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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Functional balance, motor competence and their relationship in children with cerebral palsy compared to typically developing children: A case-control study

Maurene Billen
Laure Fonteyn

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij kinderen

PROMOTOR :
dr. Evi VERBECQUE

BEGELEIDER :
Mevrouw Charlotte JOHNSON

2021
2022

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Functional balance, motor competence and their relationship in children with cerebral palsy compared to typically developing children: A case-control study

To what extent is functional balance affected in children with cerebral palsy between 5 and 10 years old, with a GMFCS level I-III, compared to their typically developing peers?

Are functional balance and motor competence interrelated? If yes, how strong is their relationship?

Highlights:

- Children with cerebral palsy (CP) have poorer functional balance compared to their typically developing (TD) peers.
- Children with CP show significantly poorer motor competence than TD children.
- Significant correlations between domains biomechanical constraints, transitions and anticipatory postural adjustments, reactive postural responses and the total score of the Kids-BESTest and the subscale locomotion and total score of the TGMD-3 were found, indicating it belongs to a distinct but similar construct.

Master 2 in Rehabilitation Sciences and Physiotherapy

2021-2022

Supervisor and mentor:

dr. Evi Verbecque

dra. Charlotte Johnson

Students:

Maurene Billen

Laure Fonteyn

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The authors would like to express their sincere acknowledgements to a few people. First, supervisor dr. Evi Verbecque to guide the authors through the process of accomplishing their master's thesis and mentor dra. Charlotte Johnson for recruiting and testing the participants and providing data to the authors. Also, Rehabilitation Research Center (REVAL) of the University of Hasselt, University Antwerp and Antwerp University Hospital for providing the necessary facilities. Finally, all the children and their family who participated in this study.

Wellen (BE), 06/06/2022 M. B.

Lommel (BE), 06/06/2022 L. F.

Research context

This duo master's thesis is part of the research domain of pediatric rehabilitation, which is part of REVAL (Rehabilitation Research Center). One of the main research goals of the cluster pediatric rehabilitation is to investigate underlying mechanisms of motor development which focuses on alignment, balance and postural control. The research project performed by dra. Charlotte Johnson (C.J.) fits within the central aim of this master's thesis. Dra. C.J. investigates the heterogeneity of balance control in children with developmental coordination disorder by comparing them to children with cerebral palsy (CP) and typically developing (TD) children.

Balance deficits can lead to limitations during functional tasks in daily life which can impact the child's activity and participation levels of functioning. Therefore, balance control is a common request for help in clinical practice. Currently, there are two main problems: 1) comprehensive testing is necessary to address the entire construct of balance control, i.e. a multi-systemic framework must be included in the testing, 2) targeted testing still does not happen routinely in practice. Usually, therapists administer balance tasks that are part of a global motor scale, which does not cover the framework sufficiently. Therefore, deficits are not always found and the problem is underestimated. This could have implications for targeted treatment.

One aim of this study was to investigate the differences in functional balance in children with CP compared to their TD peers, by comparing their performances on the Kids Balance Evaluation Systems Test (Kids-BESTest) which has a multisystemic character. The Kids-BESTest is a conceptual framework which evaluates all underlying systems of balance control (i.e. biomechanical constraints, limits of stability and verticality, anticipatory postural adjustments and transitions, reactive postural responses, sensory orientation and stability in gait) and therefore approximates its multisystemic nature. This is related to clinical relevance in rehabilitation because a specific intervention can be given if one has knowledge of the underlying disturbed balance control system. However, little research is done about this specific topic. Another aim of this study was to have a closer look at the functional level of the children during daily life activities, using the Test of Gross Motor Development, third edition (TGMD-3). Because balance control is a prerequisite for motor competence, the relationship between the domains of the Kids-BESTest and the subscales of the TGMD-3 is examined in this study. In this way it is possible to investigate if these tests belong to a distinct but similar construct.

This study is part of an ongoing PhD project funded by The Research Foundation - Flanders (FWO): “Understanding the heterogeneity of balance control in children with Developmental Coordination Disorder and its impact on motor performance: a synergistic approach using brain imaging, neuromechanics and functional assessments”. This PhD project is conducted by dra. C.J. with assistance of a team of supervisors: prof. dr. Ann Hallemans (UAntwerpen), prof. dr. Katrijn Klingels (UHasselt), prof. dr. Pieter Meyns (UHasselt), dr. Evi Verbecque (UHasselt). Project ID: 43498.

The introduction was written by student Maurene Billen (M.B.) and student Laure Fonteyn (L.F.) wrote the method. The test protocol was developed by dra. C.J. and her supervising team and subsequently the research question was formulated in consensus between M.B. and L.F. and their supervisor dr. Evi Verbecque. They also discussed what to do in case of missing data. M.B. selected the included participants based on their age and sex. The students thought independently about what kind of statistics should be used. Data were analyzed by L.F. using IBM SPSS Statistics (Version 28) predictive analytics software. Together they wrote down the results and discussion of the study. The conclusion and abstract was written by M.B.

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1. Abstract

Background: Children with cerebral palsy (CP) demonstrate disturbances in posture and movement, causing problems in functional balance (FB). Their FB has not been reported in the literature with the help of a comprehensive assessment tool that provides insights into deficient balance domains. The link between their FB and motor competence (MC) has not yet been investigated.

Objectives: The purpose of the study was to investigate differences in FB and MC in children with CP compared to TD peers and how these performances relate to each other.

Participants: Seven children with CP and 14 TD children participated. Children with a medical diagnosis of CP had a Gross Motor Function Classification System level I or II. Typical development was verified with the Movement Assessment Battery for Children - Second edition.

Measurements: All children performed the Kids Balance Evaluation Systems Test (Kids-BESTest) to investigate FB. MC was measured with the Test of Gross Motor Development, third edition (TGMD-3). Differences between groups were assessed with the Independent-Samples Mann-Whitney U Test and a Spearman's rho correlation coefficient was calculated to assess the relationships between FB and MC.

Results: Children with CP scored significantly poorer on all TGMD-3 subscales ($p=]0.001;0.031]$) and the total score ($p<0.001$) as well as all Kids-BESTest domain scores ($p=[0.002;0.031]$) and the total score ($p<0.001$), except for domain V. Significant correlations were found between domain scores I, III, IV and the total score of the Kids-BESTest and the subscale locomotion and the total score of the TGMD-3.

Conclusion: Children with CP perform significantly poorer on FB and MC than TD peers and FB and MC are related to each other. There also seems to be a relationship between locomotion and biomechanical constraints, anticipatory postural adjustments and reactive postural responses.

Key words: cerebral palsy; CP; balance control; assessment; functional balance; Kids-BESTest; motor competence; TGMD-3

2. Introduction

Cerebral palsy (CP) is one of the most common causes of motor impairment in children. This nonprogressive disease occurs in two to three out of 1000 live births (Tecklin, 2014). Due to brain injury, these children experience permanent disorders in the development of movement and posture. These are requirements when performing activities, causing limitations during gross motor skills that require balance (Liao & Hwang, 2003; Rosenbaum et al., 2007). Disturbed balance control leads to limitations during functional tasks in daily life which explains why children with CP experience difficulties at activity and participation level (Kembhavi et al., 2002).

Several frameworks were developed to understand balance control. For example, Shumway-Cook and Woollacott (2017) describe that there are three control mechanisms (steady-state, reactive and proactive balance control) and that it is the interaction between the body, the environment and the task that will ensure whether balance is maintained. Another point of view is to look at the characteristics of base of support and its predictability (Huxham et al., 2001). Horak et al. (2009) describe that there are many underlying mechanisms (biomechanical constraints, limits of stability and verticality, anticipatory postural adjustments and transitions, reactive postural responses, sensory orientation and stability in gait) that must be coordinated and work together to ensure adequate balance control, which emphasizes that balance is multisystemic.

CP is a very heterogeneous disorder with a large variety in the level of functioning which may also impact the degree to which these children present themselves with balance difficulties (Huang et al., 2014; Ju et al., 2010; Katz-Leurer et al., 2009; Soares et al., 2019). Depending on the severity of motor deficit, children require more or less aids to move around independently. Up to Gross Motor Function Classification System (GMFCS) level III, the children have the ability to stand independently without physical support of a caregiver (Gorter et al., 2009). As such, it is possible and plausible that not all children with CP will have a similar degree of balance control (Pavão et al., 2014). However, little research is available on functional balance in children with CP (Kembhavi et al., 2002; Seyyar et al., 2019).

In the study of Kiss et al. (2018) exclusively small-sized correlations between types of balance performance were revealed, indicating that balance control is task-specific. Therefore they recommend therapists to use a test battery rather than a single test for balance assessment.

Implementing various balance tasks into functional assessment results in more in-depth insights into the extent of the balance deficit (one system versus multiple systems or all systems deficient). The Kids Balance Evaluation Systems Test (Kids-BESTest) provides a unique opportunity for identifying functional balance deficits in children, covering the multi-systemic framework (R. Dewar et al., 2017, 2019). The test enables guidance in therapy and the opportunity for the therapist to focus more on the specific deficits in children with CP. The result is a therapy that is more efficient and aimed at improving functional balance within the specific problem areas of the Kids-BESTest (R. Dewar et al., 2014; Horak et al., 2009).

Balance control is a prerequisite for motor competence. Kwon and Ahn (2016) found that the Pediatric Balance Scale in children with CP had a positive correlation with different items of the Gross Motor Performance Measurement such as dissociated movement, alignment and stability. The link between fundamental movement skills and balance performance has not been established yet. Fundamental gross motor skills are needed for a child to participate in gymnastics class, to play on the playground or to engage during sports (Brian et al., 2018; Ulrich, 2017, 2020). A potential test for measuring this is the Test of Gross Motor Development, third edition (TGMD-3). The differences in motor performance, related to the features of the movement disorder in children with CP, have an influence on balance control ability to maintain stability (Kwon & Ahn, 2016).

Although children with CP experience balance deficits in daily activities, little research has been done into their functional balance (Kembhavi et al., 2002; Seyyar et al., 2019) and the extent to which this is disturbed, as well as the link with their motor competence. This study therefore aims to examine potential differences between children with CP and TD children in terms of functional balance, motor competence and their relationship. An answer to the following research questions will be sought: 1) To what extent is functional balance affected in children with CP between 5 and 10 years old, with a GMFCS level I-III, compared to their typically developing (TD) peers? and 2) Are functional balance and motor competence interrelated? If yes, how strong is their relationship? It is hypothesized that: 1) children with CP score significantly poorer on the Kids-BESTest, mainly on the domains that involve complex balance tasks such as anticipatory postural adjustments and transitions, reactive postural responses and stability in gait and 2) there is a positive correlation between functional balance and motor competence i.e. if a child has a poorer balance performance, his gross motor function is also poorer.

3. Method

The purpose of this case-control study was to reveal the deficient balance domains and motor competence in children with CP in comparison to their TD peers and to investigate a possible relationship between functional balance (Kids-BESTest) and motor competence (TGMD-3).

Approval for this research was given by the Ethics committee of Antwerp University Hospital, University Antwerp and the University of Hasselt (B300201941833). Before a child enrolled in the study, their parents or guardians gave their written informed consent and the child gave written assent. Both child and parents received information on the purpose and procedures of the research by letter (Appendix 8.1.).

