. Heart rate variability (HRV).
6. Quasi-experiment.
7. Modelling.
8. Control exercise method.
9. Statistical methods.

Theoretical and methodological basis of the study

The theoretical and methodological basis of the study is formed:

Insights into the backstroke and front crawl swimming as a complex skills of coordinated movements with a high level of interaction components (Cardelli, Lerda & Chollet, 2000; Castro, Minghelli, Floss & Guimaraes, 2003; Maglischo, 2003; Chollet et al., 2008; Colado, Tella & Triplett, 2008; Schnitzler, Seifert, Ernwein & Chollet, 2008; Psycharakis & Sanders, 2010; Sortwell, 2011; Gourgoulis et al., 2014; Virag et al., 2014; McCabe, Sanders & Psycharakis, 2015; Riewald & Rodeo, 2015; Gonjo et al., 2016; Silveira et al., 2017; Solovjova, 2017).

Insights into the sensory system in the child's ontogenetic development in the context of dynamic systems theory (Barela, Jeka & Clark, 2003; Bartlett & Birmingham, 2003; Hadders-Algra, 2005; 2018; Peterson, Christou & Rosengren, 2006; Ferber-Viart et al., 2007; Ponitz et al., 2008; Charpiot, Tringali, Ionescu, Vital-Durand & Ferber-Viart, 2010; Davids et al., 2012, 2013; de Sousa, de França Barros & de Sousa Neto, 2012; Sharma, Ford & Calvert, 2014; Verbecque, Vereeck & Hallemans, 2016; Renshaw & Chow, 2019; Blaszczyk, Fredyk, Blaszczyk & Ashtiani, 2020; Sinno et al., 2021).

Insights into Dual Task Theory (Whitall, 1991; Huang, Mercer & Thorpe, 2003; Blanchard et al., 2005; Huxhold, Li, Schmiedek & Lindenberger, 2006; Cherng, Liang, Hwang & Chen, 2007; Asai et al., 2013; Polskaia & Lajoie, 2016; McGeehan et al., 2017).

Insights into the presence of primitive reflexes in children and their influence on the execution of movements and the acquisition of new movement skills (Schott & Rossor, 2002; Zafeiriou, 2004; Morningstar et al., 2005; McPhillips & Jordan-Black, 2007; Sharma, Ford & Calvert, 2008; Blythe, 2011; Sohn, Ahn & Lee, 2011; Montgomery et al., 2015; Grzywniak, 2016; Skotáková, Vaculíková & Sebera, 2016; Bilbilaj, Gjipali & Shkurti, 2017; Gieysztor, Sadowska & Choińska, 2017; Gieysztor, Choińska & Paprocka-Borowicz, 2018a; Rashikj-Canevska & Mihajlovska, 2019; Demiy et al., 2020; Pecuch et al., 2020; Blythe, Duncombe, Preedy & Gorely, 2021).

Insights into the part-practice teaching method of swimming strokes and its impact on the acquisition of swimming skills (Shlyachkov, 2006; Sanders, 2007; Oh et al., 2008; Donaldson et al., 2010; Matsuda et al., 2016).

Insights into the interaction of upper and lower limbs as stabilisation of automatic neuromuscular movements (Dietz, 1996; Adolph, Vereijken & Denny, 1998; Cartmill, Lemelin & Schmitt, 2002; McElroy, Hickey & Reilly, 2008; Patrick, Noah & Yang, 2012; Kobesova & Kolar, 2014; Myers, 2014; Hoffmann & Bardy, 2015; Shea et al., 2016; Sellers & Hirasaki, 2018; Vitali, Cain, Davidson & Perkins, 2019; Wagner, 2021), in the context of swimming (Millet, Chollet, Chalies & Chatard, 2002; Maglischo, 2003; Seifert, Chollet & Allard, 2005; Martínez-Sobrino, Veiga & Navandar, 2017; Guignard et al., 2019; Sanders & Levitin, 2020).

Knowledge of the functioning and evaluation of the organism autonomic nervous system (Task Force, 1996; Iannotti, Claytor, Horn & Chen, 2004; Armstrong & Welsman, 2006; Buchheit, Papelier, Laursen & Ahmaidi, 2007; Friedman, 2007; Park, Lee & Jeong, 2007; Koposova, Lukina & Savenkova, 2008; McManus et al., 2008; Gamelin et al., 2009; Martins et al., 2010; Fleming et al., 2011; Chalencon et al., 2012; Muratori et al., 2013; Ahmadian, Roshan & Dabirian, 2014; White & Raven, 2014; Okano, Fontes & Montenegro et al., 2015; Dong, 2016; Guilkey, Dykstra, Erichsen & Mahon, 2017).

Type of the research/study: a quantitative experimental study.

Novelty of the Thesis

This Thesis is the first in Latvia to seriously investigate the teaching of swimming to 6–7-year-old children with preserved primitive reflexes.

The study has developed a model for the optimisation of teaching swimming strokes for 6–7-year-old children with residual primitive reflexes.

The created optimisation model for teaching swimming strokes to 6–7-year-old children with residual primitive reflexes is based on the theories of children's ontogenetic sensorimotor development, dynamical systems and dual tasks.

When teaching the backstroke and front crawl, specific bilateral movement relationships within a cycle, the diagonal or contralateral interaction of the upper and lower limbs is a key component that improves swimming skills acquisition in 6–7-year-old children.

The Thesis demonstrates the impact of an optimisation model for teaching swimming strokes on better acquisition of swimming stroke skills. A statistically significant positive effect on the acquisition of swimming strokes is established, which is manifested in a better functional performance (ability to perform longer work) of children with less activity in the main organ systems.

Practical relevance of the study

The Thesis presents a scientifically based model for optimising the teaching of swimming strokes to 6–7-year-old children with residual primitive reflexes.

The practical application of this model reduces the influence of residual primitive reflexes, by improving the child's ability to consciously control bilateral movement relationships with the diagonal interaction of the upper and lower limbs within a single movement cycle.

These bilateral movement relationships, with diagonal interactions between the upper and lower limbs restored within a single movement cycle, positively impact the acquisition of swimming strokes. This is evident in children's improved performance, demonstrated by their ability to swim longer distances with lower heart rates.

Swimming coaches can apply the main principles of the developed teaching optimisation model to help children with residual primitive reflexes acquire swimming strokes.

The results of the study can also be used by practitioners of other sports when working with children with residual primitive reflexes.

Theses proposed for defence

Swimming strokes acquisition in 6–7-year-old children is influenced and made more difficult by the residual primitive reflexes.

The developed and applied model for optimisating swimming stroke teaching for 6–7 year-olds with residual primitive reflexes improves the learning of swimming strokes. Applying certain bilateral movement relationships involving diagonal movements of the upper and lower limbs within one movement/stroke cycle reduces the influence of preserved primitive reflexes in 6–7-year-old children.

Teaching bilateral movement relationships with upper and lower limb diagonal/contralateral movement interactions within the same movement cycle is statistically significant in improving swimming skill acquisition and increasing a child's functional performance.

Limits of the study / Study boundaries

The limits of the research of the Thesis are determined by the need to expand scientific research on scientifically based findings and the influence of residual primitive reflexes on teaching swimming strokes to children with residual primitive reflexes at the age of 6–7.

The limits of the Thesis research are defined by the lack of scientific research on teaching swimming to children with residual primitive reflexes at the age of 6–7 years.

Teaching swimming to children with residual primitive reflexes aged 6–7 years is analysed in light of scientific literature on ontogenetic sensorimotor development, the influence of retained primitive reflexes on movement performance, and the interaction between backstroke and front crawl movements.

The boundaries of the Thesis research are defined by the participants of the individual sessions – children with retained/residual primitive reflexes aged 6–7 years.

This study presents and validates a model for optimising the teaching of backstroke and front crawl techniques. The effect of the teaching optimisation model is compared with the part-practice method of teaching swimming strokes.

The quasi-experimental case study design is determined by the study group of children aged 6–7 years with retained/residual primitive reflexes. Based on the assessment of swimming strokes skills acquisition, the length of the swimming distance and the child's functional status, the effect of an optimisation model for teaching the backstroke and front crawl in children with retained primitive reflexes aged 6–7 years is determined.

The effect of an optimisation model for teaching swimming strokes to children with preserved primitive reflexes at the age of 6–7 years was evaluated based on swimming stroke skill acquisition, swimming distance, heart rate and heart rate variability for statistically significant results.

This study provides swimming coaches with recommendations on how to teach backstroke and front crawl to children aged 6–7 years with retained primitive reflexes.

1 Methods, material and organisation of the Thesis

1.1 Methods of the Thesis

Analysis of scientific information sources: the theoretical grounding of the Thesis is based on the research and analysis of scientific literature. 421 literature sources have been used for the elaboration of the Thesis, of which 4 – in Latvian, 411 – in English and 6 – in Russian.

Measurement of primitive reflexes. The study evaluates three preserved primitive reflexes: the asymmetrical tonic neck reflex (ATNR), the tonic labyrinthine reflex (TLR) and the symmetrical tonic neck reflex (STNR) (Gieysztor et al., 2018; Blythe et al., 2021).

The TLR, ATKR and STKR assessment tests "Assessing Neuromotor Readiness for Learning" were used to determine primitive reflexes in children (Blythe, 2012). To facilitate a more reliable result, the same researchers tested all children.

Residual primitive reflexes were assessed by observing the child's body response/reaction to irritation when the head position is changed by turning, tilting or moving the head forward or backward (Blythe, 2009). Each primitive reflex was assessed and analysed on a five-point rating scale from zero (0) to four (4). Zero meant complete lack of reflex (no reflex occurs/full integration), 1 – reflex present in 25 % (evident/low activity); 2 – reflex up to 50 % (residual/middle activity), 3 – reflex up to 75 % (virtually retained/high activity), 4 – reflex present in 100 % (retained/maximum activity).

ATNR un STNR were carried out of the child in a quadruped position with hips flexed to 90°, elbows extended, hands flat, fingers extended, and head in a neutral position, facing the floor.

During ATNR test, the examiner turned the head to the right side and held for 5 seconds. The head was slowly rotated back to the midline, and then the procedure was repeated for the other side.

This sequence was repeated four times. The ATNR was measured for the left (ATNR L) and right (ATNR R) side.

Evaluation:

0 = no movement of the opposite arm, shoulder or hip;

1 = slight deflection of the opposite arm or movement of shoulder or hip;

2 = clear deflection of the opposite arm with or without involving the shoulder or hip;

3 = significant deflection of the opposite arm with or without involving the shoulder or hip;

4 = descent of the opposite arm as a result of rotation of the head. Uncontrolled hip movement can also occur – reflex survived in 100 % on the facial side/maximum activity.

STKR test was carried out in a quadruped position with the head passively bent and extended. The STNR was measured for flexion (STNR FLX) and extension (STNR EXT).

Evaluation:

0 = no reaction – no evidence of reflex;

1 = shaking of one or two arms or minimal movement of the trunk;

2 = elbow movement and/or hips or bending of the hips or spine;

3 = deflection of the arms when lowering the head and spontaneous straightening of the hands when lifting the head;

4 = bending arms or going back to sitting on the heels.

TLR was tested in standing position, feet pushed together, hands along the trunk. The child was asked to tilt the head back "as if looking at the ceiling" and close the eyes. The child was supported by the examiner. After 10 seconds the child was asked to bend the head slowly "as if looking at the toes" and stand in the position for 10 seconds. The movement was repeated four times. The TLR was measured for flexion (TLR FLX) and extension (TLR EXT).

Points were assigned as follows:

0 = no reaction;

1 = minimal balance disturbances whilst changing head position;

2 = balance disturbances during the test and/or changes in muscle tone – reflex up to 50 % (remaining/moderate activity);

3 = the child almost loses balance and/or shows disorientation after the task;

4 = loss of balance and/or significant muscle tone change whilst attempting balance stabilisation. Dizziness and nausea may occur.

The median/mode of the set of scores posted by the three researchers was taken as the final score for each individual test. The maximum total score for the stored primitive reflexes was the sum of the scores for each reflex (24 points). The sum of the scores for all reflexes was additionally converted into a reflex activity level on a scale from zero (0) to four (4) (Table 1.1). Zero means no reflex activity (full integration), 1 means low activity (incomplete integration), 2 means medium level of integration, 3 means high activity (low integration) and 4 means maximum activity (no integration). Based on the results of the studies, descriptive statistics were used for further analysis.

Table 1.1

Degree of primitive reflexes integration scale

Primitive reflexes integration level		
Total points	**Level**	**Level interpretation**
20–24	4	no integration / maximum activity
15–19	3	low integration / high activity
8–14	2	medium level of integration
1–7	1	incomplete integration / low activity
0	0	full integration

(from Gieysztor et al., 2017)

Pedagogical observation. The aim of the pedagogical observation was to assess the level of swimming skills acquisition after the application of the content of the optimisation model for learning swimming strokes in children with residual primitive reflexes at the age of 6–7 years. In order to objectively assess the level of learning of the swimming strokes, assessment protocols were developed that included the individual movement components of the swimming strokes. The protocols were based on the tests of Oh et al., 2008, and Donaldson et al., 2010, for the assessment of individual movement components of swimming strokes. In order to assess the level of movement skills of the swimming strokes, arm-leg diagonal coordination components were additionally assessed. The performance of each individual movement component is scored as follows: 0 = movement not performed; 1 = sometimes performed; 2 = performed almost all the time; 3 = performed all the time. Data were collected by scoring the individual movements/components (Table 1.2). The endpoint for each individual movement/component of the swimming form was determined as the arithmetic mean of the three swimming teachers. Each swimming teacher with > 7 years of teaching experience, completed the assessments independently. The results of the assessment were recorded in a protocol for further analysis.

