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AND HEALTH SCIENCES

WHAT ARE THE EARLY QUALITATIVE MOTOR SIGNS IN INFANTS WITH DEVELOPMENTAL COORDINATION DISORDER OPTIONALLY IN COMORBIDITY WITH AUTISM SPECTRUM DISORDER DURING THE FIRST TWO YEARS OF LIFE COMPARED TO TYPICALLY DEVELOPING INFANTS? A RETROSPECTIVE VIDEO ANALYSIS

Word count: 8,327

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A dissertation submitted to Ghent University in partial fulfillment of the requirements for the degree of Master of Rehabilitation Sciences and Physiotherapy

Academic year: 2020 – 2021

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Emma, Charlotte and Marthe

FACULTY OF MEDICINE AND HEALTH SCIENCES

Table of contents

FACULTY OF MEDICINE AND HEALTH SCIENCES

List of figures

FACULTY OF MEDICINE AND HEALTH SCIENCES

List of tables

List of abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
ASD	Autism Spectrum Disorder
ATNR	Asymmetrical Tonic Neck Reflex
CP	Cerebral Palsy
DCD	Developmental Coordination Disorder
DCDQ	Developmental Coordination Disorder Questionnaire
DCDQ'07	Developmental Coordination Disorder Questionnaire Edition 2007
DD	Developmental Delays
DSM-V	Diagnostic and Statistical Manual of Mental Disorders Fifth Edition
ID	Identity
ICC	Intraclass Correlation Coefficient
IMMACS	Infant Motor Maturity Scale and Atypical Coding Scales
LE	Lower extremity
M-ABC-2	Movement Assessment Battery for Children Second Edition
Q-Q plots	Quantile-Quantile plots
RD	Reading Disorder
RVA	Retrospective Video Analysis
SPSS-27	Statistical Package for the Social Science version 27
SRS-2	Social Responsiveness Scale Second Edition
TD	Typically Developing
UE	Upper extremity

Abstract

BACKGROUND: Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder, which is often comorbid with Autism Spectrum Disorder (ASD). DCD is primarily subclassified as a motor disorder where children move qualitatively different and in an uncoordinated way.

OBJECTIVES: The main objective of this study was to investigate whether infants (0-2 years) with DCD and infants with DCD in comorbidity with ASD can be distinguished from typically developing (TD) infants based on early differences in motor maturity using home videos. In addition, researchers investigated the observation of motor abnormalities in early development.

STUDY DESIGN: Retrospective study.

METHODS: The participants in this study were 25 children including eleven TD children, eight children with DCD and six children with DCD in comorbidity with ASD. The early motor development of these children was examined in eight different postures namely supine, prone, rolling from supine to prone, rolling from prone to supine, sitting, crawling, standing and walking. In addition, the protective responses of these children were compared and the extent to which motor abnormalities (e.g., Asymmetrical Tonic Neck Reflex (ATNR), W-sit, shuffling, bunny hop and toe walking) were prevalent in the three groups was examined.

RESULTS: Minimal differences in motor maturity were found between the three groups for the majority of the postures and there were no notable differences in movement abnormalities. The most mature form of development per posture was not reached earlier by the TD infants than the other two groups.

CONCLUSIONS: There are no remarkable differences in the early development of TD infants, infants with DCD and infants with DCD in comorbidity with ASD. Besides, delayed development of motor milestones cannot be confirmed. Further research is needed with larger sample sizes and more video material.

5 KEYWORDS: DCD, ASD, motor maturity, motor abnormalities, early identification

ACHTERGROND: Developmental Coordination Disorder (DCD) is een neurologische ontwikkelingsstoornis, die vaak samen voorkomt met Autisme Spectrum Stoornis (ASS). DCD wordt voornamelijk gezien als een motorische stoornis waarbij kinderen kwalitatief anders en ongecoördineerd bewegen.

DOELSTELLINGEN: Het hoofddoel van deze studie was om zuigelingen (0-2 jaar) met een typische ontwikkeling en zuigelingen met DCD al dan niet in comorbiditeit met ASS te vergelijken. Dit werd onderzocht op basis van mogelijke verschillen in de vroege motorische ontwikkeling aan de hand van video's in de thuisomgeving. Daarnaast werden motorische afwijkingen/abnormaliteiten onderzocht in de vroege ontwikkeling.

ONDERZOEKSDESIGN: Retrospectieve studie.

METHODE: Aan dit onderzoek namen 25 kinderen deel waaronder elf typisch ontwikkelende kinderen, acht kinderen met DCD en zes kinderen met DCD in comorbiditeit met ASS. De vroege motorische ontwikkeling van deze kinderen werd onderzocht in acht verschillende houdingen namelijk ruglig, buiklig, rollen van ruglig naar buiklig, rollen van buiklig naar ruglig, zitten, kruipen, staan en stappen. Bovendien werden de opvangreacties van deze kinderen vergeleken en werd nagegaan in welke mate motorische afwijkingen/abnormaliteiten (bv. Asymmetrische Tonische Nek Reflex (ATNR), W-zit, poepschuiven, bunny hop en tenen lopen) voorkwamen in de drie groepen.

RESULTATEN: Minimale verschillen in motorische rijpheid werden gevonden tussen de drie groepen voor het merendeel van de houdingen en er waren geen opmerkelijke verschillen in bewegingsabnormaliteiten. Tenslotte werd gezien dat de meest rijpe vorm van ontwikkeling per houding niet sneller werd bereikt door de typisch ontwikkelende zuigelingen dan door de andere twee groepen.

CONCLUSIES*:* Uit deze studie blijkt dat er geen opmerkelijke verschillen zijn in de vroege ontwikkeling van typisch ontwikkelende zuigelingen, zuigelingen met DCD en zuigelingen met DCD in comorbiditeit met ASS. Bovendien kan een vertraagde ontwikkeling van motorische mijlpalen niet worden bevestigd. Verder onderzoek is nodig met grotere steekproeven en meer videomateriaal.

5 TREFWOORDEN: DCD, ASS, motorische rijpheid, motorische afwijkingen, vroege herkenning

1. Introduction

Developmental Coordination Disorder (DCD) is a common neurodevelopmental disorder affecting 5-10% of school-aged infants. To be diagnosed with DCD, infants have to meet the four DCD-criteria according to the latest edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (1, 2).
Firstly, infants with DCD typically have a delayed development and difficulties with the coordination of either gross or fine motor movements or both. Coordination difficulties are generally characterized by clumsiness, rigid movements and a slow and inaccurate performance of motor skills. Therefore, individuals with DCD may exhibit complications with postural control (hypotonia or hypertonia, immature distal control, poor static and dynamic balance), sensorimotor coordination and motor learning (motor planning, learning new movements, adaptation to change) (3). Consequently, the performance of several motor tasks, for instance, the application of scissors, cutlery, handwriting skills or catching and throwing a ball is significantly below the expected level for the chronological age of the infant, assessed by a validated and standardized motor skills scale (4). Secondly, developmental deficits can vary from very specific limitations to general impairments of motor skills. Although, in all cases, the fragile motor development persistently disturbs their activities of daily living and interferes with school performance, leisure activities, sports and the preparation of professional activities. Consequently, the academic achievement is often lower in this population (5, 6). Thirdly, the first symptoms occur early in the developmental period. Fourthly, the deficiency in motor skills is not explained by a mental disorder or a visual impairment and cannot be attributed to a medical condition or a severe neurological disease that influences the normal motion (e.g., Cerebral Palsy (CP), muscle dystrophy or a degenerative disease) (5-7).

Although DCD is described as a “mild” problem, infants encounter a major “handicap”. These children gradually lose motivation and experience repeated failures resulting in lower self-esteem and less self-confidence compared to their peers. In addition, children with DCD tend to avoid physical activity with the occurrence of secondary problems concerning obesity, overweight and increased risk for cardiovascular diseases. Also problems on the socio-emotional level such as anxiety, social isolation, depression, an increased risk of psychological problems and a raised probability to being bullied occur in the long term (8-10).

DCD is a relatively common disorder. However, the etiopathogenesis of the impairment is still unknown and symptoms are often insufficiently recognized by healthcare professionals. Mostly, parents, caregivers and schoolteachers express concerns that the infant is clumsy and shows delays in fine and gross motor development, but early objective clinical biomarkers remain unclear. Little is known about the motor development of infants later diagnosed with DCD. Some infants may have delays in early motor milestones such as crawling and walking (11). Sometimes, difficulties with oral motor coordination such as closing lips to blow bubbles or blowing out birthday candles may be reported (11).

Comorbidities are common in children with DCD. These associated problems include Attention Deficit Hyperactivity Disorder (ADHD), Reading Disorder (RD), dyslexia, dyscalculia and Autism Spectrum Disorder (ASD) making the DCD group an extremely heterogeneous population (12).
Clinicians are sure that the co-occurrence of several conditions causes a higher negative impact on the children's functioning and participation, resulting in a lower quality of life. Unfortunately, the scientific evidence of a link between DCD and other developmental disorders remains absent (13-15). A frequently associated disorder in children with DCD is ASD. Approximately 50% of the children with DCD also have a comorbid ASD diagnosis. ASD is a persistent disabling neurodevelopmental disorder of which the symptoms manifest themselves early in life. Generally, children with ASD experience difficulties in social communication, language development, flexibility in thinking and handling, eye contact, response to name, facial expressions and stereotyped behaviors and interests. Additionally, difficulties in motor skills frequently occur in ASD. There is evidence that ASD infants have more problems with motor anticipation tasks (16, 17) and motor milestones such as sitting, crawling and walking (18). Also problems with postural changes (19, 20) and difficulties with symmetry and midline positions (21-23) occur in these infants. All these elements indicate that the majority of the infants with ASD show a reduced motor development making a comorbidity with DCD evident.

High-quality research of the early motor development of infants with DCD is imperative. To begin, adequate motor skills are crucial during child development to give infants the ability to move, interact with the world and enhance the parent-child relationship (24). Moreover, the knowledge of early motor markers and abnormalities may be convenient in order to facilitate early diagnosis and intervention. Usually, DCD is diagnosed at elementary school age. However, this is not a favorable time to address motor problems, given the large pressure to perform in new school skills. In contrast, it is more beneficial to give a child a boost in motor development in the second or third grade of kindergarten. Moreover, early recognition brings relief to parents as they finally have an explanation for the motor problems of their child. Finally, early treatment can also prohibit the automatization of ineffective or "incorrectly performed" motor skills (e.g., a faulty automated pen grip is difficult to reverse). The earlier the treatment can start, the more efficient, given the greatest brain neuroplasticity at a young age (25).

As DCD is usually diagnosed at primary school age, research on early markers is scarce and difficult. Retrospective Video Analysis (RVA) offers a possibility to observe early clinical features of infants who are later diagnosed with DCD. This method allows researchers to gather information in an effective way and gives them the opportunity to examine the early development of the “non-diagnosed” infant. In addition, researchers are able to observe the infant in its familiar environment. This is a major advantage as clinicians have a neutral perception of the infant and the occurrence of biased opinions can be prevented. Using RVA gives experts the opportunity to examine the spontaneous motor skills of the infant, which is a reflection of daily life and behavior. This study primarily examines the early motor signs of typically developing (TD) infants, infants with DCD and infants with DCD in comorbidity with ASD during the first two years of life using RVA. The main objective of the research was to evaluate the hypothesis that infants with DCD and infants with DCD in comorbidity with ASD can be distinguished from TD infants based on early differences in motor maturity seen in home videos. In addition, researchers observed motor abnormalities in early development. The registration of early motor differences may assist in early identification of infants with neurodevelopmental disorders which leads to a quicker diagnostic procedure and treatment. This way, the developmental delays can be diminished, resulting in a better quality of life.