3.1. Research question

1) To what extent is functional balance and motor competence affected in children with CP between 5 and 10 years old, with a GMFCS level I-III, compared to their TD peers?

2) Are functional balance and motor competence interrelated? If yes, how strong is their relationship?

3.2. Study design

3.2.1. Setting

Children between 5 and 10 years old were selected for this case-control study. They were recruited from schools in the vicinity of Antwerp and Hasselt. The recruitment of the children with CP was promoted via confirmed partnerships (Rehabilitation Centre for Children and Youth Pulderbos, Cerebral Palsy Reference Centre Antwerp (CePRA), COS Antwerp, Heder, Sint-Lodewijk in Wetteren, IEvzw and Sint-Gerardus in Diepenbeek). The children were recruited between May 2021 and March 2022 and the data were collected between August 2021 and March 2022.

The children were either tested at school, in the Multidisciplinary MOtor CEntre Antwerp (M^2OCEAN) lab of Antwerp University or in the gait lab of the faculty of Rehabilitation sciences of Hasselt University. The location depended on the possibilities of the parents/guardians.

3.2.2. Participants

The group of cases were defined as having a medical diagnosis of CP with a GMFCS level I, II or III, being able to stand for one minute and walk independently for six meters and to follow instructions given by the researchers. The control group consisted of TD children. Typical development was confirmed through a general questionnaire and the child's result on the Movement Assessment Battery for Children – Second Edition (MABC-2). Children were excluded from the study - in the TD group if they 1) obtained a score on the MABC-2 less than percentile 25, 2) had any medical or behavioral disorder that could impede motor functioning or balance performance, or 3) were born prematurely (≤ 37 weeks).

The study population consisted of a convenience sample. To minimize the risk of selection bias, the researcher performed a targeted sample strategy to enhance heterogeneity and variability within the study sample.

The choice for a case-control study is because the researchers want to reveal possible differences in functional balance and motor competence in children with CP compared to their healthy peers (TD). The TD children and children with CP were matched for age and sex according to a ratio of 2:1. When multiple controls are used for each case, power increases strongly. However, little additional power is gained at ratios higher than 4:1 (Woodward, 1999).

To ensure a probability (power) of 80% each group had to consist of 36 children, considering a drop-out rate of 20%. The statistical power is based on the request of dra. Charlotte Johnson to The Research Foundation – Flanders (FWO). In this study the researchers tried to conduct a first analysis of the preliminary results because it was only possible to collect data of 21 children in the time frame of this master's thesis.

3.3. Outcome assessment

3.3.1. Motor performance tests

The MABC-2 ascertained typical motor development for the TD group and therefore served as a screening tool. The TGMD-3 was applied to assess motor competence in all children.

3.3.1.1. The MABC-2

The MABC-2 is a norm-referenced developmental motor scale. The test consists of three domains: *manual dexterity* (3 items), *aiming and catching* (2 items) and *balance* (3 items).

Each domain consists of age-specific items. There are three age bands defined: 3-6, 7-10 and 11-16 years old. Component scores and a total score are determined using the raw scores. Percentiles at or above 25 are considered to represent typical motor development. The reliability and validity of the Dutch version is sufficient to good. Good preparation and preferably training of the test administrators is highly recommended (Griffiths et al., 2018; Smits-Engelsman, 2010).

3.3.1.2. The TGMD-3

To have a closer look at the functional level of the children during daily life activities, the TGMD-3 is used. This test focuses specifically on fundamental gross motor skills that a child needs to participate in gymnastics class, to play on the playground or to engage during sports. This is a standardized observational, process-oriented, norm- and criterion-referenced skill assessment tool, evaluating gross motor competence in children from 3 to 10 years old. It consists of two subscales: *locomotion* and *ball skills*. The test assesses the child's movement patterns regarding running, jumping and throwing. The raw score can be converted to standard scores or percentiles rank scores. This assessment is valid and reliable for assessing children's gross motor development (Brian et al., 2018; Ulrich, 2017, 2020; Ulrich & Webster, 2016; Valentini et al., 2021; Webster & Ulrich, 2017).

3.3.2. Balance performance test

Balance performance was assessed with the Kids-BESTest.

3.3.2.1. The Kids-BESTest

The Kids-BESTest is a criterion-referenced assessment tool which exists of six domains: *biomechanical constraints* (domain I), *limits of stability and verticality* (domain II), *anticipatory postural adjustments and transitions* (domain III), *reactive postural responses* (domain IV), *sensory orientation* (domain V) and *stability in gait* (domain VI). Each item is scored on a four-point ordinal rating scale where a score of zero means impossible to perform and a score of three equals a perfect performance (Dewar et al., 2017, 2019; R. M. Dewar, Tucker, Claus, van den Hoorn, et al., 2021; R. M. Dewar, Tucker, Claus, Ware, et al., 2021). In this study the extended, age-specific Kids-BESTest version is used, which consists of 5 age-bands: age 5, 6, 7, 8-10 and 11-14. The scoring-criteria are age-adjusted to allow for submaximal performance in case of TD, increasing the test's sensitivity in identifying balance deficits. This version is still in development and not yet published. Therefore, Appendix 8.2. contains one example of this

version. The scores of the Kids-BESTest are presented as raw scores and as percentages of the maximum score of corresponding domain or total score. Preliminary unpublished analyses show that the extended age-specific version of the Kids-BESTest is reliable. Its validity still needs to be established.

3.4. Procedure

3.4.1. Screening

All parents/guardians, regardless of the group that the child belonged to, filled in a general questionnaire about the pregnancy, birth, early motor milestones and medical history of their child (Appendix 8.3.). The case group was screened for a medical diagnosis of CP, confirmed by a neurologist, with a GMFCS level I-III. Children in the control group were screened with the MABC-2 to verify typical motor development.

3.4.2. Assessment

The generic questionnaire was administered by phone or online, depending on the preference of the parents. To minimize the impact of fatigue or reduced attention because of prolonged testing, the entire protocol was administered either in one day with sufficient rest periods or spread over two days. The latter depended on the setting where the tests were administered and/or the preferences of the parents and the child. The protocol consisted of mapping demographic characteristics, motor performance tests (MABC-2 and TGMD-3) and a balance performance test (Kids-BESTest). The MABC-2 was exclusively administered in TD children to ascertain typical motor development. The investigator collected biomechanical (accelerometers) and electromyographic data (EMG-sensors) and registered the brain activity of the child (fNIRS) during specific items of the Kids-BESTest. Each test, examination or questionnaire was administered once, except for EMG, accelerometry and fNIRS which contained five trials each to have enough repetitions.

During the test session only the child, the researcher (C.J.) and one or two students, depending on the need, were present in the room to assist the researcher. When a child was giving the impression of being less concentrated, the investigator asked if he or she needed a short break. A break was allowed at any time during the test administration if requested by the child. All examinations and tests were performed by the same researcher.

Test administration took place barefoot (Kids-BESTest) and with sports shoes (MABC-2, TGMD-3), children were not allowed to wear any orthoses. If a child met the inclusion criteria, his height and weight were documented before starting the assessments.

3.5. Data-analysis

Students (M.B. and L.F.) were involved in scoring the performances of the Kids-BESTest of the children. All performances were scored independently using video recordings. Afterwards, consensus was made for the final scoring sheet used for statistical analysis.

Percentages per domain (Kids-BESTest) and subscale (TGMD-3) were calculated as well as the total percentage for all domains and subscales by means of the formula '(number of points obtained / maximum number of points to be obtained) * 100)'. Missing data in case of unclear video footage that would make scoring unreliable, was corrected by removing the item score from the domain score. For example, if one item of ‘domain I’ could not be scored, resulting in missing data, the domain score would be 12 instead of 15.

3.6. Statistical analysis

To check if the data were normally distributed, the Kolmogorov-Smirnov test was performed in IBM SPSS Statistics (Version 28) predictive analytics software. Because only some variables were normally distributed and sample sizes were small (CP $n = 7$; TD $n = 14$ and thus < 30) nonparametric statistics were selected.

The Independent-Samples Mann-Whitney U Test was applied to compare both baseline characteristics (age, body weight, body length, body mass index and gestational age), total and domain scores of the Kids-BESTest and total and subscale scores of the TGMD-3 between both groups (TD and CP children). The significance level was set at $p < 0.05$. To investigate the relationship between balance performance and motor competence, a Spearman’s rho correlation coefficient was calculated. A correlation was (very) strong if the coefficient is greater than 0.75, moderate to good between 0.50 and 0.75, fair between 0.25 and 0.50 and (very) weak if less than 0.25 (Portney & Watkins, 2015). If a correlation was positive this represented a higher score on both the Kids-BESTest and the TGMD-3.

4. Results

4.1. Participants

Fourteen TD children and seven children with CP were included in this study. The TD children were randomly matched from a dataset of 37 participants with the CP children for sex and age. Only data for CP children with a GMFCS level I (n = 3) and II (n = 4) were available. One of them had diplegia with a more affected left side, two had quadriplegia with a more affected right side and four of the CP children had hemiplegia, two of which were left sided and two were right sided.

Details about these demographic characteristics can be found in Table 1. The groups were similar except for body length ($p = 0.019$) and gestational age ($p = 0.006$) (Table 1).

4.2. Functional balance

The children with CP performed significantly poorer on the *total score* of the Kids-BESTest compared to their TD peers ($p < 0.001$). *All domain scores*, except for *domain V* ($p = 0.322$), were significantly ($p = [0.002;0.031]$) poorer in the group of children with CP. The results are presented in Table 2 and Figure 1.

4.3. Motor competence

The Mann-Whitney U Test proved that all components of the TGMD-3 were significantly different between the CP and TD children: the subscale *locomotion* ($p < 0.001$), the subscale *ball skills* ($p = 0.031$) and the *total score* of the TGMD-3 ($p < 0.001$) (Table 3).

4.4. Relationship between functional balance and motor competence

A significant correlation was found between the subscale *locomotion* and *domain I* ($r = 0.63$, $p = 0.002$), *domain III* ($r = 0.49$, $p = 0.025$), *domain IV* ($r = 0.61$, $p = 0.003$) and the *total score* ($r = 0.72$, $p < 0.001$) of the Kids-BESTest. The correlation analysis demonstrated a significant correlation between the *total score* of the TGMD-3 and *domain I* ($r = 0.62$, $p = 0.003$), *domain III* ($r = 0.45$, $p = 0.042$), *domain IV* ($r = 0.45$, $p = 0.042$) and the *total score* ($r = 0.63$, $p = 0.002$) of the Kids-BESTest. An overview of the correlation coefficients and their significance is presented in Table 4. No significant correlations were found between the results on the subscale *ball skills* of the TGMD-3 and *any domain* nor the *total score* of the Kids-BESTest.