Table 1.2

Assessment of components of individual movements of swimming strokes

Backstroke assessment components	**Front crawl assessment components**
M1. Head stabilisation is in line with the spine	K1. Horizontal alignment of the trunk in water
M2. Stomach – at the surface of the water	K2. Minimal body rotation
M3. Minimal body rotation	K3. Head holding angle: neutral head position – looking down
M4. Horizontal alignment of the trunk in water	K4. The head turns to side to inhale without lifting it up
M5. Coordination of movement rhythms	K5. Bubbles are blown out slowly into water
M6. Fingers are closed together	K6. Regular breathing patterns linked to arm action

Table 1.2 continued

Backstroke assessment components	**Front crawl assessment components**
M7. Slow, straight arm backstroke	K7. Arms recovery involves initial lift of upper arm, flexed elbow and relaxed hand
M8. Little finger leads and enters water first	K8. Hand exits water at upper thigh level
M9. Hand pulls through and exits water at upper thigh level	K9. Hand enters the water between shoulder and midline of body
M10. Kick initiated at the hips	K10. Kick initiated at the hips
M11. Knees extended with straight legs kicking action	K11. Knees extended with straight legs kicking action
M12. Relaxed feet with ankles pointed	K12. Relaxed feet with ankles pointed
M13. Kicking feet just break surface	K13. Kicking feet just break surface
M14. An upkick of the leg occurs at the same time as the contralateral arm is lifted out of the water	K14. Arm entry phase accompanies the ipsilateral leg downbeat
M15. An upkick of the leg accompanies the ipsilateral arm clearing phase	K15. Arm backward aquatic phase accompanies the contralateral leg downbeat
M16. An upkick of the leg occur simultaneously with the contralateral arm backward movement	K16. Arm exit from water accompanies the contralateral leg upbeat

Assessment of the reaction of the autonomic nervous system

Pulsometry. Heart rate during swimming/tests was determined using a “GARMIN HRM1G” heart rate monitor. Before the test, the study participant was fitted with an individually fitted chest belt. Researchers defined moderate physical activity (equivalent to brisk walking) as generating a heart rate ≥ 140 beats/min and vigorous physical activity (equivalent to jogging) as generating a heart rate ≥ 160 beats/min (Armstrong & Welsman, 2006; Simons-Morton, Parcel, O’Hara, Blair & Pate, 1988).

Heart rate variability assessment. During the study, heart rate variability (HRV) was measured. The diagnostic equipment used was the computer program “Omega. Sports” for heart rate variability analysis developed by the laboratory “Dinamika” (Manufacturer – company Scientific Research Laboratory “Dinamika”, 2012, St. Petersburg). It is a complex scientific apparatus (Certificate of Conformity No POCC RU.ME01.BO5487) that records and analyses heart rhythm. The software “Omega” recorded and analysed the electronic potential of the heart – 300 heartbeat cycles. In 1996, the European Society of Cardiology and the North American Society of Pacing and Electrophysiology endorsed as reliable two methods of processing and analysing heart rate variability: the time domain method and the frequency domain method (Task Force, 1996). In the present study, time and frequency domain methods were used for the analysis of HRV.

The heart rate diagnostic method is used to assess changes in children’s functional status after control exercise. The measurements were taken before and after the swimming lesson. Before the heart rate diagnostics, all participants observed a 5-minute period of inactive recovery and rested quietly for 5 minutes in a sitting position on a chair. Five minutes is considered to be a marker of both parasympathetic reactivation and sympathetic withdrawal (Peçanha et al., 2017). By analysing the dynamic changes of the HRV indicators, it is possible to assess the reactivation of the child’s organism (parasympathetic nervous system activity) soon after the swimming types of movement teaching session and to infer the quality of movement/exercise execution depending on the swimming types of teaching exercises.

Quasi-experiment. In the present study, the quasi-experimental case study design is chosen as the type of case study to evaluate the effect of the optimisation model for teaching swimming strokes in children with residual primitive reflexes at the age of 6–7 years. Based on several different sources of evidence, focusing on the process/content as well as the measure, based on the theory, a quasi-experimental study leads to several analyses that allow to analyse the result of the study within a certain range (Rogers & Révész, 2019).

The aim of the quasi-experiment in the Thesis was to study children with preserved primitive reflexes aged 6–7 years who attended swimming lessons at the sports complex "Ķeizarmežs". The sampling of the quasi-experiment for the study was mainly influenced by accessibility. The convenience method was used to select a non-probability sample (Geske & Grīnfelds, 2006). To test whether there is a causal relationship between independent and dependent variables, the researchers collected data from several cases and analysed them as a whole (group) (Madureira et al., 2012). The independent variable is expected to cause some change in the dependent variable. In the present study, which investigated the effect of an optimisation model for teaching swimming strokes on swimming skill acquisition, heart rate (HR), heart rate variability (HRV) and distance swum in children with preserved primitive reflexes at 6–7 years of age, the optimisation model was used as the independent variable, while swimming type skill acquisition, HRV, HRV and maximum distance swum were used as the dependent variables. During the quasi-experiment, the effect of the optimisation model for teaching swimming strokes (study group) on the acquisition of swimming strokes in children with retained/residual primitive reflexes aged 6–7 years was compared with the part-practice method of teaching swimming strokes (comparison group). At the end of the quasi-experiment in the Thesis, data were collected from several cases and analysed as a whole (group).

Modelling. The actual form of a study model is the diagram (or qualitative description) and it emphasises the relationships between entities without attempting to quantify them. The effectiveness/impact of the model is usually tested by comparing the data generated by the model with the data collected from the actual modelling case. Diagrammatic models show the interrelationships of the variables in a system on paper, portray the components of a system and its environment, or show the causal or other links between variables in a system, charts an organisation. (Walliman, 2011).

A research model only provides a visual representation of the event – a simulation – that show the relationships between the variables.

Control exercise method. To evaluate the effect of the optimisation model for teaching swimming strokes to children with retained primitive reflexes at the age of 6–7 years, three control exercises were performed at the end of the swimming stroke teaching phase. No special swimming aids were used during the control exercise.

The first control exercise aims to assess the child's acquisition of the swimming stroke and heart rate (HR) after swimming 25 m. The lower the HR scores, as well as the level of physical activity intensity and the better the proficiency in the stroke of swimming, the higher the efficiency of the swimming stroke achieved by the children during learning. The assessment was performed when the participant swam the 25 m distance (no time control).

The second control exercise aims to assess the length of the distance swum by the child. The maximum swimming distance (Dmax) was assessed for each swimming stroke. Before the control exercise, the child was verbally asked to voluntarily swim as many 25 m distances as possible until exhaustion. For each full 25 m distance completed, 1 point was awarded. The total score corresponds to the maximum distance swum continuously.

The third control exercise aims to determine changes in the child's functional status (heart rate and heart rate variability) after a set of swimming exercises. The control exercise was a set of exercises that the child had already mastered during the learning process and performed at his/her optimum speed. To ensure an unbiased analysis of the results, children in both the treatment and control groups performed the same set of exercises (n = 5) and swam the same distance.

For the study group, a set of exercises focused on swimming the backstroke and front crawl with accurate arm-leg frequency ratios with diagonal interaction:

- frequency ratios: 1:4, 2:6, in backstroke swimming;
- frequency ratios: 1:1, 1:4, 2:6, in front crawl swimming.

In these ratios, with the number of arm stroke at the numerator and the number of leg kick at the denominator within one stroke movement cycle (e. g. 1:4 signifies that four leg kicks are observed during one arm stroke, 2:6 or six leg kicks for two arm stroke and 1:1 or one leg kick for one arm stroke).

The aim for the comparison group is to accurately perform the individual components of the arm and leg movements of the swimming stroke.

Each child had the option not to continue with the control exercise, depending on their ability. In this case, the results of the control exercise were not analysed. For each child, the dynamics of change in HRV and HR parameters as well as the mean heart rate (HRm) during the control exercise were determined. The better the functional status after the control exercise and the lower the HRm, the greater the efficiency of the swimming types achieved by the children during the learning.

1.2 Statistical methods

The data obtained in the Thesis were entered and mathematically processed using Microsoft Office Excel and SPSS for Windows data processing software. The Kolmogorov-Smirnov approach was used to test the conformity of the distribution of the study variables to the normal distribution. The mean and standard deviation (SD) were calculated for the variables that followed a normal distribution. For the comparison of quantitative variables between groups, a paired t-test was used to compare the means of two dependent samples, where significant differences are determined by a p-value < 0.05. For the comparison of quantitative variables between groups, in the case of normal distribution, one-factor analysis of variance (One Way ANOVA) with Post Hoc testing performed with the Henry Scheff test was applied. Results were considered significant if the p-value was less than 0.05. Cohen's d value (Cohen's d index) was used to determine the effect size: small, 0.2–0.5; medium, 0.5–0.8; large, ≥ 0.8.

1.3 Organisation of the research

The study lasted eight years, from its launch in 2016 to its conclusion in 2024. The research was carried out in several phases.

The first phase of the research, conducted between September 2016 and the end of 2017, involved analysing and generalising scientific literature, defining the research objectives, and formulating the object, the subject and the hypothesis. A theoretically grounded model for optimising the teaching of swimming forms to children with preserved/residual primitive reflexes at the age of 6–7 years was developed. Along with the theoretical research, tests of the preserved primitive reflexes were carried out, suitable necessary equipment was selected, and components of the swimming stroke acquisition assessment were determined, which in general enable the results of the measurements to be fully determined.

The practical part of the study was carried out in the swimming pool of the sports complex "Ķeizarmežs", Ezermalas 30, Riga, and lasted from February 2017 to February 2020 and included the determination of retained primitive reflexes in children, as well as the validation of a swimming learning optimisation model for children with retained/residual primitive reflexes aged 6–7 years. Participants were children aged 6–7 years who attended swimming lessons at the sports complex "Ķeizarmežs". Parents were approached and asked to agree to their child's participation in the study to verify the existence of primitive reflexes and to participate in the process of teaching swimming within the study.

After obtaining parental consent, indicating that the child's indicators/results are confidential and will only be used within the framework of the study, and after explaining the study methodology, parents were offered forms to fill in, giving their written consent for their child's participation in the study.

Primitive reflexes were assessed in healthy children aged 6–7 years. A total of 78 children (40 boys and 38 girls) were assessed. All participants' health condition included in the study was defined by their general practitioner as "practically/somatically healthy" with permission to attend swimming lessons.

Children with normal physical development or a slight deviation from the anthropometric standard were included in the quasi-experiment. The child's anthropometric parameters (height (cm), body mass (kg), body mass index (BMI)) were assessed according to their position within a defined "corridor" of percentile curves, with normative values ranging from 35 to 65 per cent (Krūmiņa, Kokare & Biķis, 2007; Lārins, 2022). In the course of the study, the effects of an optimisation model for teaching swimming strokes are compared with a part-practice method of teaching swimming strokes. A total of 46 children with preserved primitive reflexes (reflex activity level 1 or 2) aged 6–7 years, including 24 boys and 22 girls, were included in the quasi-experiment. In this age group, there were no significant differences in cognitive development and motor abilities between genders (girls and boys) (Ardila et al., 2011; Polimac, Vukadinovic, & Obradovic, 2013). It has also been established that retained primitive reflexes affect motor abilities in both girls and boys (Gieysztor, Choińska, & Paprocka-Borowicz, 2016). Therefore, the results of the quasi-experiment were processed and analysed without taking into account the participant's gender. Based on the methods used for teaching swimming styles, the effectiveness of swimming instruction was analysed across four groups:

1 Backstroke study group (n = 12).
2 Backstroke comparison group (n = 12).
3 Front crawl study group (n = 11).
4 Front crawl comparison group (n = 11).

Participants in the quasi-experiment were assigned to groups with as similar characteristics as possible. The average group indicators (age (years), height, weight (kg), body mass index (BMI), and the level of preserved primitive reflexes (PRL)) were homogeneous ($p > 0.05$), confirming that there are no significant differences in physical development levels between the groups, thereby ensuring baseline equivalence.

All children with retained primitive reflexes were given a similar level of swimming skills before being taught how to swim. Criteria for participation in the study:

- no backstroke or front crawl skills;
- the ability to stay afloat in the supine position for at least 20 seconds;
- the ability to stay afloat in a prone position on the chest while exhaling into the water for at least 20 seconds;
- the ability to remain upright in the water for at least 15 seconds by exhaling into the water.

The practical part of the study was carried out in the 25-metre swimming pool of the sports complex "Ķeizarmežs". The water depth varied from 1.80 m in the shallow part to 2.50 m in the deep part, and the water temperature was 28–29°C.

Each child was given an individual approach to learning how to swim. Children attended one 30-minute lesson per week. Scientific studies show a significant change after 10 lessons × 30 min/week ($p < 0.05$). However, the authors point out that swimming skills in front crawl are more difficult compared to backstroke (Donaldson et al., 2010; Oh, Licari, Lay & Blanksby, 2011). In view of the above, the teaching phase for backstroke and front crawl consisted of 12 and 16 sessions respectively. All lessons had to be attended in order to compare the results of the independent samples.

A break of one week was allowed, provided that it was once in the process of teaching the swimming strokes.

In order to analyse/verify the effectiveness of backstroke teaching, three control exercises (summarised in “Control exercise method” of Chapter 1.1) were performed after 12 teaching sessions. In order to analyse the effectiveness of teaching front crawl, three control exercises were performed after 16 teaching sessions. In the practical part of the study, an optimisation model for teaching swimming strokes (study group) was implemented for children with retained primitive reflexes aged 6–7 years and compared with a part-practice method of teaching swimming strokes (comparison group) for children with retained primitive reflexes aged 6–7 years.

The third phase of the study, from March 2020 to June 2024, continued the analysis of the scientific literature, summarised and analysed the results of the study, drew conclusions and made recommendations for teaching swimming to children with retained primitive reflexes aged 6–7 years.

2 Results

2.1 Evaluating of retained primitive reflexes in children aged 6–7 years.

The present study has focused on the three primitive reflexes: asymmetrical tonic neck reflex (ATKR), symmetrical tonic neck reflex (STKR), tonic labyrinthine reflex (TLR), descriptive statistics analyse were used for further analysis. Seventy-eight children were tested.

The results of the primitive reflex test showed that most children aged 6–7 years (97.4 %) retained the primitive reflexes mentioned above. The asymmetrical tonic neck reflex (ATNR) was observed in 76 children or 97.4 % of the total number of children (n = 78), the symmetrical tonic neck reflex (STNR) was preserved in 74 children or 94.9 % of them, and the tonic labyrinthine reflex (TLR) was determined in 72 children or 92.3 % of them. The results show that the level of activity of the retained primitive reflexes in children aged 6–7 years varies widely. The individual range of ATNR and STNR activity levels was from 0 to 4 points. The individual range of TLR reflex activity was from 1 to 3 points.

In children, several retained primitive reflexes were observed very frequently. The results show a significant number of children (47.4 % of the sample) with all three reflexes retained at 50 % or more, indicating moderate/middle to high individual retained primitive reflex activity.

When analysing the level of primitive reflex integration, it was observed that 46.2 % of children had an medium of primitive reflex integration (level 2), 44.9 % had an incomplete of primitive reflex integration (level 1) and 6.4 % had a low integration of primitive reflex (level 3). Two children showed complete integration (level 0) of primitive reflexes. Maximum primitive reflex activity (level 4) was not observed in any child.

2.2 Development/creation of optimisation model for teaching swimming strokes to children with preserved primitive reflexes aged 6–7 years

In this Thesis, the acquisition of swimming strokes is considered a complex activity that relates to cognitive processes in which voluntary movement tasks are performed, manifesting directly in the child's controlled/conscious physical body movements. The content of the optimisation model for teaching swimming strokes is based on the child's ontogenetic movement development in dynamic systems and dual-task theories, taking into account the influence of retained primitive reflexes on swimming stroke acquisition, as well as analysing limb movement coordination.

