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Deliverable 6.1

CGA standard protocol

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Abbreviations

CGA	clinical gait analysis
DLT	direct linear transformation
MPP	marker placement protocols
OPWF	operational protocols and workflow
STA	soft tissue artifacts
TQA	technical quality assurance
VBS	video based stereophotogrammetric systems

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Nature of this Deliverable

This Deliverable provides detailed description of both technical and clinical procedures developed in the WP6 context to ensure reliable, accurate and standardized dat collection in the WP6 workpackge (Task 6.2 and Task 6.3) on patients in the NND area. This comprises:

1. Assess the quality of measurements conducted in the clinical gait labs;
2. Standardized markerplacement protocols in 3D optoelectronic Clinical Gait Analysis
3. Definion of Operational workflows in used in clinical practise

Short description

The aim of WP6 is to collect data from patients affected by Neurological and Neuromuscolar disease in order to provide the basics for the modelling partners to build patient specific models as part of the WP11, as well as to provide a large dataset of both retrospective and prospective data for probabilistic modelling in WP14. All the collected data within this WP will be stored in the digital repository.

Regarding the gait data, it has to be considered that the acquisition protocols have to be standardized so that all gait labs can unambiguously interpret the data. The use of these protocols will enable comparison and aggregation of data, which will yield potential clinical meaningful application in both the biophysical as well as the probabilistic models.

Besides the technical protocols, also standardized clinical protocols and guidelines (i.e. models as well as instruction given to the subjects during gait and MRI exams) are needed. This avoids any external influences on the estimated parameters and indices, which are going to be stored in the digital repository for future exploration of the data as well. The clinical partners should come up with standard descriptions of the situation of the patients. Also exposure to therapies needs to be described in a standard and quantitative manner.

Task 6.1

The task 6.1 is started with a complete description of the protocols used in the clinical institutes, which is the base for a common descriptive format and its default values. Three levels have been considered:

1. Technical Quality assurance (TQA) protocols in Gait analysis laboratories;
2. Marker placement protocols (MPP) in 3D Optoelectronic CGA;
3. Operational protocols and workflow (OPWF) used in clinical practice.

As a next step the partners set up a survey, taken from Clinical Gait Analysis (CGA) laboratories in EU, based on the network provided by ESMAC (European Society of Movement Analysis in Adults and Children). The analysis of this survey resulted in a complete EU inventory on the protocols (TQA, MPP, OPWF) used in Clinical Gait Analysis CGA. (see appendix)

A Consensus Proposal for EU CGA gait labs for all three levels has been drawn up. For the TQA and MPP, the clinical partners will perform reliability measures of the protocols, to ensure quantitative levels of reliability. These data will be used as input for sensitivity analysis and reliability estimates of model outputs.

Task 6.1.1

Technical Quality Assurance (TQA)

Two levels of protocols are considered: the technical quality assurance of the performance of the equipment in the 3 laboratories (also called “low level”), as well as the overall performace of the repeatability of measurements in the lab on actual subjects (“high level”).

For both levels URLS, who is the responsible for the Technical Quality Assurance, has developed the protocols and perfromemed measurements to assess the quality of the measurements conducted in the involved labs. The CGA centers involved in the experimental protocol are:

i. KU Leuven;
ii. VU Medisch Centrum;
iii. Children’s Hospital ‘Bambino Gesù’.

Task 6.1.1.1Technical Quality assurance of CGA equipment

Literature review

As stated by Page and colleagues 1 a critical issue in clinical gait analysis is the correct evaluation of uncertainty intervals associated to data collected to estimate body segment kinematics kinematics and kinetics, as well as electromyography (EMG). These data are frequently collected by means of video based stereophotogrammetric systems (kinematics) applying reconstruction algorithms, force platforms (kinetics) and electromyography and signiocal synchronization (EMG). Focusing the analysis on video-based stereophotogrammetric systems (VBS), the reconstruction of the marker position strongly depends on the calibration procedure and then it is operator dependent (how the operator sweeps the calibration volume with the wand, the velocity imposed to the wand, etc.). As the dynamic calibration procedure is completed, VBS makes available the calibration residuals to estimate data quality; however, it is not fully exploited the effects induced by the chosen algorithm in data quality. Actually, the accuracy of computerized systems and the precision and reliability of the chosen algorithm remain not fully assessed 2.

Briefly, the overall error associated to VBS is induced by several causes: experimental system 3, soft tissue artifacts (STA) 4, and marker position 5.

The reconstruction uncertainty of marker position is associated with centroid measurement, camera calibration and data processing as highlighted by Burner and Liu [20]. The authors showed that the uncertainty in target centroid measurement is associated with camera noise, target dimension and spatial quantization of the CCD sensor. For this reason, the random error related to the camera noise can be collectively represented by the centroid variations for spatially fixed targets. A good idea for quantifying this fluctuation is to acquire some recordings of fixed points and calculate the mean value and the standard deviation of recorded position. However, it has been decided not to deal with this aspect because the random errors are largely deleted by the filter applied on the signals.

From a literature survey, it emerges that to assess the metrological performances of VBS, in terms of accuracy and precision, experimental trials are generally conducted by imposing, by ad-hoc systems, known marker trajectories and by comparing them with positions estimated by VBS.

Furthermore, there is no way to quantify the STA error with non-invasive methods and, as this is not the main aim of the project, we and the ethical committees will never approve a protocol that includes any attachment of the markers on the patient bones.

Reconstruction algorithms

As it is known, given a marker moving in the laboratory, the VBS is able to reconstruct the 3D time history position relative to a fixed reference frame (LabFrame). Looking at the same reference, the position, the orientation and the optical characteristics (addressed as *calibration parameters*) of each camera can be considered time invariant and have been calculated with the calibration procedure. As the calibration data are collected, the reconstruction algorithm performs a fitting proces and provides “error residuals” as output. The calibration algorithms for the main commercial VBS systems are based on: the colinearity equation (CESNO) 7 and the direct linear transformation (DLT) 8-10. The DLT method is also used to evaluate the interval of uncertainty associated to 3D position reconstruction in some papers 11-15.

In order to assess the accuracy and precision of VBS, Klein and DeHaven 15 proposed to investigate the calibration volume with a movable device, which consists of a rectangular frame constructed of metal pipe to which reflective tape was attached at various locations. The rectangular frame was manually pushed along one direction at an average speed of approximately 0.75 m/s. The main limitations are the low number of cameras (equal to 2), the frame was moved only in one direction, and only a few points have been tested.

Everaert et al. 16 proposed an *ad-hoc* sliding device (Figure 1) to examine the calibration volume and to statically assess the distortion of the reconstructed volume. The device consisted in an aluminum frame mounted on a wooden board. On the device two stops controlled the movement of the slider: one was fixed, the other one was adjustable and determined the reference displacement to be measured. The authors imposed reference displacements by placing calibrated steel blocks (with an accuracy of 1 µm) between the sliding block and the adjustable stop. The reference-sliding device was clamped onto the surface of a table at the halfway from the height of a calibration frame. The device is positioned in 3 different zones relative to this frame. The accuracy has been evaluated as the difference between the mean measured value of the displacement for each trial and its reference value. Instead, the inter-trial standard deviation SD has given the precision.

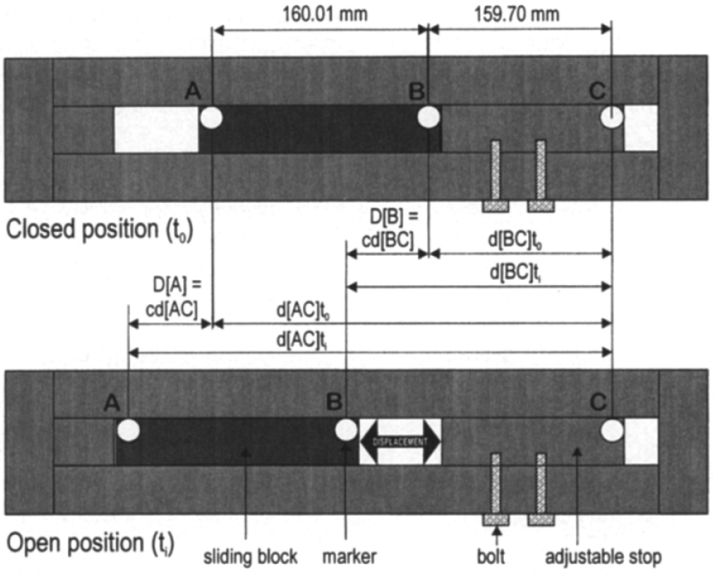


Figure 1 - The device proposed by Everaert et al. 16.

In 17 a calibration and measurement (x, y)-robot has been developed to achieve a repeatable dynamic calibration simultaneously with a semi-automatic accuracy and precision analysis. The robot, see Figure 2, consists in:

- A servo-motor-driven sliding carriage configuration;
- Three orthogonally arranged axes with built-in linear encoders;
- Four retroreflective markers arranged in a L-shape used for setting up the VBS coordinate system at static calibration; and
- A cardanic joint allowed free oscillation of the wand for the dynamic calibration.

In this paper an uniformly spaced grid (30 mm) of 180×180×150 mm^3 was analyzed. The implemented procedure was articulated in: (i) static calibration, (ii) dynamic calibration (the wand has been driven along a programmed motion path), (iii) grid measurement (a marker has been moved by the robot in an uniformly spaced gridpoints), and (iv) accuracy and precision have been calculated for each coordinate direction.

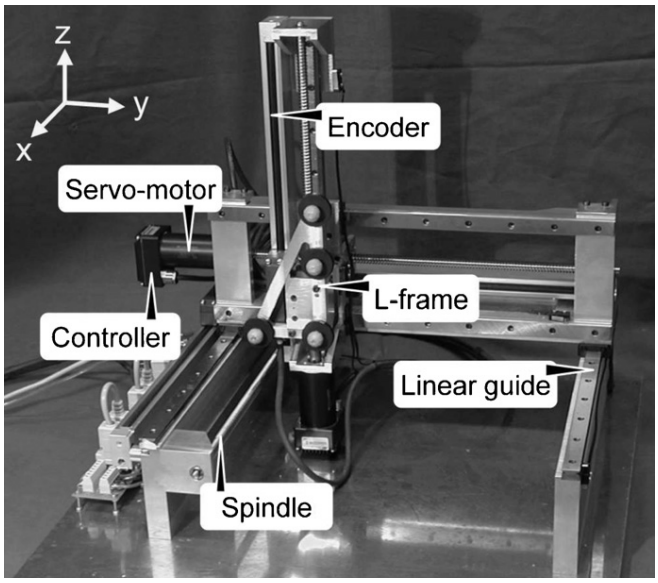


Figure 2 - The device proposed by Windolf, Gotzen, and Morlock 17.

The main limitations of this study are: (i) the dimension of measurement volume, which is too low and uncomparable with the one typical for CGA, and (ii) the low number of used cameras (equal to 3).

Force platforms

Reviewing the literature, numerous papers are focused on the procedure to check the accuracy and the precision of a force platform (for example, Bobbert et al. 20 and Della Croce et al. 21).

The problems related to the accuracy and precision of a force platform for gait analysis can be divided into two groups: (i) the metrological performances of the force platform as it is, and (ii) the ones of the force platform *in-situ*, which means the accuracy of the combined use of two force platforms and the optoelettronic system.

For what concern accuracy and precision of the force platform as it is, what has to be checked is the goodness in estimating the correct value of applied forces and moments.

While regarding to the *in-situ* accuracy and precision, the metrological performances of the force and moment vectors have to be checked not only in terms of modulus, but also in terms of estimated direction relative to the ground reference frame given by the optoelectronic system.

Electromyography

All the centres involved in European project own the same EMG system (COMETA zero wire, I), which is considered as the golden standard. The main problem related to the EMG signal acquisition is the cross talk: the electrodes are placed on the skin of the subjects in certain positions to acquire the muscle activation signal. To avoid the overlap of different signals, the electrodes must be placed on the skin at known distances from the insertion point of muscles. The standardized protocol for the electrode placement is the SENIAM protocol 23.

Signal synchronization

The other relevant problem relative to the use of different instruments as optoelectronic system, force plates and EMG during gait analysis is the synchronization among them. Usually, the optoelectronic system is the master sync and for the particular EMG system the decleared delay due to transmission is 0.014 s.

For what concern the delay compensation related to the force plate, the manufacturer does not provide any value.

Protocols for Technical Quality Assurance of Equipment

The centers have been asked to provide the technical characteristics of their own instruments to measure the marker position, the ground reactions and EMG signals during the gait trials. See table below.