Table 1

Overview of the Population- and Demographic Characteristics

	Control group: TD (N = 14)					Case group: CP (N = 7)					p-value
	N	Median	IQR	Min	Max	N	Median	IQR	Min	Max	
Age (years)	14	7.51	2.30	5.60	9.30	7	7.75	1.90	5.80	8.70	0.971
Female	5					2					
Male	9					5					
BMI (kg/m²)	13	15.46	2.80	13.80	18.80	7	14.40	3.20	13.20	20.10	0.351
Body weight (kg)	14	26.85	5.10	23.00	33.00	7	22.50	8.00	18.50	35.50	0.056
Body length (cm)	13	133.50	11.00	119.00	144.00	7	125.00	6.50	113.50	133.00	0.019*
Gestational age (weeks)	14	40.00	1.50	38.10	41.30	7	29.57	10.70	28.00	41.00	0.006**
Affected side:											
Hemiplegia L						2					
Hemiplegia R						2					
Diplegia L						1					
Quadriplegia R						2					
GMFCS I						3					
GMFCS II						4					

Note. * p<0.05; ** p<0.01; BMI: Body Mass Index; CP: cerebral palsy; GMFCS: Gross Motor Classification System; IQR: interquartile range; L: left; Max: maximum; Min: minimum; R: right; TD: typically developing children

Table 2

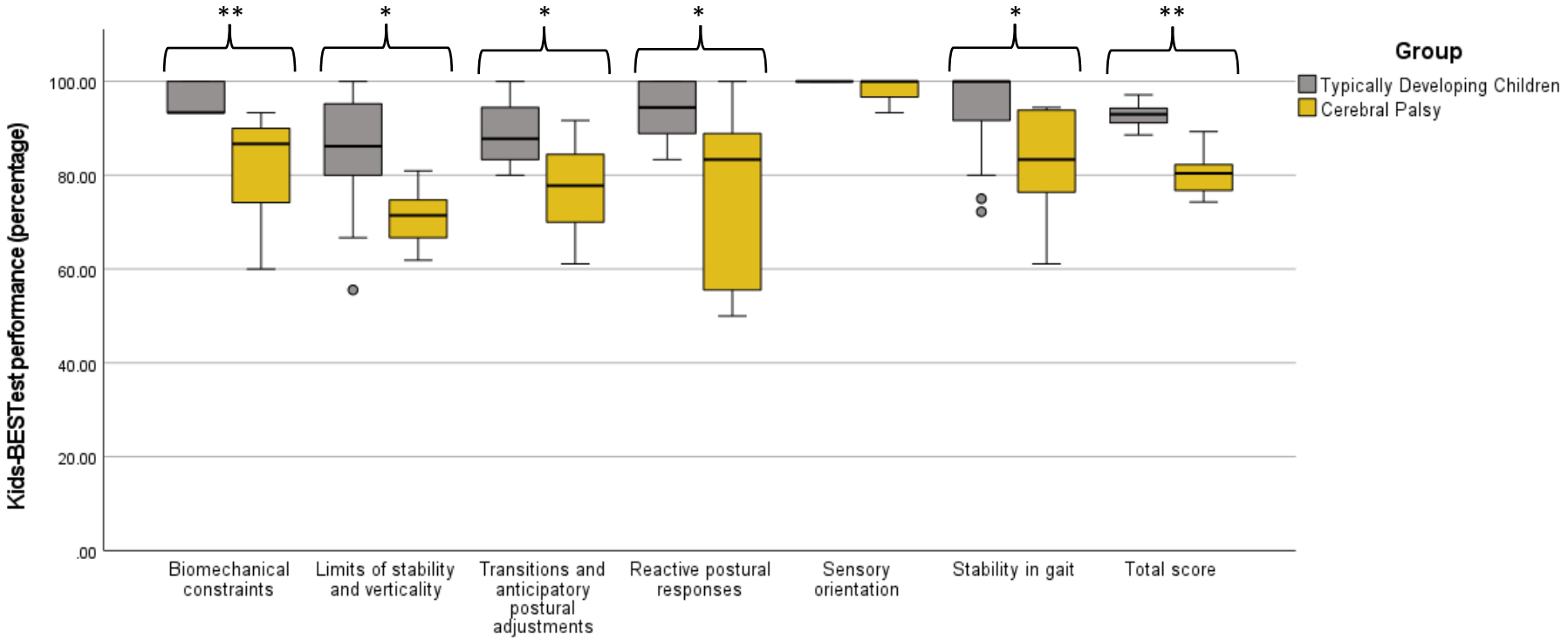
Overview of the Child's Performances (Percentages) on the Kids-BESTest

Domains Kids-BESTest	TD (N = 14)				CP (N = 7)				p-value
	Median	IQR	Min	Max	Median	IQR	Min	Max	
Biomechanical constraints	93.33	6.67	93.33	100.00	86.67	20.00	60.00	93.33	0.002**
Limits of stability and verticality	86.19	16.91	55.56	100.00	71.43	9.52	61.90	80.95	0.016*
Transitions and anticipatory postural adjustments	87.78	12.50	80.00	100.00	77.78	22.22	61.11	91.67	0.020*
Reactive postural responses	94.44	11.11	83.33	100.00	83.33	38.89	50.00	100.00	0.025*
Sensory orientation	100.00	0.00	100.00	100.00	100.00	6.67	93.33	100.00	0.322
Stability in gait	100.00	11.25	72.22	100.00	83.33	19.44	61.11	94.44	0.031*
Total score	93.00	3.36	88.57	97.14	80.39	6.99	74.29	89.29	< 0.001**

Note. * p<0.05; ** p<0.01; CP: cerebral palsy; IQR: interquartile range; Kids-BESTest: Kids Balance Evaluation Systems Test; Max: maximum; Min: minimum; TD: typically developing children

Figure 1

Boxplot of the Children's Performances on the Kids-BESTest



Note. * p<0.05; ** p<0.01; Kids-BESTest: Kids Balance Evaluation Systems Test

Table 3

Overview of the Child's Performances (Scale Scores) on the TGMD-3

Subscales TGMD-3	TD (N = 14)				CP (N = 7)				p-value
	Median	IQR	Min	Max	Median	IQR	Min	Max	
Locomotion	9.00	2.00	7.00	11.00	2.00	4.00	1.00	7.00	< 0.001**
Ball skills	8.00	3.00	5.00	10.00	6.00	2.00	1.00	8.00	0.031*
Total score	17.00	4.00	12.00	20.00	9.00	4.00	2.00	12.00	< 0.001**

Note. * p<0.05; ** p<0.01; CP: cerebral palsy; IQR: interquartile range; Max: maximum; Min: minimum; TD: typically developing children; TGMD-3: Test of Gross Motor Development, third edition

Table 4

Correlations Between the Domains of the Kids-BESTest and the Subscales of the TGMD-3

Domains Kids-BESTest	Subscales TGMD-3		
	Locomotion	Ball skills	*Total score*
Biomechanical constraints	0.63**	0.34	0.62**
Limits of stability and verticality	0.41	0.28	0.38
Transitions and anticipatory postural adjustments	0.49*	0.22	0.45*
Reactive postural responses	0.61**	0.01	0.45*
Sensory orientation	0.34	0.34	0.39
Stability in gait	0.22	0.16	0.22
Total score	0.72**	0.31	0.63**

Note. * p<0.05; ** p<0.01; Kids-BESTest: Kids Balance Evaluation Systems Test; TGMD-3: Test of Gross Motor Development, third edition

5. Discussion

5.1. Reflection on answers on research question

The aim of the study was to examine potential differences in functional balance (Kids-BESTest) and motor competence (TGMD-3) between children with CP and TD children and how these performances relate to each other. Our results showed that children with CP performed significantly poorer on *all domains* of the Kids-BESTest, except for domain V (*sensory orientation*) and had poorer TGMD-3 *subscale* and *total scores*. These results indicate that motor competence and all balance domains, apart from domain V, are deficient in children with CP. Furthermore, the children's motor competence was related to their balance performance. Higher scores on the Kids-BESTest indicate better motor competence and vice versa. These findings could be a possible explanation for the balance problems that they experience during their daily life as good results on all domains of the Kids-BESTest are the condition to achieve appropriate functional balance.

5.1.1. Balance performance

Domain II (*limits of stability and verticality*) comprises test items requiring sufficient internal representation and perception of verticality (Horak, 2006). Di Vita et al. (2020) showed that body structural representation (a topographic map of the different body parts) and body scheme (arising from sensory-motor information leading to action planning and execution) are poorer in children with CP compared to TD children. This may explain why children with CP performed significantly poorer than TD children on this domain. Especially, when reaching or leaning too far thereby evoking signs of instability suggests their internal representation is insufficient. When they would have reached or leaned without any signs of instability but less far, this would indicate that they are aware of their limits of stability but do not have sufficient control to go further. This may be caused by insufficient muscular strength or joint mobility or the presence of spasticity. Indeed, previous research in children with CP has shown that they could have a smaller range of motion in their shoulders and trunk (Soares et al., 2019). It can also be due to poor dynamic postural control which could be caused by high levels of co-activation, abnormal muscle recruitment or a different sequence in muscle recruitment which are associated with the upper motor neuron lesion (Bigongiari et al., 2011; Pavão et al., 2013).

In domain III (*anticipatory postural adjustments and transitions*), transitions from one posture to the next and anticipatory postural adjustments are assessed, requiring an efficient feedforward mechanism. This will help to make an adequate motor plan to prepare our body for the movement. As hypothesized, significantly poorer scores were also seen in this domain for children with CP compared to their TD peers. In particular, the one leg stance seems to be more difficult for children with CP. Only a limited studies have investigated this aspect of balance control in children with CP. Nevertheless, they all conclude the same: these children do have problems with pre-tensioning the muscles during any task. As a result, a reactive correction is required which manifests itself in signs of instability, such as using their arms to regain their balance (Bigongiari et al., 2011; Girolami et al., 2011; Liu et al., 2007; Tomita et al., 2013, 2016).

Domain IV (*reactive postural responses*) evaluates the automatic movement patterns and strategies that a child uses when balance is suddenly disturbed. As hypothesized, children with CP showed significantly poorer reactive balance than TD children. This was shown by stepping responses when a hip strategy was expected (small perturbation) and multiple steps or even a need for assistance instead of a single step (large perturbation). These findings suggest that their postural emergency back-up system is insufficient, and may explain why falls occur more frequently in children with CP. In real-life, when children lose their balance during ADL, they need to depend upon their reactive control as well. If this does not work up to standard, they will fall. Although no records are available in children with CP on functional assessment of the reactive system, several force plate studies have been performed (Burtner et al., 2007; Chen & Woollacott, 2007; Woollacott & Shumway-Cook, 2005), all confirming our findings. Chen & Woollacott (2007) did a kinetic analysis of the reactive postural adjustments in children with CP and TD children. They discovered that children with CP were more likely to show a stepping strategy at a slower velocity (force plate) than their TD peers or TD younger children at the same velocity. This is confirmed by Burtner et al. (2007). They also found that children with CP lose their balance more often (% of the trials). In another study on reactive balance children with CP demonstrated less efficiency concerning their reactive balance, evidenced by an increased sway while recovering balance, a longer duration until balance is recovered and a delayed activation of the ankle muscles (Woollacott & Shumway-Cook, 2005). Apart from the insufficient movement strategies, other disease-specific factors may be in play as well, such

as spasticity since reactive balance requires a quick and sudden adjustment of movement which can be complicated by the spasticity of the child.