2. Methods

2.1. Research design

A retrospective study was performed. Using RVA, motor maturity and movement abnormalities were compared in three groups of infants (TD, DCD and DCD+ASD) between 0 and 2 years of age. The study was approved by the research Ethics Committee and the Rehabilitation Sciences and Physiotherapy research group at Ghent University.

2.2. Recruitment

2.2.1. Participants

Researchers aimed to recruit a total of 45 elementary school children (15 TD, 15 DCD, 15 DCD+ASD) with a current age between 6 and 12 years in Belgium and the Netherlands. Recruitment sources included schools, Students Guidance Centers, Center for Developmental Disorders, 'Kind&Gezin', pediatric physiotherapists, rehabilitation centers and specific organizations serving TD infants and infants with DCD, optionally in comorbidity with ASD. The recruitment was performed by sending emails, distributing flyers and sharing flyers on social media platforms (Facebook, Instagram, Twitter). Candidates could register on a website leaving their contact details. Parents of participants were contacted by phone in order to explain the aim of the study and to check the inclusion criteria (e.g., age, diagnosis, hospitalization…). If participants fulfilled the study criteria, parents were asked to fill in an electronic questionnaire to check more detailed inclusion criteria. Figure 1 shows the flow diagram for participants enrolment.

2.2.2. Inclusion – and exclusion criteria

All children were free from serious early childhood conditions that could affect development (e.g., brain haemorrhage, cancer, severe trauma…) and had no long-term hospitalization period (≥ 3 weeks) between 0 and 2 years of age. Children born premature and/or dysmature were not excluded from the study.

2.2.2.1. TD children

Children in the TD group had no known medical diagnosis that could affect motor development (DCD, ASD, ADHD, CP and other conditions). Additionally, these children presented no motor problems, indicated by a total percentile score >16 on the Movement Assessment Battery for Children Second Edition (M-ABC-2) and a score on the Developmental Coordination Disorder Questionnaire (DCDQ'07) not indicative for a risk of DCD. Social-responsiveness problems were absent, indicated by a T-score ≤60 on the Social Responsiveness Scale Second Edition (SRS-2) (26-28).

2.2.2.2. Children with DCD optionally with ASD

The diagnosis of DCD was confirmed by a total percentile score ≤16 on the M-ABC-2 and a score on the DCD-Q'07 indicative for a risk of DCD.
The diagnosis of ASD was confirmed by a T-score >61 on the SRS-2 indicative of mild, moderate to severe deficits in social responsiveness (26-28).

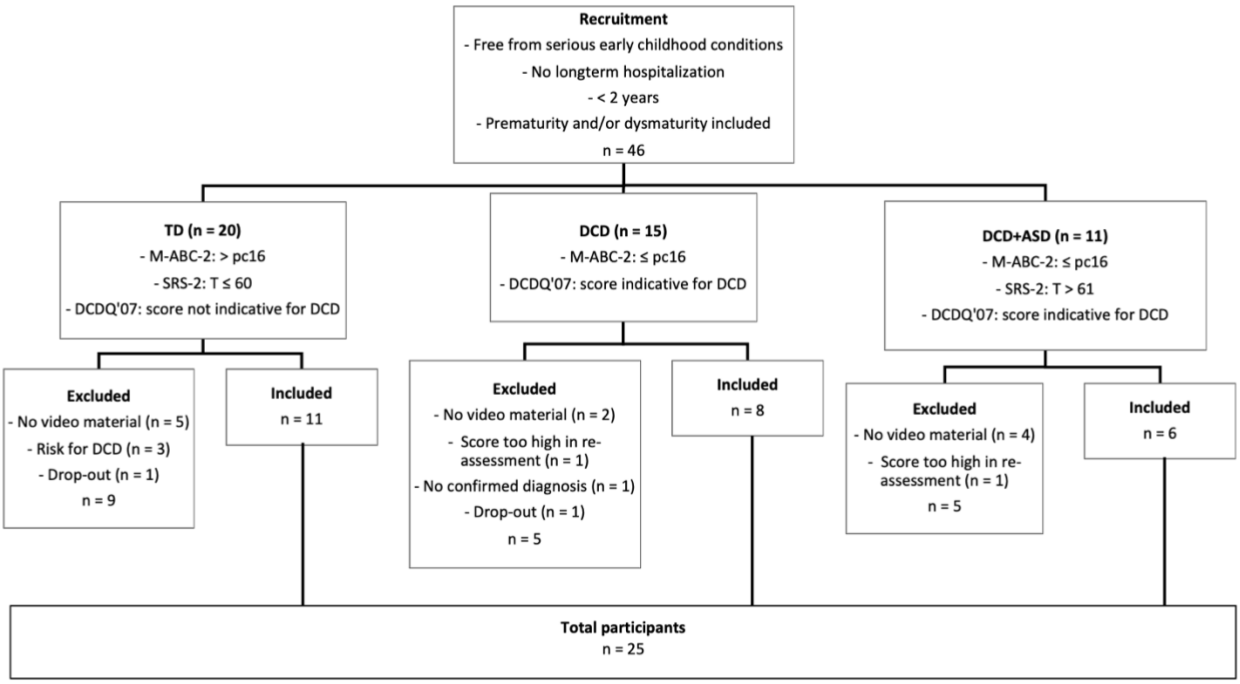

Figure 1: Flow diagram for participants enrolment

Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD, Movement Assessment Battery for Children Second Edition = M-ABC-2, Social Responsiveness Scale Second Edition = SRS-2, Developmental Coordination Disorder Questionnaire Edition 2007 = DCDQ'07

2.3. Instruments

Movement Assessment Battery for Children Second Edition (M-ABC-2) (26)

The M-ABC-2 is a standardized and norm referenced tool developed to assess deviant motor skills and delayed motor development. The test contains three subscales with a total of eight items for three age ranges: manual dexterity, ball skills and static and dynamic balance. Raw scores on each item are converted to standard scores. Subsequently, these scores are summed to produce a total score. The test can be used as a diagnostic tool to identify infants with DCD. According to Griffiths et al., the M-ABC-2 is one of the most reliable assessments in the age group 3-12 years. Regarding reliability, the M-ABC-2 has the following values: an internal consistency α = .88, an intra-rater reliability ICC = .88, an inter-rater reliability ICC = .96-.99 and a test-retest reliability ICC = .85-.96. Besides, the M-ABC-2 has good predictive validity at 4 years of age to predict motor impairment at 8 years (positive predictive value of 79, sensitivity 79%, specificity 93%) (29).

Social Responsiveness Scale Second Edition (SRS-2) (27)

The SRS-2 is a parent and/or teacher rating scale drawn up to identify social disabilities in children with ASD. The test offers four forms adjusted for age: preschoolers (2.5-4.5 years), school-aged children (4-18 years), adults (≥ 19 years) and adults self-report. Each form consists of 65 items. Raters evaluate the symptoms using a quantitative scale representing a range of severity. In addition to a total score, five treatment subscale scores are provided: social awareness, social cognition, social communication, social motivation and restricted interests and repetitive behavior. The manual of the SRS-2 shows an internal consistency higher than 0.8 for the total score of the SRS-2, at all ages. In addition, the test has moderate inter-rater reliability with values ranging from r = 0.24-0.82. In terms of validity, for 4–18-year-olds there is a sensitivity of 0.90 and a specificity of 0.88. (27)

Developmental Coordination Disorder Questionnaire Edition 2007 (DCDQ'07) (28)

The DCDQ'07 is an improved version of the DCDQ and is considered to have stronger psychometric properties than the 2000 version (30). The major difference with the previous version is the population-based sample and the larger age range. The tool is a 15-item parent report questionnaire designed to assist in the identification of DCD, in children aged 5-15 years. Parents are asked to compare their child's motor performance to his/her peers using a 5-point Likert scale. It provides a standard method to measure a child's coordination in everyday, functional activities. The test has an overall sensitivity of 84.6% and a specificity of 70.8%. The DCDQ'07 has an internal consistency of α = .94 (28).

Infant Motor Maturity Scale and Atypical Coding Scales (IMMACS) (31)

To determine the motor maturity of the infant, a maturity scale was made based on Ozonoff's IMMACS (See Addendum A). Minor adjustments were made to the scale and maturity scores were renamed. Ozonoff et al. (31) used a score '0' to describe the most mature development and a score '3' to describe the least mature development. This coding manual was modified so that a lower number represented lower maturity and a higher number represented higher maturity. In addition, in each posture multiple criteria were added to the maturity scores to make the distinction between them clearer. In this study, motor maturity and protective responses were scored using a rating scale ranging from 1 to 4, with a score of '1' indicating the least mature form of motor development and a score of '4' indicating fully mature development. In addition, the presence of an Asymmetrical Tonic Neck Reflex (ATNR), W-sit, shuffling, bunny hop and toe walking was assessed.

2.4. Video recruitment and selection

Parents were asked to provide all available video fragments of their child between birth and the age of two years. Videos were transferred, copied and the original media returned to the families. Videos were renamed by ID number to preserve confidentiality. Using an Excel tab per child, the following information was logged for every provided video file: new name of the video, former name, video type, date of the video, date of birth, chronological age of the infant in months and weeks, video duration, context (e.g., outside, in the bathtub…), motricity (e.g., rolling over, sitting, crawling...), activity (e.g., playing, eating...) and whether the infant was fully visible in the video. Videos that did not contain the infant, undated videos, videos with poor quality and videos where the infant was crying or sleeping were excluded. When no date was available, parents were asked to estimate the infants' age in the video. If parents were unable to reliably estimate the infants' age, the specific video fragment was excluded. All videos concerning motor stimulation were excluded. Each video was provided with sound to hear the parental influence on the motor behavior. The parent-infant interaction was relatively minimal (e.g., pull to sit, sustained sit and stand, indicate an object…). For example, videos where parents facilitated their infant to roll or helped their infant crawling, were excluded from the study.

Parents were allowed to talk to their infants and to provoke their behavior, but infants had to initiate the movements independently. A movement was marked as infant-initiated when the infant spontaneously moved into the posture. Videos where parents or caregivers sat near the infant but not generally engaged with the infant, were included. Infants had to be completely visible for at least three seconds during the video, except negligible body parts (e.g., small and large toe in a pull to sit task). Infants with less than ten minutes of video material were excluded from the study.

2.5. Video editing

As the study aimed at evaluating the differences in motor milestones between the three groups, researchers had to gather video fragments in eight different postures: supine, prone, rolling from supine to prone, rolling from prone to supine, sitting, crawling, walking and protective responses. This way, all the videotapes were cut in separate fragments by three researchers who were blind to group membership. A new fragment was defined when the posture of the infant in the video changed. For example, when an infant was lying in supine, sitting and crawling in one video, the video was cut into three fragments. Infants had to hold each posture for at least three seconds to suffice as a separate video fragment, except when rolling. Using an Excel tab per posture, all cut video fragments were then classified in the new categories.

Specific criteria were formulated for the eight postures in order to guarantee a homologous categorization between the three researchers.

2.5.1. Supine

Infants were lying in supine (i.e., lying on their back) when there was no identifiable angle at the hip joint and the infant's body was flat to the bottom line. To be included for supine, infants had to be positioned on a mat, ground or in a crib. Positioning aids like pillows, Maxi Cosi and bouncers were allowed.