		KUL	VUA	OPBG
Optoelectronic system	*Model*	Vicon MX	Grail	Vicon MX
	Sample frequency	100 Hz	100 Hz	200 Hz
	Marker size/type	Spherical 12.5 mm	Spherical 13 mm	Spherical 12.5 mm
	Marker protocol	PiG (SACR + KAD)	HBM	PiG
Force Platform	*Model*	AMTI OR6-7 1000	R-MILL	AMTI OR6-6 1000
	Output channel	6 components (Fx, Fy, Fz, Mx, My, Mz)	6 components (Fx, Fy, Fz, Mx, My, Mz) – Dual Belt	6 components (Fx, Fy, Fz, Mx, My, Mz)
	Sample frequency	1500 Hz	100 Hz	1000 Hz
	FSO	4450 N (Fz)	10000 N (Fz)	4450 N (Fz)
EMG system	*Model*	Cometa Zero Wire	Cometa Zero Wire	Cometa Zero Wire
	Output channel	16 channels	16 channels	16 channels
	Output type	Analog	Analog	Analog
	Sample frequency	1000 Hz	1000 Hz	1000 Hz
	Sensor placement protocol	SENIAM	SENIAM	SENIAM

Table 1: technical characteristics of motion analysis systems used at KU Leuven (KUL), VU University Amsterdam (VUA) and Children's Hospital 'Bambino Gesù' (OPBG). PiG: PlugInGait Marker set, HBM: Human Body Model, KAD: Knee Alignment Device, AMTI: Advanced Mechanical Technology Inc., R-MILL: Forcelink treadmill, FSO: Full Scale Output, SENIAM: Surface EMG for the Non-Invasive Assessment of Muscles

Technical validation of measurement systems

The accuracy of the reconstructed data (high-level data) depends on the accuracy of the raw data acquired by means of each measurement system. Some tests have been performed to check the accuracy and the precision of the instruments as they are. The experimental protocol of the low-level validation for each measurement system is reported in the following.

1. Optoelectronic Systems

A spot check of the functionality/accuracy of the optoelectronic systems have been performed by means of a fixed length wand equipped with reflective markers, as proposed by 22. An effective example of this wand can be the calibration wand itself, which is equipped with 5 active/passive markers at a known distance between each other.

2. Force platforms

In order to check the functionality of the force platforms, a device equipped with a 6-component load cell has been developed. The Figure 3 shows this device also equipped with reflective markers to allow the optoelectronic system to register the position of the load cell coordinate frame relative to the ground coordinate frame. Seventeen points on all the force platforms available in the labs have been tested applying a force in some directions with the device. The selected 6-component load cell can be assumed as the gold standard to which the force platform outputs have to be compared.

Figure 3 – The device developed to test the force platform.

3. Signal synchronization

The signal syncronization between the optoelectronic system, the force platform and the EMG system have been tested using the following procedure (also shown in Figure 4):

1. A Foot-switch (an on/off pressure sensor) that is stored by the same acquisition system of the EMG was put on each force platform;
2. A pointer was used to apply a pressure on the Foot-switch;
3. The signals from the optoelectronic system, force platform and foot-switch were registered;
4. A cross-correlation algorithm will be applied to estimate the delays among the measurement systems.

Figure 4 – Pointer, foot-switch and force platform.

Current status of the work

Concerning the low-level validation, the data have already been collected in all the involved centres following the described protocol. It follows a detailed list of the sessions:

1. OPBG, Palidoro (Rome) – 10 February 2014;
2. VUA, Amsterdam – 12 February 2014;
3. KUL, Leuven – 13 February 2014.

The partner responsible for the TQA is now analyzing the data.

Task 6.1.1.2. Technical Quality assurance of measurements

This is also refered to as TQA of high level data

High-level validation of measurement systems

The Figure 5 shows the developed procedure to evaluate the inter-laboratory and inter-rater repeatabilities. Briefly, the protocol incudes the following features:

- Two healthy children have been recruited (they have to be in the same range of age of the patients involved in the MD-PAEDIGREE);
- The subjects must be the same in each center;
- Five walking trials for each subject in each involved center have to be acquired;
- Maximum two therapists per center will perform the marker placement for each subject (those therapist must be the ones who usually performed CGA in the centers).

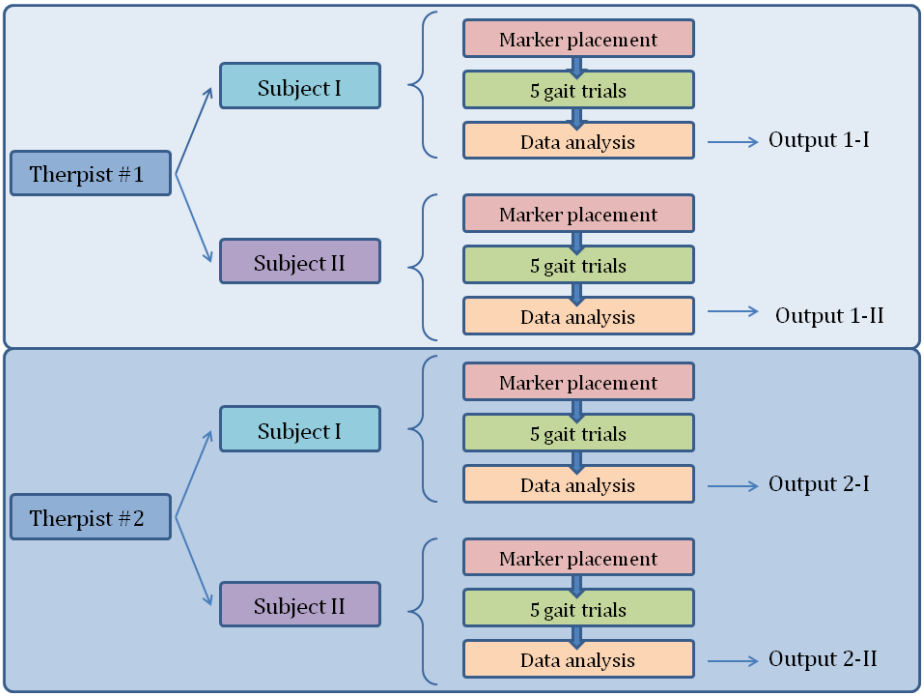


Figure 5 – Flow-chart of the experimental protocol for the high-level validation of the TQA.

The collected data will be processed with typical procedures (pipeline procedure) adopted in each center including:

- Filtering;
- Fill gap;
- Labeling;
- Static and Dynamic Kinematics, and Kinetics pipelines.

The data have been already collected at the OPBG, and are going to be collected in the other center as well.

URLS will analyze the data comparing the following parameters:

:

- Joint angles (Kinematics);
- Joint moments (Kinetics);
- Timing on EMG signal activation.

As the filtering and the daily pipelines can be different between the centers, URLS will analyse also the gait data without any applied pipeline (see the graph in Figure 6).

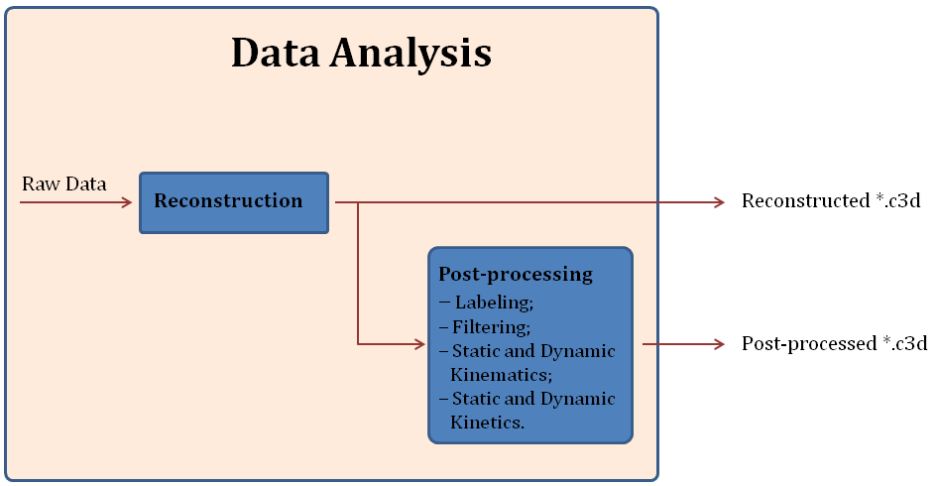


Figure 6 – Flow-chart of data analysis.

Regarding the high-level validation, the data were collected at the OPBG on the 29 April 2014. A dedicated session is scheduled on the 20th of October in Leuven. While, in Amsterdam the session has not been scheduled yet due to the delay of the ethical committee to provide the approval for the protocols, which has just given. A session is expected by the first half of September 2014, perfectly on time for the deadline of the Deliverable 6.2 when the report on the TQA will be provide.

6.1.2. Marker placement protocols (MPP)

Introduction

Both in literature and clinical practice, many different marker protocols are currently used, as decribed for instance by Ferrari et al. [24]. The markers used as well as the accompanying underlying human body model can have a large influence on gait analysis outcomes, i.e. joint angles, joint moments and powers. To obtain comparable outcomes, an essential step in the MD-Paedigree project was to gain consensus about the markers used.

Consensus was reached by performing the following steps:

- We created a detailed overview of the current marker protocols used by all three clinical partners (KUL, OPBG, VUmc) as well as one of the technical partners (Motek Medical). This comparison showed essential differences both in the method applied (anatomical markers versus cluster markers with virtual anatomical markers).
- We performed an investigation on the frequently used marker protocols amongst clinical centers throughout the world (appendix 1). This analysis showed that the so-called 'plug-in-gait'-model is the most widely used in clinical practice, but many centers use their own additions or adaptations to this model.
- After extensive discussion, we agreed upon general guidelines for the new consensus marker placement protocol (CMPP), ie:
    - The protocol should be compatible with the standard Vicon protocol (Plug-in-gait), as it is the most widely used in clinical practice.
    - At least three markers should be used per segment, so that all six degrees of freedom per segment can be tracked
    - Wand markers should be avoided if possible, to reduce soft-tissue artifacts
    - Ideally, all body models as used by the partners (PiG [ref], CAST [ref cappozzo], HBM [ref geijtenbeek]) in the project should be able to run with the CMPP, as this allows a comparison of outcomes.
    - The protocol should be a balance between data quality and practical execution. Hence, it was decided to come up with both a minimal and an optimal marker set. The minimal marker set should be applied in all prospective data collection, while the optimal data set will be applied for a limited set of patients undergoing extensive testing. The miminal set allows for running PiG and HBM models, while the optimal set allows for running CAST (ISB recommendations) as well.
    - A limited set of markers should be applied during MRI data collection in a limited set of patients, to allow for matching MR images to gait analysis data.
- The above guidelines were then combined resulting in the actual protocol, consisting of specifications and guidelines for marker use and placement, as described below.

Protocol

The marker protocol incorporates the following requirements:

Minimal: *required*; based on PiG and HBM, with at least three markers per segment

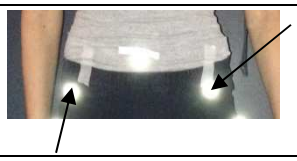
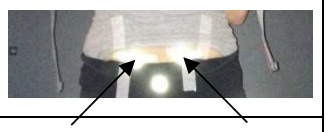
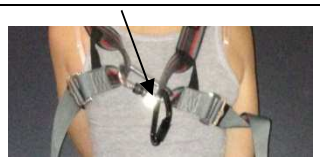
Optimal: *required for modelling*; allows running both PiG, HBM, and ISB (CAST) protocols

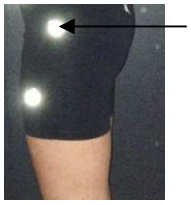
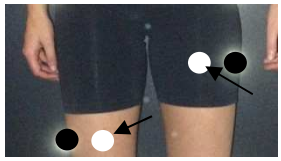
MRI: *required for modelling*; essential markers to link MRI images to ('optimal') motion capture data

Precise description of placement of each marker including pictures is shown below.