The items in domain VI (*stability in gait*) are used to assess stability in different walking tasks. Walking with head turns, pivot turn and the Timed Up and Go test with a cognitive dual task are age-dependent and therefore not performed by all children. All children did perform the items level walking, changing gait speed, obstacle crossing and the Timed Up and Go test. As hypothesized, children with CP showed significantly poorer stability in gait than TD children. The children with CP showed a mildly deviant gait pattern accompanied by occasional, repeated or even constant signs of instability. These tasks all require anticipatory postural adjustments to some degree, which could serve as a possible explanation as shown by the significant differences in domain III scores between both groups. Furthermore, previous research into obstacle crossing and changing gait speed indeed showed that children with CP can cross obstacles and change gait speed, but do so with increased signs of instability. This manifested in a broadened step width, adapted gait visible as altered trunk and pelvis movement and smaller steps (Cappellini et al., 2020; Malone et al., 2016; Law & Webb, 2007; Davids et al., 2019). Besides, a poorer reactive balance can contribute to the problems with gait which is reflected in the results of this study concerning domain IV (*reactive postural adjustments*) and confirmed by Woollacott & Shumway-Cook (2005), who emphasize the importance of reactive balance to successfully perform functional tasks such as walking.

Although domain I (*biomechanical constraints*) does not assess a balance system, it does play an important role as a confounding factor for balance control, since it evaluates the presence of biomechanical constraints such as strength, alignment and range of motion (ROM). Therefore, this domain can negatively affect the other domains of the Kids-BESTest and may be a possible explanation for a poorer score on these domains. Children with CP scored significantly poorer on domain I. CP, the disease itself, leads to primary, secondary and tertiary problems. Primary problems are related to the neuronal lesion, secondary problems are a result of the primary problems (in combination with growth and lack of normal movement) and tertiary problems are the coping responses used to overcome the primary and secondary problems. For instance, a lack of muscle strength is a primary problem and is tested in domain I (A. Van Campenhout, personal communications, November 1 2021). In addition, spasticity, weaker muscle strength and passive stiff contractures can also have an impact on the

performance (Koman et al., 2004). For these reasons, the degree of a qualitative performance may be lesser in a child with CP. These problems are due to the disease and are not present in TD children.

Finally, in contrast to our expectations, domain V scores (*sensory orientation*) of the Kids-BESTest did not significantly differ between both groups. A possible explanation is that only children with GMFCS level I and II were included in this study whose sensory skills may be less severely affected. Nevertheless, a lot of research has been done on sensory processing in children with CP. It is proven that they experience disturbances in the processing of sensory information. Children with CP have problems with the registration and modulation of sensory information and with organizing the afferent inputs to ensure adaptive behavior for successfully accomplishing their daily activities (Pavão & Rocha, 2017). Maybe a ceiling effect for this domain for the children with a GMFCS level I and II is present, but this is not to be expected because all children with CP have sensory problems. However, a more plausible explanation is that the foam (AIREX®) on which the children were standing, is not sufficiently compressible to provoke balance disturbances as opposed to the NeuroCom® foam pad (Verbecque et al., 2016).

5.1.2. Motor competence and its relationship with balance performance

The correlation analysis between the results on the Kids-BESTest and TGMD-3 revealed significant correlations between domain I (*biomechanical constraints*), III (*transitions and anticipatory postural adjustments*), IV (*reactive postural responses*), the *total score* of the Kids-BESTest and the subscale *locomotion* and *total score* of the TGMD-3. This can be explained by the underlying constructs measured with these tests. The Kids-BESTest evaluates functional balance and the TGMD-3 evaluates the gross motor skills in children (*locomotion* and *ball skills*). Balance control is often seen as a requisite for gross motor skill development and has been called “the shadow of motor development” (Liao & Hwang, 2003; Pavão et al., 2014; Overlock & Yun, 2006; Kwon & Ahn, 2016). The significant correlations were positive indicating a relationship between both constructs. To establish whether balance performance can predict the degree of motor competence a regression analysis would be required. However, the small sample did not allow this type of analysis and could provide additional insights into this relationship in future research. Overall balance performance correlates good to motor

competence, indicating it belongs to a distinct but similar construct; whereas specific domain scores showed less strong correlations, indicating they are still related, but less similar.

No correlation was found between subscale *ball skills* of the TGMD-3 and *any of the domains* or *total score* of the Kids-BESTest, indicating they measure a different construct. However, in the study of Van Waelvelde et al. (2014) it was found that the *balance subscore* of the MABC correlates significantly but mildly with the Ball Catching Test (BCT) for mild impaired children aged between 7 and 9 years old, none of whom have a specific diagnosis. More detailed, the item *standing on one leg* of the MABC correlates significantly with the BCT in 7-9-year-olds and the item *balance in walking* correlates significantly with the BCT in 9-year-old children. There may be stronger correlations between the BCT and MABC in children with CP as they have a more severe disability than the participants in the study of Van Waelvelde et al. (2014). To investigate this, one should look within the subgroup CP alone and with a larger sample size.

5.2. Reflection on the strengths and weaknesses of the study

There were missing data for both the demographic characteristics and the items of the Kids-BESTest. For one child in the TD group there was no data for body length (BL) and consequently no BMI could be calculated. The missing data of the Kids-BESTest was only minor (n = 7 data points). This can be explained by the filming perspective hampering objective scoring. These missing data were not a problem because it is to be expected that if a child generally has problems with a certain balance domain, this will be manifested in all item scores of the domain and consequently the domain itself.

Only children with GMFCS level I, II and III were included in this research because a minimal requirement was that the child was able to stand and walk without the help of others. A level IV on the GMFCS corresponds to a child with CP that has a severely impaired walking ability even with assistive devices and uses most of the time a (powered) wheelchair. Thus, children with a level IV and V were not able to fulfill this criterion. Only children with a GMFCS level I and II participated in this research but this was a coincidence. Consequently, no conclusions made in this study are directly applicable to children with CP GMFCS level III (Cerebral Palsy Alliance Research Foundation - USA, 2018).

This study focused on children between 5 and 10 years of age and a GMFCS level I-III. However, no statement can be made about 10-year-olds and children with a GMFCS level III because these were not part of the examined data. The age and GMFCS range about which something can be said is therefore smaller than the ones in the predetermined research question.

Children of both groups were matched on age and sex to obtain two homogeneous groups at baseline for these characteristics and minimize the risk of bias. The baseline characteristics between the children with CP and typical development were the same except for body length and gestational age. The CP children were significantly smaller than the TD children and were born significantly earlier. The significantly lower gestational age can be explained by the risk of CP increasing more in children born (to) early/prematurely than in children born at their due date (Himpens et al., 2008).

The parents of the children with CP were asked if their child was wearing ankle-foot orthoses (AFOs) or other orthotic devices while walking during the day but they were not allowed to do so during the test sessions. The purpose of the study was to measure the capacity of the children with CP concerning functional balance and AFOs could bias this measurement as they provide stability to the ankle-foot segment.

5.3. Recommendations for further research

Significant correlations were not found for all domains of the Kids-BESTest and the subscale *locomotion* and the *total score* of the TGMD-3. Some correlations were borderline insignificant. There is a suspicion that there could be significant correlations between all domains if the sample sizes were larger. To find out which domains would also correlate, this should be investigated in future similar studies, but with a larger sample size.

Unpublished research shows that the severity of the movement disorders tends to affect the degree of balance control. Therefore, future research should disentangle the extent to which the severity of the functional deficit in children with CP is related to the severity of the underlying balance deficit, i.e. difficulties in one or more domains and how they relate to or predict each other.

In this study correlations between the two tests were examined with data from children with CP and TD children combined. It would be interesting to investigate these correlations in the subgroups (CP vs TD) as well, but this requires a larger sample.

6. Conclusion

Children with CP and a GMFCS level I or II perform significantly poorer on functional balance tasks and motor competence compared to TD peers. Significant correlations were found between overall functional balance and specific balance components of the Kids-BESTest, i.e. *biomechanical constraints* (e.g. range of motion), *transitions and anticipatory postural adjustments* (e.g. alternate stair touch) and *reactive postural responses* (e.g. compensatory stepping correction), and motor competence, i.e. the subscale *locomotion* and the *total score* of the TGMD-3. Most of these correlations were moderate to good. Future similar studies, consisting of larger samples with a larger age range and including GMFCS level III as well, need to confirm these findings and should investigate if other domains would also correlate.

7. References

Bigongiari, A., de Andrade E Souza, F., Franciulli, P. M., Neto, S. E. R., Araujo, R. C., & Mochizuki, L. (2011). Anticipatory and compensatory postural adjustments in sitting in children with cerebral palsy. *Human Movement Science, 30*(3), 648–657. https://doi.org/10.1016/j.humov.2010.11.006

Brian, A., Taunton, S., Lieberman, L. J., Haibach-Beach, P., Foley, J., & Santarossa, S. (2018). Psychometric Properties of the Test of Gross Motor Development-3 for Children With Visual Impairments. *Adapted Physical Activity Quarterly, 35*(2), 145–158. https://doi.org/10.1123/apaq.2017-0061

Burtner, P. A., Woollacott, M. H., Craft, G. L., & Roncesvalles, M. N. (2007). The capacity to adapt to changing balance threats: A comparison of children with cerebral palsy and typically developing children. *Developmental Neurorehabilitation*, *10*(3), 249–260. https://doi.org/10.1080/17518420701303066

Cappellini, G., Sylos-Labini, F., MacLellan, M. J., Assenza, C., Libernini, L., Morelli, D., Lacquaniti, F., & Ivanenko, Y. (2020). Locomotor patterns during obstacle avoidance in children with cerebral palsy. *Journal of Neurophysiology*, *124*(2), 574–590. https://doi.org/10.1152/jn.00163.2020

Cerebral Palsy Alliance Research Foundation - USA. (2018). *Gross Motor Function Classification System (GMFCS) | Cerebral Palsy Alliance Research Foundation - USA*. Cerebral Palsy Alliance Research Foundation (CPARF). Retrieved 2 May 2022, from https://cparf.org/what-is-cerebral-palsy/severity-of-cerebral-palsy/gross-motor-function-classification-system-gmfcs/

Chen, J., & Woollacott, M. H. (2007). Lower Extremity Kinetics for Balance Control in Children With Cerebral Palsy. *Journal of Motor Behavior*, *39*(4), 306–316. https://doi.org/10.3200/jmbr.39.4.306-316

Davids, J. R., Cung, N. Q., Chen, S., Sison-Williamson, M., & Bagley, A. M. (2019). Control of Walking Speed in Children With Cerebral Palsy. *Journal of Pediatric Orthopaedics*, *39*(8), 429–435. https://doi.org/10.1097/bpo.0000000000000978

Dewar, R., Claus, A. P., Tucker, K., Ware, R. S., & Johnston, L. M. (2019). Reproducibility of the Kids-BESTest and the Kids-Mini-BESTest for Children With Cerebral Palsy. *Archives of Physical Medicine and Rehabilitation, 100*(4), 695–702. https://doi.org/10.1016/j.apmr.2018.12.021