In the process of ontogenetic movement development, the child's sensory (somatosensory, vestibular, visual, auditory) integration is focused around gravitational force, which acts as the vertical axis of space under gravity's influence to maintain a vertical position (postural balance). However, a horizontal position in water and body oscillation are necessary components for acquiring swimming stroke skills. Consequently, teaching swimming strokes is a situation where postural control is constantly mechanically disturbed and can complicate learning to swim. Studies show that postural reactions to regain a vertical position occur automatically, regardless of whether performers are instructed to regain balance. Additionally, a horizontal position in water is associated with significant visual limitations, vestibular system irritation, and proprioceptive changes in the body's base area. When interacting with the aquatic environment in a horizontal position, proprioceptive information becomes the only source of sensory information available to the child to regulate body balance and stability and to learn new movement skills in the initial stage of swimming stroke teaching. In the context of dual-task theory, when learning swimming strokes, the child must simultaneously pay attention to two closely related tasks:

1 Balance control and body stabilisation in a horizontal position in water;
2 Performing swimming stroke movements under conditions of constant postural control disturbance (instability state.)

The above affects the activity of the central nervous system (CNS), as the processing of sensory information was not fully integrated in the brain due to sensory limitation, and sensory integration, which organises sensation from the body and the environment, does not allow the child to use the body effectively (task/voluntary movements) in interaction with the aquatic environment. On the other hand, learning to swim can be interpreted as exceeding the maximum attentional capacity of the central nervous system (CNS), as the child would have to divide his/her attention in order to perform these dual tasks (control balance and body stability in a horizontal position in the water and perform voluntary movements) simultaneously. Considering the child's sensory system in the ontogenetic context of movement development, learning to perform swimming strokes acquisition could be considered a complex task for a child in an unnatural environment.

During the learning of the swimming strokes, the movements of the head and body constantly trigger the primitive reflexes, if they are still present in the child. As a result, the retained primitive reflexes influence the child's ability to keep his or her body balanced in a horizontal position in the water, as well as the voluntary movement of the limbs. In this context, controlled voluntary movement is made more difficult by involuntary motor responses and muscle tone due to the activity of the retained primitive reflexes. As a result, a child with retained primitive reflexes tends/needs to expend more energy and cognitive effort during self-regulation/learning and this can be considered as an additional factor/cause that practically hinders the stabilisation of the body and the acquisition of swimming skills.

The aim of the optimisation model for teaching swimming techniques in children with residual primitive reflexes at the age of 6–7 years is to develop a conscious bilateral movement sequence with a certain frequency ratio of arm and leg movements – 2:6 within one stroke movement cycle. In the process of teaching swimming strokes, the sequence and frequency ratio of limb movements within a single movement cycle are key components of the child's conscious action, which minimises the impact of reflexes on the acquisition of swimming skills. In turn, conscious coordination of diagonal arm-leg movements influences balanced horizontal head-neck-body stabilisation in the water (Figure 2.1).

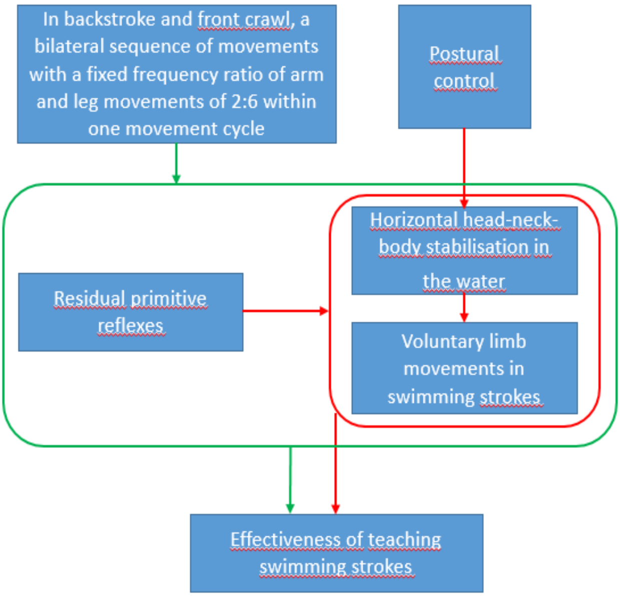

Figure 2.1 **The optimisation model for teaching swimming strokes to children with residual primitive reflexes aged 6–7 years**
(created by study author)

The main task to reduce the influence of retained primitive reflexes is diagonal "left-right/right-left" inter-limb movement coordination. This coordination is clearly expressed in the arm recovery phase (when the arm is carried over water), during which the opposite arm and leg move in the same direction, resulting in a stable body position in water.

To achieve the goal of the backstroke teaching optimisation model for children aged 6–7 years with retained primitive reflexes, the execution of three conscious diagonal arm-leg movement components in backstroke (Figure 2.2.) as well as three conscious diagonal arm-leg movement components in front crawl (Figure 2.3) was taken as a basis. By combining all components into one movement chain, the child practically develops/forms the ability to consciously control a bilateral movement sequence with a specific arm and leg movement frequency ratio of 2:6 within one movement cycle.

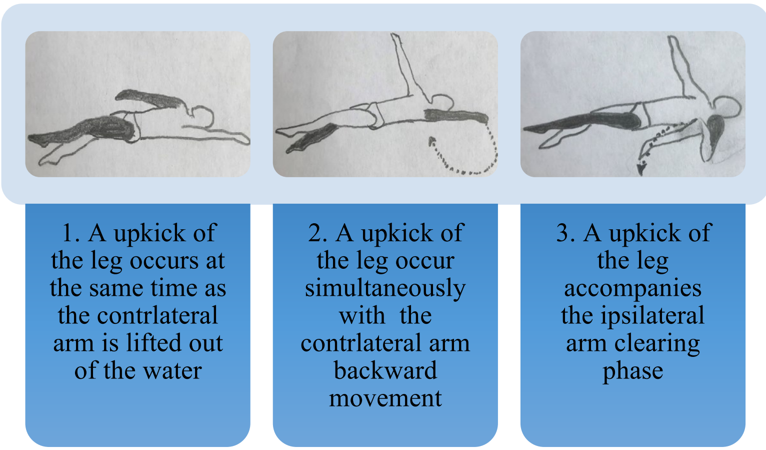

Figure 2.2 **Components for teaching the sequence of arm-leg diagonal movements in backstroke**
(created by study author)

Despite body oscillations around its longitudinal axis being one of the components of swimming, studies show that swimming speed does not affect the swimmer's shoulder and hip oscillation angles in backstroke swimming (Gonjo et al., 2016). Therefore, in backstroke swimming, body oscillation around its longitudinal axis is not given attention. Breathing control during backstroke swimming instruction was performed in coordination with leg kicks and arm movements.

Head turning and body oscillation are necessary components when performing inhalation in accordance with upper and lower limb interaction within one cycle during the front crawl swimming teaching process. Therefore, the optimisation model for teaching front crawl swimming to children aged 6–7 years with retained primitive reflexes included learning breathing, body oscillation around its longitudinal axis, and arm-leg diagonal movement coordination. To reduce primitive reflex activity during head turning, attention was paid to hip oscillation/movement with the aim of coordinating bilateral breathing, body oscillation around its longitudinal axis, and diagonal arm-leg action. Inhalation was coordinated when lifting an arm out of water while simultaneously lifting a contralateral (diagonal) leg.

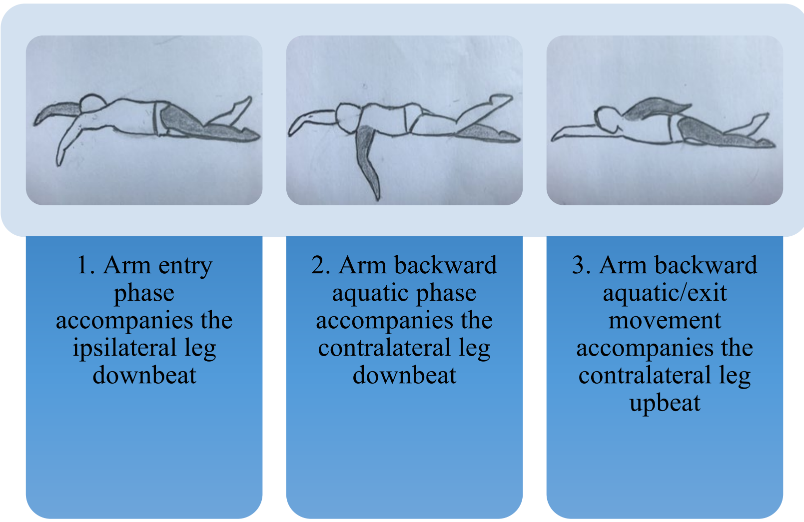

Figure 2.3 **Components for teaching the sequence of arm-leg diagonal movements in front crawl**
(created by study author)

2.3 Effect of applying optimisation model of teaching backstroke to children with residual primitive reflexes at the age of 6–7 years

When assessing the overall skill level of all individual movement components (M1–M16), the research group achieved an average score of 38.14 ± 3.03 points, which constitutes 82.9 % of the maximum possible score. In the comparison group, the average result was 28.72 ± 1.25 points, corresponding to 59.8 % of the maximum possible score. The study also confirms a significant difference in results between the groups ($p < 0.05$). The average total score for all individual movement components in the research group (38.14 ± 3.03) is statistically significantly higher than that of the children in the comparison group (28.72 ± 1.25) (Table 2.1).

Table 2.1

Backstroke swimming skill acquisition results after applying the optimisation model

Components of assessment	Study group (n = 12) (*χmean* ±)	Comparison group (n = 12) (*χmean* ±)	Reliability of the difference p value	Kohen's d value
M1. Head stabilisation is in line with the spine	**2.83 ± 0.22**	1.92 ± 0.35	.000*	3.113
M2. Stomach – at the surface of the water	**2.50 ± 0.52**	1.89 ± 0.22	.001*	1.528
M3. Minimal body rotation	0.17 ± 0.22	1.7 ± 0.41	.000*	4.802
M4. Horizontal alignment of the trunk in water	**2.83 ± 0.22**	2.44 ± 0.59	.045*	0.876
M5. Coordination of movement rhythms	**2.72 ± 0.28**	2.06 ± 0.42	.000*	1.849
M6. Fingers are closed together	1.75 ± 0.81	2.53 ± 0.39	.006*	1.227
M7. Slow, straight arm backstroke	**2.78 ± 0.33**	2.28 ± 0.31	.001*	1.562

Table 2.1 continued

Components of assessment	**Study group (n = 12) (χmean ±)**	**Comparison group (n = 12) (χmean ±)**	**Reliability of the difference p value**	**Kohen's d value**
M8. Little finger leads and enters water first	0.58 ± 0.35	2.31 ± 0.26	.000*	5.611
M9. Hand pulls through and exits water at upper thigh level	**2.81 ± 0.26**	2.47 ± 0.22	.003*	1.412
M10. Kick initiated at the hips	**2.67 ± 0.28**	2.08 ± 0.25	.000*	2.223
M11. Knees extended with straight legs kicking action	**2.61 ± 0.37**	1.61 ± 0.37	.000*	2.703
M12. Relaxed feet with ankles pointed	2.61 ± 0.42	2.78 ± 0.30	.275	0.466
M13. Kicking feet just break surface	2.28 ± 0.55	1.94 ± 0.40	.102	0.707
M14. An upkick of the leg occurs at the same time as the contralateral arm is lifted out of the water	**3.00**	0.67 ± 0.28	.000*	–
M15. An upkick of the leg accompanies the ipsilateral arm clearing phase	**3.00**	0.00	.000*	–
M16. An upkick of the leg occur simultaneously with the contralateral arm backward movement	**3.00**	0.00	.000*	–
Backstroke overall skill level (Total: M1–M16)	**38.14 ± 3.03**	28.72 ± 1.25	.000*	4.064

Table 2.1 continued

Components of assessment	Study group (n = 12) (*χmean* ±)	Comparison group (n = 12) (*χmean* ±)	Reliability of the difference p value	Kohen's d value
HR	**127.92 ± 6.11**	152.42 ± **5.3**	.000*	–
PhIL	**1 ± 0**	2.08 ± 0.29	.000*	–
D*max*	**15.67 ± 3.08**	**3.5** ± 0.9	.000*	–

HR (beats/min.) – heart rate after 25 m swim (control exercise 2), PhIL – physical intensity level; D*max*. – max distance – points (control exercise 3); * – indicates that the difference between the group scores is statistically significant ($p < 0.05$); p – value, calculated according to the Henry Scheff test, indicates whether there is a difference between groups after intervention. Cohen's d for the difference/effect size (small – 0.20; medium – 0.50; large – 0.80)

A statistically significant difference ($p < 0.05$) was found between the maximum swimming distance achieved by children in the research group and those in the comparison group, with results of 15.67 ± 3.08 points versus 3.50 ± 0.9 points, respectively. When measuring heart rate after completing a 25-meter distance, the average result for the research group was 127.92 ± 6.11, compared to 152.42 ± 5.33 in the comparison group. The difference in results, amounting to 25.42, is statistically significant ($p < 0.05$) and indicates that participants in the research group completed this distance with significantly greater efficiency and less strain on their cardiovascular system (Table 2.1).

When evaluating average heart rate results during various sets of control exercise, the research group achieved an average of 127.76 ± 5.59, while the comparison group averaged 141.22 ± 5.72. The difference of 14.46 is statistically significant ($p < 0.05$) and shows that participants in the research group performed optimisation model control exercises with significantly greater efficiency and less strain on their cardiovascular system (Table 2.2).

Table 2.2

Average heart rate (HR) results during 3rd control exercise

Indicators	Study group (n = 12)	Comparison group (n = 12)	p
HRpre	90.25 ± 6.50	85.58 ± 10.90	.216
HRm	127.76 ± 5.59	141.22 ± 5.72	.000*
PhIL	1.08 ± 0.29	1.58 ± 0.51	.008*

HRpre – heart rate/rate (beats/min) before control exercise; HRm– mean heart rate (beats/min) during control exercise; PhIL – physical intensity level; * – indicates that the difference between groups before and during control exercise is statistically significant ($p < 0.05$); p – value calculated by Henry Scheff test indicates whether there is a difference between groups after intervention.

To determine the dynamics of changes in heart rate variability (HRV) indicators, two measurements were performed: before and after completing various teaching exercise sets (control exercise 3). This control exercise allows assessing changes in the autonomic nervous system (ANS) by determining HRV heart rate indicators, HRV statistical analysis indicators, and HRV spectral analysis indicators before and after applying experimental and comparative strategy exercise sets.