Segment	ID	Anatomical name	Minimal	Optimal	MRI
		Total #	25/26 + 4 static	32 + 8 static	24
Trunk	C7	Cervical vertebra 7	X	X	
	T10	Thoracic vertebra 10	X	X	
	XYPH	Proc. Xyphoideus	X	X	
	STRN	Sternum/Incisura jugularis	X	X	
Pelvis	SIASR	SIAS rechts	X	X	X
	SIASL	SIAS links	X	X	X
	SIPSR	SIPS rechts	X	X	X
	SIPSL	SIPS links	X	X	X
	SACR	Mid of SIPS	Optional i/o SIPS		
Thigh	GTRO	Greater Trochanter		X	X
	THI1	Thigh L 1/3, R 2/3 GTRO - LEK	X	X	
	THI2	2nd technical marker on thigh (anterior)	X	X	
	THI	Wand, lower 1/3 of the thigh	Optional i/o THI1		
	LEK	Lateral epicondyle of knee	X	X	X
	MEK	Medial epicondyle	X (static or KAD)	X (static only)	X
Shank	SHA1	1/3 Tibia (lateral)	X	X	
	SHA2	2nd technical shank marker (anterior)	X	X	
	TIA	Wand, lower 1/3 of the shank	Optional i/o SHA1		
	LM	Lateral malleolus	X	X	X
	MM	Medial Malleolus	X (static only)	X (static only)	X
	CF	Caput Fibulae		X (static only)	
	TT	Tuberositas Tibiae		X (static only)	X
Foot	HEE	Calcaneus (dorsaal), height of toe	X	X	X
	CM1	Caput Metatarsale 1		X	
	CM2	Caput Metatarsale 2 (PiG 'TOE')	X	X	X
	CM5	Caput Metatarsale 5	X	X	X
	TOE	Tip of big toe		X	X

Marker placement guidelines

Segment	ID.	Landmark	Description	Picture
Pelvis	RASIS	Right SIAS	Most pronounced part. Stick directly on the skin, not on the short	
	LASIS	Left SIAS		
	RPSIS	Right SIPS	Dimple (if visible) or most pronounced part. Stick directly on the skin, not on the short	
	LPSIS	Left SIPS		
Thorax	C7	Proc. Spinosus C7	Bend head forward, most pronounced vertebra is C7. Then bring head back to stick. Check: when rotating head, C7 will move, Th1 won't	
	T10	Proc. Spinosus Th10	On the spine, at the level of the bottom of the shoulder blades (with arms hanging down). Make sure it is in the middle.	
	JN	Jugular noth / Incisura jugularis	Upper edge of sternum; make sure it is in the middle	
	XIPH	Proc. Xiphoideus	Lower edge of sternum; make sure it is in the middle	

Thigh	GTRO	Greater trochanter	Most pronounced part. Palpate from proximal direction. Push hip outward (‘model pose’) or rotation of the leg can help find the landmark.	
	THI1	Lateral technical thigh marker	On the lateral side of the thigh Right: ~2/3 of line GTRO - LEK Left: ~1/3 of line GTRO - LEK	
	THI2	Antorior technical thigh marker	On the anterior side of thigh; exact location not relevant, but not in line with other markers	
	LEK	Lateral epicondyle of the knee	Most pronounced part. Palpate from proximal with knee straight LEK and MEK are used to define knee axis, so both should be at similar height: check by holding both points and bending the knee: markers should not (hardly) move	
	MEK	Medial epicondyle of the knee		

Shank	SHA1	Lateral technical thigh marker	On the lateral side of the shank; ~halfway LEK and LM	
	SHA2	Anterior technical shank marker	On the anterior side of thigh; exact location not relevant, but not in line with other markers	
	LM	Lateral malleolus	Most pronounced part. If shoes are worn, preferably stick on skin, not on shoe	
	MM	Medial malleolus	Most pronounced part.	
	CF	Caput Fibulae	Most pronounced part, just underneath LEK. Palpate from distal direction.	
	TT	Tibial tuberositas	In the middle, underneath pattelar tendon insertion. Palpate Stick at same height as from distal direction	

Foot	HEE	Heel / Dorsal calcaneus	At same height as MT2, with foot flat on the ground. HEE and MT2 define foot sole, so this line should be parallel with ground.	
	MT1	1st metatarsal head	On top (dorsal)of 1st metatarsal head	
	MT2	2nd metatarsal head	On top (dorsal)of 2nd metatarsal head	
	MT5	5th metatarsal head	On top (dorsal)of 5th metatarsal head	
	TOE	Big toe	On top (dorsal)of tip of big toe	

Current status of the work

The consensus MPP has been tested on a single subject during a consensus meeting in Leuven in January. It has also been applied in several research studies at the Vumc. Hence, the practical applicability of the MPP has been confirmed. The MPP will from now on be used in all prospective MD-P data collection.

6.1.3. Operational protocols and workflow (OPWF)

Introduction

The purpose of the OPWF protocol is to achieve uniformity of the execution of gait analyses among the partners of the project, and other centres that wish to follow the same standards. This uniformity allows for standardized data sharing in the European database set up within the MD-Paedigree project.

The protocol was composed partly out of available protocols from the three clinical centres involved in the MD-Paedigree project, the KU Leuven University Hospital (KUL), VU University Medical Center Amsterdam (VUmc), and the Paediatric Hospital 'Bambino Gesù' (OPBG) in Rome. Furthermore, an inventory on clinical protocols was held amongst 13 gait labs throughout the world (appendix 1), so that the protocol matches as good as possible with current clinical practice. Finally, several extensive consensus meetings were held to achieve agreement between the three partners on all aspects of the protocol.

The protocol contains all information needed to perform standardized gait analyses data collection specific for children (age 5-15) with cerebral palsy (CP), Duchenne Muscular Dystrophy (DMD) and Charcot Marie Tooth (CMT). It also contains standards for additional data collection required for modelling purposes, and several optional measurements. Besides the gait analysis measurements itself, the protocol also elaborates on the anamnesis, physical examination, strength measurements, energy expenditure test, 6-minute walk test, and lower extremity MRI. The protocol is limited to data collection procedures, data processing or analysis are not described.

The actual protocol

See appendix 2.

Current status of the work

So far, all aspects of the protocol have been tested for their executibility:

- The anamnesis is comparable to what has been performed for many years at UZ Leuven
- The gait analysis measurements are a combination of protocols as used for many years at both UZ Leuven, OPBG ad Vumc
- The physical examination is similar to the standard protocol of the Vumc. It was practiced by all partners at the consensus meeting in Leuven in January 2014.
- The hand-held dynamometry (HHD) has been tested on a healthy subject at Vumc, and during the consensus meeting in Leuven in January 2014.
- The energy expenditure and 6-minute walk tests are often performed in both clinical practice and research at all three centers.
- The MRI protocol has been performed at OPBG (14 healthy children, 11 patients: 7 DMD, 1 CMT1A, 3 CP) and at Vumc (1 healthy adult test scan).

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Appendices.

Appendix 1. Gait analysis protocol inventory;

Appendix 2. OPWF protocol.

Appendix 1

Questionnaire: Gait analysis procedures in your lab

ESMAC – September 2013

	Heidel-motion lab	Anderson Gait Lab	Biomechanics & Neuromotor Lab	Gillette	Oxford Gait Lab	Clinical measurements lab	Westmarc Gait lab	Sint maartens-kliniek	VUmc	Pellenberg	Movement Analysis and Robotics Laboratory
General											
Where is the lab situated?	Heidelberg, Germany	Edinburgh, UK	Adelaide, Australia	St.Paul, USA	Oxford, UK	Birmingham, UK	Glasgow, UK	Nijmegen, NL	Amsterdam, NL	Pellenberg, Belgium	Rome, Italy
How many patients come into the lab on average per week?	10	3	15	12	9	5	2-3	6	15	20	5
What are the main pathologies you see?	(1) CP and other Neuro (2) Amputee (3) shoulder patients	(1) CP (2) Spina Bifida (3) Amputee	(1) Post orthopedic trauma surgery	(1) CP (2) Spina Bifida	(1) CP	(1) CP (2) Amputee (3) Stroke (4) Sports	(1) CP (2) Prosthetic patients	(1) CP (2) all diagnoses	(1) CP (2) OPBL (3) all diagnoses	(1) CP (2) CVA (3) Club foot (4) Spina bifida	CP and other Neuro

Equipment											
What equipment do you have available in the lab?											
Video	√	√	√	√	√	√	√	√	√	√	√
EMG	√	√	√	√	√	√	√	√	√	√	√
3D motion analysis	√	√	√	√	√	√	√	√	√	√	√
Force plates – How many?	√ (3)	√ (2)	√ (5)	√ (6)	√ (3)	√ (2)	√ (2)	√ (2)	√ (2)	√(5)	√ (2)
Treadmill	-	-	√	√	√	√	-	-	√	-	-
Other	-	-	-	-	Plantar pressure	Energy expenditure	-	-	Energy equipment	Plantar pressure (PP) and energy expenditure	Plantar pressure (PP) and energy expenditure
What 3D motion capture system do you have?											
Vicon	√	√	√	√	√	√	√	√	√	√	√
Qualisys	-	-	-	-	-	-	-	-	-	-	-
Motion Analysis	-	-	-	-	-	-	-	-	-	-	-
Optotrak	-	-	-	-	-	-	-	-	√	√	-
Other	-	-	-	-	-	-	-	-	-	-	-
Procedures											
What marker protocol do you use?											
Plug-in-gait, or related:	√	√	-	√	√	√	√	√	√	√	√
OLGA	-	-	-	-	-	-	-	√	-	-	-
KYLIE	-	-	-	-	-	-	-	-	-	-	-

Own adaptations:	Matlab toolbox MoMo = motion modiller by Jen Simon foot model	-	Visual 3D	-	-	-	-	-	-	Matlab / opensim / python	-
Other:	-	-	-	-	-	-	-	-	-	-	-
Cluster markers with virtual markers (CAST / ISB protocol)	-	-	-	√	-	-	-	-	√	for research purposes	-
T3Dg	-	-	-	-	-	-	-	-	-	-	-
SAFlo	-	-	-	-	-	-	-	-	-	-	-
LAMB	-	-	-	-	-	-	-	-	-	-	-
Other:	-	-	-	-	Foot model	-	-	-	-	Foot model (Leardini) R3DFM	-
Do you make use of functional calibration (joint center or axis determined based on range of motion measurements)?	n.a.	Yes	No	Yes	No	No	No	No	No	Only for research purposes	-
Hip, knee and/or ankle?	n.a.	Knee	-	Hip, Knee	-	-	-	-	-	Hip and knee	-
What method do you use?	n.a.	Knee alignment device	-	n.a.	-	-	-	-	-	n.a.	-
Can you identify main problems (things for improvements) you encounter with your current procedures?	n.a.	(1) Delay between EMG and Kinematics (2) Old software still using	(1) Lack of normative reference data	n.a.	Correcting for thigh wand position	Thigh marker placement, validation at measurements, summarizing + interpreting	Staff not familiar with using 3D/EMG equipment	n.a.	-	Time limitations (not possible to extend a GA with more tests) related to restricted	-

										registration	
Technical quality assurance											
Do you have procedures in place to monitor or improve technical quality? If yes,….:	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Motion capture accuracy:		Vicon calibration / 6 month check	Periodic accuracy test	SAMSA	√	Camera residuals	Calibration procedures. Poker test	-	Calibration procedures	Calibration procedures	Calibration procedures
Synchronization between equipment:		Pole test / Force plate and Kinematic synchronization.	-	-	√	FP + overlay check	√	-	Hammer and Pole test FP. EMG calibration once a while.	FP, EMG and kinematics, Between FP and PP; FP and overlay check (started)	-
Consistency of measurements between days (Within-tester repeatability):		Every year – comparison of kinematics	Training of assessors	Regular QA test. 2 patients every month	√	Annual repeatability	-	-	-	Recently performed on 5 CP and 5 TD children	-
Consistency/repeatability of measurements between different testers:		Every year – comparison of kinematics	Training of assessors	Regular QA test. 2 patients every month	√	Annual repeatability	-	-	-	Training of assessors	-
Other:		-	-	-	-	-	-	2 times a year quality check	-	Combination with software updates. Monthly check of EMG data. Attention to quality of FP and EMG data during GA.	1 year quality check

To be continued…											
Would you like to be informed about future MD-P progress, would you be available for future inquiry, and/or would you like to contribute in some other way? If yes,….:	Yes	Yes	-	-	-	Yes	Yes	Yes	YES!!	YES!!	Yes
Name	Sebastian Wolf	Graham Henderson				Philip Davenport	Andy Dunne	Hilde Latour	-	-	Maurizio Petrarca
Email	Sebastian.wolf@cos.uni-heidelberg.de	Graham.Henderson@nhslothian.scot.nhs.uk				Philip.davenport@shamcommunity.nhs.uk	Andrew.Dunne2@ggc.scot.nhs.uk	h.latour@maartenskliniek.nl	-	-	Maurizio.petrarca@opbg.net
Comments	Good Luck!								Great project	Great project	

√ = Yes
- = No
n.a. = No answer

Appendix 2

Consensus Gait Analysis Protocol

Cerebral Palsy – Duchenne Muscular Dystrophy – Charcot Marie Tooth

Version history

Version	*Date adjusted*	*Saved as word-doc*	*Saved as PDF*	*Name*
1	25-11-2013	yes	yes	Marije Goudriaan (Leuven)
2	02-05-2014	yes	Yes	VUmc, OPBG, URLS, KUL
3	28-05-2014	Yes	no	VUmc
4	30-05-2014	yes	yes	KUL
5	12-08-2014	yes	No	KUL/VUmc
6	18-08-2014	yes	no	KUL/VUmc
7	29-08-2014	yes	no	KUL/VUmc/OPBG

Index.

Introduction.

This consensus gait analysis protocol (C-GAP) was drafted within the European project *MD-Paedigree: Model-driven Paediatric European Digital Repository*.

The purpose of this protocol is to achieve uniformity of the execution of gait analyses among the partners of the project, and other centres that wish to follow the same standards. This uniformity allows for standardized data sharing in the European database set up within the MD-Paedigree project.