Dewar, R., Claus, A., Tucker, K., Ware, R., & Johnston, L. (2017). Reproducibility of the Balance Evaluation Systems Test (BESTest) and the Mini-BESTest in school-aged children. *Gait & Posture, 55,* 68–74. https://doi.org/10.1016/j.gaitpost.2017.04.010

Dewar, R., Love, S., & Johnston, L. M. (2014). Exercise interventions improve postural control in children with cerebral palsy: a systematic review. *Developmental Medicine & Child Neurology, 57*(6), 504–520. https://doi.org/10.1111/dmcn.12660

Dewar, R. M., Tucker, K., Claus, A. P., van den Hoorn, W., Ware, R. S., & Johnston, L. M. (2021). Evaluating validity of the Kids-Balance Evaluation Systems Test (Kids-BESTest) Clinical Test of Sensory Integration of Balance (CTSIB) criteria to categorise stance postural control of ambulant children with CP. *Disability and Rehabilitation*, 1–8. https://doi.org/10.1080/09638288.2021.1887374

Dewar, R. M., Tucker, K., Claus, A. P., Ware, R. S., & Johnston, L. M. (2021). Postural Control Performance on the Functional Reach Test: Validity of the Kids-Balance Evaluation Systems Test (Kids-BESTest) Criteria. *Archives of Physical Medicine and Rehabilitation, 102*(6), 1170–1179. https://doi.org/10.1016/j.apmr.2020.12.018

di Vita, A., Cinelli, M. C., Raimo, S., Boccia, M., Buratin, S., Gentili, P., Inzitari, M. T., Iona, T., Iosa, M., Morelli, D., Ruggeri, F., Russo, G., Guariglia, C., & Palermo, L. (2020). Body Representations in Children with Cerebral Palsy. *Brain Sciences, 10*(8), 490. https://doi.org/10.3390/brainsci10080490

Girolami, G. L., Shiratori, T., & Aruin, A. S. (2011). Anticipatory postural adjustments in children with hemiplegia and diplegia. *Journal of Electromyography and Kinesiology, 21*(6), 988–997. https://doi.org/10.1016/j.jelekin.2011.08.013

Gorter, J. W., van Tol, E., van Schie, P., & Ketelaar, M. (2009). Gross Motor Function Classification System Expanded and Revised. Retrieved from https://www.netchild.nl

Griffiths, A., Toovey, R., Morgan, P. E., & Spittle, A. J. (2018). Psychometric properties of gross motor assessment tools for children: a systematic review. *BMJ Open, 8*(10), 1–14. https://doi.org/10.1136/bmjopen-2018-021734

Himpens, E., van den Broeck, C., Oostra, A., Calders, P., & Vanhaesebrouck, P. (2008). Prevalence, type, distribution, and severity of cerebral palsy in relation to gestational age: a meta-analytic review. *Developmental Medicine & Child Neurology, 50*(5), 334–340. https://doi.org/10.1111/j.1469-8749.2008.02047.x

Horak, F. B. (2006). Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and Ageing, 35*(suppl_2), ii7–ii11. https://doi.org/10.1093/ageing/afl077

Horak, F. B., Wrisley, D. M., & Frank, J. (2009). The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits. *Physical Therapy, 89*(5), 484–498. https://doi.org/10.2522/ptj.20080071

Huang, P. C., Pan, P. J., Ou, Y. C., Yu, Y. C., & Tsai, Y. S. (2014). Motion analysis of throwing Boccia balls in children with cerebral palsy. *Research in Developmental Disabilities, 35*(2), 393–399. https://doi.org/10.1016/j.ridd.2013.11.017

Huxham, F. E., Goldie, P. A., & Patla, A. E. (2001). Theoretical considerations in balance assessment. *Australian Journal of Physiotherapy, 47*(2), 89–100. https://doi.org/10.1016/s0004-9514(14)60300-7

IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp

Ju, Y. H., You, J. Y., & Cherng, R. J. (2010). Effect of task constraint on reaching performance in children with spastic diplegic cerebral palsy. *Research in Developmental Disabilities, 31*(5), 1076–1082. https://doi.org/10.1016/j.ridd.2010.04.001

Katz-Leurer, M., Rotem, H., Keren, O., & Meyer, S. (2009). Balance abilities and gait characteristics in post-traumatic brain injury, cerebral palsy and typically developed children. *Developmental Neurorehabilitation, 12*(2), 100–105. https://doi.org/10.1080/17518420902800928

Kembhavi, G., Darrah, J., Magill-Evans, J., & Loomis, J. (2002). Using the Berg Balance Scale to Distinguish Balance Abilities in Children with Cerebral Palsy. *Pediatric Physical Therapy, 14*(2), 92–99. https://doi.org/10.1097/00001577-200214020-00005

Kiss, R., Schedler, S., & Muehlbauer, T. (2018). Associations Between Types of Balance Performance in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. *Frontiers in Physiology, 9.* https://doi.org/10.3389/fphys.2018.01366

Koman, L. A., Smith, B. P., & Shilt, J. S. (2004). Cerebral palsy. *The Lancet, 363*(9421), 1619–1631. https://doi.org/10.1016/s0140-6736(04)16207-7

Kwon, H. Y., & Ahn, S. Y. (2016). Correlation between the gross motor performance measurement and pediatric balance scale with respect to movement disorder in children with cerebral palsy. *Journal of Physical Therapy Science, 28*(8), 2279–2283. https://doi.org/10.1589/jpts.28.2279

Law, L. S., & Webb, C. Y. (2007). Gait adaptation of children with cerebral palsy compared with control children when stepping over an obstacle. *Developmental Medicine & Child Neurology*, *47*(5), 321–328. https://doi.org/10.1111/j.1469-8749.2005.tb01143.x

Liao, H. F., & Hwang, A. W. (2003). Relations of Balance Function and Gross Motor Ability for Children with Cerebral Palsy. *Perceptual and Motor Skills*, *96*(3_suppl), 1173–1184. https://doi.org/10.2466/pms.2003.96.3c.1173

Liu, W. Y., Zaino, C. A., & McCoy, S. W. (2007). Anticipatory Postural Adjustments in Children with Cerebral Palsy and Children with Typical Development. *Pediatric Physical Therapy, 19*(3), 188–195. https://doi.org/10.1097/pep.0b013e31812574a9

Malone, A., Kiernan, D., French, H., Saunders, V., & O'Brien, T. (2016). Obstacle Crossing During Gait in Children With Cerebral Palsy: Cross-Sectional Study With Kinematic Analysis of Dynamic Balance and Trunk Control. *Physical Therapy*, *96*(8), 1208–1215. https://doi.org/10.2522/ptj.20150360

Overlock, J. A., & Yun, J. (2006). The relationship between balance and fundamental motor skills in children. *Journal of Human Movement Studies*, *50*(1), 29–46. https://www.researchgate.net/publication/286692547_The_relationship_between_balance_and_fundamental_motor_skills_in_children

Pavão, S. L., Barbosa, K. A. F., Sato, T. D. O., & Rocha, N. A. C. F. (2014). Functional balance and gross motor function in children with cerebral palsy. *Research in Developmental Disabilities*, *35*(10), 2278–2283. https://doi.org/10.1016/j.ridd.2014.05.024

Pavão, S. L., Pessarelli Visicato, L., da Costa, C. S. N., de Campos, A. C., & Rocha, N. A. C. (2018). Effect of the severity of manual impairment and hand dominance on anticipatory and compensatory postural adjustments during manual reaching in children with cerebral palsy. *Research in Developmental Disabilities, 83*, 47–56. https://doi.org/10.1016/j.ridd.2018.08.007

Pavão, S. L., & Rocha, N. A. C. F. (2017). Sensory processing disorders in children with cerebral palsy. *Infant Behavior and Development*, *46*, 1–6. https://doi.org/10.1016/j.infbeh.2016.10.007

Portney, L. G., & Watkins, M. P. (2015). Chapter 23: Correlation. In *Foundations of Clinical Research: Applications to Practice* (Third Edition). F. A. Davis Company. https://fadavispt.mhmedical.com/content.aspx?bookid=1987§ionid=149505338

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., Dan, B., & Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy April 2006. *Developmental Medicine & Child Neurology, 49*, 8–14. https://doi.org/10.1111/j.1469-8749.2007.tb12610.x

Seyyar, G. K., Aras, B., & Aras, O. (2019). Trunk Control in Children With Ataxic Cerebral Palsy. *Perceptual and Motor Skills, 126*(5), 815–827. https://doi.org/10.1177/0031512519858275

Shumway-Cook, A., & Woollacott, M. H. (2017). Understanding the nature of movement. In *Motor Control: Translating Research into Clinical Practice* (Fifth edition, pp. 4–7). Wolters Kluwer.

Smits-Engelsman BCM. Movement ABC-2-NL Dutch manual. Amsterdam: Pearson, 2010.

Soares, L. M. D. S., Rozane, J. M. S. G., & Carvalho, R. D. P. (2019). Motor performance of children with cerebral palsy in anterior reach. *Clinical Biomechanics, 68,* 158–162. https://doi.org/10.1016/j.clinbiomech.2019.06.007

Tecklin, J. S. (2014). The Infant and Child with Cerebral Palsy. In J. Beaman, F. R. Kalisperis, & K. Miller Skomorucha (Eds.), *Pediatric Physical Therapy* (Fifth edition, pp. 187–246). Lippincott Williams & Wilkins.

Tomita, H., Fukaya, Y., Takagi, Y., & Yokozawa, A. (2016). Effects of severity of gross motor disability on anticipatory postural adjustments while standing in individuals with bilateral spastic cerebral palsy. *Research in Developmental Disabilities, 57*, 92–101. https://doi.org/10.1016/j.ridd.2016.06.017

Tomita, H., Fukaya, Y., Totsuka, K., & Tsukahara, Y. (2013). Deficits in anticipatory inhibition of postural muscle activity associated with load release while standing in individuals with spastic diplegic cerebral palsy. *Journal of Neurophysiology, 109*(8), 1996–2006. https://doi.org/10.1152/jn.00253.2012

Ulrich, D. A. (2017). Introduction to the Special Section: Evaluation of the Psychometric Properties of the TGMD-3. *Journal of Motor Learning and Development, 5*(1), 1–4. https://doi.org/10.1123/jmld.2017-0020

Ulrich, D. A.. Test of gross motor development (3rd ed.). 2020; Austin, TX: Pro-Ed. http://www.kines.umich.edu/tgmd3

Ulrich, D. A., & Webster, E. K. (2016). *TGMD-3 - General Information.* Test of Gross Motor Development 3rd Edition. Retrieved 14 May 2022, from https://sites.google.com/view/tgmd-3/general-information

Valentini, N. C., Nobre, G. C., Zanella, L. W., Pereira, K. G., Albuquerque, M. R., & Rudisill, M. E. (2021). Test of Gross Motor Development–3 Validity and Reliability: A Screening Form. *Journal of Motor Learning and Development, 9*(3), 438–455. https://doi.org/10.1123/jmld.2020-0061

van Waelvelde, H., de Weerdt, W., de Cock, P., & Smits-Engelsman, B. (2004). Aspects of the validity of the Movement Assessment Battery for Children. *Human Movement Science, 23*(1), 49–60. https://doi.org/10.1016/j.humov.2004.04.004

Verbecque, E., Costa, P. H. L. D., Meyns, P., Desloovere, K., Vereeck, L., & Hallemans, A. (2016). Age-related changes in postural sway in preschoolers. Gait & Posture, 44, 116–122. https://doi.org/10.1016/j.gaitpost.2015.11.016

Verbecque, E., Johnson, C., Rameckers, E., Thijs, A., van der Veer, I., Meyns, P., Smits-Engelsman, B., & Klingels, K. (2021). Balance control in individuals with developmental coordination disorder: A systematic review and meta-analysis. *Gait & Posture, 83*, 268–279. https://doi.org/10.1016/j.gaitpost.2020.10.009

Webster, E. K., & Ulrich, D. A. (2017). Evaluation of the Psychometric Properties of the Test of Gross Motor Development—Third Edition. *Journal of Motor Learning and Development, 5*(1), 45–58. https://doi.org/10.1123/jmld.2016-0003

Woodward, M. (1999). Epidemiology Study Design and Analysis. In *Epidemiology* (p. 265). Boca Raton: Chapman and Hall.