When determining the HRV statistical and spectral analysis indicators before applying the 3rd control exercise, the results obtained during testing across all measurable parameters showed homogeneity between groups ($p < 0.05$), indicating that the groups were uniform and corresponded to a normal distribution according to the Kolmogorov-Smirnov test. To better illustrate the obtained results, the HRV indicators were normalised. The indicators obtained in the first HRV measurement were considered as 100 % (Table 2.3).

Table 2.3

Heart rate variability (HRV) change (x*mean* ± s) after backstroke swimming 3rd control exercise

Indicators	Study group (n = 12)	Comparison group (n = 12)	p
HRV heart rate indicators			
PR	−10.62 ± 6.99*	4.07 ± 5.32*	.000
VBP	−34.55 ± 10.51*	78.62 ± 80.27*	.005
RVF	13.32 ± 17.49	−15.86 ± 20.68	.006
RPAP	−26.32 ± 14.11*	39.06 ± 32.04*	.000
TP	−40.93 ± 13.26*	89.86 ± 93.47*	.015
HRV statistical analysis indicators			
RRNN	12.28 ± 8.92*	−2.65 ± 4.92	.001
SDNN	25.98 ± 13.58*	−26.46 ± 16.82*	.000
CV	12.62 ± 11.93*	−24.94 ± 15.20*	.000
RMSSD	41.10 ± 28.34*	−18.87 ± 24.36*	.000
NN50	143.07 ± 183.84*	−34.30 ± 51.20*	.002
pNN50	127.53 ± 175.73*	−33.30 ± 50.49*	.003
HRV spectral analysis parameters			
HF	90.67 ± 51.96*	−34.99 ± 41.50*	.000
LF	45.20 ± 85.63	−29.40 ± 45.36*	.037
VLF	78.11 ± 107.86	−56.18 ± 21.83*	.028
LF/HF	−22.17 ± 38.40*	24.59 ± 58.44	.572
TP1	61.04 ± 36.47*	−42.63 ± 26.61*	.000

* – indicates that the difference between the groups before and after the control exercise is statistically significant ($p < 0.05$). p – value calculated using the Henry Scheff test indicates whether there is a difference between groups after intervention.

Based on the results obtained, children in the research group experienced increased activation of the parasympathetic division of the ANS and reduced sympathetic influence on heart activity (decreases in PR, VBP, RPAP, TP, and increases in RVF, RRNN, SDNN, RMSSD, NN50, pNN50, HF, LF, VLF, and TP1). Conversely, children in the comparison group showed increased sympathetic influence and reduced parasympathetic influence (decreases in

RVF, RRNN, SDNN, RMSSD, NN50, pNN50, HF, LF, TP1 and increases in PR, VBP, RPAP, TP), indicating changes in the activity balance between both ANS divisions. The results suggest activation of the parasympathetic nervous system (Table 2.3). This indicates that children in the research group had already recovered to a conditionally initial resting state after completing the control exercise. Conversely, children in the comparison group showed increased sympathetic influence and reduced parasympathetic influence. The results for children in the comparison group indicate activation of the sympathetic nervous system, with heart rate not yet restored within 5 minutes after completing the 3rd control exercise (Table 2.3).

2.4 Effect of applying the optimisation model of teaching front crawl to children with residual primitive reflexes at the age of 6–7 years

When evaluating the overall skill level of all individual movement components (K1–K16), the research group achieved an average score of 34.91 ± 3.03 points, which constitutes 72.7 % of the maximum possible score. In the comparison group, the average result was 29.3 ± 2.81 points, corresponding to 61 % of the maximum possible score. The study also confirms a significant difference in results between the groups ($p < 0.05$). The average total score for all individual movement components in the research group (34.91 ± 3.03) is statistically significantly higher than that of the children in the comparison group (29.3 ± 2.81) (Table 2.4).

A statistically significant difference ($p < 0.05$) was identified between the maximum swimming distance achieved by children in the research group and those in the comparison group, with results of 4.82 ± 1.08 points versus 1.82 ± 0.87 points, respectively. When measuring heart rate after completing a 25-meter distance, the average result for the research group was 142.82 ± 5.76 beats per minute, compared to 173.73 ± 6.05 beats per minute in the comparison group (Table 2.4). The difference in results is statistically significant ($p < 0.05$) and indicates that participants in the research group completed this distance with significantly greater efficiency and less strain on their cardiovascular system.

Table 2.4

Front crawl swimming skill acquisition results after applying the optimisation model

Components of assessment	Study group (χ*mean* ±)	Comparison group (χ*mean* ±)	Reliability of the difference p value	Kohen's d value
K1. Horizontal alignment of the trunk in water	**2.91 ± 0.22**	2.18 ± 0.4	.000*	2.261
K2. Minimal body rotation	1.82 ± 0.27	1.7 ± 0.31	.346	–
K3. Head holding angle: neutral head position – looking down	0.52 ± 0.35	0.61 ± 0.39	.596	–
K4. The head turns to side to inhale without lifting it up	**2.91 ± 0.16**	1.88 ± 0.45	.000*	3.05
K5. Bubbles are blown out slowly into water	2.85 ± 0.23	2.7 ± 0.28	.178	–
K6. Regular breathing patterns linked to arm action	2.88 ± 0.17	2.76 ± 04	.362	–
K7. Arms recovery involves initial lift of upper arm, flexed elbow and relaxed hand	1.24 ± 0.63	1.64 ± 0.31	.080	–
K8. Hand exits water at upper thigh level	**2.82 ± 0.27**	2.12 ± 0.27	.000*	2.593
K9. Hand enters the water between shoulder and midline of body	**2.85 ± 0.23**	2.21 ± 0.22	.000*	2.844
K10. Kick initiated at the hips	1.55 ± 0.52	1.64 ± 0.43	.662	–

Table 2.4 continued

Components of assessment	**Study group (χmean ±)**	**Comparison group (χmean ±)**	**Reliability of the difference p value**	**Kohen's d value**
K11. Knees extended with straight legs kicking action	2.36 ± 0.53	2.3 ± 0.43	.771	–
K12. Relaxed feet with ankles pointed	2.24 ± 0.65	2.73 ± 0.42	.051	–
K13. Kicking feet just break surface	2.24 ± 0.37	2.42 ± 0.37	.260	–
K14. Arm entry phase accompanies the ipsilateral leg downbeat	**2.73 ± 0.2**	0.85 ± 0.23	.000*	8.723
K15. Arm backward aquatic phase accompanies the contralateral leg downbeat	**1 ± 0**	0.79 ± 0.22	.005*	–
K16. Arm backward aquatic/exit movement accompanies the contralateral leg upkick	**2 ± 0**	0.79 ± 0.22	.000*	–
Front crawl overall skill level: K1–K16 (48 points)	**34.91 ± 3.03**	29.3 ± 2.81	.000*	1.92
HR	**142.82 ± 5.76**	173.73 ± 6.05	.000*	–
PhIL	**1.45 ± 0.52**	3 ± 0	.000*	–
D*max*	**4.82 ± 1.08**	1.82 ± 0.87	.000*	–

HR (beats/min.) – Heart rate after 25 m swim (control exercise 2), PhIL – physical intensity level; D*max*. – max distance – points (control exercise 3); * – indicates that the difference between the group scores is statistically significant ($p < 0.05$); p – value, calculated according to the Henry Scheff test, indicates whether there is a difference between groups after intervention. Cohen's d for the difference/effect size (small – 0.20; medium – 0.50; large – 0.80)

When determining the average heart rate results during various teaching exercise sets (control exercise 3), the research group achieved an average heart rate of 142.82 ± 5.76 beats per minute, while the comparison group averaged 164.82 ± 5.60 beats per minute. The difference of 22 beats per minute is statistically significant ($p < 0.05$) and shows that participants in the research group performed these exercises with significantly less strain on their cardiovascular system, resulting in more economical swimming performance (Table 2.5).

Table 2.5

Average heart rate (HR) results during 3rd control exercise

Indicators	Study group (n = 11)	Comparison group (n = 11)	p
HRpre	89.00 ± 9.03	91.36 ± 7.62	.515
HRm	142.04 ± **3.5**2	164.82 ± 5.60	.000*
PhIL	1.82 ± 0.40	2.73 ± 0.47	.000*

HRpre – heart rate/rate (beats/min) before control exercise; HRm – mean heart rate (beats/min) during control exercise; PhIL – physical intensity level; * – indicates that the difference between groups before and during control exercise is statistically significant ($p < 0.05$); p – value calculated by Henry Scheff test indicates whether there is a difference between groups after intervention

To determine changes in heart rate variability (HRV) indicators over time, two measurements were performed: before and after completing various teaching exercise sets (control exercise 3). When analysing HRV statistical and spectral analysis indicators before applying the 3rd control exercise, results showed that all measurable parameters were homogeneous between groups ($p < 0.05$), indicating that both groups were uniform and followed a normal distribution according to the Kolmogorov-Smirnov test.

To better illustrate these results, HRV indicators were normalised, with values obtained from the first HRV measurement considered as 100 % (Table 2.6).

Table 2.6

Heart rate variability (HRV) change (x*mean* ± s) after front crawl swimming 3rd control exercise

Indicators	Study group (n = 11)	Comparison group (n = 11)	p
HRV heart rate indicators			
PR	−6.39 ± 5.51*	10.21 ± 9,95*	.000
VBP	−15.73 ± 36.46	158.55 ± 115.76*	.000
RVF	4,29 ± 19.55	−30.11 ± 16.97*	.001
RPAP	−18.08 ± 14.77*	67.60 ± 44.35*	.000
TP	−21.92 ± 35.57	195.13 ± 160.79*	.000
HRV statistical analysis indicators			
RRNN	7,27 ± 6.46*	−7.15 ± 10.83*	.002
SDNN	20.66 ± 29.86*	−41.67 ± 17.74*	.000
CV	11.84 ± 3.83	−37.58 ± 14.81*	.000
RMSSD	19.10 ± 29.31*	−49.53 ± 25.01*	.000
NN50	27.40 ± 58.59	−82.68 ± 23.41*	.112
pNN50	29,22 ± 59.88	−83.00 ± 22.92*	.084
HRV spectral analysis parameters			
HF	37.69 ± 52.64*	−63.37 ± 29.57*	.000
LF	30.85 ± 67.19	−69.11 ± 16.83*	.004
VLF	76.11 ± 113.26	−9.83 ± 138.35*	.302
LF/HF	−0.23 ± 53.12	43.31 ± 137.78	.660
TP	40.52 ± 74.71	−63.52 ± 20.73*	.000

* – indicates that the difference between the groups before and after the control exercise is statistically significant ($p < 0.05$). p – value, calculated using the Henry Scheff test, indicates whether there is a difference between groups after intervention.

When analysing differences in results from the 3rd control exercise between groups, statistically significant differences were observed across all HRV scales except for NN50, pNN50, VLF, and LF/HF indicators. Analysing average heart rate variability responses to physical activity during various front crawl swimming exercises for children with retained primitive reflexes aged 6–7 years revealed a clear trend in HRV dynamics. In the research group, parasympathetic activation of the autonomic nervous system (ANS) increased while sympathetic influence on heart activity decreased (reductions in PR, VBP, RPAP, TP; increases in RVF, RRNN, SDNN, RMSSD, NN50, pNN50, HF, LF, VLF, and TP). Conversely, in the comparison group, sympathetic influence increased while parasympathetic influence decreased (reductions in RVF, RRNN, SDNN, RMSSD, NN50, pNN50, HF, LF; increases in PR (heart rate), VBP, RPAP, TP).

The results indicate parasympathetic nervous system activation for children in the research group after completing exercises – they returned to a conditionally initial resting state more quickly compared to children in the comparison group.

In contrast, children in the comparison group experienced increased sympathetic activation and reduced parasympathetic influence after exercises; their heart rates had not returned to baseline levels within five minutes post-exercise (Table 2.6).

2.5 Recommendations for swimming coaches on teaching swimming strokes to children with retained primitive reflexes aged 6–7 years

Based on the results of the study, specific recommendations have been developed for coaches to improve the acquisition of backstroke and front crawl swimming skills in children aged 6–7 years with retained primitive reflexes:

The swimming stroke movement cycle is a functional unit of movement where sequential inter-limb coordination repeats and includes an in-phase coordination mode with diagonal arm-leg interaction at a specific frequency ratio. In describing the optimisation model for teaching swimming strokes, arm-leg movement coordination/sequence within one cycle is identified as the main teaching component for children with retained primitive reflexes aged 6–7 years.

When working with children with retained primitive reflexes aged 6–7 years, coaches should focus on diagonal “left-right/right-left” (arm-leg) movement coordination, which results in a stable body position in water.

When teaching children diagonal arm-leg interaction, it is important to direct their attention to performing exercises at specific frequency ratios within one cycle. Coaches should emphasise precise execution of diagonal arm-leg movement components and accurate frequency ratios. The child’s actions should be deliberate and purposeful to achieve precise exercise performance.

The acquisition of backstroke movements for children with retained primitive reflexes aged 6–7 years should begin with learning the components of diagonal arm-leg interaction. These include:

(1) An upkick of the leg occurs at the same time as the contralateral arm is lifted out of the water (arm recovery)

(2) An upkick of the leg occurs simultaneously with the contralateral arm backward movement

(3) An upkick of the leg accompanies the ipsilateral arm clearing phase

Skill acquisition – An upkick of the leg occurs at the same time as the contralateral arm is lifted out of the water (arm recovery) – is learned in parallel with the skill where the An upkick of the leg accompanies the ipsilateral arm clearing phase. These skills must be mastered first, achieving their execution at a habitual level. Body oscillations during backstroke are skill components that automatically trigger involuntary motor reactions in the child’s body if primitive reflexes are retained. When training diagonal arm-leg interaction in backstroke, body oscillation is not addressed until overall arm-leg movement coordination at a frequency ratio of 2:6 within one cycle is achieved at a habitual level.

The acquisition of front crawl movements for children with retained primitive reflexes aged 6–7 years should also begin with learning the components of diagonal arm-leg interaction. These include: (1) the arm catch phase synchronised with contralateral leg kick downward, (2) the arm push phase synchronised with contralateral leg kick downward, (3) arm recovery from water and overwater transfer synchronised with ipsilateral leg kick downward.

Head turning and body oscillation are necessary components when performing inhalation according to upper and lower limb interaction within one cycle during the front crawl swimming teaching process. To reduce primitive reflex activity during head turning in children with retained primitive reflexes, attention was paid to hip oscillation/movement to coordinate bilateral breathing, body oscillation around its longitudinal axis, and diagonal arm-leg action. Inhalation is synchronised when lifting an arm out of water while simultaneously lifting a contralateral (diagonal) leg.