The protocol was composed partly out of available protocols from the three clinical centres involved in the MD-Paedigree project, the KU Leuven University Hospital (KUL), VU University Medical Center Amsterdam (VUmc), and the Paediatric Hospital 'Bambino Gesù' (OPBG) in Rome. Furthermore, an inventory on clinical protocols was held amongst 13 gait labs throughout the world, so that the protocol matches as good as possible with current clinical practice. Finally, several extensive consensus meetings were held to achieve agreement between the three partners on all aspects of the protocol.

The protocol contains all information needed to perform standardized gait analyses data collection specific for children (age 5-15) with cerebral palsy (CP), Duchenne Muscular Dystrophy (DMD) and Charcot Marie Tooth (CMT). It also contains standards for additional data collection required for modelling purposes, and several optional measurements. Besides the gait analysis measurements itself, the protocol also elaborates on the anamnesis, physical examination, strength measurements, energy expenditure test, 6-minute walk test, and lower extremity MRI. The protocol is limited to data collection procedures, data processing or analysis are not described.

Three types of measurements are indicated throughout the protocol:

- *Required*: data of which we believe it is important and which should be available for each subject undergoing clinical gait analysis.
- *Optional*: data which can be clinically relevant for individual patients or patient groups, and which could be collected in a standardized manner if clinicians or gait labs so decide..
- *Required for modelling*: data that may not be directly clinically relevant, but that is collected within the MD-Paedigree project to allow for detailed patient-specific musculoskeletal modelling and model validation.

Workflow Gait Analysis

This Workflow Gait Analysis provides an overview of the steps to be performed during a gait lab visit. The items are chronological, although the order of tests may be altered for practical reasons.

A. Preparation of the lab

The laboratory preparation differs between labs depending on the system used and specific lab set-up. However, it should follow several standard rules which are described in section A.

B. General anamnesis

The general anamnesis contains basic patient information that is needed to correctly interpret clinical gait analysis data in a broader patient perspective. It contain 'static' patient information, i.e. historical and clinical data of the patient that do not change (often) over time. This information should be collected only once, through patient/parent interviews and/or from clinical database retrieval. At new visits of the same patient, the data should only be checked for changes or updates. The anamnesis protocol is written in such a way that it could be printed and filled out on paper for individual patients.

C. Gait-specific anamnesis

The gait-specific anamnesis contains items that may have direct influence on a patient's gait, such as orthotics used, current therapies, current medication, etc. These items can change over time and therefore the gait-specific anamnesis should be collected again at each new visit, by patient/parent interview or written questionnaires.

D. Gait analysis measurements

a. Anthropometry measurements

The actual gait analysis starts with several anthropometric measurements which are necessary for most gait analysis acquisition and processing software. The protocol describes which measurements to take and how to perform them.

b. EMG electrode placement

EMG electrodes are placed first, since this needs to be done according to defined standards. The protocol describes which muscle to measure and how to place the electrodes.

c. Marker placement

Next, the motion capture markers are placed. The protocol describes which markers to use and where and how to place them. This protocol assumes a passive marker system, but the same markers can be collected with active marker set-ups as well.

d. Gait analysis measurement protocol

This paragraph described both the calibration trials and walking trials. Static analysis and barefoot, self-selected pace trials are required. Functional hip and knee joint calibration as well as fast, slow, and shod walking trials are recommended but optional.

E. Physical examination

The physical examination is an essential part of the gait analysis protocol. The protocol describes what measurements to perform and how to perform them. It includes functional assessment of several gross motor tasks, range of motion, spasticity, strength, selectivity, alignment and sensibility assessments.

F. Energy expenditure

Oxygen uptake can be measured to determine how much energy is used during comfortable walking, per time unit or per meter. This is a general measure of walking effort. It is recommended for standard gait analysis, but optional.

G. 6-minute walk test

The 6-minute walk test is not typically performed in CP patients, but required for DMD and CMT patients to give a general measure of walking capacity.

H. MRI

The MRI protocol is required for modelling only. It provides the general settings for collection of lower extremity MRI images of bone and muscle tissue of the legs. The information that can be extracted from these images can be used to generate personalized musculoskeletal models.

Gait analysis protocol

A. Preparation of the lab.

General.

This section describes some general rules for the daily lab preparation. These procedures are system-dependent but roughly follow the same approach To assure general spatial and temporal accuracy of each gait lab's motion capture and forceplate systems, a technical quality assessment (TQA) protocol was drafted by La Sapienza University of Rome. This protocol comprises both the assessment of reproducibility of measurements (high-level validation) and the accuracy and precision of the measurement instruments (technical-level validation).

Daily calibration.

Each gait lab needs to be calibrated at least once every day. Daily calibration is system-dependent but generally consists of the following steps:

- Dynamic camera calibration: Dynamic calibration of 3D motion analysis cameras. Usually with a wand, aligning the coordination frames of all camera's to one frame of reference
- Static calibration: Setting the origin of the lab (this might need a wand also) , in a sense that alignment with Forceplates is assured
- Calibration force plates (FP): force plates typically do not need to be calibrated each day, but are reset before each measurement to avoid offset ('Zero level FP')
- Spatial synchronization of video and motion capture / force plate data can be performed if MoCap/force data need to be overlaid on the video (optional)

The daily calibration should ensure that spatial, temporal and synchronization errors are within the system's requirements.

B. General anamnesis.

Required

Patient information

This information can be removed when uploaded to the database.

Patient research code:

Hospital-specific identification nr:

Last name:
First name:
Middle name

Date of birth (DD/MM/YYYY):
Age:

Gender (M/F):

Address line 1:
Address line 2:
City:
Postal code:

Phone number 1:
Phone number 2:

Email:

Family doctor:
Family doctor phone number:

Insurance company:
Insurance number:

Anonymous patient information

Patient research code:

Gender: M / F

Date of birth (MM/YYYY):

Age (Y):

Diagnosis

In compliance with the ICD 10.

Date of diagnosis:

Age of first symptoms of DMD/CMT1A (Y / M):

Age at which diagnosis is made (Y / M):

Primary diagnosis:

- ☐ CP
- ☐ DMD
- ☐ CMT1A
- ☐ Other, …

Secondary diagnosis: …

In case of CP:

Localization

- ☐ Hemiplegia (Unilateral CP)
- ☐ Diplegia (Bilateral CP)
- ☐ Quadriplegia (Bilateral CP, arms strongly involved)

Most affected side

- ☐ Right
- ☐ Left
- ☐ Equal

CP type (more than one options possible)

- ☐ Spastic

- ☐ Ataxic
- ☐ Dyskinetic

GMFCS level
I / II / III/ IV / V

In case of DMD or CMT1A:

Affected family members (Y / N):

Specify: …

Carrier status: …

Further investigation to confirm diagnosis

Type	*Date*	*Confirms diagnosis*	*Comment*
☐ Brain/spinal MRI		y/n	
☐ Brain CT scan		y/n	
☐ Brain Ultrasound		y/n	
☐ Electromyography		y/n	
☐ Nerve conduction study		y/n	
☐ Muscle Biopsy		y/n	
☐ Genetics		y/n	
☐ Other			

Pregnancy / birth

Parameter	*Score*	*Comments*
Gestational age (weeks):		
Birth weight (g):		
APGAR score (1/5/10 min)	… / … / …	
Number of births (single/ twins / triplet)		
Complications at birth.	Yes / no	
Complications during first year of the child's life. - Neonatal care given - Neonatal care duration (days) - Artificial breathing - Artificial breathing duration (days)	Yes / no Yes / no ……. Yes / no …….	
Complications after first year of the child's life.	Yes / no	

Other impairments.

Impairment	*Score*	*Comments/specifications*
Epilepsy	Yes/no	
Visual impairments	Yes/no	
Cognitive disorders - Test performed (BSID, or similar) - Test score - School	Yes/no Yes/no Abnormal(<70)/ Normal Regular / special	
Behavioral disorders	Yes/no	

Specific disability , speech Reading disorder Disorder of written expression Math disability Speech or language disorder ADHD	Yes/no	
Other		

Patient milestones (as much as known)

What	***Score***
Rolling	…….. months
Crawling	…….. months
Sitting	…….. months
Standing with support	…….. months
Walking with support	…….. months
Walking without support	…….. months

General Comments.

……

……

……

Treatment history.

Surgery (incl Botulinum toxin A)	Date	Specifics (muscles, dosage)	Post-surgery treatment
Physical therapy (school, private, rehabilitation)	Duration per session in min	Times per week	Specifics
Medication (oral, pump etc)	Dosage	Days per week	
Orthotics (type)	Duration (hours per day)	Days per week	
X-ray (pelvis, spine etc)			
Echocardiography			
Spirometry			

C. Gait specific anamnesis.

Required

Date

Referral information

Referring physician name:

Patient demand:

Parent / environmental demand:

Physician demand:

Reason for gait analysis:

- ☐ First evaluation
- ☐ Re-evaluation
- ☐ Pre-treatment: … (indicate treatment if known)
- ☐ Post-treatment … (indicate treatment)

General

Total number of gait analysis done in patients life:

Actual walking distance without resting, with/without walking aid (in meters):

- o 0-20
- o 20-100
- o 100-500
- o 500-1000
- o 1000-3000
- o >3000

Assistive devices

Walking aid

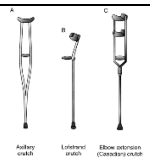
Following appendix 1: FMS

Walking aid 5m (inside the house): FMS score 1 / 2 / 3 / 4 / 5 / 6

Walking aid 50m (small distances): FMS score 1 / 2 / 3 / 4 / 5 / 6

Walking aid 500m (outside the house): FMS score 1 / 2 / 3 / 4 / 5 / 6

If a walking aid or wheelchair is used, please specify:

☐ 2 crutches ☐ 1 crutch		☐ Sitting orthotic	
☐ Anterior walker		☐ Buggy	
☐ Walker		☐ Wheelchair	
☐ Posterior walker		☐ (Quad) cane	
☐ Other walking aids	Specify:		
☐ Support (from care-giver) on one hand	☐ Support (from care-giver) on both hands	☐ Support (from care-giver) on trunk	

Orthotics used during the day.

Type right leg	***Additional information***	***Frequency*** *(% of time used per day during the last month)*
☐ None		
☐ Type 1 (Shoes): o Normal shoe o Semi orthopaedic shoe o Orthopaedic shoe o Stiff footplate	Right heel/sole increment …….. cm	Right Freq: 0-25-50-75-100%
☐ Type 2 (AFO): Type: solid/flexible Support: dorsal/ventral Hinge: y/n Stiff footplate: y/n	Right heel/sole increment …….. cm	Right Duration:…….. Freq: 0-25-50-75-100%

Type left leg	***Additional information***	***Frequency*** *(% of time used per day during the last month)*
☐ None		
☐ Type 1 (Shoes): o Normal shoe o Semi orthopaedic shoe o Orthopaedic shoe o Stiff footplate	Left heel/sole increment …….. cm	Left Freq: 0-25-50-75-100%
☐ Type 2 (AFO): Type: solid/flexible Support: dorsal/ventral Hinge: y/n Stiff footplate: y/n	Left heel/sole increment …….. cm	Left Duration:…….. Freq: 0-25-50-75-100%

Wearing of the shoes/soles.

……

……

……

Other orthotics.

……

Comments

……

……

……

<u>Orthotics used during the night.</u>

Type	***Additional information***	***Frequency (% of time used)***
☐ None		
☐ AFO	☐ Right ☐ Left	Freq: ……..%
☐ Knee extensor	☐ Right ☐ Left	Freq: ……..%
☐ KAFO	☐ Right ☐ Left	Freq: ……..%
☐ Abduction bar		Freq: ……..%

☐ Other		

Bike.

Type	***Adjustments***
☐ Regular bike	
☐ Bike with support/side wheels	
☐ Tricycle / recumbent / orthopaedic bike	
☐ Hand bike	
☐ Riding a bike is not possible	
☐ Other (specify)	

Therapy

Physical therapy

	Location	Frequency	%UL/LL
☐ Yes ☐ No	☐ Peripheral / Private ☐ School ☐ Rehabilitation centre ☐ Hospital	Freq:……. session/w Duration:…… min	UL: ……% LL:……..%

Content of the physical therapy treatment and/or other comments.

……

……

……

Other therapies.

☐ Occupational therapy	☐ Speech therapy	☐ Hydro therapy	☐ Hippo therapy	☐ Other

Home exercises.

……

……

……

Sports and other activities.

At school.

……

……

……

Outside of school.

……

……

……

Medical information

Medication.

Medication	***Comments***
☐ Tonus reduction o Oral o Baclofen pump	
☐ Anti-epileptic medication	
☐ Steroids	Type: Dosage: Regimen:
☐ Other	
☐ None	

Current physical complaints.

- Pain during daily-life walking y/n
- Fatigue during daily-life walking y/n
- Falling during daily-life walking y/n
- Other physical complaints …
  - o No
  - o Yes, specify:

……

……

Other medical problems.