2.5.2. Prone

Infants spending time in prone (i.e., lying on the stomach) on a lap were not excluded.

2.5.3. Rolling

The start of the roll was defined as the point where the infant rotated from supine to prone or vice versa and initiated the roll independently. The roll started when there was no longer contact between the body part that initiated the roll and the underground. The roll ended when the infant finished in prone or supine or when the infant remained in side lying for more than ten seconds. Infants attempting to roll were also scored.

2.5.4. Sitting

Infants were categorized in sitting position when there was an identifiable hip flexion ≥ 45° at the hip joint and there was contact between the ischium tubercles and the underground. Alternative sitting positions such as supported sitting (e.g., pillows, chair, couch, hands of the caregiver…) and infants fastened in a baby chair or a bumbo floor seat were included. Situations where infants were sitting on the lap were allowed, if the infant was sitting in an active way. Videos in which the infant was positioned in W-sit or where the infant was shuffling were included and were collected in a separate list. Video material in which a parent was carrying an infant on the arm was excluded. Also crouch and squat positions were excluded.

2.5.5. Crawling

Crawling was defined as the moment when an infant in a quadruped position started propelling. Propelling was defined when an infant initiated a forward movement with at least one limb leaving the ground.

2.5.6. Standing

When the infant was positioned on both feet without taking a step in any direction, it was categorized as standing. Trampling on location for more than three seconds, was classified as standing instead of walking, otherwise this could incorrectly rank the infant as less mature. No forward movements neither a heel strike could be observed during these videos. In addition, these videos were only used to score protective responses.

2.5.7. Walking

Walking was scored if the infant took at least one step. Infants walking with support (e.g., walking aids, parental help, leaning against the wall…) were included.

2.5.8. Protective responses

The protective responses were evaluated in sitting, crawling, standing and walking if present.

After cutting all videos into shorter fragments per pose, a total of 3606 videos were obtained of which 614 videos in supine, 164 videos in prone, 92 videos in rolling from supine to prone, 32 videos in rolling from prone to supine, 1213 videos in sitting, 181 videos in crawling, 600 videos in walking and 710 videos in protective responses.

2.6. Video coding procedures

2.6.1. Motor maturity

The same procedures presented by Ozonoff et al. were followed (31). A coding system for scoring the infants' motor maturity and protective responses was used. Pediatric student physiotherapists who were blind for classification coded the video tapes. The motor maturity and protective responses were scored using a rating scale ranging from 1 to 4 (cf. supra).

2.6.2. Content coding

In addition to maturity, a number of other items were coded based on the coding system of Ozonoff et al. (31). The first item was the event category which described the infants' activity and environment (e.g., mealtime, special event (party or holiday), active play, passive activity, bath/self-care…). Secondly, the number of persons seen in the video fragment was noted. The third item was the level of physical restriction. This was coded as '3' if the infant was sustained/"bound" by equipment. A score '2' was given when the infant was partially limited in its movements and a score '1' indicated that the infant was completely free to move. The fourth item was "structure" which referred to the level of social interaction. A score '1' indicated that the infant was socially interactive with its environment, a score '2' was given when the infant made eye-contact without spontaneous interaction and a score '3' indicated that the infant was barely interactive, i.e. eye-contact was avoided in all situations. It was useful to compare the three groups based on these four environmental items and examine the possible influence of these items on their motor skills. See Addendum B for more specific descriptions of this coding system.

2.6.3. Movement abnormalities

Abnormalities were checked for each posture. The presence of ATNR was assessed in the video files of supine and prone. W-sit and shuffling were detected during sit, whereas bunny hop and toe walking were administered during the video fragments of crawling and walking.

2.7. Inter-rater reliability

The raters were three Master Students Pediatric Physiotherapy. Raters were blind to the categorization of infants and were trained in the "motor maturity coding system". Training was accomplished by coding video clips of infants who were excluded from the study. The inter-rater reliability was assessed comparing the coding skills of the three researchers calculating mean percent agreement. Twenty percent of the video segments were scored by two researchers. Raters agreed on the level of motor maturity in 80% of the cases.

2.8. Statistical analysis

Statistical Package for the Social Science version 27 (SPSS-27) was used to compare maturity scores between the three groups. To assess violations of normality, Q-Q plots, the Kolmogorov-Smirnov test and the Shapiro-Wilk's test were applied. The Levene's test was applied to evaluate violations of homoscedasticity. As the data did not exhibit a normal distribution, the Kruskal-Wallis was conducted for group comparisons of motor maturity. To further consider significant differences between two groups, the Mann-Whitney U test was performed. When a significant difference in motor maturity was found, mean age was further analyzed for significant differences. The cut-off level for statistical significance was set at $p = .01$. Considering the small sample sizes, this level of significance was chosen to interpret the results more strictly. For the statistical analysis of the movement abnormalities, the percentage of all codable videos where abnormalities occurred were noted per group per posture.

3. Results

3.1. Participant characteristics

Participant characteristics are described in Table 1. A total of 25 infants participated in this study. The participants were categorized in three groups based on group inclusion criteria. Both the TD group and the clinical groups (DCD group and DCD+ASD group) represented approximately half the total sample (44%, n = 11, 56%, n = 14, respectively). The proportion of infants with a diagnosis of DCD was slightly higher (32%, n = 8) than the proportion of infants with a diagnosis of DCD in comorbidity with ASD (24%, n = 6). Relatively more boys were included in the DCD (75%, n = 6) and DCD+ASD group (83,3%, n = 5) as compared with the TD group (36,4%, n = 4), although no significant differences between the three groups were found for gender ($\chi 2$ = 4.672, df = 2, p = .097). All infants had the Belgian nationality.

Table 1: Group demographics and characteristics

	TD (n = 11)	DCD (n = 8)	DCD+ASD (n = 6)
Gender (male/female)	4/7	6/2	5/1
M-ABC-2 (mean standard score (SD))	10.8 (0.44)	2.6 (0.60)	2.2 (0.65)
SRS-2 (mean T-score (SD))	48.3 (1.81)	62.1 (4.89)	81.2 (5.82)
DCDQ'07 (mean raw score (SD))	70.9 (0.83)	32.8 (2.61)	30.7 (4.74)

Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD; Movement Assessment Battery for Children Second Edition = M-ABC-2; Social Responsiveness Scale Second Edition = SRS-2; Developmental Coordination Disorder Questionnaire Edition 2007 = DCDQ'07

3.2. Videotape characteristics

Characteristics of video segments are described in Table 2. A total of 3606 video clips were examined, of which 2152 (59.7%) within the TD group, 597 (16.6%) within the DCD group and 857 (23.7%) within the DCD+ASD group. The total duration of all included videos was approximately 34 hours and 23 minutes with a notable larger duration in the TD group (57.7%) compared to the DCD group (18%) and the DCD+ASD group (24.3%). The mean ages of the three samples were calculated by all included videos, with a mean age of 10.2 months in the TD group, 7.9 months in the DCD group and 9.4 months in the DCD+ASD group. The mean age range was calculated for the total sample ranging between 3 weeks and 23 months. A large number of videos was examined but excluded for statistical analysis. These videos were scored as 'not codable' (e.g., the infants' posture was constrained by the environment, poor quality, no protective response while standing).

Table 2: Videotape characteristics

	TD (n = 11)	DCD (n = 8)	DCD+ASD (n = 6)
Total segments	2152	597	857
Mean number of segments per infant	195.6	74.6	142.8
Total duration (minutes)	1191	371	501
Mean duration of segments per infant (minutes)	108.3	46.8	83.5
Mean age in video (m)	10.2	7.9	9.4
Mean age range in video (m)	22.3	18.4	17.8

Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.3. Motor development

3.3.1. Developmental assessments

The M-ABC-2 (26) was used to analyze group differences in motor development. Post hoc comparisons exposed that the TD group had significantly higher standard scores on the M-ABC-2 than both DCD and DCD+ASD groups ($p < .001$). In contrast, there were no significant differences between the DCD group and the DCD+ASD group ($p = .997$). A second instrument in which averages were compared between groups, is the SRS-2 (27). After performing post hoc analyses, a significantly higher T-score was noticed for the DCD+ASD group in comparison with both the TD group and the DCD group ($p < .001$, $p = .007$, respectively). However, there was no significant difference between the TD group and the DCD group ($p = .017$). A comparison of the total scores of the DCDQ'07, used to confirm criterion B of the DSM-V in DCD, was performed between the three groups (28). Statistical analysis demonstrated no significant difference for the DCD group and the DCD+ASD group ($p = .854$). A significant difference was found between the TD group and both clinical groups ($p < .001$). The data of the three instruments can be seen in Table 1.

3.3.2. Motor milestone achievement

The age at which infants achieved their motor milestones (i.e., crawling and walking independently) was also analyzed via retrospective parental reports (See Table 3). The purpose of the retrospective parental reports was to further chart the infants' motor functioning. Analysis of the post hoc tests showed no significant differences between the groups for the mean age of achieving the motor milestone crawling ($p = .591$) and the motor milestone independent walking ($p = .183$). Parents of infants with DCD+ASD reported remarkably higher ages for independent walking compared to the other groups. This is not in agreement with our statistical analysis which revealed that the TD group (14.1 months) was not significantly younger than both the DCD group (14.6 months, $p = .914$) and DCD+ASD group (16.7 months, $p = .189$).

Table 3: Parental report: age of achieving motor milestones (in months)

	TD (n = 11)	DCD (n = 8)	DCD+ASD (n = 6)
Crawling	9.2	10	9
Walking	14.1	14.6	16.7

Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4. Motor maturity

To compare motor maturity, age intervals of four months were selected (e.g., 0-4 months contains months 0, 1, 2 and 3).

3.4.1. Supine

The total number of all codable video segments was 557 (TD = 71.8%, DCD = 11.1%, DCD+ASD = 17.1%). Mean maturity scores of two age intervals (0-4 months and 4-8 months) were calculated and compared between the three groups. No significant differences in maturity score were found for all age intervals (H(2) = 5.408, p = .067; H(2) = 3.783, p = .151, respectively). As described in Figure 2, the highest maturity score was reached at 8 months for all groups.

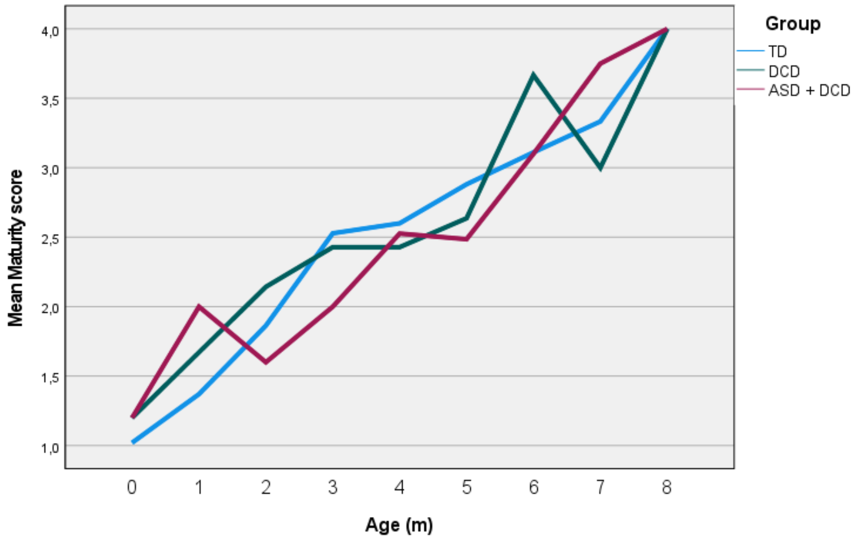

Figure 2: Line graph supine: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder DCD+ASD

3.4.2. Prone

The total number of all codable video segments was 122 (TD = 49.2%, DCD = 27.1%, DCD+ASD = 23.7%). No significant differences were found for all age intervals (0-4 months: H(2) = 3.886, p = .143; 4-8 months: H(2) = 7.326, p = .026; 8-12 months: H(2) = 0.915, p = .633). Both TD and DCD+ASD groups achieved their highest maturity score at 7 months. The DCD group did not reach their highest maturity score until 9 months (See Figure 3).