Woollacott, M. H., & Shumway-Cook, A. (2005b). Postural Dysfunction During Standing and Walking in Children With Cerebral Palsy: What are the Underlying Problems and What New Therapies Might Improve Balance? *Neural Plasticity*, *12*(2–3), 211–219. https://doi.org/10.1155/np.2005.211

8. Appendices

8.1. Informed consent and information on the purpose and procedures of the research

INFORMATIEDOCUMENT VOOR DE DEELNEMER AAN EEN
NIET-COMMERCIEEL EXPERIMENT OP DE MENSELIJKE PERSOON

Onderzoek naar balanscontrole bij jonge kinderen met DCD van 5 tot 10 jaar.

Opdrachtgever:
Deze studie wordt uitgevoerd in opdracht van de Universiteit Antwerpen, Faculteit Geneeskunde en Gezondheidswetenschappen. Adres: Universiteitsplein 1, 2610 Antwerpen

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Contactpersoon voor informatie:
Indien u vragen heeft over het onderzoek of de rechten van uw kind als studiedeelnemer, nu, tijdens of na de deelname; of indien u meent studiegebonden schade te hebben opgelopen, dan kan u contact opnemen met:

- *Prof. Dr. Ann Hallemans verbonden aan de Universiteit Antwerpen. E-mail: ann.hallemans@uantwerpen.be; Tel. +32 3 265 29 12*
- *Dr. Evi Verbecque verbonden aan de Universiteit Hasselt. Email: evi.verbecque@uhasselt.be*

Commissie voor Medische Ethiek:
Ethisch Comité UZA-UA
UZA, Wilrijkstraat 10, B-2650 Edegem
Tel. +32 3 821 38 97 – Fax +32 3 821 42 54
Ethisch.Comite@uza.be

Commissie voor Medische Ethiek:
Comité voor Medische Ethiek UHasselt
Faculteit geneeskunde en levenswetenschappen, Universiteit Hasselt
Campus Diepenbeek, Agoralaan gebouw D, 3590 Diepenbeek
Tel. tel: + 32 11 26 85 02 - fax: + 32 11 26 85 99
CME@uhasselt.be

INFORMATIE VOOR DE OUDER OF RECHTHEBBENDE

Beste ouder of rechthebbende

Uw kind wordt uitgenodigd om vrijwillig deel te nemen aan een onderzoek met betrekking tot de evaluatie van het evenwichtssysteem.

Vooraleer u toestemt om aan dit onderzoek deel te nemen, is het belangrijk dat u dit formulier leest. In dit informatie- en toestemmingsformulier worden het doel van de studie, de onderzoeken waaraan uw kind onderworpen wordt, de voordelen, risico's en ongemakken gepaard gaande met de studie beschreven. Ook de beschikbare alternatieven voor uw kind en het recht om op elk ogenblik de studie te verlaten, zijn hieronder beschreven. Er kunnen geen beloften gedaan worden noch waarborgen gegeven worden betreffende de resultaten van de klinische studie. U hebt het recht om op elk ogenblik vragen te stellen over mogelijke en/of bekende risico's die deze studie inhoudt.

1. Studiespecifieke inlichtingen

Dit onderzoek werd op .....*(datum)* goedgekeurd door het onafhankelijke Ethisch Comité UZA-UA.

Achtergrond

Balanscontrole gaat over de controle om je evenwicht in zowel stand als tijdens bewegingen (bv. wandelen, springen, lopen etc.) te behouden. Een goede balanscontrole vormt een belangrijke voorwaarde om houdingen (bv. zitten en staan) aan te kunnen nemen en om complexere grof- en fijn-motorische taken (bv. lopen, springen, dubbeltaken etc.) uit te kunnen voeren en daarom belangrijk bij de ontwikkeling van uw kind. Er zijn veel onderliggende systemen en mechanismen die gecoördineerd moeten samenwerken om adequate balanscontrole te garanderen. Als één van deze systemen of mechanismen faalt, zal dit waarschijnlijk resulteren in problemen bij de balanscontrole.

Doel van de studie

Deze studie heeft tot doel om de grote variatie van kinderen met ontwikkelings-coördinatiestoornis of beter bekend als Developmental Coordination Disorder (DCD) beter te begrijpen op vlak van het evenwicht, de onderliggende mechanismen en op vlak van de motoriek. Op die manier kunnen we kinderen met DCD beter helpen bij de evaluatie en behandeling van het evenwicht en zullen ze bijgevolg minder beperkt zijn in hun dagdagelijks functioneren.

Dit onderzoek is een observationele studie wat inhoudt dat er geen interventies plaatsvinden. Wij observeren enkel het gedrag en de prestatie van uw kind. Dit wetenschappelijk onderzoek zal naar verwachting in totaal ongeveer 108 kinderen rekruteren om deel te nemen aan deze studie.

Beschrijving van de studie

Indien u aanvaardt dat uw kind aan dit onderzoek zal deelnemen en indien uw kind voldoet aan alle voorwaarden voor deelname, dan zullen de volgende *tests / onderzoeken* worden uitgevoerd:
U zal gevraagd worden een algemene vragenlijst en een specifieke vragenlijst (DCD-Q) over uw kind te beantwoorden en er zal uw kind gevraagd worden om de *Movement Assessment Battery for Children 2e Editie (M-ABC-2)* en de *Balance Evaluation Systems Test voor kinderen (Kids-BESTest)* uit te voeren, terwijl worden bewegings-, spier- en hersenanalyses uitgevoerd. Hieronder verdere toelichting:

1) **Algemene vragenlijst**
   Er zullen algemene vragen over uw kind worden gesteld, namelijk over lichaamskenmerken, de zwangerschap, de medische voorgeschiedenis en het bewegen. Deze vragen geven ons een algemeen beeld over uw kind.

2) Specifieke vragenlijst
   De ***DCD questionnaire*** zal de impact van DCD evalueren op het dagdagelijkse leven.

3) **Test om typische ontwikkeling vast te stellen**
   Bij de eerste test die uw kind zal uitvoeren zal worden vastgesteld of uw kind voldoet aan een typische ontwikkeling. Deze test heet de ***Movement Assessment Battery scale for Children, 2de editie (M-ABC-2).*** Deze test gaat motorische vaardigheden na en bestaat uit acht verschillende onderdelen. Vervolgens zal de totaalscore berekend en geëvalueerd worden.

4) **Biomechanische parameters en hersenactiviteit**
   Tijdens het uitvoeren van de uiteindelijke evenwichtstest (Kids-BESTest) zullen er ***bewegingsanalyses,analyses van spieractiviteit en analyses van hersenactiviteit*** gebeuren. Voor dit mogelijk is, zullen er nog een aantal voorbereidingen moeten plaatsvinden. Deze voorbereidingen bestaan uit het plaatsen van sensoren op specifieke plaatsen op de benen en voeten en een muts met sensoren op het hoofd, zodat de juiste analyses kunnen gebeuren.

5) **Evaluatie van het evenwichtssysteem**
   Als laatste zal uw kind worden gevraagd om een test af te leggen, welke bestaat uit zes delen. Elk deel is dan nogmaals opgesplitst in kleine opdrachten om een globaal beeld te krijgen over het evenwichtssysteem van uw kind en over de verschillende mechanismen. De ***Balance Evaluation Systems Test voor kinderen (Kids-BESTest) is*** een wijdverspreide test, maar er is nog niet nagegaan of deze test verschillen kan opmerken bij kinderen van 5 tot en met 7 jaar.
   Deze testafname zal volledig worden vastgelegd op videobeelden.

Duur van het onderzoek
Er wordt één meetmoment voorzien van ongeveer 1.5 uur, maar dit kan worden opgesplitst in twee of meer meetmomenten van 30 tot 45 minuten.

Plaats van het onderzoek
Het onderzoek vindt plaats op …… [in te vullen op het moment van testafname]

Risico's en ongemakken
Er worden minimale risico's en ongemakken verwacht.
Mogelijke ongemakken van dit onderzoek kunnen zijn:

1) Irritatie op de huid na het dragen van merktekens, nodig voor de bewegings- en spieranalyses;

2) Aangezien de opdrachtjes van dit onderzoek het evenwicht zullen uitdagen, kan het zijn dat er een risico op vallen bestaat. Natuurlijk zal er altijd een therapeut in de buurt zijn om het kind op te vangen, zodat het valrisico zo klein mogelijk gemaakt wordt.

Voordelen

De studie waaraan uw kind deelneemt, kan bijdragen tot het beter begrijpen van DCD, zodat deze kinderen een meer gepaste evaluatie en therapie kunnen krijgen van hun evenwichtsproblemen. Dit onderzoek behoort tot het basiswetenschappelijk onderzoek. Bij vragen of onduidelijkheden kan u de onderzoekers steeds om extra informatie vragen.

2. Algemene informatie over de deelname aan een onderzoek

Vrijwillige deelname

Uw kind neemt geheel vrijwillig deel aan deze studie en u en uw kind hebben het recht te weigeren aan deze studie deel te nemen. Indien u toestemt dat uw kind deelneemt aan het onderzoek, dient u deze informatiefolder te bewaren en zal er u gevraagd worden het aangehechte toestemmingsformulier te ondertekenen.

U en uw kind hebben ook het recht de deelname aan het onderzoek op elk ogenblik stop te zetten, zelfs nadat u het toestemmingsformulier ondertekend heeft. U hoeft hiervoor geen reden te vermelden. Het intrekken van uw toestemming zal geen enkel nadeel of verlies van voordelen met zich meebrengen.

De deelname van uw kind aan het onderzoek kan ook, zonder uw toestemming, op elk ogenblik stopgezet worden door de onderzoeker(s), het Ethisch Comité of de opdrachtgever. Mogelijke redenen voor zulke beslissing kunnen onder andere zijn:

- U of uw kind houdt zich niet aan de instructies voor deelname aan het onderzoek;
- De verdere deelname blijkt schadelijk te zijn voor uw kind;
- Er wordt tijdens het onderzoek vastgesteld dat uw kind toch niet of niet meer aan de voorwaarden voor deelname voldoet.