- ☐ None
- ☐ Yes, specify:

……

……

General comments.

……

……

D. Gait analysis measurements.

Anthropometric measurements.

Required

Parameter	***Description***	***Score***	
Mass (kg)	Medical (calibrated) scale. Measured without shoes, underwear only.		
Height (mm)	Specific height measurement device on the wall, which is put on top of the child's head. Compliance with anatomical position needed.		
Inter ASIS distance (mm)	Palpate both ASIS and measure the distance between them with tape-measure.		
		Right	Left
Leg length (mm)	From ASIS to homolateral medial malleolus.		
Knee width (mm)	Distance between medial and lateral femoral epicondyle with sliding caliper (don't push too hard).		
Ankle width (mm)	Distance between medial and lateral malleolus with sliding caliper.		
Thigh circumference (mm)	At widest part of thigh, i.e. upper part of thigh		
Shank circumference (mm)	At widest part of shank		
Foot circumference (mm)	Around midfoot		
Foot length (mm)	Length of sole of foot, from back of heel to tip of longest toe, with tape-measure or foot measurement device		

EMG placement.

Required

Preparation.

- Shave the appropriate area (optional).
- Clean and rub the (shaved) area with alcohol.

Electrodes.

- Shape: circular/rectangular
- Size: 10 mm

Electrode placement.

Distance between electrodes (centre to centre):

- Standard: 20mm (electrodes directly next to each other)
- Optional for small muscles in small children: use smaller electrodes

Location with respect to the muscle fiber direction:

- Parallel
- Location according to Seniam guidelines AND perpendicular to this line (to comply with individual variation): halfway the palpable boundaries of the muscle belly, or: where muscle is most bulging

Muscles measured

(see Appendix 4 for muscle-specific placement [1], [2].

- Rectus femoris
- Vastus lateralis
- Lateral hamstrings/Biceps femoris
- Medial hamstrings/Semitendinous
- Tibialis anterior
- Medial gastrocnemicus
- Soleus
- Gluteus medius

Marker placement

Marker placement is described separately in the Marker Placement Protocol (MPP) of Task 6.1.2 of Deliverable 6.1 of the MD-Paedigree project.

Gait analysis measurement protocol.

Calibration trials

Static analysis barefoot (required)

- ✓ Subject is standing on one force plate
- ✓ Video, motion capture and force plate data are collected
- ✓ All markers must be visible
- ✓ Video: dorsal, ventral and lateral view are collected
- ✓ Standard reference position (anatomical pose, T-pose) not required

Functional hip joint calibration (optional, required for modelling)

- ✓ Have patient well supported on both sides by family or other staff.
- ✓ A star motion is made with the leg by the subject:
  - o First the leg moves from neutral (0°) to 40° anteflexion, then back to neutral
  - o Next, the leg is moved to 40° anteflexion/abduction, back to neutral, 40° abduction, back to neutral, 40° retroflexion/abduction and back to neutral
  - o Finally, a circumduction movement is made with the hip.
- ✓ The entire motion should be one fluent movement and take approximately 10s in total.
- ✓ If the subject is not well able to perform the movement himself, the same movement is performed passively by the therapist, while the subject supports him/herself on the other leg.
- ✓ Care should be taken to create as little soft tissue movement as possible in the thigh.
- ✓ Repeat for other leg.
- ✓ If the system has difficulty locating markers it may be helpful to:
  - move the patient forward or backward in the walkway
  - ensure that the supporting personnel and therapist are not blocking the camera lines of vision
  - rotate the patient to bring the thigh markers more toward the front of the room
  - stand the patient on an elevated box if the patient is short

Functional knee joint calibration (optional, required for modelling)

- ✓ Have the patient stand on an elevated box with one foot off the side (not touching the floor) of the box, supported by people on both sides
- ✓ Flex and extend the knee three times through a range from approximately 10-60° of flexion
- ✓ Repeat for other leg

KAD (knee alignment device) measurement (optional)

- ✓ This can be done after or previous to (a couple) dynamic trials
- ✓ Subject is standing on the force plate
- ✓ Remove the markers from the lateral femur epicondyle
- ✓ Place KAD on the lateral and medial femur epicondyle
- ✓ Motion capture data is recorded
- ✓ If done after the dynamic trials, kinematic plots of one of the dynamic trials (gait cycles need to be determined beforehand) can immediately be checked to see of the KAD was placed correctly.

Walking trials

Barefoot, self-selected pace (required)

- ✓ Subject walks up and down the walk-way without explicit instruction to step into the force plates
- ✓ The subject is given instruction to walk at his/her own comfortable speed
- ✓ Lines on the floor or pylons can be used to indicate the starting position, which is adjusted to make the subject hit the force plate(s)
- ✓ Three correct right and left foot placements on the force plate are collected
- ✓ Video measurements from ventral, dorsal, right and left direction
- ✓ At least five good gait cycles for left and right EMG measurements in total
- ✓ *Required for modelling*: at least one trial with two consecutive force plate hits R→ L and L→ R.

Barefoot, slow/fast pace (optional, required for modelling)

- ✓ The above measurement will be repeated while walking (in order of priority):
  - o as fast as possible, without running
  - o at a 'somewhat faster' than normal walking speed
  - o at a 'somewhat slower' than normal walking speed
- ✓ Kinetic data are collected if possible

Shoes (+ AFO) (optional)

- ✓ Measurement with shoes or shoes with AFO (if worn)
- ✓ At self-selected speed
- ✓ Three correct right foot placements on the force plate
- ✓ Three correct left foot placements on the force plate
- ✓Video measurements from ventral, dorsal, right and left direction

Trial information

For each trial, indicate:

Footwear

- o Barefoot
- o Shoes
- o Shoes + AFO

Speed condition

- o Self-selected
- o Fast
- o Fastest
- o Slow

Walking aids

- ☐ None
- ☐ Cane
- ☐ 1 Crutch
- ☐ 2 Crutches
- ☐ Anterior rollator
- ☐ Posterior rollator (Kaye walker)
- ☐ Walker
- ☐ One hand support
- ☐ Two hands support
- ☐ Trunk support

Data collected	***Notes***
☐ Video	
☐ Kinematics	
☐ Force plates	
☐ EMG	
☐ Other	

E. Physical examination

General

All clinical assessments are performed according to the book and DVD 'Handleiding Standaard Lichamelijk Onderzoek' ('Guidelines standard Physical Exam') [3]. The present protocol contains a list of tests to perform and a short description for each test. For a more extensive explanation of how to perform the various tests including pictures and videos, we refer to the book and related movies.

Functional assessment.

For the CP children, the functional assessment as described below will be performed.
Required for CP.

Item nr	Parameter name	Description						Score
	Motor skill	**Explanation**	**Provide support?**	**Score (+)**	**Score (±)**	**Score (-)**	**GMFM-66** Item nr:	**(+/ ±/-)**
1	Lie to Sit	From supine to sit on floor	No	Without help	With help	Not possible	19 or 20	
2	Sit to Stand	From sit on floor to stand	For balance	Without help	With help	Not possible	52	
3	Stand with support		Yes	≥ 3 sec.		< 3 sec.		
4	Stand without support		No	≥ 3 sec.		< 3 sec.	53	
5	Stand on 1 leg (R and L)		No	≥ 10 sec.	3-9 sec	< 3 sec.	57 and 58	R: L:
6	Tiptoe stand on 1 leg (R and L)		For balance	≥ 10 times	3-9 times / incomplete 10 times	< 3 times		R: L:
7	Tiptoe walking		For balance	≥ 10 times	3-9 times	< 3 times		
8	Walking on the heels		For balance	≥ 10 times	3-9 times	< 3 times		
9	Deep squats	As deep as possible	For balance	≥ 8 times	< 8 times	Not possible or pulling up		
10	On hands and knees	Stand on all fours	-	≥ 10 sec.	3-9 sec	< 3 sec.	39	
11	Crawling		-	≥ 3 strides		< 3 strides	45	
12	High knee pose	From sitting on knees to standing on knees and maintain	For balance	≥ 10 sec.	3-9 sec	< 3 sec.	48	
13	Walking on knees		For balance	≥ 10 strides	3-9 strides	< 3 strides	51	
14	Half knee pose	From standing on knees to rifleman's pose on R / L knee	For balance	≥ 10 sec.	3-9 sec	< 3 sec.	49 and 50	R: L:
15	Half knee pose to standing	Attains standing from rifleman's pose on R / L knee	For balance	Without help	With help for balance	Not possible or pulling up	60 and 61	R: L:

For DMD the North star ambulatory assessment will be used and for the CMT1A the CMTPedS will be used for functional assessment (see apendics 7 & 8).
Required for DMD and optional for CMT.

Passive range of motion

Required

Scoring.

Angle in degrees as measured with a goniometer.

Test positions.

See Appendix 6A

Outcome parameters.

Parameter	Description (see appendix 6 for more detail)	Score (deg)	
Hip		**RIGHT**	**LEFT**
Hip flexion	Maximum hip flexion supine		
Hip extension supine	Maximum hip extension supine (Thomas test) (substitute for psoas length)		
Hip extension prone	Maximum hip extension prone (Staheli test) (substitute for psoas length)		
Hip abduction (knee extended)	Maximum hip abduction supine with knees extended		
Hip abduction (knee flexed)	Maximum hip abduction supine with knees flexed in 90 degrees		
Hip adduction	Maximum hip adduction supine with knees and hips extended		
Hip external rotation	Maximum hip external rotation prone, knee in 90 degrees flexion		
Hip internal rotation	Maximum hip internal rotation prone, knee in 90 degrees flexion		
Knee			
Knee flexion supine	Maximum knee flexion supine		
Knee flexion prone	Maximum knee flexion prone, without pelvic movement (substitute for rectus femoris length)		
Knee extension	Maximum knee extension supine with hip in extension		
Popliteal angle	Maximum knee extension supine with hip in 90 degrees flexion; contralateral leg extended (substitute for hamstrings length)		
Ankle			
Ankle plantar flexion	Maximum ankle plantar flexion supine		
Ankle dorsiflexion (knee flexed)	Maximum ankle dorsiflexion supine, hip and knee in 90 degrees flexion (substitute for soleus length)		
Ankle dorsiflexion (knee extended)	Maximum ankle dorsiflexion supine, hip and knee extended (substitute for gastrocnemius length)		
Ankle varus	Maximum varus calcaneus prone, knee in 90 degrees flexion		
Ankle valgus	Maximum valgus calcaneus prone, knee in 90 degrees flexion		
Ankle supination	Maximum supination lower hock prone, knee in 90 degrees flexion		
Ankle pronation	Maximum pronation lower hock prone, knee in 90 degrees flexion		

Spasticity

Required

General

Spasticity will be scored according to the spasticity test (Spat)[4], since the Ashworth was proven not to be reliable[5]. The Spat test is based on the Tardieu test, only with the passive stretch at two velocities instead of three. First, the muscle is passively stretched with a slow velocity (≥ 3 seconds) to measure the maximum range of motion (ROM). Then, spasticity is assessed during a passive stretch with fast velocity (< 1 second) to measure the joint angle of the catch (AOC) and to grade the intensity of the muscle resistance.

Scoring

Muscle tone: Slow passive stretch

1	Hypertonia. Resistance is not velocity dependent
0	Normal resistance
-1	Hypotonia. Decreased resistance

Quality: Fast passive stretch.

0	Normal, no catch
1	Increase in resistance, no clear catch
2	Clear catch at a specific angle that does not occur during the slow passive stretch and is followed by a release
3	Clear catch at a specific angle that does not occur during the slow passive stretch

If quality is 2 or 3, the *angle of catch (AOC)* is scored as the angle in degrees as measured with a goniometer.

Ankle Clonus

Clonus Yes or NO

In case of Yes:

1. Less than 5 beats (Y < 5)
2. More than 5 beats (Y > 5)

Test positions.

Same as during the passive range of motion.

Outcome parameters.