Discussion

The choice of the Doctoral Thesis topic – "Optimisation Model for Teaching Swimming Strokes to 6–7-Year-Old Children with Residual Primitive Reflexes" – was based on scientific studies concerning the prevalence of retained primitive reflexes in the healthy child population (Gieysztor, Sadowska & Choińska, 2017; Gieysztor, Choińska & Paprocka-Borowicz, 2018a; Demiy et al., 2020; Blythe et al., 2021). The literature indicates that retained primitive reflexes significantly affect children's motor development, movement coordination, balance, and muscle tone (Blythe, 2009), which can cause difficulties in acquiring new motor skills, including swimming.

The doctoral study involved 78 children aged 6 to 7 years who participated in swimming lessons during the initial phase of learning to swim. The analysis of the Asymmetrical Tonic Neck Reflex (ATNR), Symmetrical Tonic Neck Reflex (STNR), and Tonic Labyrinthine Reflex (TLR) revealed that the majority of children in this age group (97.4 %) retained these primitive reflexes. The testing results showed considerable variability in reflex activity levels: ATNR and STNR activity ranged from 0 to 4 points, while TLR ranged from 1 to 3 points. Many children exhibited several simultaneously retained reflexes. The analysis indicated that a significant proportion of children (47.4 % of the sample) retained all three reflexes at a level of 50 % or higher, indicating moderate to high reflex activity. Assessing the level of primitive reflex integration revealed that 46.2 % of the children had a moderate level of integration, 44.9 % – incomplete, and 6.4 % – low integration. Only two children demonstrated complete reflex integration, while no child exhibited maximal reflex activity. These findings are consistent with previous studies confirming the widespread presence of retained primitive reflexes among children (Blythe, 2012; Gieysztor, Sadowska & Choińska, 2017; Gieysztor, Choińska & Paprocka-Borowicz, 2018a) and support the observation that a child may retain up to three primitive reflexes simultaneously (Blythe et al., 2021).

Considering that retained primitive reflexes influence children's motor abilities, coordination, muscle tone, and movement symmetry (Gieysztor et al., 2018a, 2020; Pecuch et al., 2020; Deutsch et al., 1987; Zafar et al., 2018), it can be concluded that testing for primitive reflexes is essential for all children. This allows for the early identification of children whose motor coordination difficulties may not be pronounced enough to be detected through medical assessment but nonetheless affect their motor skill development. These children are capable of learning new movements, but this process requires significantly greater effort and time (Montgomery et al., 2015; Grzywniak, 2016). Research also indicates that children with retained primitive reflexes may experience difficulties in learning to read (McPhillips & Jordan-Black, 2007) and in telling time using an analog clock (Kalemba, Lorent, Blythe & Gieysztor, 2023). Therefore, to facilitate the acquisition of new skills and promote full academic and physical development, these children require targeted support, including within the process of learning to swim.

During the course of the doctoral study, both the experimental and comparison groups demonstrated specific levels of skill acquisition in swimming techniques. The quasi-experimental results showed that after 12 back crawl swimming lessons (30 minutes once a week), the overall skill level for individual movement components in the experimental group reached 82.9 % of the maximum possible score, while in the comparison group it reached 59.8 %. After 16 front crawl swimming lessons (30 minutes once a week), the total skill level across all movement components in the experimental group reached 72.7 % of the maximum possible score, compared to 61 % in the comparison group. The groups of children involved in this study differed from those described in the available scientific literature. However, a study by Oh et al. (2008) found that significant improvements in swimming skill acquisition occurred after just 10 sessions (30 minutes once a week) among children with developmental coordination disorders ($p < 0.05$). These findings are consistent with the understanding that repeated performance of the same movements during the learning process promotes movement automatisation and skill consolidation (Taubert et al., 2010; Landi, Baguear & Della-Maggiore, 2011). Both the present doctoral study and that of Oh and colleagues (2008) found that none of the participants achieved the maximum possible score in swimming skill acquisition. This result may be explained by the potential link between motor skill development and retained primitive reflexes, which, as noted by several authors, may limit a child's ability to achieve optimal movement efficiency. This connection is confirmed by the study conducted by Gieysztor and colleagues, which analysed the effect of retained primitive reflexes on motor skill development levels in healthy preschool children. The study employed 18 tasks divided into four domains: stability, locomotion, object control, and fine motor skills. The tasks were evaluated on a three-point scale, where "0" indicated an unacquired skill and "2" a fully acquired skill, with a maximum total score of 34. The study revealed that none of the children with retained primitive reflexes achieved the maximum score, and that even a slight persistence of these reflexes affected motor development (Gieysztor, Choińska & Paprocka-Borowicz, 2018a). In light of these findings, it can be concluded that the development of motor skills in children is closely linked to the maturity of the nervous system and the process of reflex integration. Therefore, the effectiveness of swimming skill acquisition is influenced not only by the intensity and regularity of instruction but also by the individual neurological development characteristics of the child.

Analysis of limb movement synchronisation in backstroke revealed that children in the experimental group, who were taught to perform bilateral movement sequences consciously and precisely with a specific arm-to-leg movement frequency ratio of 2:6 per cycle (corresponding to an integrated movement coordination model), demonstrated significantly higher overall limb coordination scores (9.00 ± 0 points). In contrast, participants in the comparison group, who learned swimming strokes using the traditional part–whole teaching method, achieved statistically significantly lower scores (0.67 ± 0.29 points). In front crawl, the experimental group's results were –5.73 ± 0.2, while the comparison group achieved 2.42 ± 0.45. These findings indicate that after 12 backstroke lessons and 16 front crawl lessons (30 minutes each, once per week), participants in the experimental group had substantially mastered the integrated coordination model for backstroke, whereas in front crawl the mastery was partial. In the comparison group, the overall movement coordination of swimming strokes remained very low, reflecting significant differences in instructional effectiveness between the two teaching approaches. Our study results are consistent with the literature on traditional teaching methods. The conventional part–whole method of teaching swimming is based on the premise that the human neurophysiological system is capable of self-organisation, thereby establishing optimal phase relationships between joints and limbs through the process of sensorimotor adaptation (Zehr et al., 2016; Kerkman et al., 2020; Sanders & Levitin, 2020). Such adaptive movement patterns are considered a response to fatigue (Sparrow & Newell, 1998); however, in practice, they usually emerge only during the third stage of learning, which involves improving the efficiency of movement coordination (Newell, 1985).

The available literature does not include studies analyzing the duration of sensorimotor adaptation or the number of sessions required to develop such coordination skills without direct instructional influence. Lerda and colleagues (2005) examined whole-body movement coordination in backstroke among physical education students with no prior swimming experience. Before the study, men's 100 m swim times ranged from 76.9 ± 5.9 to 101.0 ± 9.2 seconds, while women's results ranged from 78.7 ± 6.8 to 100.04 ± 4.0 seconds. After 40 lessons (twice weekly), only 52.8 % of the 36 students demonstrated a global movement coordination pattern approximating the relative phase relationships of limb movements in backstroke. Elite swimmers naturally adopt a relative phase coordination regime as an adaptive stabilisation of interlimb movements. However, no absolute phase stabilisation was found in any of the swimmers studied, indicating that complete overall limb coordination is not fully developed (Lerda et al., 2005; Martínez-Sobrino, Veiga & Navandar, 2017; Guignard et al., 2019). Moreover, Bruijn and colleagues (2013) found that all ten adults in their study still exhibited retained primitive reflexes. This suggests that primitive reflexes may affect the duration of sensorimotor adaptation in the process of learning and refining swimming techniques. Retained reflexes complicate voluntary arm and leg movements, disrupt body stabilisation, hinder stroke skill acquisition, and limit the full development of an integrated interlimb coordination model.

In summary, it can be concluded that the effectiveness of swimming coordination skill acquisition in children with retained primitive reflexes is strongly influenced by the teaching method and the level of movement awareness. Direct instruction of whole-stroke coordination models can significantly shorten the sensorimotor adaptation process, thereby accelerating the formation of optimal movement patterns.

The results of the quasi-experimental study indicate that the overall level of swimming skill acquisition in the experimental group was higher than in the comparison group for both backstroke and front crawl (82.9 % vs. 59.8 % and 72.7 % vs. 61 % of the maximum possible score, respectively). Considering that the instructional process in the experimental group focused on the conscious coordination of diagonal "left–right / right–left" interlimb movements with the aim of developing an integrated movement coordination model, and that the results statistically exceeded those of the comparison group, it can be concluded that teaching overall movement coordination positively influences the acquisition of swimming stroke components. In backstroke, children in the experimental group demonstrated improved leg movement performance, while in front crawl they showed superior arm movement acquisition ($p < 0.05$). Moreover, the more efficient acquisition of swimming techniques was supported by heart rate measurements taken after a 25 m swim. The mean heart rate in the experimental group was statistically significantly lower than in the comparison group ($p < 0.05$), and there was also a statistically significant difference ($p < 0.05$) in the maximum distance swum between the groups. Children in the experimental group covered a significantly longer distance in both backstroke and front crawl, indicating that they completed the swimming distances with greater efficiency and less cardiovascular strain. The findings of this doctoral study are supported by Wilson et al. (2008), who concluded that the performance of triple jump athletes improved only after mastering the corresponding movement patterns that determine the overall coordination model. Refinement of these movements ensures more effective skill development. Other studies have found that loss of coordination or range of motion within the kinetic chain can result in suboptimal performance (Roy, Moffet & McFadyen, 2008; Wilson et al., 2008; Myer et al., 2014) and may also hinder the efficient acquisition of motor skills (Martínez-Sobrino, Veiga & Navandar, 2017). Furthermore, researchers have noted that in swimming, the adaptation of an integrated interlimb coordination model in both backstroke and front crawl – where frequency ratios approach an in-phase coordination regime – indicates effective stroke acquisition (Maglischo, 2003; Seifert, Chollet & Allard, 2005).

Applying the optimised model for teaching backstroke and front crawl to children aged 6–7 with retained primitive reflexes, it can be concluded that sequential teaching of diagonal arm and leg movements has a positive impact on maintaining the body in a horizontal position in water. Comparison of the mean indicators of body and head balance in a horizontal position between the experimental and comparison groups revealed that the experimental group achieved statistically significantly higher results ($p < 0.05$) in both swimming styles. These findings suggest more effective acquisition of body and head balance in children from the experimental group. This conclusion is supported by Wagner's (2021) research, which demonstrated that diagonal interlimb interaction has a significant effect on dynamic stability during locomotion.

The acquisition of swimming techniques is regarded both as a form of physical activity (Caspersen, Powell & Christenson, 1985) and as an important component of a child's cognitive functioning, which promotes the development of precise movements during various learning exercises. To prevent excessive physical strain that might cause a significant increase in heart rate and a reduction in heart rate variability (HRV) (Aras, Akça & Akalan, 2013), participants were allowed to perform the tasks at an individually optimal swimming pace. Each child had the right to withdraw from further participation in the evaluation of learning efficiency, depending on their physical abilities; in such cases, the data obtained were excluded from analysis.

The study results indicate that, in children with retained primary reflexes, swimming instruction based on conscious coordination of diagonal arm and leg interactions led to a smaller increase in heart rate and a more positive effect on heart rate variability (HRV) compared with the traditional segmented teaching method, in which the movements of the arms and legs are learned separately and later combined into a unified movement cycle. The traditional method is more often associated with pronounced autonomic reactions, indicating greater stress on adaptive mechanisms. This assertion is indirectly supported by previous research, which shows that in the initial stages of swimming skill acquisition, high variability in biomechanical and electrophysiological swimming parameters is considered an indicator of incomplete motor control, reflecting increased muscular energy expenditure for movement regulation and stability maintenance (Sanders, 2007; Matsuda et al., 2016). In contrast, well-developed motor skills are characterised by stability in temporal, spatial, and force parameters (Seifert et al., 2010; Lauer et al., 2013).

Considering that HRV dynamics were assessed while the children performed familiar exercises at their preferred pace, the observed changes in heart rhythm indicators reflect coordination disturbances caused by retained primary reflexes. This interpretation aligns with previous findings demonstrating correlations between retained primary reflexes and various neurological or psychoneurological disorders, such as cerebral palsy (Zafeiriou, 2004; Pavão et al., 2013), attention deficit hyperactivity disorder (Konicarova & Bob, 2013), Asperger's syndrome (Teitelbaum et al., 2004), and autism spectrum disorders (Chinello, Gangib & Valenzab, 2018). Chen et al. (2015) have noted that children with motor impairments exhibit increased heart rate and reduced HRV in response to cognitive load, reflecting sympathetic nervous system dominance. Such autonomic imbalance indicates lower flexibility of the autonomic nervous system and limited ability to adapt cardiovascular responses to changing task demands, emphasizing the close interconnection between motor and autonomic functions. Similar trends were observed by Kholod, Jamil, and Katz-Leurer (2013), who reported that children with cerebral palsy exhibited higher heart rates and significantly lower HRV than their healthy peers, with these changes correlating with poorer motor coordination.

Shlyka (2009) reported that swimming lessons in children aged 6–7 years result in a significant increase in sympathetic nervous system activity and a concurrent decrease in parasympathetic activity, indicating a high physiological load during physical activity. Considering that retained primitive reflexes influence the development of motor skills (Gieysztor, Choińska & Paprocka-Borowicz, 2018a), and in light of our findings showing that the majority of 6–7-year-old children continue to exhibit these reflexes, it can be inferred that primitive reflex activity also affects the acquisition of swimming skills. At a functional level, this may manifest as excessive muscle tension, reduced muscle strength, muscle imbalances, and restricted joint mobility, all of which negatively impact children's overall functional abilities. These observations are consistent with previous research indicating that the acquisition of swimming skills in children is frequently associated with inadequate movement coordination (Donaldson et al., 2010; Shlyachkov, 2006), which is, in turn, attributable to disruptions in muscle function (Sanders, 2007; Matsuda et al., 2016).

From the neurophysiological perspective of motor learning, it is emphasised that kinetic chains involving both sides of the body – including diagonal limb interactions – promote higher levels of sensory and motor integration and enhance interhemispheric cooperation. This mechanism is illustrated by Waters, Wiestler, and Diedrichsen (2017), who demonstrated that both the contralateral and ipsilateral motor cortices are actively involved in motor task acquisition, confirming the principle of interhemispheric collaboration in movement coordination. Della Tommasina et al. (2023) found that dry-land diagonal movement exercises in swimmers improved functional muscle coordination and reduced the risk of shoulder injuries. Kajal et al. (2017) demonstrated that neurofeedback training enables participants to consciously regulate the connection between the right and left motor cortices, improving bimanual movement precision and synchrony, as well as promoting neuroplastic changes in brain structure.

Based on these findings, it can be concluded that conscious regulation of bilateral diagonal limb movement sequences (with an arm-to-leg movement frequency ratio of 2:6 within a single cycle) reduces the influence of retained reflexes and promotes not only more efficient motor skill acquisition but also improvement in neuro-autonomic regulation – an aspect particularly important for children with immature motor control elements.