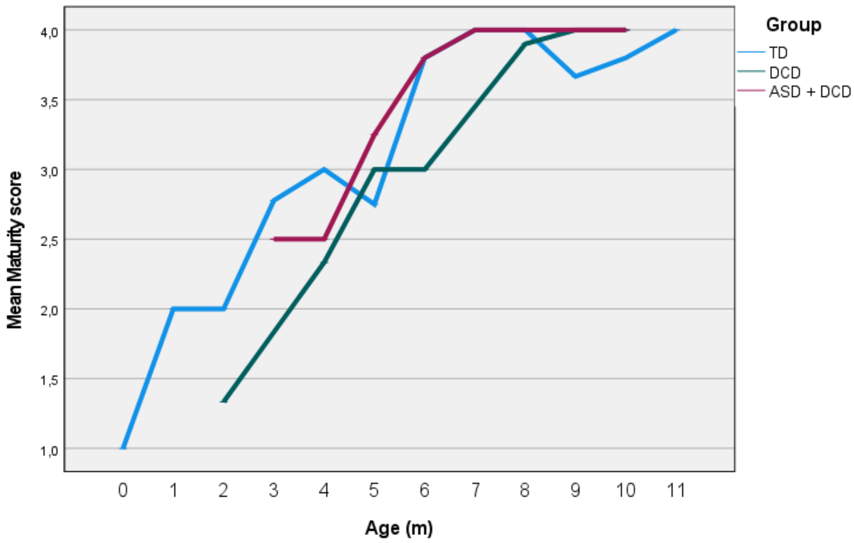

Figure 3: Line graph prone: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4.3. Rolling from supine to prone

The total number of all codable video segments was 85 (TD = 57.6%, DCD = 20%, DCD+ASD = 22.4%). Differences in mean maturity scores were analyzed in two age intervals, 4-8 months and 8-12 months. No significant differences were found for both age intervals (4-8 months: $H(2) = 6.115$, $p = .047$; 8-12 months: $H(2) = 2.464$, $p = .292$). The TD group reached their highest maturity score at the age of 10 months, whereas the DCD+ASD group at the age of 14 months. After the age of 9 months, no data in the DCD group was available. Consequently, the age at reaching the highest maturity score for the DCD group could not be determined (See Figure 4).

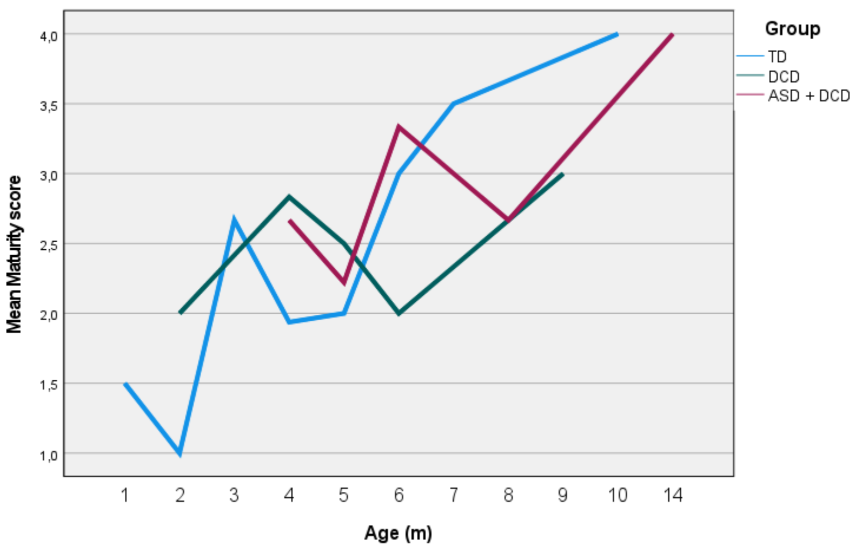

Figure 4: Line graph rolling supine to prone: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4.4. Rolling from prone to supine

The total number of all codable video segments was 31 (TD = 32.3%, DCD = 33.4%, DCD+ASD = 32.3%). The difference in mean maturity score between 4-8 months and 8-12 months was analyzed. No significant differences were found for both age intervals (4-8 months: H(2) = 2.215, p = .330; 8-12 months: H(2) = 4.125, p = .127). As can be seen in Figure 5, the highest maturity score was reached at the age of 9 months in the DCD group whereas the TD and DCD+ASD groups reached their highest maturity score at the age of 10 months.

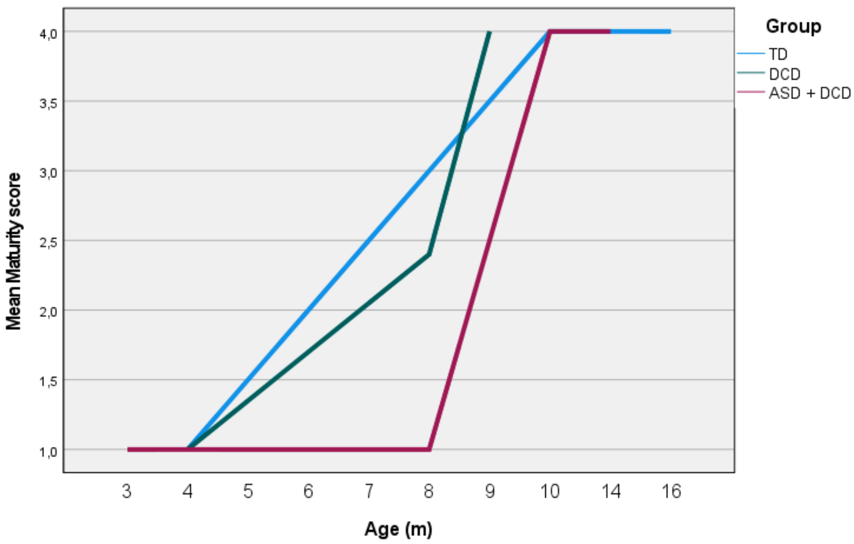

Figure 5: Line graph rolling prone to supine: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4.5. Sitting

The total number of all codable video segments was 848 (TD = 65.5%, DCD = 12.7%, DCD+ASD = 21.8%). At all age intervals, there was no significant difference in sitting maturity between the three groups (0-4 months: H(2) = .300, p = .861; 4-8 months: H(2) = 2.904, p = .234; 8-12 months: H(2) = .059, p = .971; 12-16 months: H(2) = 1.686, p = .430; 16-20 months: H(2) = .464, p = .793; 20-24 months: H(2) = 4.036, p = .133). The highest maturity score was first reached in the DCD group and in the DCD+ASD group, respectively at 14 and 16 months. The TD group reached their highest maturity score at 19 months (See Figure 6).

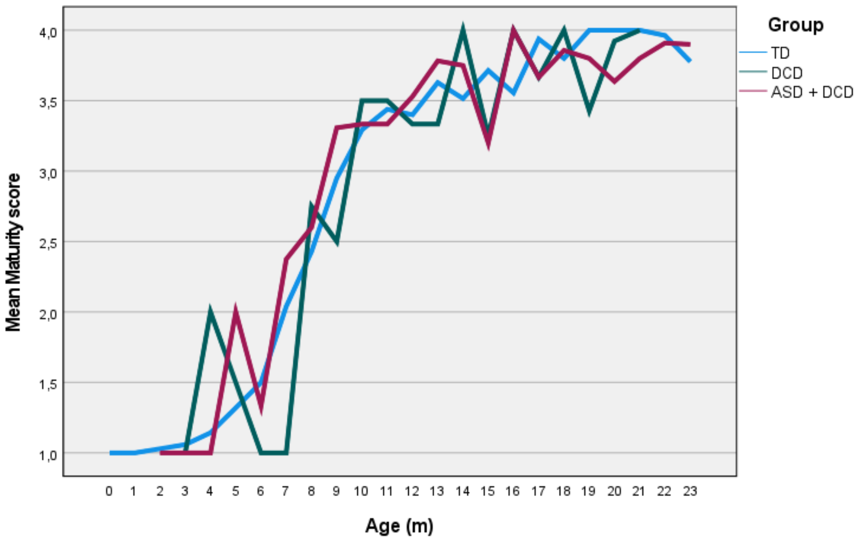

Figure 6: Line graph sitting: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4.6. Crawling

The total number of all codable video segments was 140 (TD = 57.1%, DCD = 19.3%, DCD+ASD = 23.6%). No significant differences were found in all age intervals (8-12 months: H(2) = 7.436, p = .024; 12-16 months: H(2) = 3.218, p = .200; 16-20 months: H(2) = 4.375, p = .112; 20-24 months: H(2) = .855, p = .652). The highest maturity score was achieved at 15 months for the DCD group. The DCD+ASD and TD groups reached their highest maturity score at 17 and 21 months, respectively (See Figure 7).

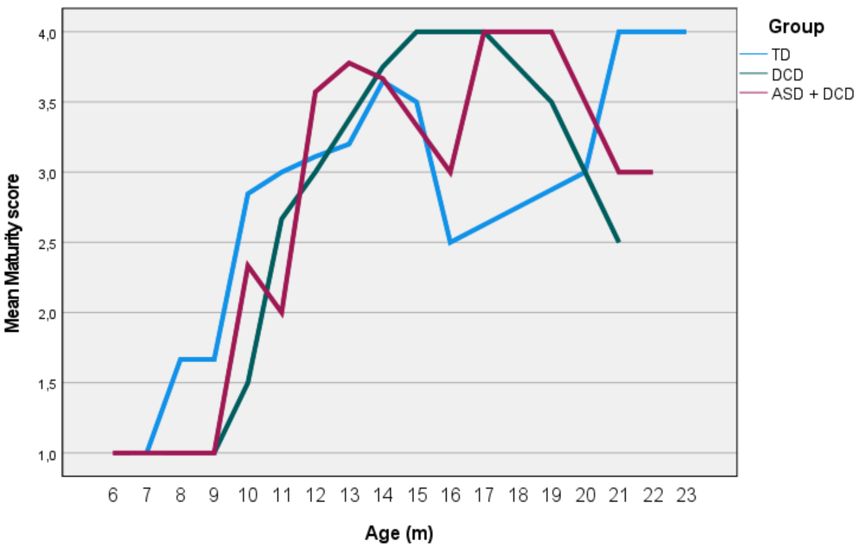

Figure 7: Line graph crawling: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.4.7. Walking

The total number of all codable video segments was 567 (TD = 55.4%, DCD = 19.4%, DCD+ASD = 25.2%).