Parameter	Description (see appendix 5 for more detail)			Score					
Spasticity				**RIGHT**			**LEFT**		
	Muscle tone	AOC	Quality	Muscle tone	AOC	Quality	Muscle tone	AOC	Quality
				-1/0/+1	deg	0-3	-1/0/+1	deg	0-3
Hip adduction	Same position as during passive ROM of hip adduction knee flexed								
Hamstrings	Same position as passive ROM for popliteal angle								
Rectus femoris	Same position as during passive ROM of knee flexion prone								
Gastrocnemius	Same position as during passive ROM of ankle dorsiflexion (knee extended)								
Soleus	Same position as during passive ROM of ankle dorsiflexion (knee flexed)								
Tib. Posterior	Same position as during passive Rom of ankle plantar flexion								
Clonus									
	Yes or No. If yes Y > 5 or Y < 5								
Gastrocnemius	Same position as during passive ROM of ankle dorsiflexion (knee extended)								
Soleus	Same position as during passive ROM of ankle dorsiflexion (knee flexed)								

Strength

Clinical strength test (MRC scale)

Optional

Scoring

The patient's effort is graded on a scale of 0-5:

0	Contraction cannot be palpated
1	Evidence of slight contraction of the muscle but joint motion is not visible
2-	Initiates motion if gravity is eliminated
2	Complete range of motion in gravity eliminated plane (available ROM, ROM can be slightly decreased because of co-contraction)
2+	Initiates motion against gravity
3-	Incomplete range of motion against gravity (almost perfect motion against gravity, incomplete range, motion with little help)
3	Perfect motion against gravity (almost full available ROM, ROM can be slightly decreased because of co-contraction)
3+	Motion against gravity with minimal resistance (almost full available ROM, ROM can be slightly decreased because of co-contraction)
4	Motion against gravity with some (moderate) resistance (full available ROM)
5	Motion against gravity with maximal resistance (full available ROM)

Test positions

See Appendix 6B

Outcome parameters

Parameter	Description (see appendix 5 for more detail)	Score (0-5)	
Hip		**RIGHT**	**LEFT**
Hip flexors	Maximal isometric strength assessment of the hip flexors (psaos major and iliacus) seated.		
Hip extensors	Maximal isometric strength assessment of the hip extensors (gluteus maximus and hamstrings) prone.		
Hip abductors	Maximal isometric strength assessment of the hip abductors (gluteus medius and minimus) supine knee extended.		
Hip adduction (knee flexed)	Maximal isometric strength assessment of the hip adductors (adductor magnus, brevis and longus; pectineus) supine		
Hip adduction (knee extended)	Maximal isometric strength assessment of the hip adductors (gracilis) supine		
Knee			
Knee flexion	Maximal isometric strength assessment of the knee flexors (hamstrings) prone		
Knee extension	Maximal isometric strength assessment of the knee flexors (quadriceps femoris) seated		
Ankle			
Ankle dorsiflexion (knee flexed)	Maximal isometric strength assessment of the ankle dorsiflexors (tibialis anterior) seated		

Ankle dorsiflexion (knee extended)	Maximal isometric strength assessment of the ankle dorsiflexors (tibialis anterior) supine		
Ankle plantar flexion	Maximal isometric strength assessment of the ankle plantar flexors (gastrocnemicus and soleus) seated		
Inversion	Maximal isometric strength assessment of ankle inversion (tibialis anterior and posterior) seated		
Eversion	Maximal isometric strength assessment of ankle eversion (peroneus longus and brevis) seated		

Hand-held dynamometry

Optional , Required for modelling

Scoring

Each strength measurement will be repeated 3 times. The maximal value in Newton will be reported.

Test positions

See Appendix 6B

Outcome parameters

Parameter	**Description (see appendix 6 for more detail)**	**Score (Newton)**	
Hip		**RIGHT**	**LEFT**
Hip flexors	Maximal isometric strength assessment of the hip flexors (psaos major and iliacus) supine with the hip flexed.		
Hip extensors	Maximal isometric strength assessment of the hip extensors (gluteus maximus and hamstrings) supine with the hip flexed.		
Hip abductors	Maximal isometric strength assessment of the hip abductors (gluteus medius and minimus) supine hip and knee neutral.		
Knee			
Knee flexion	Maximal isometric strength assessment of the knee flexors (hamstrings) seated knee flexed		
Knee extension	Maximal isometric strength assessment of the knee flexors (quadriceps femoris) seated knee flexed		
Ankle			
Ankle dorsiflexion	Maximal isometric strength assessment of the ankle dorsiflexors (tibialis anterior) supine knee extended		
Ankle plantar flexion (knee extended)	Maximal isometric strength assessment of the ankle plantar flexors (gastrocnemicus and soleus) supine		
Ankle plantar flexion (knee flexed)	Maximal isometric strength assessment of the ankle plantar flexors (gastrocnemicus and soleus) seated		

Selectivity

Required

Scoring

0	No selective control. Total synergy
1	Medium selective control; Starts with selective movement but ends in a synergy
2	Perfect selective control; no synergies

Test positions

See clinical strength test.

Outcome parameters

Parameter	Description (see appendix 6 for more detail)	Score (0-2)	
Selectivity		**RIGHT**	**LEFT**
Hip flexors	Selective control of the hip flexors (psoas major and iliacus) seated.		
Hip abduction	Selective control of the hip abductors (gluteus medius and minimus) supine knee side posture		
Knee extension	Selective control of the knee extensors (quadriceps femoris) seated		
Ankle dorsiflexion (knee extended; Confusion test)	Selective control of the ankle dorsiflexors (tibialis anterior) supine.		
Ankle dorsiflexion (knee flexed; Confusion test)	Selective control of the ankle dorsiflexors (tibialis anterior) seated.		
Inversion	Selective control of ankle inversion (tibialis anterior and posterior) seated		
Eversion	Selective control ankle eversion (peroneus longus and brevis) seated		

Alignment.

Required

Scoring.

For the alignment assessment scoring is in degrees.

Test positions.

Fem. anteversion

Testing position	Prone, with the knee 90^0 flexed.
Stabilization	Body weight
Goniometer axis	Axis is at the ventral part of the patella
Proximal arm	Stationary, perpenidicular to the table
Distal arm	Moving, in line with the tibia
Movement	Internal and external rotation of the hip until the trochanter is most prominent

Tib. fem angle

Testing position	Prone, with the knee 90^0 flexed, ankle and foot in neutral position (or as neutral as possible). Femur condyles neutral (no rotations)
Stabilization	Body weigth
Goniometer axis	Axis is at the calcaneus
Proximal arm	Longitudinal axis of the foot
Distal arm	Perpendicular to the line trouhgh both ASIS

Outcome parameters

Parameter	Description	Score (deg)	
Bony deformities		**RIGHT**	**LEFT**
Femoral anteversion	Shank angle with vertical Prone, knee in 90 degrees		
Tibio-femoral angle	(thigh-foot angle) (degrees)		
Foot deformities			
Pes planus	Medial foot arc while standing upright, medial view	yes/no	yes/no
Subtalar joint	Calcaneus angle while standing upright, dorsal view	Varus/ valgus/ neutral	Varus/ valgus/ neutral
Forefoot	Forefoot relative to hindfoot while standing upright	Abduction/ Adduction/ neutral	Abduction/ Adduction/ neutral
Midfootbreak	Talonaviculaire subluxation	yes/no	yes/no

Sensibility

Optional

Scoring

According to the ASIA impairment Scale (AIS).

A	Complete. No sensory or motor function is preserved segments S4-5
B	Sensory incomplete. Sensory but nor motor function is preserved below the neurological level and inlcuded the sacral segments (S4-5)
C	Motor incomplete. Motor function is preserved below the neurological level, and more than half of key muscles below th eneurological level have a muscle grade less than 3.
D.	Motor incomplete. Motor function is preserved below neurological level, and at least half of key muscles below neurological level have a msucle grade of 3 or more.
E	Normal. Motor and sensory function are normal.

Test positions.

Exteroceptive sensibility.

In supine (or while sitting) the patient closes his/her eyes while the examiner is touching the segments of both legs randomly. The patient has to indicate whether he/she feels the touch.

Pain sensibility.

In supine (or while sitting) the patient closes his/her eyes while the examiner touches the segments of both legs with a sharp or stump object randomly. The patient has to indicate whether the touch is sharp or stump.

Properioceptive sensibility.

In supine (or while sitting) the patient closes his/eyes while the examiner is moving the hallux or keeping the hallux still. The patient has to indicate whether the hallux is moved or not.

Outcome parameters

Parameter	Description	Score (A-E)	
Exteroceptive sensiblity		**RIGHT**	**LEFT**
L2-L3	Exteroceptive sensibility of skin segment L2-3 supine		
L3-L4	Exteroceptive sensibility of skin segment L3-4 supine		
L4-L5	Exteroceptive sensibility of skin segment L4-5 supine		
L5-S1	Exteroceptive sensibility of skin segment L5-S1 supine		
Pain sensibility			
L2-L3	Pain sensibility of skin segment L2-3 supine		
L3-L4	Pain sensibility of skin segment L3-4 supine		
L4-L5	Pain sensibility of skin segment L4-5 supine		
L5-S1	Pain sensibility of skin segment L5-S1 supine		
Proprioception			
Hallux	Proprioceptive sense of the hallux		

F. Energy expenditure

Optional
Required for modelling in CP; in DMD and CMT1 if possible

General

Energy expenditure during gait is measured with a walk test at comfortable walking speed. The test takes place at a track without any sharp turns, preferably about 40 meters long. Oxygen uptake (VO_2, ml/kg/min), respiratory exchange ratio and walking distance are measured.

Test protocol.

First, resting metabolism is measured using indirect calorimetry while the children are seated in a recumbent position during 5 minutes in order to determine net energy expenditure. To avoid distraction and assure real rest, the children can watch a relaxing movie or read a book e.g.

After the resting period, the children are asked to walk six minutes at a self-selected, comfortable walking speed to determine energy expenditure.

After the six minute walking period, the children have a resting period of two minutes.

Instructions.

- No food or drinks containing sugar two hours prior to the measurements
- No excessive effort prior to the test
- Careful instructions
- No practice walk
- No laugh/talk or coughing during the first resting period
- At least 6 minutes of walking (first 3 minutes are not useable)
- Use daily foot wear (shoes / orthotics: notate which type was worn)

Outcome parameters.

Parameter	Description	Score
VO2 rest	Oxygen uptake in rest	ml/kg/min
VO2 gait	Oxygen uptake during walking	ml/kg/min
Respiratory exchange ratio (RER)	Ratio between O2 consumed and CO2 produced in one breath	%
Walking distance	Total walking distance	m
Walking velocity	Walking speed	m/s
Gross energy expenditure (EE)	Gross energy expenditure during walking	J/kg/min
Gross energy cost	Gross energy cost during walking	J/kg/m
Net energy expenditure	Net energy expenditure during walking	J/kg/min
Net energy cost	Net energy cost during walking	J/kg/m
Normalized energy expenditure	EE normalized for leg length and expressed as a percentage of speed-matched controls	%

G. 6 Minutes walk test

Optional
Required for modelling in DMD and CMT1A patients

General

This evaluation is a modified version of the 6MWT as currently used in clinical trials for Duchenne muscular Dystrophy [11].
The test should be performed indoors, along a flat, straight, quiet corridor at least 2 meters wide with a non-carpeted surface. The test area will be marked with a 25-meter tape line. The tape line should be placed in the middle of the corridor. Arrows indicating the anticlockwise direction and path of movement should be placed in half a circle at the ends of the course. A tape should be placed as a starting line to the right of the first cone. Note that due to the possibility of participant falls, the course should be within easy access of appropriate medical assistance. Decide who will follow the participant around the course and who will document the lap times. One "lap" is the distance from one cone to the other i.e. 25 metres

Test protocol

The participant should be instructed to walk up and down the corridor, around the cones without crossing the line in the middle. Remind them not to slow down when going round the cones and that the test is to see how far and how fast they can walk in 6 minutes without running. Ask them to try not to stop along the way but to keep going for the whole 6 minutes. If they have to stop and rest they can, but should then be asked to continue until the 6 minutes are completed. Extra instruction about 'not to talk' during the test.
The clinical evaluator should remain in a position where they can easily view the participant.
The assistant should follow 1-2 meters behind the participant and if the participant falls should assist him back to a standing position as soon as it is safe to do so.

Encouragement.
Give positive verbal encouragement along the way. Encouragement should be similar to any of the following phrases:

- "You're doing great! Keep it up!"
- "Remember, walk as fast as you can!"(without running)
- "Well done (participant name)! Keep Going!"

Let the participant know how long he has been walking. For example

- "three minutes done, only three to go / you are half way there or one minute left"
- If the participant stops to rest, ask then to continue as soon as they feel able.

If the participant falls.

- Evaluator should record the time of the fall.
- Assistant should assist him back to a standing position as soon as it is safe to do so
- If the participant is uninjured, he should resume walking as soon as he is able.
- If the participant is injured or cannot rise from the floor, the test is over.

Total time and distance should be recorded, and any necessary medical attention should be given to the participant.
At the final seconds of the test count down, the evaluator will announce:
"Five fifty seven, five fifty-eight, five fifty-nine, six minutes! Stop! Well done.

Mark the point at which the participant stopped at 6 minutes using a piece of tape on the floor. Bring a chair or wheelchair for him to sit and rest. Offer the participant a drink or water. Measure the distance from the last cone rounded to the point at which the participant stopped at 6 minutes (or when unable to continue).

Add the distance from the last cone to the distance completed on the previous lap. This is recorded as the total distance walked in 6 minutes.

Instructions.