In summary, conscious synchronisation of bilateral upper and lower limb diagonal movements within a single movement cycle during swimming instruction is more energy-efficient than traditional segmented teaching methods that focus on the isolated acquisition of individual swimming components (body position, head alignment, breathing control, arm and leg movements). This conclusion is supported by several previous studies.

The results of this study confirm the proposed hypothesis that the use of the developed optimised swimming instruction model can significantly improve swimming skill acquisition in children aged 6–7 years with retained primitive reflexes. When the teaching process purposefully establishes bilateral diagonal coordination of upper and lower limb movements within a single movement cycle, swimming skill acquisition and movement coordination become more efficient.

When comparing the results of this study with previous research, it should be noted that existing scientific literature primarily addresses the presence of primitive reflexes in children and their influence on psychomotor development and movement coordination, which in turn affect the acquisition of new skills. Therefore, several limitations must be acknowledged in the interpretation of the current study's findings. First, there is a lack of research analyzing various teaching methods aimed at reducing the impact of retained primitive reflexes and facilitating new skill acquisition. Consequently, the results and conclusions of this dissertation pertain specifically to the data obtained within the scope of this study. Second, a limitation of the research is the absence of a control group (children without retained primitive reflexes) for comparison.

Despite these limitations, this study provides a significant scientific contribution to understanding swimming skill acquisition in children with retained primitive reflexes. In the international context, this topic has been little explored; therefore, the obtained results enrich existing knowledge about adapting teaching methods for children with neurophysiological developmental peculiarities. In the Latvian context, this is one of the first qualitative studies addressing this issue, thereby offering a valuable contribution to the fields of pedagogy and child psychomotor development science.

Conclusion

Based on the analysis of the literature, the conducted empirical research, and the obtained results, the following conclusions can be drawn:

1 The literature review demonstrates that swimming freestyle on the front and back in children aged 6–7 years is a complex coordination task requiring precise synchronisation of movements and stabilisation of the body in a horizontal position in water. At this developmental stage, the most effective teaching approach is the part-method (segmented learning), which enables gradual acquisition of movement components and reduces both physical and cognitive load. The development of swimming skills depends not only on chronological age and lessons frequency but also on individual characteristics such as movement asymmetry, increased muscle tone, and insufficient postural stability. The main underlying cause of these features is the persistence of primitive reflexes, which influence movement coordination and balance. The lack of evidence-based recommendations for teaching swimming to children with retained primitive reflexes highlights the need for a theoretically and methodologically grounded teaching model for this specific population.

2 The research findings reveal that the majority of children (97.4 %) exhibited retained primitive reflexes – the asymmetrical tonic neck reflex, the tonic labyrinthine reflex, and the symmetrical tonic neck reflex. The activity level of these reflexes was predominantly moderate (46.2 %) or low (44.9 %), with a high level observed in only 6.4 % of cases. No child demonstrated maximal reflex activity, and two children showed no presence of primitive reflexes. These findings confirm that the persistence of primitive reflexes must be taken into

account when designing and implementing swimming instruction for children of early school age.

3 A swimming strokes teaching optimisation model (for backstroke and n front crawl) was developed for children aged 6–7 years with retained primitive reflexes. The model is based on the principle of diagonal limb coordination to minimise the impact of uncontrolled muscle activation patterns induced by reflexes on body balance and stabilisation in the horizontal position. The model promotes conscious coordination and voluntary control of upper and lower limb movements, incorporating three main components of diagonal motion with an arm-to-leg movement frequency ratio of 2:6 within one movement cycle.

4 Experimental results confirm that the proposed swimming strokes optimisation model significantly enhances the acquisition of swimming skills and improves children's functional performance:

- In the experimental group, the overall skill level of movement components in backstroke reached 82.9 %, and in freestyle on the front crawl – 72.7 % of the maximum score, compared to 59.8 % and 61 % in the control group ($p < 0.05$).
- During a 25 m swim, children in the experimental group performed movements more economically: heart rate after swimming backstroke was 24.5 bpm lower, and after front crawl – 30.61 bpm lower than in the control group ($p < 0.05$).
- The maximum swimming distance (in points) for backstroke was 15.67 ± 3.08 in the experimental group and 3.50 ± 0.9 in the control group; for front crawl – 4.82 ± 1.08 and 1.82 ± 0.87, respectively ($p < 0.05$).

- Heart rate variability analysis revealed statistically significant differences in adaptive responses ($p < 0.05$): the experimental group showed increased parasympathetic nervous system activity and reduced sympathetic influence on cardiac function, whereas the control group demonstrated the opposite trend.

5 The core exercises within the swimming technique optimisation model aim to develop conscious bilateral movement sequencing, maintaining an arm-to-leg movement frequency ratio of 2:6 within one cycle.

- In backstroke, coordination is achieved by synchronizing: (a) arm recovery from the water with the contralateral leg's upward movement; (b) the main pull and propulsion phase with the contralateral leg's upward movement; and (c) the final phase of the arm stroke with the ipsilateral leg's upward movement.
- In front crawl, coordination is established by aligning: (a) the arm catch phase with the contralateral leg's downward kick; (b) the arm push phase with the contralateral leg's downward kick; and (c) the arm recovery and overwater transfer with the ipsilateral leg's downward kick.

The developed set of exercises with clearly defined objectives is recommended for swimming coaches as a practical tool for developing swimming skills in children aged 6–7 years with retained primitive reflexes.

The proposed model is theoretically and empirically validated, providing an effective pedagogical framework for swimming instruction in children with specific neurodevelopmental characteristics.

By accomplishing the tasks set out in this research and based on the results obtained, the study achieved its goal – developing and validating an optimisation model for teaching swimming strokes to children aged 6–7 years with retained primitive reflexes, as well as creating recommendations for swimming coaches on teaching swimming strokes to these children. The hypothesis proposed in this study was confirmed – applying the developed optimisation model for teaching swimming strokes improves skill acquisition for children aged 6–7 years with retained primitive reflexes. If bilateral diagonal coordination of upper and lower limb movements within one movement cycle is purposefully established during swimming stroke teaching for children aged 6–7 years with retained primitive reflexes, their skill acquisition will improve.The results obtained in this study demonstrate better skill acquisition after applying the optimisation model for teaching swimming strokes to children aged 6–7 years with retained primitive reflexes compared to traditional part-practice teaching methods.

List of publications and reports on the topic of the Thesis

Publications:

1 Bogdanoviča, I., Lāriņš, V. (2021) Backstroke teaching methods in healthy children with residual primitive reflexes. Rēzekne. *Proceedings of the International Scientific Conference*. May 28–29, 2021. Vol. 4, Society. Integration. Education, Volume IV, ISSN1691-5887.

2 Bogdanoviča, I., Lāriņš, V. (2020) Case study of primitive reflexes impact on swimming skill acquisition by healthy children. *Proceedings of the International Scientific Conference*. May 22–23, 2020. Vol.6, , Society. Integration. Education, Volume VI, ISSN1691-5887.

Reports and abstracts at international and local scientific conferences:

1 Bogdanoviča, I., Lāriņš, V. 2025. Persistence of Residual Primitive Reflexes during Acquisition of Swimming Strokes in Healthy Children. *International Conference on Medical and Health Research "Knowledge for Use in Practice"*, RSU, Riga, Latvia, March 26–28, 2025. Abstract, 428.

2 Bogdanoviča, I., Lāriņš, V. 2025. Effect of Different Teaching Methods on Acquisition of Front Crawl in Healthy Children with Residual Primitive Reflexes. *International Conference on Medical and Health Research "Knowledge for Use in Practice"*, RSU, Riga, Latvia, March 26–28, 2025. Abstract, 420.

3 Bogdanoviča, I., Lāriņš, V., 2023. Effects of teaching methods on front crawl acquisition in healthy children with residual primitive reflexes. *International scientific conference "European Aquatics learn to swim 2023 conference"*, LPF, Yurmala, Latvia, November 11–12, 2023.

4 Bogdanoviča, I., Lāriņš, V., 2019. The effect of different backstroke techniques on children's heart rate variability on the initial stage of swimming learning: case study. *12th Baltic Scientific Conference "Sport science for sports practice, teacher training and health promotion"*, LSU, Vilnius, Lithuania, April 25–26, 2019. Abstract, 20.

5 Bogdanoviča, I., Lāriņš, V., 2018. Efficient pattern and technique problems on the initial stage of learning swimming strokes: case study. *11th Baltic Scientific Conference "Integrated Effects of exercises: From Performance to Health and Prevention"*, TU, Tartu, Estonia, April 25–27, 2018.

6 Bogdanoviča, I., Lāriņš, V., Kratiņa, M., 2017. Problems in teaching swimming skills on the initial stage of the teaching process in the age group 5–7 years old. *10th Baltic Scientific Conference "Multiplicity of sport science in practice"*, LSPA, Riga, Latvia, April 26–28, 2017. Abstract, 21.

References

1 Adolph, K. E., Vereijken, B., & Denny, M. A. (1998). Learning to crawl. *Child development*, *69*(5), 1299–1312.

2 Ahmadian, M., Roshan, V.D., & Dabirian, M. (2014). Effect of Arm and Leg Exercise on Heart Autonomic Function in Children. *International Journal of Sport Studies*, 4 (7), 799-805

3 Aras, D., Akça, F., & Akalan, C. (2013). *The effect of 50 m sprint swimming on heart rate variability in 13-14 year-old boys. SPORMETRE Beden Eğitimi Ve Spor Bilimleri Dergisi, 11(1), 13-18.* https://doi.org/10.1501/Sporm_0000000233

4 Ardila, A., Rosselli, M., Matute, E., & Inozemtseva, O. (2011). Gender differences in cognitive development. *Developmental psychology*, *47*(4), 984–990. https://doi.org/10.1037/a0023819

5 Armstrong, N., & Welsman, J. R. (2006). The physical activity patterns of European youth with reference to methods of assessment. *Sports medicine (Auckland, N.Z.)*, *36*(12), 1067–1086. https://doi.org/10.2165/00007256-200636120-00005

6 Asai, T., Doi, T., Hirata, S., & Ando, H. (2013). Dual tasking affects lateral trunk control in healthy younger and older adults. *Gait & posture*, *38*(4), 830–836. https://doi.org/10.1016/j.gaitpost.2013.04.005

7 Assaiante, C. (1998). Development of locomotor balance control in healthy children. *Neuroscience and biobehavioral reviews*, *22*(4), 527–532. https://doi.org/10.1016/s0149-7634(97)00040-7

8 Barbosa, T. M., Fernandes, R., Keskinen, K. L., Colaco, P., Cordoso, C., Silva, J., & Vilas-Boas, J. P. (2006). Evaluation of the energy expenditure in competitive swimming strokes. International Journal of Sports Medicine, 27, 894–899. PubMed doi:10.1055/s-2006-923776

9 Barela, J. A., Jeka, J. J., & Clark, J. E. (2003). Postural control in children. Coupling to dynamic somatosensory information. *Experimental brain research*, *150*(4), 434–442. https://doi.org/10.1007/s00221-003-1441-5

10 Bartlett, D., & Birmingham, T. (2003). Validity and reliability of a pediatric reach test. Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association, 15(2), 84–92. https://doi.org/10.1097/01.PEP.0000067885.63909.5C

11 Bastiere, J., Lussiana, T., Young, D., Gindre, C., & Mourot, L. (2024). Persistence and activity levels of primitive reflexes in young high-level football players. *Frontiers in sports and active living*, *6*, 1409257. https://doi.org/10.3389/fspor.2024.1409257

12 Bilbilaj, S., Gjipali, A., & Shkurti, F. (2017). Measuring Primitive Reflexes in Children with Learning Disorders. *European Journal of Multidisciplinary Studies*, *2*(5), 285–298. ISSN 2414-8385

13 Blanchard, Y., Carey, S., Coffey, J., Cohen, A., Harris, T., Michlik, S., & Pellecchia, G. L. (2005). The influence of concurrent cognitive tasks on postural sway in children. *Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association*, *17*(3), 189–193. https://doi.org/10.1097/01.pep.0000176578.57147.5d

14 Blanksby, B. A., Parker, H. E., Bradley, S., & Ong, V. (1995). Children's readiness for learning front crawl swimming. *Australian Journal of Science and Medicine in Sport*, *27*(2), 34–37

15 Blaszczyk, J. W., Fredyk, A., Blaszczyk, P. M., & Ashtiani, M. (2020). Step Response of Human Motor System as a Measure of Postural Stability in Children. *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*, *28*(4), 895–903. https://doi.org/10.1109/TNSRE.2020.2974784

16 Blythe, S. G. (2009). *Attention, Balance and Coordination: The A.B.C. of Learning Success*. Wiley-Blackwell. Pp: 4, 39–43, 80, 71–78, 100.

17 Blythe, S. G. (2011). Neuro-motor maturity as an indicator of developmental readiness for education. *TAC Journal*, 4(12), 1–12. Retrieved from http://www.novreflextherapie.nl/pdf-bestanden/bibliotheek-neuro-motor.pdf

18 Blythe, S. G. (2012). The Right to Move Assessing Neuromotor Readiness for Learning Why physical development in the early years supports educational success. In book: Improving the Quality of Childhood in Europe, Volume 3 (pp.16–39), Chapter: 1 Publisher: ECSWE (European Council for Steiner Waldorf Education), East Sussex, UK. (In collaboration with the Alliance for Childhood European Network Group). Retrieved from: https://www.researchgate.net/publication/343570692_The_Right_to_Move_Assessing_Neuromotor_Readiness_for_Learning_Why_physical_development_in_the_early_years_supports_educational_success

19 Blythe, S. G., Duncombe, R., Preedy, P & Gorely, T. (2021). 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). DOI: 10.1080/03004279.2021.1895276

20 Bouisset, S., & Do, M. C. (2008). Posture, dynamic stability, and voluntary movement. *Neurophysiologie clinique = Clinical neurophysiology*, *38*(6), 345–362. https://doi.org/10.1016/j.neucli.2008.10.001

21 Bruijn, S. M., Massaad, F., Maclellan, M. J., Gestel van, L., Ivanenko, Y. P., & Duysens, J. (2013). Are effects of the symmetric and asymmetric tonic neck reflexes still visible in healthy adults? *Neuroscience letters*, *556*, 89–92. https://doi.org/10.1016/j.neulet. 2013.10.028

22 Buchheit, M., Papelier, Y., Laursen, P. B., & Ahmaidi, S. (2007). Noninvasive assessment of cardiac parasympathetic function: postexercise heart rate recovery or heart rate variability? *American journal of physiology. Heart and circulatory physiology*, *293*(1), H8–H10. https://doi.org/10.1152/ajpheart.00335.2007

23 Cardelli, C., Lerda, R., & Chollet, D. (2000). Analysis of breathing in the crawl as a function of skill and stroke characteristics. *Perceptual and Motor Skills*, 90 (3Pt1), 979–987.