In the age interval 8-12 months, a significant difference in motor maturity was noted (H(2) = 11.013, p = .004). The DCD group scored significantly better than the TD group (U = 0,0001, Z = -2.960, p = .003). There was no significant difference between the DCD+ASD group and the TD group, neither with the DCD group (U = 9.000, Z = - 0.908, p = .364; U = .0001, Z = -2.449, p = .057, respectively). There was no significant difference in age between the three groups in this age interval (H(2) = 5.440, p = .066).

In the age interval 12-16 months, there was a significant difference in maturity score (H(2) = 37.997, p < .001). The DCD group and the DCD+ASD group scored significantly better than the TD group (U = 554.500, Z = -5.284, p < .001; U = 877.000, Z = -4,991, p < .001, respectively). No significant difference was found between the DCD group and the DCD+ASD group (U = 552.500, Z = -2.019, p = .044). There was a significant difference in age (H(2) = 29,868, p = .001). The DCD group was significantly older than the TD group (U = 480.500, Z = -5.208, p < 0.001).

In the age interval 16-20 months, no significant differences were found (H(2) = 4.878, p = .087).

In the age interval 20 and 24 months, there was a significant difference in maturity score (H(2) = 59.564, p < .001). Both TD and DCD+ASD groups scored significantly better than the DCD group (TD: U = 1478, Z = -7.306, p < .001; DCD+ASD: U = 743, Z = -4.303, p < .001). There was no significant difference between the TD group and the DCD+ASD group (U = 3727, Z = -1.895, p = .058). Significant age differences were found (H(2) = 27.630, p < .001). The TD group was significantly older than the DCD group (U = 1340, Z = -5.904, p < 0.001).

As can be seen in Figure 8, the highest maturity score was reached at 17 months in the DCD+ASD group, at 19 months in the TD group and at 23 months in the DCD group.

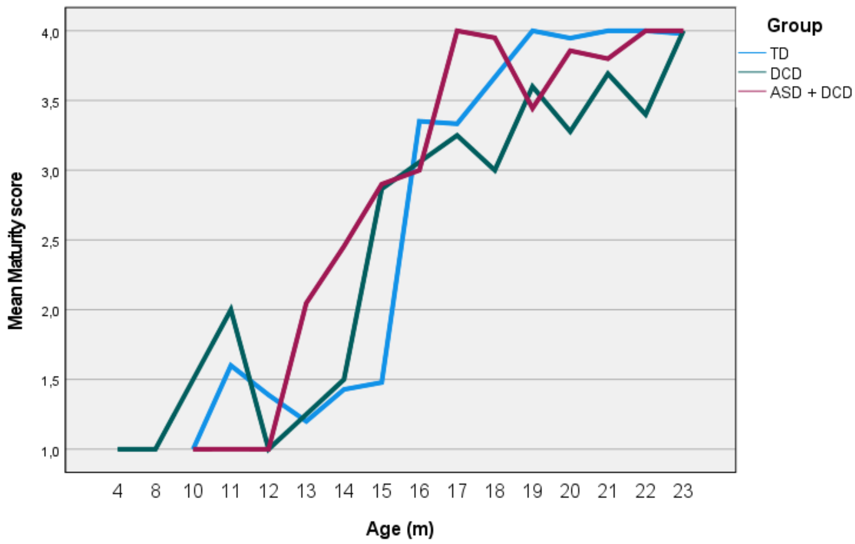

Figure 8: Line graph walking: between-group comparisons for motor maturity evolution in age intervals in months (m)
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

3.5. Protective responses and movement abnormalities

The total number of all codable video segments was 187 (TD = 37.4%, DCD = 30%, DCD+ASD = 32.6%). The protective responses were coded during the following four postures: sitting, crawling, standing and walking. In the first year of life (0-12 months), no significant differences in maturity score were found, neither in the 12-16 month age interval (0-12 months: H(2) = 1,340, p = .512; 12-16 months: H(2) = 0.128, p = .938). In the 16-20 month age interval, a significant difference was noted (H(2) = 11.823, p = .003). The DCD group demonstrated significantly more mature protective responses than both TD and DCD+ASD groups (U = 74, Z = -3.026, p = .002; U = 40, Z = - 3.218, p = .001, respectively). There was no significant difference between the TD group and DCD+ASD group (U = 138.500, Z = -.302, p = .762). A significant difference in age was found. The DCD group was significantly older than both TD and DCD+ASD groups (TD: U = 1096, Z = - 4.073, p = .000; DCD+ASD: U = 416.500, Z = -3.248, p = .001). In contrast to the previous age interval, there were no significant differences in maturity between 20 and 24 months (H(2) = 3.143, p = .208).

Exploring atypical movements in supine and prone, the ATNR was seen in 25 video fragments representing 4.5% (TD = 3.9%, DCD = 0.1%, DCD+ASD = 0.5%) of all codable videos in supine, however in prone no video fragments with ATNR occurred. A more detailed analysis showed that four infants in the TD group, one infant in the DCD group and two infants in the DCD+ASD group demonstrated an ATNR. Abnormalities in the sitting position, concerning W-sit and shuffling, were investigated. W-sit was seen in 33 video fragments which represented 3.9% (TD = 2.8%, DCD = 0.3%, DCD+ASD = 0.8%) of all codable videos in sit. These percentages represented six infants in the TD group, two in the DCD group and one infant in the DCD+ASD group. Shuffling was seen in 42 video fragments representing 4.9% (TD = 4.2%, DCD = 0.6%, DCD+ASD = 0.1%) of all codable videos in sit. A more detailed analysis showed three infants in the TD group, three infants in the DCD group and one infant in the DCD+ASD group. Abnormalities in crawling and walking (i.e., bunny hop and toe walking) were evaluated during coding procedures, but were not observed.

Summarizing these previous results, minimal differences were found for motor maturity except for walking and protective responses. In these cases, the DCD group scored significantly better than the other two groups. In addition, this group had a higher mean age. Regarding the movement abnormalities, no significant differences were found.

3.6. Associated parameters

The effect of three study variables on motor maturity was evaluated during the coding procedures (See Table 4). Generally, for all postures, TD infants were significantly more passive compared to both DCD and DCD+ASD groups. Further analysis demonstrated significant differences in physical restriction in all groups. Remarkably, TD infants were significantly more sustained by equipment compared to DCD+ASD infants. Finally, the social interaction was evaluated, proving that the DCD+ASD group was significantly less socially interactive in comparison with the other groups.

Table 4: Associated parameters

	TD (n = 11)	DCD (n = 8)	DCD+ASD (n = 6)	p
Event category				
Mealtime	4.6%	5.7%	4.7%	
Holiday or party	6.3%	6.6%	5.2%	
Active playing	51.9%	**63.4%***	**66.8%***	p <.01
Passive	**28.8%***	21.9%	17.6%	p <.01
Washing	**4.8%***	1.4%	2.1%	p <.01
Other	3.6%	0.9%	3.7%	
Level of physical restriction				
No physical restriction	61.9%	**71.9%***	65.7%	p <.01
Partially limited	24.2%	19.8%	26.8%	
Sustained by equipment	**12.8%***	8.3%	7.5%	p <.01
Structure				
Social interaction	40.1%	42.6%	35.1%	
Social but not interaction	34.2%	33.8%	29.7%	
Non-social	25.7%	23.6%	**35.1%***	p <.01

Significance level: .01 (: p <.01)*
Typically Developing = TD; Developmental Coordination Disorder = DCD; Developmental Coordination Disorder + Autism Spectrum Disorder = DCD+ASD

4. Discussion

In this study, the early motor development of infants with DCD, optionally in comorbidity with ASD, was examined using RVA. Based on the hypothesis of a delayed development, the main purpose of this study was to analyze their evolution in motor maturity during the first two years of life. A second purpose was to investigate the occurrence of movement abnormalities.

Using a coding manual, based on the manual of Ozonoff et al., minimal differences in motor maturity were found for the majority of the postures (31). TD infants achieved their most mature development at similar ages compared to the other groups. These results may suggest that these infants had an identical motor maturity evolution and that motor maturity could not serve as an early sign to discover developmental delays or motor differences. However, general analysis of the associated parameters demonstrated that TD infants were significantly more passive and more physically restricted than DCD and DCD+ASD infants. Consequently, this could be a possible explanation for their lower maturity scores in the majority of the postures. Therefore, a more detailed analysis per posture considering the secondary variables and limitations is required to interpret these outcomes.

A number of significant between-group differences were found for the level of walking maturity. No significant delay in achieving mature walking between infants was detected. Surprisingly, significantly better maturity scores in the DCD and DCD+ASD group were found compared to the TD group. These outcomes are in contrast with the study of Ozonoff et al. (31) who revealed that infants with ASD achieved most mature walking at significantly later ages. TD infants may have been impeded to exhibit a mature walking pattern as significantly younger mean ages were found in this group at later age intervals. Consequently, the result that DCD and ASD infants had better walking performances may be unreliable. Based on the parent reports, both TD and DCD infants started walking independently at the age of 14 months, which was in agreement with observed outcomes in this study, but in disagreement with Sumner et al. (32). Similar to this study, Sumner et al. conducted a parent report regarding independent walking, which showed a significant difference between the TD and the DCD group in age achieving this motor milestone (13 and 16 months, respectively). Other studies showed that infants who achieved the motor milestone independent walking at later ages, were later diagnosed with DCD. For example, Zhu et al. reported that infants who walked independently at the age of 16 months had a notable higher risk for DCD (33). Holst et al. reported that 20% of the infants who had an age at attainment of walking independently above the 95% centile, received the diagnosis of DCD at the age of 7 years (34). Parents of infants in the DCD+ASD group reported a mean age of 16 months to start walking independently, while in this research no significantly higher ages were detected for these infants. This is in contrast to the findings of Ozonoff et al., who found that both infants with ASD and developmental delays (DD) started walking later than the TD infants (31). This could possibly be explained by the more extensive population of different developmental delays as opposed to our specific DCD group. A contradiction was found between the statistical results and the observations of the parent report for the motor milestone crawling. Even though the TD group was considered as the first group to start crawling at the age of 7 months, this was in conflict with the parental observation of the TD group indicating an average age of 9 months. This disparity may be explained as parents often have difficulties recalling the early development of their infant. In addition, "creeping" (i.e., belly on floor) was defined as less mature crawling while parents may have described crawling as a four-pointed position which can clarify the age difference. It is also possible that parents may have misinterpreted the questions in the parent survey which may have affected the outcomes. In contrast to the TD group, infants of both the DCD and the DCD+ASD groups started crawling at the average age of 9 to 10 months, which was in line with parental observations. A profound analysis of the protective responses revealed that DCD infants obtained significantly better scores between 16 and 20 months. However, when comparing mean ages between groups, the DCD group was also significantly older which could possibly explain the differences.

The second purpose of this study was to investigate whether movement abnormalities (e.g., ATNR, W-sit, shuffling, bunny hop, toe walking) could be discovered in infants with DCD, optionally in comorbidity with ASD, at a young age. In all groups, ATNR occurred before the age of 5 months which can be seen within normal development. Particularly, W-sit and shuffling were more frequently observed in the TD group. This was not a remarkable finding as the TD group had the largest number of participants and video material which may have led to a higher frequency of motor variation in this group. As a result, these motor abnormalities should be confirmed as a variant development. Contrary to our initial expectations, no form of toe walking was seen in infants with ASD. Referring to Ming et al (35)., toe walking is considered as a more temporary symptom and it is not certain that it can be seen in all ASD infants. Moreover, this study reported that infants with ASD were more likely to walk on their toes when they were bare feet (35). This way, the presence of toe walking might have been missed in some cases as infants were often wearing shoes in videos. From our practical-based experiences, toe walking may be observed more often in infants with a severe ASD diagnosis in comorbidity with a mental disorder. As infants with mental disorders were excluded from this study, this may be a reason for the lower prevalence of toe walking in infants with ASD. Finally, it is quite sure that the occurrence of motor abnormalities in infants of the clinical groups may be of higher incidences. These abnormalities were probably underevaluated considering the major influence of the secondary variables and limitations in this study (cf. infra).