- A 10 minute rest period should always be given prior to the start of the test. The participant should be asked if they need to use the toilet before beginning.
- A wheelchair should always be used to transport the participant to the test area.
- Two members of staff are required for this test for safety reasons. This should be the clinical evaluator and an assistant – not a parent or caretaker.
- Participants should wear comfortable clothing and appropriate shoes for walking (i.e., trainers, etc). Since participants will be tested at multiple time points, they should make an effort to wear the same type of shoes each time.
- No orthotic devices are allowed other than insoles (extending below the ankle joint only).
- No support may be given by an assistant unless the participant needs help to rise from a fall or to sit down
- Participant may not touch the wall

Outcome parameters

Parameter	Description	Score
Walking distance	Total walking distance obtained during the test	m

H. MRI

Required for modelling

Subject procedures

Subjects are carefully prepared before starting the MRI scan. If possible, this is done by taking the subject to an MRI practice scanner, so the subject can experience what it is to lay in the MRI coil. The researcher explains in detail the procedures of the scan. Furthermore, the subject can listen to MRI sounds, to have an idea of what those will be like.

A selection of lower limb markers as used in the gait analysis (see Appendix 5: Marker placement) are measured during in the MRI scan using liver grains (Vit.E pills) or glycerin pills, in order to relate the MR images to gait analysis data.

Technical settings

Parameter	Description	Setting
Sequence	FLASH (Fast low angle shot), a 3D isotropic spoiled gradient echo T1W sequence.	
T1W	An image created typically by using short TE and TR times whose contrast and brightness are predominately determined by T1 signals.	
Anatomic landmarks	Volumetric acquisition of the entire lower limb including pelvic region	
Coils	Body coil and dedicated lower limb coil.	
Stack parameters		
Rows	Number of rows per stack	384
Columns	Number of columns per stack	384
Slice thickness	Thickness of one MRI slice	1 mm
Repetition time (TR)	The amount of time that exists between successive pulse sequences applied to the same slice	3.25 s
Echo time (TE)	Represents the time in seconds between the application of the 90° pulse and the peak of the echo signal in Spin Echo and Inversion Recovery pulse sequences	1.14 s
FA	Fractional anisotropy (degree of anisotropy of a diffusion process)	23°
FOV	Field of view	399*399
Acquisition time	The period of time required to collect the image data.	61 s

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Appendices

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Appendix 7	North star ambulatory assessment
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Appendix 1: FMS

Appendix I: *The Functional Mobility Scale.*

Rating 6

Independent on all surfaces:

Does not use any walking aids or need any help from another person when walking over all surfaces including uneven ground, curbs etc., and in a crowded environment.

Rating 5

Independent on level surfaces:

Does not use walking aids or need help from another person. *Requires a rail for stairs.

*If uses furniture, walls, fences, shop fronts for support, please use 4 as appropriate description.

Rating 4

Uses sticks (one or two):

Without help from another person.

Rating 3

Uses crutches:

Without help from another person.

Rating 2

Uses a walker or frame:

Without help from another person.

Rating 1

Uses wheelchair:

May stand for transfers, may do some stepping supported by another person or using a walker/frame.

Walking distance	Rating: select the number (from 1–6) which best describes current function
5 metres (yards)	
50 metres (yards)	
500 metres (yards)	

Rating C

Crawling:

Child crawls for mobility at home (5m).

Rating N

N = does not apply:

For example, child does not complete the distance (500m).

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Appendix 2: GMFCS

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GMFCS – E & R
Gross Motor Function Classification System
Expanded and Revised

(Reference: Dev Med Child Neurol 1997;39:214-223)

INTRODUCTION & USER INSTRUCTIONS

The Gross Motor Function Classification System (GMFCS) for cerebral palsy is based on self-initiated movement, with emphasis on sitting, transfers, and mobility. When defining a five-level classification system, our primary criterion has been that the distinctions between levels must be meaningful in daily life. Distinctions are based on functional limitations, the need for hand-held mobility devices (such as walkers, crutches, or canes) or wheeled mobility, and to a much lesser extent, quality of movement. The distinctions between Levels I and II are not as pronounced as the distinctions between the other levels, particularly for infants less than 2 years of age.

The expanded GMFCS (2007) includes an age band for youth 12 to 18 years of age and emphasizes the concepts inherent in the World Health Organization's International Classification of Functioning, Disability and Health (ICF). We encourage users to be aware of the impact that **environmental** and **personal** factors may have on what children and youth are observed or reported to do. The focus of the GMFCS is on determining which level best represents the **child's or youth's present abilities and limitations in gross motor function**. Emphasis is on usual **performance** in home, school, and community settings (i.e., what they do), rather than what they are known to be able to do at their best (capability). It is therefore important to classify current performance in gross motor function and not to include judgments about the quality of movement or prognosis for improvement.

The title for each level is the method of mobility that is most characteristic of performance after 6 years of age. The descriptions of functional abilities and limitations for each age band are broad and are not intended to describe all aspects of the function of individual children/youth. For example, an infant with hemiplegia who is unable to crawl on his or her hands and knees, but otherwise fits the description of Level I (i.e., can pull to stand and walk), would be classified in Level I. The scale is ordinal, with no intent that the distances between levels be considered equal or that children and youth with cerebral palsy are equally distributed across the five levels. A summary of the distinctions between each pair of levels is provided to assist in determining the level that most closely resembles a child's/youth's current gross motor function.

We recognize that the manifestations of gross motor function are dependent on age, especially during infancy and early childhood. For each level, separate descriptions are provided in several age bands. Children below age 2 should be considered at their corrected age if they were premature. The descriptions for the 6 to 12 year and 12 to18 year age bands reflect the potential impact of environment factors (e.g., distances in school and community) and personal factors (e.g., energy demands and social preferences) on methods of mobility.

An effort has been made to emphasize abilities rather than limitations. Thus, as a general principle, the gross motor function of children and youth who are able to perform the functions described in any particular level will probably be classified at or above that level of function; in contrast, the gross motor function of children and youth who cannot perform the functions of a particular level should be classified below that level of function.

OPERATIONAL DEFINITIONS

Body support walker – A mobility device that supports the pelvis and trunk. The child/youth is physically positioned in the walker by another person.

Hand-held mobility device – Canes, crutches, and anterior and posterior walkers that do not support the trunk during walking.

Physical assistance – Another person manually assists the child/youth to move.

Powered mobility – The child/youth actively controls the joystick or electrical switch that enables independent mobility. The mobility base may be a wheelchair, scooter or other type of powered mobility device.

Self-propels manual wheelchair – The child/youth actively uses arms and hands or feet to propel the wheels and move.

Transported – A person manually pushes a mobility device (e.g., wheelchair, stroller, or pram) to move the child/youth from one place to another.

Walks – Unless otherwise specified indicates no physical assistance from another person or any use of a hand-held mobility device. An orthosis (i.e., brace or splint) may be worn.

Wheeled mobility – Refers to any type of device with wheels that enables movement (e.g., stroller, manual wheelchair, or powered wheelchair).

GENERAL HEADINGS FOR EACH LEVEL

LEVEL I	-	Walks without Limitations
LEVEL II	-	Walks with Limitations
LEVEL III	-	Walks Using a Hand-Held Mobility Device
LEVEL IV	-	Self-Mobility with Limitations; May Use Powered Mobility
LEVEL V	-	Transported in a Manual Wheelchair

DISTINCTIONS BETWEEN LEVELS

Distinctions Between Levels I and II - Compared with children and youth in Level I, children and youth in Level II have limitations walking long distances and balancing; may need a hand-held mobility device when first learning to walk; may use wheeled mobility when traveling long distances outdoors and in the community; require the use of a railing to walk up and down stairs; and are not as capable of running and jumping.

Distinctions Between Levels II and III - Children and youth in Level II are capable of walking without a hand-held mobility device after age 4 (although they may choose to use one at times). Children and youth in Level III need a hand-held mobility device to walk indoors and use wheeled mobility outdoors and in the community.

Distinctions Between Levels III and IV - Children and youth in Level III sit on their own or require at most limited external support to sit, are more independent in standing transfers, and walk with a hand-held mobility device. Children and youth in Level IV function in sitting (usually supported) but self-mobility is limited. Children and youth in Level IV are more likely to be transported in a manual wheelchair or use powered mobility.

Distinctions Between Levels IV and V - Children and youth in Level V have severe limitations in head and trunk control and require extensive assisted technology and physical assistance. Self-mobility is achieved only if the child/youth can learn how to operate a powered wheelchair.

Gross Motor Function Classification System – Expanded and Revised (GMFCS – E & R)

BEFORE 2ND BIRTHDAY

LEVEL I: Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding on to furniture. Infants walk between 18 months and 2 years of age without the need for any assistive mobility device.
LEVEL II: Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding on to furniture.
LEVEL III: Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.
LEVEL IV: Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.
LEVEL V: Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk postures in prone and sitting. Infants require adult assistance to roll.

BETWEEN 2ND AND 4TH BIRTHDAY

LEVEL I: Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.
LEVEL II: Children floor sit but may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on a stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture and walk using an assistive mobility device as preferred methods of mobility.
LEVEL III: Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using a hand-held mobility device (walker) and adult assistance for steering and turning.
LEVEL IV: Children floor sit when placed, but are unable to maintain alignment and balance without use of their hands for support. Children frequently require adaptive equipment for sitting and standing. Self-mobility for short distances (within a room) is achieved through rolling, creeping on stomach, or crawling on hands and knees without reciprocal leg movement.
LEVEL V: Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

BETWEEN 4TH AND 6TH BIRTHDAY

LEVEL I: Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.
LEVEL II: Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for a hand-held mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.
LEVEL III: Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with a hand-held mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when traveling for long distances or outdoors on uneven terrain.
LEVEL IV: Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a powered wheelchair.
LEVEL V: Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

BETWEEN 6TH AND 12TH BIRTHDAY

Level I: Children walk at home, school, outdoors, and in the community. Children are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Children perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Children may participate in physical activities and sports depending on personal choices and environmental factors.

Level II: Children walk in most settings. Children may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas, confined spaces or when carrying objects. Children walk up and down stairs holding onto a railing or with physical assistance if there is no railing. Outdoors and in the community, children may walk with physical assistance, a hand-held mobility device, or use wheeled mobility when traveling long distances. Children have at best only minimal ability to perform gross motor skills such as running and jumping. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

Level III: Children walk using a hand-held mobility device in most indoor settings. When seated, children may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance of a person or support surface. When traveling long distances, children use some form of wheeled mobility. Children may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

Level IV: Children use methods of mobility that require physical assistance or powered mobility in most settings. Children require adaptive seating for trunk and pelvic control and physical assistance for most transfers. At home, children use floor mobility (roll, creep, or crawl), walk short distances with physical assistance, or use powered mobility. When positioned, children may use a body support walker at home or school. At school, outdoors, and in the community, children are transported in a manual wheelchair or use powered mobility. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

Level V: Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and and/or mobility but limitations are not fully compensated by equipment. Transfers require complete physical assistance of an adult. At home, children may move short distances on the floor or may be carried by an adult. Children may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

BETWEEN 12TH AND 18TH BIRTHDAY

Level I: Youth walk at home, school, outdoors, and in the community. Youth are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Youth perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Youth may participate in physical activities and sports depending on personal choices and environmental factors.

Level II: Youth walk in most settings. Environmental factors (such as uneven terrain, inclines, long distances, time demands, weather, and peer acceptability) and personal preference influence mobility choices. At school or work, youth may walk using a hand-held mobility device for safety. Outdoors and in the community, youth may use wheeled mobility when traveling long distances. Youth walk up and down stairs holding a railing or with physical assistance if there is no railing. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

Level III: Youth are capable of walking using a hand-held mobility device. Compared to individuals in other levels, youth in Level III demonstrate more variability in methods of mobility depending on physical ability and environmental and personal factors. When seated, youth may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance from a person or support surface. At school, youth may self-propel a manual wheelchair or use powered mobility. Outdoors and in the community, youth are transported in a wheelchair or use powered mobility. Youth may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

Level IV: Youth use wheeled mobility in most settings. Youth require adaptive seating for pelvic and trunk control. Physical assistance from 1 or 2 persons is required for transfers. Youth may support weight with their legs to assist with standing transfers. Indoors, youth may walk short distances with physical assistance, use wheeled mobility, or, when positioned, use a body support walker. Youth are physically capable of operating a powered wheelchair. When a powered wheelchair is not feasible or available, youth are transported in a manual wheelchair. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

Level V: Youth are transported in a manual wheelchair in all settings. Youth are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and mobility but limitations are not fully compensated by equipment. Physical assistance from 1 or 2 persons or a mechanical lift is required for transfers. Youth may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

Appendix 3: GMFM

GROSS MOTOR FUNCTION MEASURE (GMFM)
SCORE SHEET (GMFM-88 and GMFM-66 scoring)

Version 1.0

Child's Name: _____ ID #: _____

Assessment date: _____ year / month /day

Date of birth: _____ year / month /day

Chronological age: _____ years/months

GMFCS Level [1]

☐ I ☐ II ☐ III ☐ IV ☐ V

Testing Conditions (eg, room, clothing, time, others present)

Evaluator's Name: _____

_____

_____

_____

The GMFM is a standardized observational instrument designed and validated to measure change in gross motor function over time in children with cerebral palsy. The scoring key is meant to be a general guideline. However, most of the items have specific descriptors for each score. It is imperative that the guidelines contained in the manual be used for scoring each item.