Aansprakelijkheid en verzekering

Indien uw kind of rechthebbenden (familie) schade ondervinden die verband houdt met deze studie, zal deze schade door de opdrachtgever van deze studie vergoed worden overeenkomstig de Belgische wetgeving inzake experimenten op de menselijke persoon van 7 mei 2004. U hoeft hiervoor geen fout aan te tonen. De opdrachtgever heeft een foutloze verzekering afgesloten die de eventuele risico's en de schade, die zouden voortvloeien uit deze studie, dekken. U of uw rechthebbenden kunnen hiervoor op elk ogenblik deze verzekeraar rechtstreeks dagvaarden.

Kosten en vergoeding

Deze studie zal voor u geen bijkomende kosten met zich meebrengen. Alle kosten die voortvloeien uit uw deelname aan het onderzoek zijn voor rekening van de onderzoeker of de opdrachtgever. Wij voorzien materiaal dus uw kind hoeft niets mee te brengen. Er wordt van u wel een verplaatsing gevraagd. Indien u zich verplaatst heeft naar het Universitair Ziekenhuis Antwerpen voor de deelname van uw kind aan deze studie, zullen de transport- en parkeerkosten vergoed worden na het invullen van een onkostennota.

Bescherming van uw persoonlijke levenssfeer

De identiteit en de deelname van uw kind aan dit onderzoek worden strikt vertrouwelijk behandeld. Uw kind zal niet bij naam of op een andere wijze geïdentificeerd worden in dossiers, resultaten of publicaties in verband met het onderzoek.

Om de privacy van uw kind te garanderen met betrekking tot het bewaren en verwerken van de gegevens in het kader van deze studie, worden de gegevens van uw kind gepseudonimiseerd. Dit betekent dat zijn/haar naam, voornaam, geboortedatum en woonplaats vervangen worden door een code. Alle verdere verwerkingen gebeuren op deze gepseudonimiseerde gegevens. Het verband tussen de code en uw kind wordt wel bewaard.

Bescherming van uw persoonsgegevens

Indien u toestemt dat uw kind deelneemt aan dit onderzoek betekent dit dat u toestemming geeft tot het gebruik van uw kind zijn/haar persoonsgegevens die in het kader van dit onderzoek worden verzameld. U kan de toestemming om deze gegevens te verzamelen en te verwerken op elk moment intrekken. Indien de studiedeelname voortijdig gestopt wordt, zal uw oorspronkelijke toestemming het gebruik toelaten van de over u verzamelde gegevens met betrekking tot de periode dat u in het onderzoek ingesloten was.
Enkel personen die rechtstreeks bij het onderzoek betrokken zijn, zullen toegang hebben tot de persoonsgegevens van uw kind. Deze gegevens worden niet doorgegeven aan derden. De onderzoekers zullen de gegevens van uw kind bewaren gedurende een periode van 20 jaar.

U heeft het recht aan de onderzoeker te vragen welke gegevens er over uw kind worden verzameld in het kader van het onderzoek en wat de bedoeling ervan is. U kan vragen om bepaalde gegevens te verbeteren of te wissen, of om de gegevens van uw kind niet meer te gebruiken. Alle gegevens die van uw kind verzameld worden, zullen behandeld worden in overeenstemming met de "Richtlijn tot bescherming van individuen betreffende het verwerken van persoonlijke gegevens" en de nationale wetgeving die daarop van toepassing is. De Europese Algemene Verordening Gegevensbescherming (General Data Protection Regulation (AVG/GDPR) – EU2016/679) en de Belgische wetgeving die deze verordening verder uitwerkt.
Universiteit Antwerpen is als opdrachtgever voor de studie verantwoordelijk voor de verwerking van uw persoonsgegevens. Zij heeft daartoe een functionaris voor de gegevensverwerking aangesteld. Vragen betreffende het beheer van de gegevens van u/uw kind kan u stellen aan onderzoeker(s) of aan de functionaris voor de gegevensbescherming van de Universiteit Antwerpen via e-mail: privacy@uantwerpen.be.

Wanneer u vindt dat de rechten van uw kind met betrekking tot uw persoonsgegevens onvoldoende worden gerespecteerd, kan u steeds terecht bij de functionaris voor de gegevensbescherming die desgevallend de nodige maatregelen zal treffen. U hebt ook het recht om een klacht in te dienen bij de Belgische Gegevensbeschermingsautoriteit. Meer informatie kan u nalezen op https://www.uantwerpen.be/nl/overuantwerpen/missie-en-visie/privacyverklaring/ .

We hopen u met dit document voldoende informatie te hebben gegeven over het onderzoek.

U heeft het recht om op elk ogenblik bijkomende vragen te stellen over de inhoud, het doel of het verloop van het onderzoek, over de mogelijke en/of bekende voor- en nadelen die dit onderzoek voor u inhoudt, enz.. U kunt zich daarvoor wenden tot de onderzoeker(s): Prof. Dr. Ann Hallemans verbonden aan de Universiteit Antwerpen, mail: ann.hallemans@uantwerpen.be , tel.: +32 3 265 29 12

Datum *(dag/maand/jaar)*

Onderzoek naar balanscontrole bij jonge kinderen met DCD van 5 tot 10 jaar.

Deel enkel bestemd voor de wettelijke vertegenwoordiger:

Hierbij bevestig ik, ondergetekende, …… (naam en voornaam), dat ik over het onderzoek ben ingelicht en een kopie van het informatiedocument ontvangen heb.

Ik heb de informatie gelezen en begrepen. De onderzoeker heeft mij voldoende informatie gegeven met betrekking tot het doel en het opzet van het onderzoek, de voorwaarden en de duur ervan, en de mogelijke bekende voor- of nadelen die dit onderzoek voor mij kunnen inhouden. Bovendien werd mij voldoende tijd gegeven om de informatie te overwegen en om vragen te stellen, waarop ik bevredigende antwoorden gekregen heb.

- Ik ben ervan op de hoogte dat ik de toestemming tot deelname van mijn kind aan het onderzoek en tot verwerking van de gegevens van mijn kind kan weigeren en dat ik de toestemming om de data van mijn kind te gebruiken op elk moment kan intrekken, nadat ik de onderzoeker hierover heb ingelicht, zonder dat dit mij/mijn kind enig nadeel kan berokkenen.
- Mijn oorspronkelijke toestemming tot deelname aan het onderzoek en gebruik van de persoonsgegevens van mijn kind zal het gebruik van de gegevens van mijn kind toelaten met betrekking tot de periode dat ik in het onderzoek ingesloten was.
- Ik ben mij bewust van het doel waarvoor de gegevens van mijn kind verzameld, verwerkt en gebruikt worden in het kader van dit onderzoek. Ik ben ervan op de hoogte gesteld dat de gegevens van mijn kind gedurende 20 jaar zullen bewaard worden voor wetenschappelijk onderzoek.
- Ik weet dat ik het recht heb om de gegevens van mijn kind in te zien, te verbeteren of te wissen. Als ik klachten heb over het beheer van deze gegevens weet ik dat ik me kan richten tot de onderzoekers of de functionaris voor de gegevensbescherming van de Universiteit Antwerpen (privacy@uantwerpen.be).
- Ik geef toestemming aan de onderzoeker om de gegevens van mijn kind te verzamelen, te verwerken en te gebruiken zoals beschreven in het informatiedocument dat ik ontving en conform de geldende wetgeving. Deze gegevens zullen strikt vertrouwelijk behandeld worden. Wanneer de studieresultaten gepubliceerd worden, zal de identiteit van mijn kind geheim blijven.
- Ik ga ermee akkoord dat er standaard videobeelden van mijn kind worden gemaakt tijdens het uitvoeren van de Kids-BESTest en dat deze videobeelden bewaard en gebruikt worden uitsluitend voor dit onderzoek.
- Ik ga eveneens akkoord met het gebruik door de opdrachtgever van het onderzoek van de gecodeerde medische gegevens van mijn kind voor andere onderzoeksdoeleinden. Elk nieuw onderzoek vereist een beoordeling en goedkeuring door het Ethisch Comité.
- Ik stem geheel vrijwillig toe om mijn kind deel te laten nemen aan dit onderzoek en om mee te werken aan alle gevraagde onderzoekshandelingen (*bv. invullen van vragenlijsten, deelname aan een interview, …*).
- Ik ben bereid informatie te verstrekken i.v.m. de medische geschiedenis van mijn kind, zijn/haar geneesmiddelengebruik en eventuele deelname aan andere studies.
- Ik ga ermee akkoord dat mijn arts/specialist en andere zorgverleners die bij mijn behandeling betrokken zijn, indien nodig, op de hoogte worden gebracht van mijn deelname aan dit onderzoek.

_____	_____	_____
Naam *wettelijke vertegenwoordiger (hoofdletters)*	Handtekening	Datum *(dag/maand/jaar)*

Deel enkel bestemd voor het onderzoeksteam

Ik, ondergetekende, …… (naam onderzoeker) bevestig hierbij dat ik, …… *(naam van de deelnemer en/of naam van zijn/haar wettelijke vertegenwoordig(st)er)* heb ingelicht en dat hij (zij) zijn (haar) toestemming heeft gegeven om deel te nemen aan de studie.

Naam *(hoofdletters)*	Handtekening	Datum *(dag/maand/jaar)*

Informatieformulier voor kinderen van 5 tot en 10 jaar

Onderzoek naar balanscontrole bij jonge kinderen met DCD van 5 tot 10 jaar.

Beste……,

Zowel aan jou als jouw papa of mama is gevraagd of jij graag mee wil doen met een onderzoek om te kijken of jij een goed evenwicht hebt.

Wat gaan wij nu precies doen vandaag?

- We vragen aan jou en aan jouw mama of papa: hoeveel jaar jij bent, wanneer jij bent geboren, of je sport, of je een bril draagt of je oorontstekingen hebt gehad enz.
- We meten de lengte van jouw benen, jouw volledige lichaamslengte, jouw gewicht.
- We testen of jij net zo goed kan bewegen als jouw vriendjes door: op één been te staan, eens te wandelen, te springen enz.
- We testen hoe goed jij je evenwicht kan bewaren bij allerlei verschillende opdrachtjes met een grote test, zoals: op de tenen staan, rond een stoel wandelen, op de grond zitten en weer rechtkomen enz. Deze test zal in uit zes delen en 27 opdrachtjes bestaan.
- Tegelijk gaan we kijken hoe jouw spieren bewegen en wat er in je hoofd gebeurt terwijl je de evenwichtsoefeningen doet. Dit doen we met verschillende plakkertjes en een muts, zodat je net een robot lijkt.
- We gaan je filmen en je bewegingen goed volgen. Zo weten wij zeker dat jij goed bezig bent.
- Er zal steeds iemand dicht bij jou staan om je te helpen bij de opdrachten.

Waarom willen we dit nu precies doen?

We gaan bij heel veel kinderen kijken hoe zij al deze opdrachtjes kunnen uitvoeren. Zo kunnen wij zien hoe de meeste kinderen wandelen en hun evenwicht kunnen houden. Als we dat weten, kunnen we met deze opdrachtjes kinderen helpen die misschien niet meer zo goed kunnen wandelen of die moelijker kunnen staan zonder hulp.