Surprising was the higher score from the DCD group on the SRS-2 which detects problems in social interaction and stereotyped behaviors. As a first hypothesis for these high scores, previous studies showed that infants with DCD have a low self-esteem and participate less in sports and leisure activities compared to their peers (36). Besides, clumsy children are less physically active and engage less in social interaction with classmates (37). As a result, it appears that these children often have fewer playmates and are more likely to be bullied by classmates (38-40). Another hypothesis is the possibility that some of these infants exhibit ASD characteristics, but did not receive an ASD diagnosis. Concluding, the exact cause of higher scores on the SRS-2 (27) in the DCD population is unclear. However, it is recommended to conduct further research in the comorbidity of DCD and ASD.

Importantly, there are several limitations to be recognized in this study. First of all, the findings may not be generalized to the larger population of infants with neurodevelopmental disorders as the total amount of data per group was too limited. Considering the small sample sizes, it was obliged to take extended age intervals. As a result, a higher maturity score was often linked to a higher mean age. This way, the outcomes of walking remain questionable. Representation of a continuous line in the line graphs was unattainable and fluctuations were often present. Consequently, these restrictions may have biased the results making it difficult to produce accurate conclusions. Secondly, beside the difference in video material per group, also a discrepancy in the amount of video material per infant was present which could have easily influenced the results. Even though a minimum of ten minutes of video material per infant was required, the wide variety in video segments per infant could not be prevented which made it challenging to execute a correct statistical analysis. This way, some infants may have had a greater impact on the study results which may have led to inaccurate between-group comparisons. For example, it is possible that a lower maturity score in the TD group could be explained by one infant who had the greatest amount of video fragments but who had also systematically lower maturity scores in all postures. Also, the heterogeneity of infants within each sample may have led to implausible outcomes. As a result, findings have to be interpreted with caution. Despite the efforts to gather a large and equal number of participants per group, smaller and uneven sample sizes were obtained in all groups than originally intended, due to the strict inclusion criteria. Unfortunately, also a number of limitations were associated with RVA. For example, the poor quality of video material, lack of information in certain video fragments, videos where infants were not completely visible, the clothes of the infant and the infant's behavior (e.g., sleeping and crying) in the video were frequently encountered disadvantages.

Differences in motor development become apparent at a later age when more complex tasks are performed and are less evident during motor milestones. According to Missunia et al., early motor abilities (e.g., sitting, crawling and grasping) seem to develop relatively spontaneously in infants diagnosed with DCD. Coordination difficulties seem to be more evident with learned skills (e.g., handwriting, playing piano, baseball) (41). However, we do not exclude the possibility of discovering differences in motor development at a young age, but it is more notable in these learned skills. As the motor development of infants could not be reliably and easily assessed in a standardized way at a young age, spontaneous movements were observed via home videos in accordance with previous studies (21, 31). However, the limited comprehensive analysis of motor functions via video analysis should be taken into account. According to the study of Ozonoff et al., we can conclude that the application of home videos to investigate early motor development comparing motor maturity and movement abnormalities between infants, is valuable (31). Though, clinical observations via home videos are insufficient to diagnose infants in an early developmental stage.

Definitely, more research is needed, using larger sample sizes and more sensitive measures to assess early motor development. With larger sample sizes, more detailed analyses may be executed to determine whether there are fundamental motor differences between the groups.

5. Conclusion

Considering this study, there are no remarkable differences in the early development of TD infants, infants with DCD and infants with DCD in comorbidity with ASD. Motor maturity in infants with DCD do not differ from TD infants. In addition, delayed development of motor milestones cannot be confirmed. Nevertheless, it remains important to detect possible early developmental delays. Further research is needed with larger sample sizes, more video material and possibly issues other than motor maturity should be investigated to make an early diagnosis possible.

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Abstract in lekentaal

Developmental Coordination Disorder (DCD) is een term die gebruikt wordt om een groep kinderen aan te duiden die problemen hebben met taken die motorische vaardigheden vereisen. Deze kinderen gaan typisch "anders" bewegen dan leeftijdsgenoten en ervaren problemen in de thuis- en schoolomgeving. Kinderen met DCD bewegen moeizaam, houterig, stuntelig, onhandig en minder gecoördineerd. Meestal wordt de diagnose DCD op lagere schoolleeftijd gesteld wanneer het kind moeilijkheden ervaart bij het schrijven. Dit is geen gunstig moment om motorische problemen aan te pakken, gezien de grote druk om te presteren op deze leeftijd.

Een aandoening die vaak samen voorkomt met DCD is Autisme Spectrum Stoornis (ASS). Deze kinderen hebben typisch moeilijkheden op vlak van sociale interactie, communicatie, taal en hebben vaak stereotiepe interesses en gedragingen. Daarnaast kunnen deze kinderen ook motorische problemen vertonen. Zoals bij DCD wordt de diagnose ASS vaak pas in de lagere school gesteld, wat eveneens hier geen ideaal moment is.

Vroegtijdige erkenning van deze aandoeningen is om verschillende redenen belangrijk. Hoe jonger het kind, hoe "plastischer" of "kneedbaarder" het jonge zenuwstelsel en hoe effectiever vroegtijdige behandeling kan zijn. Door vroegtijdig deze kinderen te behandelen kan men eventueel "fout uitgevoerde" motorische vaardigheden voorkomen.

De huidige studie ging op zoek of er reeds in de vroege motorische ontwikkeling van deze kinderen zichtbare afwijkingen kunnen gezien worden. Er werden 25 kinderen gerekruteerd waaronder elf typisch ontwikkelende kinderen, acht kinderen met DCD en zes kinderen met de diagnose DCD en ASS. Via videomateriaal werd gekeken naar de motorische ontwikkeling van deze kinderen voor de leeftijd van 2 jaar.

De vroege motorische ontwikkeling van deze kinderen werd onderzocht in 8 verschillende houdingen namelijk ruglig, buiklig, rollen van ruglig naar buiklig, rollen van buiklig naar ruglig, zitten, kruipen, staan en stappen. Daarnaast werden de opvangreacties van deze kinderen vergeleken en werd nagegaan in welke mate motorische afwijkingen/abnormaliteiten (bv. Asymmetrische Tonische Nek Reflex (ATNR), W-zit, poepschuiven, bunny hop en tenen lopen) voorkwamen in de drie groepen. De Asymmetrische Tonische Nek Reflex is een primitieve reflex waarbij het hoofdje van de zuigeling naar één kant is

gedraaid, waarbij de arm en het been aan dezelfde kant gestrekt zijn en de andere kant gebogen blijft. Wanneer het hoofdje naar de andere kant draait, bewegen de armen en benen mee.

Deze studie vond slechts weinig verschillen in motorische ontwikkeling tussen de drie groepen. Er werden geen opmerkelijke verschillen gevonden in bewegingsabnormaliteiten en de typisch ontwikkelende kinderen waren niet sneller matuur in bepaalde houdingen.

Enkel en alleen op basis van deze studie kunnen we concluderen dat er geen opvallende verschillen zijn in de vroege motorische ontwikkeling van typisch ontwikkelende kinderen, kinderen met DCD en kinderen met DCD in combinatie met ASS. Er is nog meer onderzoek nodig omtrent dit onderwerp met een groter aantal kinderen in de studie en meer videomateriaal.

FACULTY OF MEDICINE AND HEALTH SCIENCES

Proof of submission to the Ethics Committee

Ref. n°: BC-05716 E07 (Emma D'Hondt), E08 (Charlotte Lambrecht) & E09 (Marthe Verbeke)
Titel: EEN EXPLORATIEVE RETROSPECTIEVE VIDEO-ANALYSE VAN DE MOTORISCHE EN TAALONTWIKKELING VAN KINDEREN MET DEVELOPMENTAL COORDINATION DISORDER (DCD) VOOR DE LEEFTIJD VAN TWEE JAAR.
- Scriptie: Emma D'Hondt, Charlotte Lambrecht & Marthe Verbeke

Geachte professor
Geachte dokter
Geachte mevrouw, heer

Gelieve in bijlage de goedkeuring(en) te vinden betreffend(e) bovenvermeld(e) dossier(s).

Wij benadrukken dat het onderzoek enkel uitgevoerd kan worden mits inachtname van de veiligheidsmaatregelen die werden opgelegd vanuit de overheid omtrent COVID-19 en zonder extra druk te leggen op die diensten die door de COVID-19 epidemie al sterk bevraagd zijn (longziekten, intensieve zorgen, labo's, radiologie, ..).

Met vriendelijke groeten,

Namens de Commissie voor Medische Ethiek,

MEVR. MURIEL FOUQUET
Stafmedewerker
Commissie voor Medische Ethiek

Afz.: Commissie voor Medische Ethiek

Prof. dr. Hilde Van Waelvelde
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Ons kenmerk	**Uw kenmerk**	datum	pagina
BC-05716 E07	NVT	03/04/2020	1/2

Betreft : **Advies voor monocentrische studie met als titel:**

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B.U.N.: B670202000026

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* **Begeleidende brief dd 2020-3-13**
* **Informatie- en waarschuwingsnota dd 2020-3-12 Emma D'hondt**

Advies werd gevraagd door: prof. dr. Hilde Van Waelvelde

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° *All members of the Ethics Committee have reviewed this project. (The list of the members is enclosed)*

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BC-05716 E08	NVT	03/04/2020	1/2

Betreft : Advies voor monocentrische studie met als titel:

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Advies werd gevraagd door: prof. dr. Hilde Van Waelvelde

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* *In het kader van 'Good Clinical Practice' moet de mogelijkheid bestaan dat het farmaceutisch bedrijf en de autoriteiten inzage krijgen van de originele data. In dit verband dienen de onderzoekers erover te waken dat dit gebeurt zonder schending van de privacy van de proefpersonen.*
* *Het Ethisch Comité benadrukt dat het de promotor is die garant dient te staan voor de conformiteit van de anderstalige informatie- en toestemmingsformulieren met de nederlandstalige documenten.*
* *Geen enkele onderzoeker betrokken bij deze studie is lid van het Ethisch Comité.*
* *Alle leden van het Ethisch Comité hebben dit project beoordeeld. (De ledenlijst is bijgevoegd)*
* *The Ethics Committee is organized and operates according to the 'ICH Good Clinical Practice' rules.*
* *The Ethics Committee stresses that approval of a study does not mean that the Committee*

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accepts responsibility for it. Moreover, please keep in mind that your opinion as investigator is presented in the publications, reports to the government, etc., that are a result of this research.