24 Cartmill, M., Lemelin, P., & Schmitt, D. (2002). Support polygons and symmetrical gaits in mammals. *Zoological Journal of the Linnean Society*, 136(3), 401–420, https://doi.org/10.1046/j.1096-3642.2002.00038.x

25 Castro, F., Minghelli, F., Floss, J., & Guimaraes, A. (2003). Body roll angles in front crawl swimming at different velocities. In, J.C. Chatard (Ed.): Biomechanics and Medicine in Swimming IX. St Etienne: University of St Etienne Publications. (Pp: 111–114).

26 Charpiot, A., Tringali, S., Ionescu, E., Vital-Durand, F., & Ferber-Viart, C. (2010). Vestibulo-ocular reflex and balance maturation in healthy children aged from six to twelve years. *Audiology & neuro-otology*, *15*(4), 203–210. https://doi.org/10.1159/000255338

27 Cherng, R. J., Liang, L. Y., Hwang, I. S., & Chen, J. Y. (2007). The effect of a concurrent task on the walking performance of preschool children. *Gait & posture*, *26*(2), 231–237. https://doi.org/10.1016/j.gaitpost.2006.09.004

28 Chollet, D., Seifert, L. M., & Carter, M. (2008). Arm coordination in elite backstroke swimmers. *Journal of sports sciences*, *26*(7), 675–682. https://doi.org/10.1080/02640410701787791

29 Colado, J. C., Tella, V., & Triplett, N. T. (2008). A method for monitoring intensity during aquatic resistance exercises. *Journal of strength and conditioning research*, *22*(6), 2045–2049. https://doi.org/10.1519/JSC.0b013e31817ae71f

30 Creswell, J. W. (2014). Research design: Qualitative, quantitative and mixed methods approaches. 4th ed. Thousand Oaks, CA: Sage. Pp: 244.

31 Davids, K., Araújo, D., Hristovski, R., Passos, P., & Chow, J. (2012). Ecological dynamics and motor learning design in sport.

32 Davids, K., Araújo, D., Vilar, L., Renshaw, I., & Pinder, R. (2013). An Ecological Dynamics Approach to Skill Acquisition: Implications for Development of Talent in Sport.

33 Della Tommasina, I., Trinidad-Morales, A., Martínez-Lozano, P., González-de-la-Flor, Á., & Del-Blanco-Muñiz, J. Á. (2023). Effects of a dry-land strengthening exercise program with elastic bands following the Kabat D2 diagonal flexion pattern for the prevention of shoulder injuries in swimmers. *Frontiers in physiology*, *14*, 1275285. https://doi.org/10.3389/fphys.2023.1275285

34 Demiy, A., Kalemba, A., Lorent, M., Pecuch, A., Wolańska, E., Telenga, M., & Gieysztor, E. Z. (2020). A Child's Perception of Their Developmental Difficulties in Relation to Their Adult Assessment. Analysis of the INPP Questionnaire. *Journal of personalised medicine*, *10*(4), 156. https://doi.org/10.3390/jpm10040156

35 Desorbay, T. (2013). A neuro-developmental approach to specific learning difficulties. *International Journal of Nutrition, Pharmacology, Neurological Diseases, 3*(1), 1–2. DOI: 10.4103/2231-0738.106970

36 Dietz, V. (1996). Interaction between central programs and afferent input in the control of posture and locomotion. *Journal of biomechanics*, *29*(7), 841–844. https://doi.org/10.1016/0021-9290(95)00175-1

37 Donaldson, M., Blanksby, B., & Heard, N. (2010). Progress in precursor skills and front crawl swimming in children with and without developmental coordination disorder. *International Journal of Aquatic Research and Education*, *4*(4), 390–408. Retrieved from https://scholarworks.bgsu.edu/ijare/vol4/iss4/6

38 Dong, J. G. (2016). The role of heart rate variability in sports physiology. *Experimental and therapeutic medicine*, *11*(5), 1531–1536. https://doi.org/10.3892/etm.2016.3104

39 Ferber-Viart, C., Ionescu, E., Morlet, T., Froehlich, P., & Dubreuil, C. (2007). Balance in healthy individuals assessed with Equitest: maturation and normative data for children and young adults. *International journal of pediatric otorhinolaryngology*, *71*(7), 1041–1046. https://doi.org/10.1016/j.ijporl. 2007. 03. 012

40 Fleming, S., Thompson, M., Stevens, R., Heneghan, C., Plüddemann, A., Maconochie, I., Tarassenko, L., & Mant, D. (2011). Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age: a systematic review of observational studies. *Lancet (London, England)*, *377*(9770), 1011–1018. https://doi.org/10.1016/S0140-6736(10)62226-X

41 Fontana, F. E., Mazzardo, O., Furtado, O., Jr, & Gallagher, J. D. (2009). Whole and part practice: a meta-analysis. *Perceptual and motor skills*, *109*(2), 517–530. https://doi.org/10.2466/PMS.109.2.517-530

42 Friedman, B. H. (2007). An autonomic flexibility-neurovisceral integration model of anxiety and cardiac vagal tone. *Biological psychology*, *74*(2), 185–199. https://doi.org/10.1016/j.biopsycho.2005.08.009

43 Gamelin, F. X., Baquet, G., Berthoin, S., Thevenet, D., Nourry, C., Nottin, S., & Bosquet, L. (2009). Effect of high intensity intermittent training on heart rate variability in prepubescent children. *European journal of applied physiology*, *105*(5), 731–738. https://doi.org/10.1007/s00421-008-0955-8

44 Geske, A., & Grīnfelds, A. (2006). *Izglītības pētniecība.* Rīga: LU Akadēmiskais apgāds.

45 Gieysztor, E. Z., Choińska, A. M., & Paprocka-Borowicz, M. (2018a). Persistence of primitive reflexes and associated motor problems in healthy preschool children. *Arch Med Sci*, *14*(1), 167–173. DOI: 10.5114/aoms.2016.60503

46 Gieysztor, E. Z., Sadowska, L., Choińska, A. M., & Paprocka-Borowicz, M. (2018b). Trunk rotation due to persistence of primitive reflexes in early school-age children. *Advances in clinical and experimental medicine: official organ Wroclaw Medical University*, *27*(3), 363–366. https://doi.org/10.17219/acem/67458

47 Gieysztor, E. Z., Sadowska, L., & Choińska, A.M. (2017). The degree of primitive reflexes integration as a diagnostic tool to assess the neurological maturity of healthy preschool and early school age children. *Pielęgniarstwo i Zdrowie Publiczne*, 26(1), 5–11. Retrieved from ISSN 2082–9876 (print), ISSN 2451–1870 (online)

48 Gonjo, T., McCabe, C., Coleman, S., & Sanders, R. (2016). Magnitude of maximum shoulder and hip roll angles at different swimming speeds in back crawl. *Conference: 34th International Conference on Biomechanics in Sports*. At: Tsukuba, Volume: 34

49 Gourgoulis, V., Boli, A., Aggeloussis, N., Toubekis, A., Antoniou, P., Kasimatis, P., Vezos, N., Michalopoulou, M., Kambas, A., & Mavromatis, G. (2014). The effect of leg kick on sprint front crawl swimming. *Journal of Sports Sciences*, *32*(3), 278–289. https://doi.org/10.1080/02640414.2013.823224

50 Grigg, T. M. (2018). The influences of a primitive reflex integration programme within the classroom: teacher/parent perspectives and student results. Dissertation. *School of Health Sciences College of Education, Health and Human Development University of Canterbury, Christchurch, New Zealand.*

51 Grzywniak, C. (2016). Role of early-childhood reflexes in the psychomotor development of a child, and in learning. *Acta Neuropsychologica*, Vol 14, No. 2, 113–129.

52 Guignard, B., Rouard, A., Chollet, D., Bonifazi, M., Dalla Vedova, D., Hart, J., & Seifert, L. (2019). Upper to Lower Limb Coordination Dynamics in Swimming Depending on Swimming Speed and Aquatic Environment Manipulations. *Motor control*, *23*(3), 418–442. https://doi.org/10.1123/mc.2018-0026

53 Guilkey, J. P., Dykstra, B., Erichsen, J., & Mahon, A. D. (2017). Heart Rate Response and Variability Following Maximal Exercise in Overweight Children. *Pediatric exercise science*, *29*(3), 341–349. https://doi.org/10.1123/pes.2016-0132

54 Hadders-Algra, M. (2005). Development of postural control during the first 18 months of life. *Neural Plas*, 12, 99–108.

55 Hadders-Algra, M. (2018). Early human motor development: From variation to the ability to vary and Adapt. *Neuroscience and Biobehavioral Reviews*, *90*,(7), 411–427https://doi.org/10.1016/j.neubiorev.2018.05.009

56 Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). *Circulation*, *93*(5), 1043–1065.

57 Hoffmann, C. P., & Bardy, B. G. (2015). Dynamics of the locomotor–respiratory coupling at different frequencies. *Experimental Brain Research, 233*(5), 1551–1561. https://doi.org/10.1007/s00221-015-4229-5

58 Huang, H. J., Mercer, V. S., & Thorpe, D. E. (2003). Effects of different concurrent cognitive tasks on temporal-distance gait variables in children. *Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association*, *15*(2), 105–113. https://doi.org/10.1097/01.PEP.0000067886.96352.6B

59 Huxhold, O., Li, S. C., Schmiedek, F., & Lindenberger, U. (2006). Dual-tasking postura control: aging and the effects of cognitive demand in conjunction with focus of attention. *Brain research bulletin*, 69(3), 294–305. https://doi.org/10.1016/j.brainresbull.2006.01.002

60 Iannotti, R. J., Claytor, R. P., Horn, T. S., & Chen, R. (2004). Heart rate monitoring as a measure of physical activity in children. *Medicine and science in sports and exercise*, *36*(11), 1964–1971. https://doi.org/10.1249/01.mss.0000145445.54609.82

61 Kajal, D. S., Braun, C., Mellinger, J., Sacchet, M. D., Ruiz, S., Fetz, E., Birbaumer, N., & Sitaram, R. (2017). Learned control of inter-hemispheric connectivity: Effects on bimanual motor performance. *Human brain mapping*, *38*(9), 4353–4369. https://doi.org/10.1002/hbm.23663

62 Kobesova, A., & Kolar, P. (2014). Developmental kinesiology: three levels of motor control in the assessment and treatment of the motor system. *Journal of bodywork and movement therapies*, *18*(1), 23–33. https://doi.org/10.1016/j.jbmt.2013.04.002

63 Koposova, T. S., Lukina, S. F., & Savenkova, I. A. (2008). Вариабельность сердечного ритма при умственной нагрузке у городских и сельских школьников. Arctic Environmental Research, (1), 24–30.

64 Krūmiņa, D., Kokare, I. un Biķis, E. (2007). *Latvijas bērnu fiziskas attīstības novērtēšana.* Izdevējs SIA Medicinas apgāds, 2007, Rīga. ISBN 978-9984-26-348-9.

65 Langendorfer, S. J. (2013) Which Stroke First? *International Journal of Aquatic Research and Education*, 7 (4-2). DOI: https://doi.org/10.25035/ijare.07.04.02 Available at: https://scholarworks.bgsu.edu/ijare/vol7/iss4/2

66 Lauer, J., Figueiredo, P., Vilas-Boas, J. P., Fernandes, R. J., & Rouard, A. H. (2013). Phase-dependence of elbow muscle coactivation in front crawl swimming. *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology*, *23*(4), 820–825. https://doi.org/10.1016/j.jelekin.2013.02.004

67 Lāriņš, V. (2022) *Spotra medicīna. Teorija un prakse*. 120.–122.lpp. ISBN 978-9934-20-585-9.

68 Legrand, A., Mazars, K. D., Lazzareschi, J., Lemoine, C., Olivier, I., Barra, J., & Bucci, M. P. (2013). Differing effects of prosaccades and antisaccades on postural stability. *Experimental brain research*, *227*(3), 397–405. https://doi.org/10.1007/s00221-013-3519-z

69 Madureira, F., Bastos, F. H., Corrêa, U. C., Rogel, T., & Freudenheim, A. M. (2012). Assessment of beginners' front-crawl stroke efficiency. *Perceptual and motor skills*, *115*(1), 300–308. https://doi.org/10.2466/06.05.25.PMS.115.4.300-308

70 Maglischo, E. (2003). Swimming fastest. Human Kinetics Champaign, Illinois, 121–202. ISBN: 0736031804

71 Martínez-Sobrino, J. M., Fernández, S. V., & Navandar, A. (2017). Evaluation of arm-to-leg coordination in freestyle swimming. *European Journal of Human Movement, 38*, 27–39.

72 Martins, M., Silva, A. J., Marinho, D. A., Pereira, A. L., Moreira, A., Sarmento, P., & Tiago M. Barbosa, T. M. (2010). Assessment of heart rate during infants' swim session. *International Sportmed Journal*, 11(3).

73 Massion, J. (1992). Movement, posture and equilibrium: interaction and coordination. *Progress in neurobiology*, *38*(1), 35–56. https://doi.org/10.1016/0301-0082(92)90034-c

74 Matsuda, Y., Hirano, M., Yamada, Y., Ikuta, Y., Nomura, T., Tanaka, H., & Oda, S. (2016). Lower muscle co-contraction in flutter kicking for competitive swimmers. *Human movement science*, *45*, 40–52. https://doi.org/10.1016/j.humov.2015.11.001

75 McCabe, C. B., Sanders, R. H., & Psycharakis, S. G. (2015). Upper limb kinematic differences between breathing and non-breathing conditions in front crawl sprint swimming. *Journal of biomechanics*, *48*(15), 3995–4001. https://doi.org/10.1016/j.jbiomech.2015.09.012

76 McElroy, E. J., Hickey, K. L., & Reilly, S. M. (2008). The correlated evolution of biomechanics, gait and foraging mode in lizards. *The Journal of experimental biology*, *211*(Pt 7), 1029–1040. https://doi.org/10.1242/jeb.015503

77 McGeehan, M. A., Woollacott, M. H., & Dalton, B. H. (2017). Vestibular control of standing balance is enhanced with increased cognitive load. *Experimental brain research*, *235*(4), 1031–1040. https://doi.org/10.1007/s00221-016-4858-3

78 McManus, A. M., Masters, R. S., Laukkanen, R. M., Yu, C. C., Sit, C. H., & Ling, F. C. (2008). Using heart-rate feedback to increase physical activity in children. *Preventive medicine*, *47*(4), 402–408. https://doi.org/10.1016/j.ypmed.2008.06.001

79 McPhillips, M., & Jordan-Black, J. A. (2007). Primary reflex persistence in children with reading difficulties (dyslexia): a cross-sectional study. *Neuropsychologia*, *45*(4), 748–754. https://doi.org/10.1016/j.neuropsychologia. 2006.08.005

80 Millet, G. P., Chollet, D., Chalies, S., & Chatard, J. C. (2002). Coordination in front crawl in elite triathletes and elite swimmers. *International journal of sports medicine*, *23*(2), 99–104. https://doi.org/10.1055/s-2002-20126

81 Mitra, S., Knight, A., & Munn, A. (2013). Divergent effects of cognitive load on quiet stance and task-linked postural coordination. *Journal of experimental psychology. Human perception and performance*, *39*(2), 323–328. https://doi.org/10.1037/a0030588

82 Montgomery, R. D., Nichols, C., Ornburn, C., Rudd, A., & Williams, L. W. (2015). The effects of persistent asymmetrical tonic neck reflex (ATNR) on reading scores in first and second grade children. 11th Annual Symposium on Graduate Research and Scholarly Projects, April 24, 2015, Rhatigan Student Center, Kerry Wilks GRASP Chair, Book of Abstracts, p. 57.