Wat als ik nog vragen heb?

Als er iets niet duidelijk is of als je mij niet goed begrijpt, dan mag je dat altijd vragen. Je mag dit aan iedereen vragen die hier nu bij ons in het lokaal zit.

Wat als ik wil stoppen met dit onderzoek?

Je mag altijd stoppen met het onderzoek als je echt een opdracht niet wil of kan uitvoeren, dat is helemaal niet erg.

Zou je mee willen doen aan dit onderzoek?

8.2. Example of the age-adjusted scoring-criteria of the Kids-BESTest

DOMAIN III: TRANSITIONS AND ANTICIPATORY POSTURAL ADJUSTMENTS – AGE 8-14

OBSERVATION	SCORING CRITERIA				
	0	1	2	3	Score

Item 12. ALTERNATE STAIR TOUCH

Record the time the child needs to complete at least eight steps. Look for signs of instability and at what frequency they occur. Check the boxes that correspond with your observation.

Signs of instability
O = occasional; R= repeated; C = constant
☐foot placement on step is variable: O/ R/ C
☐foot placement on floor is variable: O/ R/ C
☐inadequate weight shift to stance leg: O/ R/ C
☐hesitation: O/ R/ C
☐arrhythmical performance: O/ R/ C
☐excessive trunk movements: O/ R/ C
☐excessive trunk flexion (compensate for weight shift) : O/ R/ C
☐cannot execute movement
☐none

Check the boxes that correspond with your observation during test administration.
Lowest sore counts for overall judgement (considering quantitative and qualitative performance).

Time:_____ # steps:_____	< 8 steps	8 steps in > 20 sec	8 steps (10 – 20 sec)	8 steps in < 10 sec	
	☐***Constant*** signs of instability ☐ Cannot execute movement, not even with assistive device.	☐***Repeated*** signs of instability	☐***Occasional*** signs of instability	☐***No signs*** of instability	

Interference: ☐refuses ☐distracted /does not follow instructions correctly ☐inconsistent/ highly variable performance

DOMAIN III: TRANSITIONS AND ANTICIPATORY POSTURAL ADJUSTMENTS – AGE 5-7

OBSERVATION	SCORING CRITERIA				
	0	1	2	3	Score

Item 12. ALTERNATE STAIR TOUCH

Record the time the child needs to complete at least eight steps. Look for signs of instability and at what frequency they occur. Check the boxes that correspond with your observation.

Signs of instability
O = occasional; R= repeated; C = constant
☐foot placement on step is variable: O/ R/ C
☐foot placement on floor is variable: O/ R/ C
☐inadequate weight shift to stance leg: O/ R/ C
☐hesitation: O/ R/ C
☐arrhythmical performance: O/ R/ C
☐excessive trunk movements: O/ R/ C
☐excessive trunk flexion (compensate for weight shift) : O/ R/ C
☐requires minimal assistance (i.e. assistive device)
☐cannot execute movement, not even with assistive device
☐none

Check the boxes that correspond with your observation during test administration.
Lowest sore counts for overall judgement (considering quantitative and qualitative performance).

Time:_____ # steps:_____	< 8 steps	8 steps in > 20 sec	8 steps (10 – 20 sec)	8 steps in < 10 sec	
	☐ Cannot execute movement, not even with assistive device.	☐***Constant*** signs of instability	☐***Repeated*** signs of instability	☐***No/occasional signs*** of instability	

Interference: ☐refuses ☐distracted /does not follow instructions correctly ☐inconsistent/ highly variable performance

8.3. General questionnaire

Algemene vragenlijst

Naam: Voornaam:

Geboortedatum: Testdatum:

Lichaamslengte: Beenlengte:

Lichaamsgewicht:

Vragen zwangerschap/geboorte

Zwangerschapsduur: _____

Complicatie tijdens zwangerschap? _____

Complicatie tijdens geboorte? _____

Medische gegevens

Diagnoses?

Ontwikkelingsstoornissen? _____

Neuromotorische stoornissen? _____

Zicht

Bril? _____

Bijziend: _____

Verziend: _____

Gehoor

Oorontstekingen? _____

Buisjes? (+ wanneer?) _____

Hulpmiddelen voor gehoord? _____

Operaties?

Welke? _____

Wanneer? _____

Motoriek

Vrijetijdsbesteding _____

Sport? _____

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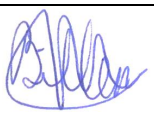
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
11/09/2021	- Bespreking opzet van masterproef en onderzoeksvragen. - Uitleg over verwachtingen m.b.t. testafnames en dataverwerking.	Promotor dr. Evi Verbecque: Begeleider dra. Charlotte Johnson: Studente Maurene Billen: Studente Laure Fonteyn:
22/03/2022	- Bespreking onduidelijkheden m.b.t. scoring en statistiek. - Draft 1: inleiding en methode	Promotor dr. Evi Verbecque: Begeleider dra. Charlotte Johnson: Studente Maurene Billen: Studente Laure Fonteyn:
20/04/2022	- Vragen bespreken m.b.t. resultaten en discussie.	Promotor dr. Evi Verbecque: Begeleider dra. Charlotte Johnson: Studente Maurene Billen: Studente Laure Fonteyn:
20/05/2022	- Draft 2: volledige versie masterproef - Nadien schriftelijke feedback	Promotor dr. Evi Verbecque: Begeleider dra. Charlotte Johnson:

		Studente Maurene Billen:  Studente Laure Fonteyn: 

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Studenten: Laure Fonteyn en Maurene Billen **Datum:** 28/05/2022

Titel Masterproef: Functional balance, motor competence and their relationship in children with cerebral palsy compared to typically developing children: A case-control study.

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

2) Niet-bindend advies: Student(e) krijgt toelating/geen toelating (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Studenten		Datum en handtekening promotor	Datum en handtekening begeleider
05/06/2022 Maurene Billen	05/06/2022 Laure Fonteyn	28/05/2022 Evi Verbecque	

Inschrijvingsformulier verdediging masterproef academiejaar 2021-2022,
Registration form jury Master's thesis academic year 2021-2022,

GEGEVENS STUDENT - *INFORMATION STUDENT*

Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1746778 Billen Maurene**
Student number + name

Opleiding/*Programme*: **2 ma revalid. & kine kinderen**

INSTRUCTIES - *INSTRUCTIONS*

Neem onderstaande informatie grondig door.

Print dit document en vul het aan met DRUKLETTERS.

In tijden van van online onderwijs door COVID-19 verstuur je het document (scan of leesbare foto) ingevuld via mail naar je promotor. Je promotor bezorgt het aan de juiste dienst voor verdere afhandeling.

Vul luik A aan. Bezorg het formulier aan je promotoren voor de aanvullingen in luik B. Zorg dat het formulier ondertekend en gedateerd wordt door jezelf en je promotoren in luik D en dien het in bij de juiste dienst volgens de afspraken in jouw opleiding.
Zonder dit inschrijvingsformulier krijg je geen toegang tot upload/verdediging van je masterproef.

Please read the information below carefully.

Print this document and complete it by hand writing, using CAPITAL LETTERS.

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Fill out part A. Send the form to your supervisors for the additions in part B. Make sure that the form is signed and dated by yourself and your supervisors in part D and submit it to the appropriate department in accordance with the agreements in your study programme.
Without this registration form, you will not have access to the upload/defense of your master's thesis.

LUIK A - VERPLICHT - IN TE VULLEN DOOR DE STUDENT
PART A - MANDATORY - TO BE FILLED* OUT *BY THE STUDENT

Titel van Masterproef/*Title of Master's thesis:*

O behouden - *keep*

O wijzigen - *change to*:

FUNCTIONAL BALANCE, MOTOR COMPETENCE AND THEIR RELATIONSHIP IN CHILDREN WITH CEREBRAL PALSY COMPARED TO TYPICALLY DEVELOPING CHILDREN: A CASE-CONTROL STUDY

/:

O behouden - *keep*

O wijzigen - *change to*:

In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s)*:

O behouden - *keep* LAURE FONTEYN

O wijzigen - *change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

O goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

Scriptie/*Thesis:*

O openbaar (beschikbaar in de document server van de universiteit)- *public (available in document server of university)*

O vertrouwelijk (niet beschikbaar in de document server van de universiteit) - *confidential (not available in document server of university)*

Juryverdediging/*Jury Defense:*

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode/*The supervisor(s) give(s) the student(s) the non-binding advice:*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

O de verdediging is openbaar/*in public*

O de verdediging is niet openbaar/*not in public*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK C - OPTIONEEL - IN TE VULLEN DOOR STUDENT, alleen als hij luik B wil overrulen
PART C - OPTIONAL - TO BE FILLED OUT BY THE STUDENT, only if he wants to overrule part B

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode/*In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

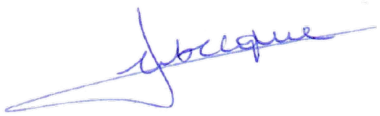
LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

Datum en handtekening student(en)
Date and signature student(s)

26/05/2022
Maurene Billen

27/05/2022
Laure Fonteyn

Datum en handtekening promotor(en)
Date and signature supervisor(s)



28/05/2022
Evi Verbecque

Inschrijvingsformulier verdediging masterproef academiejaar 2021-2022,
Registration form jury Master's thesis academic year 2021-2022,

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Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1747460 Fonteyn Laure**
Student number + name

Opleiding/*Programme*: **2 ma revalid. & kine kinderen**

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PART A - MANDATORY - TO BE FILLED* OUT *BY THE STUDENT

Titel van Masterproef/*Title of Master's thesis:*

O behouden - *keep*

O wijzigen - *change to*:

FUNCTIONAL BALANCE, MOTOR COMPETENCE AND THEIR RELATIONSHIP IN CHILDREN WITH CEREBRAL PALSY COMPARED TO TYPICALLY DEVELOPING CHILDREN: A CASE-CONTROL STUDY

/:

O behouden - *keep*

O wijzigen - *change to*:

In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s)*:

O behouden - *keep* MAURENE BILLEN

O wijzigen - *change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

O goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

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O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

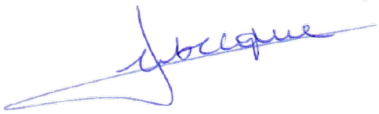
LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

Datum en handtekening student(en)
Date and signature student(s)

27 mei 2022
Fonteyn Laure

27 mei 2022
Billen Maurene

Datum en handtekening promotor(en)
Date and signature supervisor(s)



28/05/2022
Evi Verbecque

E

Evi VERBECQUE
aan Laure, mij

28 mei 2022 20:40 (17 uur geleden)

Beste Laure en Maurene,

Via deze weg geef ik jullie toestemming om jullie masterproef in te dienen en te verdediging tijdens de eerste zittijd. In bijlage de ondertekende documenten.
Mvg,

Evi Verbecque

Doctor-Assistent
REVAL - Rehabilitation Research Center
T (+32) 0489 91 54 14

www.uhasselt.be
Universiteit Hasselt - Campus Diepenbeek
Agoralaan Gebouw A - B-3590 Diepenbeek

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