- *In the framework of 'Good Clinical Practice', the pharmaceutical company and the authorities have the right to inspect the original data. The investigators have to assure that the privacy of the subjects is respected.*
- *The Ethics Committee stresses that it is the responsibility of the promotor to guarantee the conformity of the non-dutch informed consent forms with the dutch documents.*
- *None of the investigators involved in this study is a member of the Ethics Committee.*
- *All members of the Ethics Committee have reviewed this project. (The list of the members is enclosed)*

Namens het Ethisch Comité / On behalf of the Ethics Committee

Prof. dr. P. Deron
Voorzitter / Chairman

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Addendum

A: UGent adaptation of the infant motor maturity and atypicality coding scales

UGENT ADAPTATION OF THE INFANT MOTOR MATURITY AND ATYPICALITY CODING SCALES

Phase 1: Cutting fragments into different postures

3-second role: only code in posture when it is maintained during 3sec

1. Supine
2. Prone
3. Rolling supine to prone

RULE: If starting position greater than 3 seconds code in supine or prone.
Roll begins when body part that initiated the roll leaves the ground.
Roll ends when child is in a prone position or stays in side lying for 10+ seconds.

4. Rolling prone to supine

RULE: if beginning position greater than 3 seconds code in prone (or supine).
A roll begins when the body part that initiated the roll leaves the ground.
Roll ends when the child is in the supine position or remains in side lying for 10+ seconds.

5. Sitting

RULE: A sit begins when the child's bottom is fully on the ground, or resting on the back of their legs or ankles (as in a W-sit) for 3+ seconds.
A sit ends when their bottom leaves the ground, their legs, or their ankles for 3+ seconds.
If in kneel – bottom must hit floor or the back of their legs or ankles for at least 3 seconds to count as sit.

6. Crawling

RULE: A crawl begins when a child is in a quadruped position for 3+ seconds or when one limb leaves the ground. A crawl ends when the last limb to move touches the ground.

7. Walking

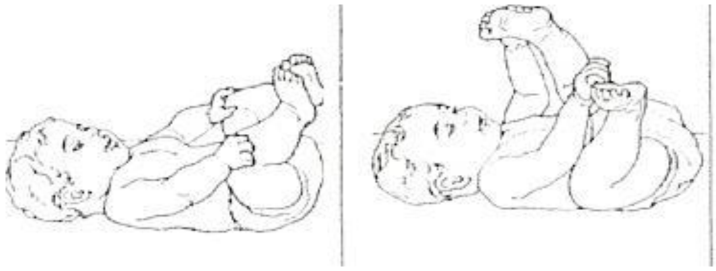
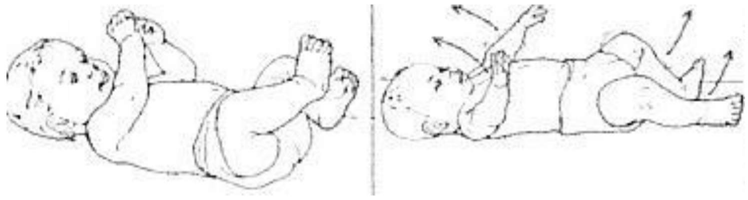
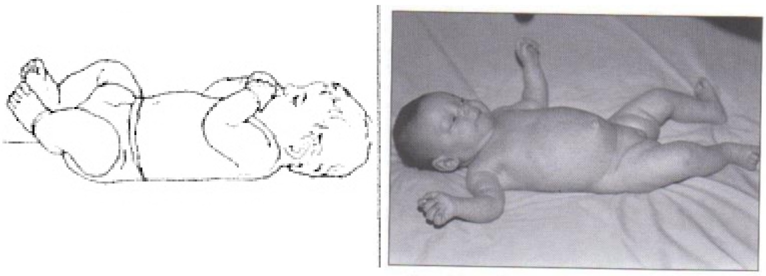
RULE: A walk begins when the child takes one weight bearing step and end when the last weight bearing step is flat on the ground.

8. Standing

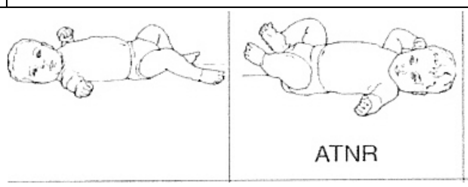
Phase 2:

When in doubt, score in the advantage of the child.

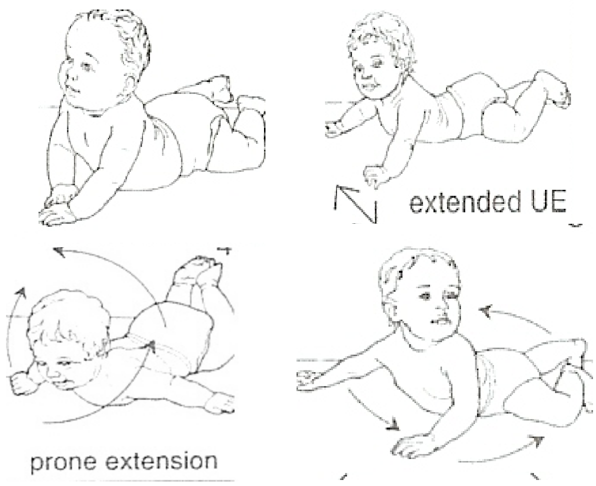
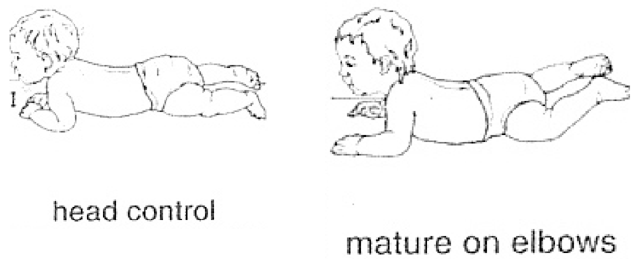
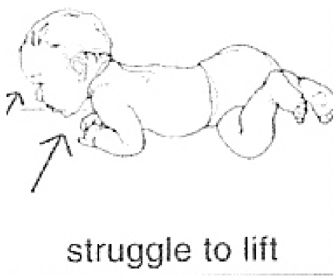
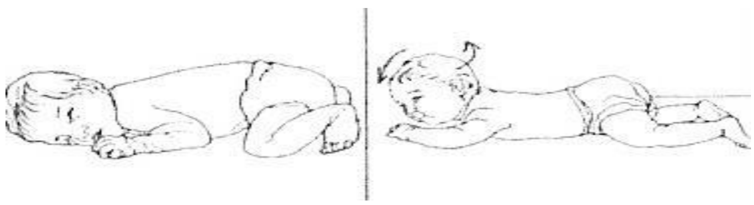
SUPINE

4 Mature with antigravity control	• **Playing with knees or feet** • Hands in mouth or with object • **Mature** head and neck control against gravity • May see **reaching** for parents • **Pelvic tilt or active bridging**	
3 Emerging antigravity control	• Upper extremity (UE) and/or lower extremity (LE) movement **against gravity** • Kicking, hands at midline • **Increased head control** against gravity • **May see chin tuck**	
2 Increasing midline control	• Head in midline may see hands in mouth • **Decreased** LE **flexion** when compared to level 1 or UE and/or LE movement through full range of motion compared to level 1 regardless of head position • Limbs more extended/ relaxed than level 1 • **No chin tuck yet**	 *Figure 2.2.* Brief fixation in midline. Lower extremities show increased hip extension and knee extension. Ankle dorsiflexion has changed very little.
1 Newborn flexed posture	• **Physiological** UE and LE **flexion** • Head not maintained in midline • Bicycle kicking	 *Figure 1.1.* In supine, the 1-month-old's head turns farther to the side than does the neonate's. *Figure 1.2.* The 1-month-old can visually track from the side to midline. Reciprocal kicking is noted.

Atypical: ATNR



PRONE

4 Mature with antigravity control	• Weight shift on UE/extended arms (elbow extension) with **hands flat** (if hands cannot be seen and arms are extended with weight bearing, code as 4) • **Chest** and head up – baby may pivot or push backwards • Code as 4 if at least 1 UE is full weight bearing with hand open/flat • **Complete 'puppy'/swimming**	
3 Emerging antigravity control	• Neck extension with weight bearing on **forearms** and lower torso, some upper chest / head and neck extension • May also have hip/leg extension • **Arms not trapped by body** • Code 3 if hands are fisted • **No complete 'puppy'** • **Elbow below or in front of shoulders**	
2 Limited Extension	• Baby in prone with neck extension. • Baby **looks ahead** with nose straight • May kick leg out into extension, arms likely under body (baby may appear stuck) • UE not weight bearing, **weight bearing on chest** • Elbows behind shoulders	
1 Baby in prone	• May have neck rotation = turning of head to either side but **not extension** against gravity	

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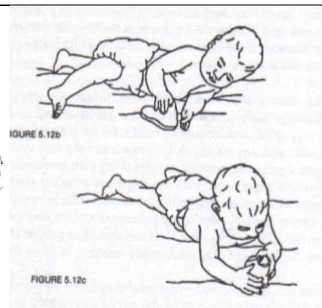
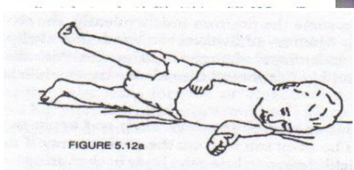
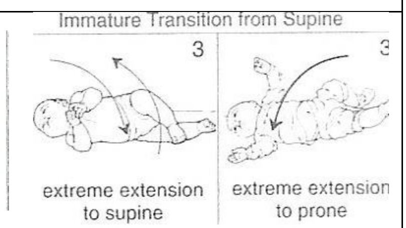
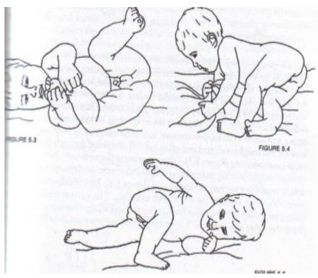
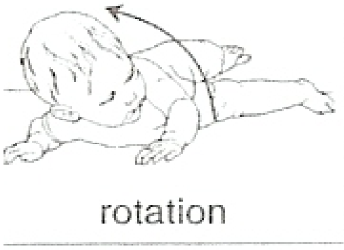
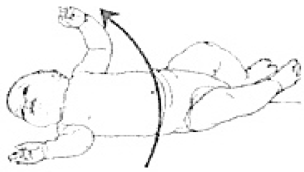
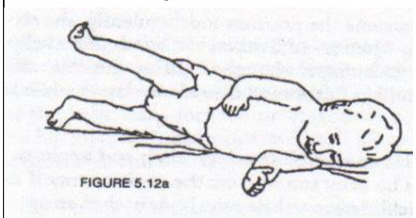
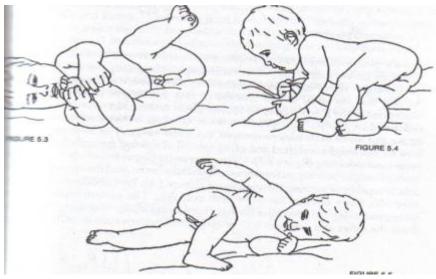
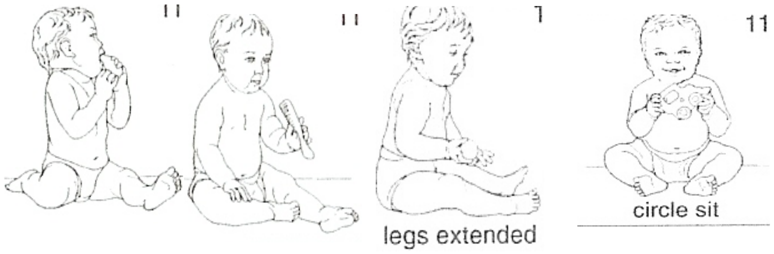
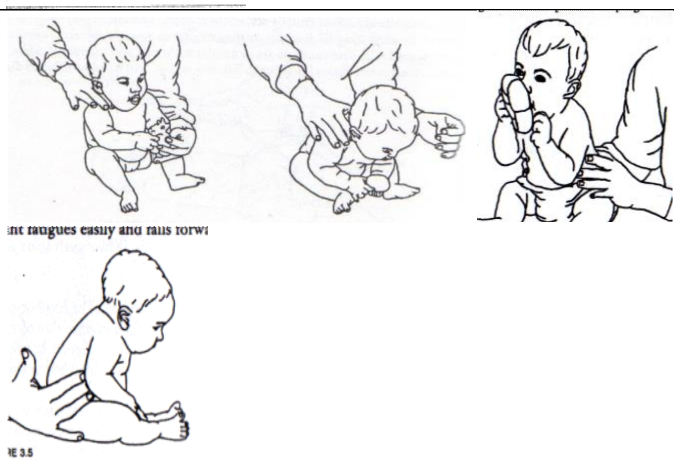
ROLLING SUPINE TO PRONE