83 Morningstar, M. W., Pettibon, B. P., Schlappi, H., Schlappi, M., & Ireland, T. V. (2005). Reflex control of the spine and posture: a review of the literature from a chiropractic perspective. Chiropractic & Osteopathy, 13(16).

84 Muratori, L. M., Lamberg, E. M., Quinn, L., & Duff, S. V. (2013). Applying principles of motor learning and control to upper extremity rehabilitation. *Journal of hand therapy : official journal of the American Society of Hand Therapists*, *26*(2), 94–103. https://doi.org/10.1016/j.jht.2012.12.007

85 Musálek, M., Scharoun Benson, S. M., Lejcarova, A., & Bryden, P. J. (2020). Cross-lateralisation in children with attention-deficit/hyperactivity disorder and motor skill performance. *International journal of psychology : Journal international de psychologie*, *55*(6), 973–982. https://doi.org/10.1002/ijop.12658

86 Myer, G. D., Kushner, A. M., Brent, J. L., Schoenfeld, B. J., Hugentobler, J., Lloyd, R. S., Vermeil, A., Chu, D. A., Harbin, J., & McGill, S. M. (2014). The back squat: A proposed assessment of functional deficits and technical factors that limit performance. *Strength and conditioning journal*, *36*(6), 4–27. https://doi.org/10.1519/SSC.0000000000000103

87 Myers, T. W. (2014). *Anatomy trains. Myofascial Meridians for Manual and Movement Therapists*. Pp: 132. ISBN 978-0-7020-4654-4

88 Oh, S., Licari, M., Lay, B., & Blanksby, B. (2011). Effects of Teaching Methods on Swimming Skill Acquisition in Children with Developmental Coordination Disorder. *International Journal of Aquatic Research and Education*, 5(4), 432–448. DOI: 10.25035/ijare.05.04.09

89 Okano, A. H., Fontes, E. B., Montenegro, R. A., Farinatti, P., Cyrino, E. S., Li, L. M., Bikson, M., & Noakes, T. D. (2015). Brain stimulation modulates the autonomic nervous system, rating of perceived exertion and performance during maximal exercise. *British journal of sports medicine*, *49*(18), 1213–1218. https://doi.org/10.1136/bjsports-2012-091658

90 Park, S. B., Lee, B. C., & Jeong, K. S. (2007). Standardised tests of heart rate variability for autonomic function tests in healthy Koreans. *The International journal of neuroscience*, *117*(12), 1707–1717. https://doi.org/10.1080/00207450601050097

91 Patrick, S. K., Noah, J. A., & Yang, J. F. (2012). Developmental constraints of quadrupedal coordination across crawling styles in human infants. *Journal of neurophysiology*, *107*(11), 3050–3061. https://doi.org/10.1152/jn.00029.2012

92 Pecuch, A., Gieysztor, E., Telenga, M., Wolańska, E., Kowal, M., & Paprocka-Borowicz, M. (2020). Primitive Reflex Activity in Relation to the Sensory Profile in Healthy Preschool Children. *International journal of environmental research and public health*, *17*(21), 8210. https://doi.org/10.3390/ijerph17218210

93 Peterka, R. J. (2002). Sensorimotor Integration in Human Postural Control. *J Neurophysiol,* 88(3), 1097–1118. DOI: 10.1152/jn.2002.88.3.1097

94 Peterson, M. L., Christou, E., & Rosengren, K. S. (2006). Children achieve adult-like sensory integration during stance at 12-years-old. *Gait & posture*, *23*(4), 455–463. https://doi.org/10.1016/j.gaitpost.2005.05.003

95 Polimac, M., Vukadinovic, M., & Obradovic, J. (2013) Differences in motor abilities of children in relation to gender and age. *Exercise and quality of life.* 5(2), 28–33. UDC: 796.012.1-053.2

96 Polskaia, N., & Lajoie, Y. (2016). Reducing postural sway by concurrently performing challenging cognitive tasks. *Human movement science*, *46*, 177–183. https://doi.org/10.1016/j.humov.2015.12.013

97 Ponitz, C. E., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly.* 2008; 23:141–158. DOI: 10.1016/j.ecresq.2007.01.004

98 Psycharakis, S. G., & Sanders, R. H. (2010). Body roll in swimming: a review. *Journal of sports sciences*, *28*(3), 229–236. https://doi.org/10.1080/026404109 03508847

99 Rashikj-Canevska, O., & Mihajlovska, M. (2019) Persistence of primitive reflexes and associated problems in children. DOI: 10.37510/godzbo1972513rc

100 Renshaw, I. & Chow, J.-Y. (2019) A constraint-led approach to sport and physical education pedagogy. *Physical Education and Sport Pedagogy*, 24(2), 103–116, DOI: 10.1080/17408989.2018.1552676

101 Riewald, S., & Rodeo, S. (2015). Science of swimming faster. Human Kinetics Champaign, IL, 54–67. DOI: 10.1186/1471-2474-15-52 DOI: 10.1186/1471-2474-15-52

102 Rogers, J., & Révész, A. (2019). Experimental and quasi-experimental designs. *The Routledge Handbook of Research Methods in Applied Linguistics*. 133–141

103 Roy, J. S., Moffet, H., & McFadyen, B. J. (2008). Upper limb motor strategies in persons with and without shoulder impingement syndrome across different speeds of movement. *Clinical biomechanics (Bristol, Avon)*, *23*(10), 1227–1236.

104 Sanders, R. H. (2007). Kinematics, coordination, variability, and biological noise in the prone flutter kick at different levels of a "learn-to-swim" programme. *Journal of sports sciences*, *25*(2), 213–227. https://doi.org/10.1080/02640410600631025

105 Sanders, R. H., & Levitin, D. J. (2020). Towards an Understanding of Control of Complex Rhythmical "Wavelike" Coordination in Humans. *Brain sciences*, *10*(4), 215. https://doi.org/10.3390/brainsci10040215

106 Schnitzler, C., Seifert, L., Ernwein, V., & Chollet, D. (2008). Arm coordination adaptations assessment in swimming. *International journal of sports medicine*, *29*(6), 480–486. https://doi.org/10.1055/s-2007-989235

107 Schott, J. M., & Rossor, M. N. (2003). The grasp and other primitive reflexes. *Journal of neurology, neurosurgery, and psychiatry*, *74*(5), 558–560. https://doi.org/10.1136/jnnp.74.5.558

108 Seifert, L., Chollet, D., & Allard, P. (2005). Arm coordination symmetry and breathing effect in front crawl. *Human movement science*, *24*(2), 234–256. https://doi.org/10.1016/j.humov.2005.05.003

109 Sellers, W. I., & Hirasaki, E. (2018). Quadrupedal locomotor simulation: producing more realistic gaits using dual-objective optimisation. *Royal Society open science*, *5*(3), 171836. https://doi.org/10.1098/rsos.171836

110 Sharma, A., Ford, S & Calvet, J. (2014). Adaptation for life: a review of neonatal physiology. *Neonatal anaesthesia*, 15(3), 89–95. https://doi.org/10.1016/j.mpaic.2014.01.002

111 Sharma, A., Ford, S., & Calvert, J. (2008). Adaptation for life: a review of neonatal physiology. *Anaesthesia & Intensive Care Medicine, 12*, 85–90.

112 Shea, C. H., Buchanan, J. J., & Kennedy, D. M. (2016). Perception and action influences on discrete and reciprocal bimanual coordination. *Psychonomic bulletin & review*, *23*(2), 361–386. https://doi.org/10.3758/s13423-015-0915-3

113 Shlika, N. I. (2009). *Сердечный ритм и тип регуляции у детей, подростков и спортсменов*. Ижевск: Изд-во «Удмуртский университет», 2009. 259.

114 Shlyachkov, R. N. (2006). Методика ускоренного обучения плаванию детей младшего школьного возраста (кроль на груди; кроль на спине). Автореферат диссертации на соискание ученой степени кандидата педагогических наук. Тамбов – 2006. Retrieved from: http://nauka-pedagogika.com/pedagogika-13-00-04/dissertaciya-metodika-uskorennogo-obucheniya-plavaniyu-detey-mladshego-shkolnogo-vozrasta

115 Silveira, R. P., Souza Castro de, F. A., Figueiredo, P., Vilas-Boas, J. P., & Zamparo, P. (2017). The Effects of Leg Kick on Swimming Speed and Arm-Stroke Efficiency in the Front Crawl. *International journal of sports physiology and performance*, *12*(6), 728–735. https://doi.org/10.1123/ijspp.2016-0232

116 Skotáková, A., Vaculíková, P., Svobodová, L., Sebera, M. (2016). The persistent primary reflexes in school age children (6–11). *European Journal of Adapted Physical Activity, 9 (Suppl.) © European Federation of Adapted Physical Activity, 2016. Book of abstract. P.115.*

117 Sohn, M., Ahn, Y., Lee, S. (2011). Assessment of Primitive Reflexes in High-risk Newborns, *J Clin Med Res*, *3*(6), 285–290.

118 Solovjova, J. (2017). *Peldēšana*. LSFP sporta metodiskā literatūra. 53–78.lpp. ISBN 978-9934-19-237-1

119 Sortwell, A. D. (2011). Relationship between Stroking Parameters and Leg Movement Quantity in 100 Metre Front Crawl. *International journal of exercise science*, *4*(1), 22–29.

120 Sousa de, A. M., França Barros de, J., & Sousa Neto de, B. M. (2012). Postural control in children with typical development and children with profound hearing loss. *International journal of general medicine*, *5*, 433–439. https://doi.org/10.2147/IJGM.S28693

121 Sousa, A. S., Silva, A., & Tavares, J. M. (2012). Biomechanical and neurophysiological mechanisms related to postural control and efficiency of movement: a review. *Somatosensory & motor research*, *29*(4), 131–143. https://doi.org/10.3109/08990220.2012.725680

122 Sparrow, W. A., & Newell, K. M. (1998). Metabolic energy expenditure and the regulation of movement economy. *Psychonomic Bulletin & Review, 5*, 173–196.

123 Tierney, A. L., & Nelson, C. A., 3rd (2009). Brain Development and the Role of Experience in the Early Years. *Zero to three*, *30*(2), 9–13.

124 Verbecque, E., Vereeck, L., & Hallemans, A. (2016). Postural sway in children: A literature review. *Gait & posture*, *49*, 402–410. https://doi.org/10.1016/j.gaitpost.2016.08.003

125 Virag, B., Hibberd, E. E., Oyama, S., Padua, D. A., & Myers, J. B. (2014). Prevalence of freestyle biomechanical errors in elite competitive swimmers. *Sports health*, *6*(3), 218–224. https://doi.org/10.1177/1941738114527056

126 Vitali, R. V., Cain, S. M., Davidson, S. P., & Perkins, N. C. (2019). Human crawling performance and technique revealed by inertial measurement units. *Journal of biomechanics*, *84*, 121–128. https://doi.org/10.1016/j.jbiomech.2018.12.030

127 Waters, S., Wiestler, T., & Diedrichsen, J. (2017). Cooperation Not Competition: Bihemispheric tDCS and fMRI Show Role for Ipsilateral Hemisphere in Motor Learning. *The Journal of neuroscience: the official journal of the Society for Neuroscience*, *37*(31), 7500–7512. https://doi.org/10.1523/JNEUROSCI.3414-16.2017

128 Wagner, M. (2021). Applying the Divergent Component of Motion Method for Quadrupedal Locomotion to a Robot with Series Elastics Actuators. *Scientific work.* Available on https://elib.dlr.de/142011/1/Wagner %20Markus_Masterarbeit_fertig.pdf

129 Walliman, N. (2011). Research Methods the Basics. Routledge. Pp: 108. ISBN 0-203-83607-3. https://doi.org/10.4324/9780203836071

130 Weerdesteyn, V., Laing, A. C., & Robinovitch, S. N. (2008). Automated postural responses are modified in a functional manner by instruction. *Experimental brain research*, *186*(4), 571–580. https://doi.org/10.1007/s00221-007-1260-1

131 Whitall, J. (1991). The developmental effect of concurrent cognitive and locomotor skills: time-sharing from a dynamic perspective. *J Exp Child Psychol*, 51(2), 245–66. https://doi.org/10.1016/0022-0965(91)90035-Q

132 White, D. W., & Raven, P. B. (2014). Autonomic neural control of heart rate during dynamic exercise: revisited. *The Journal of physiology*, *592*(12), 2491–2500. https://doi.org/10.1113/jphysiol.2014.271858

133 Wilson, C., Simpson, S. E., Emmerik van, R. E., & Hamill, J. (2008). Coordination variability and skill development in expert triple jumpers. *Sports biomechanics*, *7*(1), 2–9. https://doi.org/10.1080/14763140701682983

134 Wulf, G., & Shea, C. H. (2002). Principles derived from the study of simple skills do not generalise to complex skill learning. *Psychonomic Bulletin & Review, 9*(2), 185–211. DOI: 10.3758/BF03196276

135 Zafar, H., Alghadir, A., & Anwer, S. (2018). Effects of Head-Neck Positions on the Hand Grip Strength in Healthy Young Adults: A Cross-Sectional Study. *BioMed Research International, 2018*. https://doi.org/10.1155/2018/7384928

136 Zafeiriou, D. (2004). Primitive reflexes and postural reactions in the neurodevelopmental examination. *Pediatr Neurol*, *31*(1), 1–8. DOI: 10.1016/j.pediatrneurol.2004.01.012

137 Zaina, F., Donzelli, S., Lusini, M., Minnella, S., & Negrini, S. (2015). Swimming and spinal deformities: a cross-sectional study. *The Journal of Pediatrics*, *166*(1), 163–167. https://doi.org/10.1016/j.jpeds.2014.09.024