4 Mature rolling patterns	• Segmental/**dissociated** rolling with twisting at waist, flexion (neck, trunk, hip, etc.) rather than extension • **No arching** of head or stiffening of legs • Shoulder and UE **easily freed** after roll / not stuck under trunk	 rotation 
3 Immature pattern	• Rolling may look accidental, imbalanced and **not controlled** (seems like falling) • **As a log**, all one piece (no dissociation) • Neck extension with body following head, or **gets stuck** (shoulder or arm trapped under body) • May see a stop in side lying in transition	  
2 Partial roll	• Child makes effort to roll, **turns to side**, or extends neck back, "bridging," but is unsuccessful at rolling completely over may get to side lying • Do not code level 3 if baby stops movement and remains in side lying for 5+ seconds even if eventually rolls completely over	   
1 Attempt to roll	• Not **get to side lying** • May use immature pattern (extension) • Looks accidental, **unstable**, clumsy	

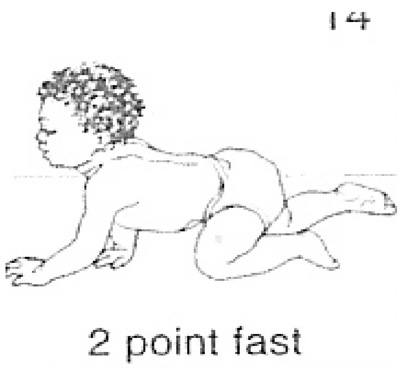
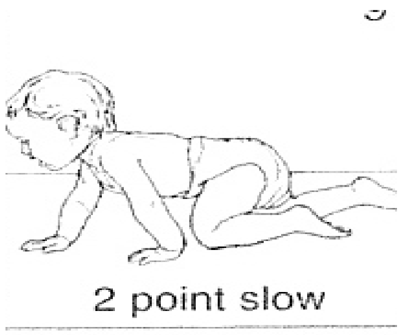
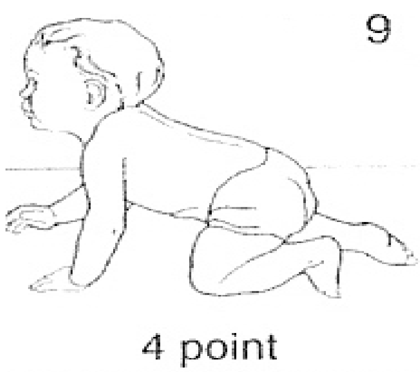
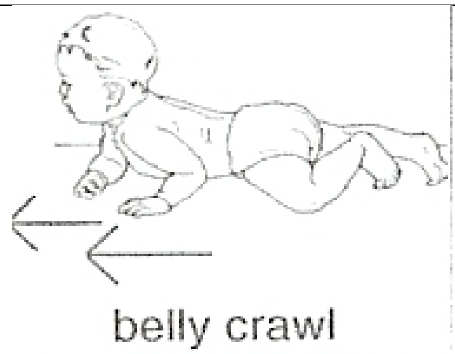
ROLLING PRONE TO SUPINE

4 Mature roll	• Segmental/dissociated rolling with twisting at waist • Use of controlled hip extension • Head control is **NOT lost** when rolling	
3 Immature roll	• Some extension driven from being propped on forearms • Rolling may look accidental, imbalanced and **not controlled** • Either **as a log**, all one piece, or **gets stuck** (shoulder or arm trapped under body) **even if segmental rolling is used, baby "falls" into back** • May see stop in side lying in transition.	  
2 Partial roll	• Child makes effort to roll, turns to side, but is unsuccessful at rolling completely over, may only get to side lying • DO NOT code a level 3 if baby stops movement and remains in side lying for 5+ seconds even if eventually rolls completely over	
1 Attempt to roll	• **Not get to side lying** • May use immature pattern (extension) • Looks accidental, unstable, clumsy	

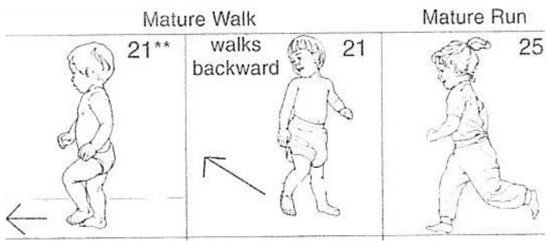
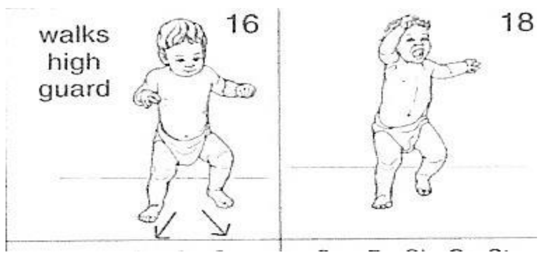
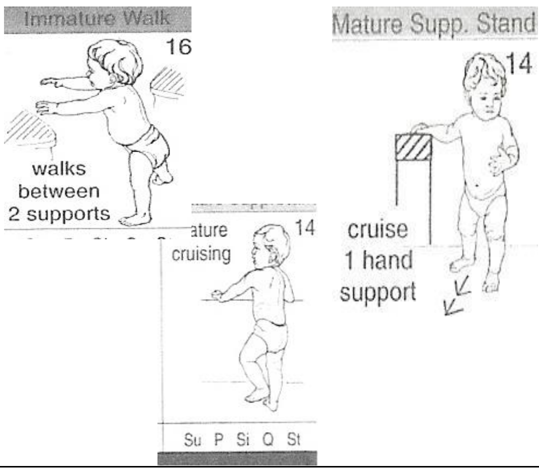
SITTING

4 Mature sit	• Sits independently • Straight lower back, stable and well balanced • **Dynamic** trunk movements (rotation, leans and recovers) • **Hands free to play**	
3 Immature independent sit	• Back is **straight** but rigid, hands are high, sitting is stable but **static** • Sits with **wide base of support** – does not meet criteria for level 4 • **Hands free to play**, may support weight with ONE hand on ground or on self but hand/arm is **NOT full weight bearing**/ dependent on maintaining posture	
2 Unstable sit	• Sits with a **rounded** back or with support from self (leans on one or both hands) • Little / no erect back and little/ **no dynamic** trunk • Or light support from adult/ object	
1 Supported Sit	• Sits with **clear** and **firm external** support – adult, furniture, toys, etc. • If unclear as to how firm the support score as a level 2/ more developed sit • Sitting without support is impossible	

CRAWLING

4 Mature crawl	• Baby up on flat hands and knees • Face faces forward, back is straight, hands and legs move in smooth, **well-coordinated** reciprocal fashion • Knees are fairly well lined up with hips • Crawl is sustained, pace is **brisk**. • "Bear" posture fluid and **swift** movement	
3 Mature crawl – slow	• Like level 4 except for speed • May "waddle" • Four limbs with forward movement, not as good as level 4 • "Bear" posture more halting and **choppy** feeling • Back is parallel to the ground	
2 Immature crawl	• Baby moves forward with **one limb** at a time • Hands may be fisted, **knees may be very wide** • Crawl is **very slow** and halting, tentative, but there are at least three "steps" (3 limbs move) • Belly off ground, knees bent in a clear hands and knees position • Back is not parallel to the ground	
1 Amphibian / Combat crawl or static	• Crawling with belly on floor and using forearms to propel forward • **Static quadruped position** with or without **front/back rocking** or UE or LE weight shifting • Any **backwards** crawl • Prone with kicking & **occasional forward movement** • Is not merely rotating on belly	

WALKING

4 Mature walk	• **Heel strike** • **Narrow base** of support • **Arms down** with or without swing • **Dynamic** trunk movements, may run	
3 Stable walk	• **Weight shift** is happening with **forward** rather than side to side • Feet still flat • Arms still elevated in **high guard**, no reciprocal hand swing, may see shoulder shrugging for stability • LE stance and base of support still likely to be **wide**	
2 Unstable, independent walk	• Steps can be **very tipsy or staggering**, yet with control from baby (movement should not look merely driven by falling / forward movement) • Steps are primarily **side to side**, may see beginning forward movement • UE in **high guard** • LE **wide base** of support/spread out. • May see stop and start movements • At least **1 independent** and unsupported step before stopping or falling	
1 Supported walk	• With at least **1 step** • Can be **weight shift** from side to side driven by baby • Includes competent **cruising** with steps along furniture • May see transitions between pieces of furniture / or adults, but baby looks like movement is driven by forward movement/falling and steps are not controlled • **Adult holds** child's hand or trunk, or child uses a push toy for support	

PROTECTIVE RESPONSES

4	• **Postural reactions** to loss of balance • Recovery from loss of balance, may include **LE weight shift** • Equilibrium righting reactions involving head, shoulder, and trunk adjustments towards midline • Baby does not rely on protective extension to protect from falling
3	• Protective Mechanisms including extension – head and face protected. • Immediate and **successful protective**, ex**tension with hands and arms,** child catches self from fall or makes very good effort and head remains in vertical plane (score 2 if head changes planes)
2	• Protective **extension** in any direction - little or delayed/slower head righting/ equilibrium • Loss of balance results in change in head position/ plane of orientation (e.g., head pitching forward / side etc. from an upright position)
1	• **No adjustment**, no protection, falls over, **head** hits floor or would if not caught

B: Content coding based on Ozonoff

Event category (examples)	1 = mealtime: child is eating meal, snack, etc., as main focus 2 = special event: party or holiday, usually involves lots of people or opening gifts 3 = active play: child is physically engaged in a social game or engaged playing with objects/pets 4 = passive activity: watching TV, looking at book, etc.; not much movement or involvement with people or objects 5 = bath/self-care: child is bathing/playing in water in tub, brushing teeth, at the hairdresser, etc. 6 = other: clearly does not meet above criteria, e.g. preschool, beach
Persons	# of people present on video including cameraperson (do not count subject).
Level of physical restriction	**NOTE: the codes for this category *increase* as level of physical restriction in*creases*.** 1 = low (<10% of the time) 2 = medium/intermittent (10-50%)-held, playpen, bathtub 3 = hi (>50%)-highchair, stroller, "bound"
Structure (level of interaction/structure with adults)	**NOTE: the codes for this category *increase* as amount of structure *decreases*.** 1 = high (>50% of the time) 2 = medium/intermittent (10-50%) 3 = low (<10%)

(31)