SCORING KEY
0 = does not initiate
1 = initiates
2 = partially completes
3 = completes
NT = Not tested [used for the GMAE scoring*]

It is now important to differentiate a true score of "0" (child does not initiate) from an item which is Not Tested (NT) if you are interested in using the GMFM-66 Ability Estimator Software.

*The GMFM-66 Gross Motor Ability Estimator (GMAE) software is available with the GMFM manual (2002). The advantage of the software is the conversion of the ordinal scale into an interval scale. This will allow for a more accurate estimate of the child's ability and provide a measure that is equally responsive to change across the spectrum of ability levels. Items that are used in the calculation of the GMFM-66 score are shaded and identified with an asterisk (*). The GMFM-66 is only valid for use with children who have cerebral palsy.

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[1] GMFCS level is a rating of severity of motor function. Definitions are found in Appendix I of the GMFM manual (2002).

Check (√) the appropriate score: if an item is not tested (NT), circle the item number in the right column

Item		A: LYING & ROLLING	SCORE				NT
	1.	SUP, HEAD IN MIDLINE: TURNS HEAD WITH EXTREMITIES SYMMETRICAL	0 ☐	1 ☐	2 ☐	3 ☐	1.
*	2.	SUP: BRINGS HANDS TO MIDLINE, FINGERS ONE WITH THE OTHER	0 ☐	1 ☐	2 ☐	3 ☐	2.
	3.	SUP: LIFTS HEAD 45°	0 ☐	1 ☐	2 ☐	3 ☐	3.
	4.	SUP: FLEXES R HIP AND KNEE THROUGH FULL RANGE	0 ☐	1 ☐	2 ☐	3 ☐	4.
	5.	SUP: FLEXES L HIP AND KNEE THROUGH FULL RANGE	0 ☐	1 ☐	2 ☐	3 ☐	5.
*	6.	SUP: REACHES OUT WITH R ARM, HAND CROSSES MIDLINE TOWARD TOY	0 ☐	1 ☐	2 ☐	3 ☐	6.
*	7.	SUP: REACHES OUT WITH L ARM, HAND CROSSES MIDLINE TOWARD TOY	0 ☐	1 ☐	2 ☐	3 ☐	7.
	8.	SUP: ROLLS TO PR OVER R SIDE	0 ☐	1 ☐	2 ☐	3 ☐	8.
	9.	SUP: ROLLS TO PR OVER L SIDE	0 ☐	1 ☐	2 ☐	3 ☐	9.
*	10.	PR: LIFTS HEAD UPRIGHT	0 ☐	1 ☐	2 ☐	3 ☐	10.
	11.	PR ON FOREARMS: LIFTS HEAD UPRIGHT, ELBOWS EXT., CHEST RAISED	0 ☐	1 ☐	2 ☐	3 ☐	11.
	12.	PR ON FOREARMS: WEIGHT ON R FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD	0 ☐	1 ☐	2 ☐	3 ☐	12.
	13.	PR ON FOREARMS: WEIGHT ON L FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD	0 ☐	1 ☐	2 ☐	3 ☐	13.
	14.	PR: ROLLS TO SUP OVER R SIDE	0 ☐	1 ☐	2 ☐	3 ☐	14.
	15.	PR: ROLLS TO SUP OVER L SIDE	0 ☐	1 ☐	2 ☐	3 ☐	15.
	16.	PR: PIVOTS TO R 90° USING EXTREMITIES	0 ☐	1 ☐	2 ☐	3 ☐	16.
	17.	PR: PIVOTS TO L 90° USING EXTREMITIES	0 ☐	1 ☐	2 ☐	3 ☐	17.
		TOTAL DIMENSION A	☐				

Item		B: SITTING	SCORE				NT
*	18.	SUP, HANDS GRASPED BY EXAMINER: PULLS SELF TO SITTING WITH HEAD CONTROL	0 ☐	1 ☐	2 ☐	3 ☐	18.
	19.	SUP: ROLLS TO R SIDE, ATTAINS SITTING	0 ☐	1 ☐	2 ☐	3 ☐	19.
	20.	SUP: ROLLS TO L SIDE, ATTAINS SITTING	0 ☐	1 ☐	2 ☐	3 ☐	20.
*	21.	SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD UPRIGHT, MAINTAINS 3 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	21.
*	22.	SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD MIDLINE, MAINTAINS 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	22.
*	23.	SIT ON MAT, ARM(S) PROPPING: MAINTAINS, 5 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	23.
*	24.	SIT ON MAT: MAINTAINS, ARMS FREE, 3 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	24.
*	25.	SIT ON MAT WITH SMALL TOY IN FRONT: LEANS FORWARD, TOUCHES TOY, RE-ERECTS WITHOUT ARM PROPPING	0 ☐	1 ☐	2 ☐	3 ☐	25.
*	26.	SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S R SIDE, RETURNS TO START	0 ☐	1 ☐	2 ☐	3 ☐	26.
*	27.	SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S L SIDE, RETURNS TO START	0 ☐	1 ☐	2 ☐	3 ☐	27.
	28.	R SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	28.
	29.	L SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	29.
*	30.	SIT ON MAT: LOWERS TO PR WITH CONTROL	0 ☐	1 ☐	2 ☐	3 ☐	30.
*	31.	SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER R SIDE	0 ☐	1 ☐	2 ☐	3 ☐	31.
*	32.	SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER L SIDE	0 ☐	1 ☐	2 ☐	3 ☐	32.
	33.	SIT ON MAT: PIVOTS 90°, WITHOUT ARMS ASSISTING	0 ☐	1 ☐	2 ☐	3 ☐	33.
*	34.	SIT ON BENCH: MAINTAINS, ARMS AND FEET FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	34.
*	35.	STD: ATTAINS SIT ON SMALL BENCH	0 ☐	1 ☐	2 ☐	3 ☐	35.
*	36.	ON THE FLOOR: ATTAINS SIT ON SMALL BENCH	0 ☐	1 ☐	2 ☐	3 ☐	36.
*	37.	ON THE FLOOR: ATTAINS SIT ON LARGE BENCH	0 ☐	1 ☐	2 ☐	3 ☐	37.
		TOTAL DIMENSION B	☐				

Item		C: CRAWLING & KNEELING	SCORE				NT
	38.	PR: CREEPS FORWARD 1.8m (6')	0 ☐	1 ☐	2 ☐	3 ☐	38.
*	39.	4 POINT: MAINTAINS, WEIGHT ON HANDS AND KNEES, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	39.
*	40.	4 POINT: ATTAINS SIT ARMS FREE	0 ☐	1 ☐	2 ☐	3 ☐	40.
*	41.	PR: ATTAINS 4 POINT, WEIGHT ON HANDS AND KNEES	0 ☐	1 ☐	2 ☐	3 ☐	41.
*	42.	4 POINT: REACHES FORWARD WITH R ARM, HAND ABOVE SHOULDER LEVEL	0 ☐	1 ☐	2 ☐	3 ☐	42.
*	43.	4 POINT: REACHES FORWARD WITH L ARM, HAND ABOVE SHOULDER LEVEL	0 ☐	1 ☐	2 ☐	3 ☐	43.
*	44.	4 POINT: CRAWLS OR HITCHES FORWARD 1.8m (6')	0 ☐	1 ☐	2 ☐	3 ☐	44.
*	45.	4 POINT: CRAWLS RECIPROCALLY FORWARD 1.8m (6')	0 ☐	1 ☐	2 ☐	3 ☐	45.
*	46.	4 POINT: CRAWLS UP 4 STEPS ON HANDS AND KNEES/FEET	0 ☐	1 ☐	2 ☐	3 ☐	46.
	47.	4 POINT: CRAWLS BACKWARDS DOWN 4 STEPS ON HANDS AND KNEES/FEET	0 ☐	1 ☐	2 ☐	3 ☐	47.
*	48.	SIT ON MAT: ATTAINS HIGH KN USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	48.
	49.	HIGH KN: ATTAINS HALF KN ON R KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	49.
	50.	HIGH KN: ATTAINS HALF KN ON L KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	50.
*	51.	HIGH KN: KN WALKS FORWARD 10 STEPS, ARMS FREE	0 ☐	1 ☐	2 ☐	3 ☐	51.

TOTAL DIMENSION C ☐

Item		D: STANDING	SCORE				NT
*	52.	ON THE FLOOR: PULLS TO STD AT LARGE BENCH	0 ☐	1 ☐	2 ☐	3 ☐	52.
*	53.	STD: MAINTAINS, ARMS FREE, 3 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	53.
*	54.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS R FOOT, 3 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	54.
*	55.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS L FOOT, 3 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	55.
*	56.	STD: MAINTAINS, ARMS FREE, 20 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	56.
*	57.	STD: LIFTS L FOOT, ARMS FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	57.
*	58.	STD: LIFTS R FOOT, ARMS FREE, 10 SECONDS	0 ☐	1 ☐	2 ☐	3 ☐	58.
*	59.	SIT ON SMALL BENCH: ATTAINS STD WITHOUT USING ARMS	0 ☐	1 ☐	2 ☐	3 ☐	59.
*	60.	HIGH KN: ATTAINS STD THROUGH HALF KN ON R KNEE, WITHOUT USING ARMS	0 ☐	1 ☐	2 ☐	3 ☐	60.
*	61.	HIGH KN: ATTAINS STD THROUGH HALF KN ON L KNEE, WITHOUT USING ARMS	0 ☐	1 ☐	2 ☐	3 ☐	61.
*	62.	STD: LOWERS TO SIT ON FLOOR WITH CONTROL, ARMS FREE	0 ☐	1 ☐	2 ☐	3 ☐	62.
*	63.	STD: ATTAINS SQUAT, ARMS FREE	0 ☐	1 ☐	2 ☐	3 ☐	63.
*	64.	STD: PICKS UP OBJECT FROM FLOOR, ARMS FREE, RETURNS TO STAND	0 ☐	1 ☐	2 ☐	3 ☐	64.

TOTAL DIMENSION D ☐

Item		E: WALKING, RUNNING & JUMPING	SCORE				NT
*	65.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO R	0 ☐	1 ☐	2 ☐	3 ☐	65.
*	66.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO L	0 ☐	1 ☐	2 ☐	3 ☐	66.
*	67.	STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS	0 ☐	1 ☐	2 ☐	3 ☐	67.
*	68.	STD, 1 HAND HELD: WALKS FORWARD 10 STEPS	0 ☐	1 ☐	2 ☐	3 ☐	68.
*	69.	STD: WALKS FORWARD 10 STEPS	0 ☐	1 ☐	2 ☐	3 ☐	69.
*	70.	STD: WALKS FORWARD 10 STEPS, STOPS, TURNS 180°, RETURNS	0 ☐	1 ☐	2 ☐	3 ☐	70.
*	71.	STD: WALKS BACKWARD 10 STEPS	0 ☐	1 ☐	2 ☐	3 ☐	71.
*	72.	STD: WALKS FORWARD 10 STEPS, CARRYING A LARGE OBJECT WITH 2 HANDS	0 ☐	1 ☐	2 ☐	3 ☐	72.
*	73.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS BETWEEN PARALLEL LINES 20cm (8") APART	0 ☐	1 ☐	2 ☐	3 ☐	73.
*	74.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS ON A STRAIGHT LINE 2cm (3/4") WIDE	0 ☐	1 ☐	2 ☐	3 ☐	74.
*	75.	STD: STEPS OVER STICK AT KNEE LEVEL, R FOOT LEADING	0 ☐	1 ☐	2 ☐	3 ☐	75.
*	76.	STD: STEPS OVER STICK AT KNEE LEVEL, L FOOT LEADING	0 ☐	1 ☐	2 ☐	3 ☐	76.
*	77.	STD: RUNS 4.5m (15'), STOPS & RETURNS	0 ☐	1 ☐	2 ☐	3 ☐	77.
*	78.	STD: KICKS BALL WITH R FOOT	0 ☐	1 ☐	2 ☐	3 ☐	78.
*	79.	STD: KICKS BALL WITH L FOOT	0 ☐	1 ☐	2 ☐	3 ☐	79.
*	80.	STD: JUMPS 30cm (12") HIGH, BOTH FEET SIMULTANEOUSLY	0 ☐	1 ☐	2 ☐	3 ☐	80.
*	81.	STD: JUMPS FORWARD 30 cm (12"), BOTH FEET SIMULTANEOUSLY	0 ☐	1 ☐	2 ☐	3 ☐	81.
*	82.	STD ON R FOOT: HOPS ON R FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE	0 ☐	1 ☐	2 ☐	3 ☐	82.
*	83.	STD ON L FOOT: HOPS ON L FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE	0 ☐	1 ☐	2 ☐	3 ☐	83.
*	84.	STD, HOLDING 1 RAIL: WALKS UP 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0 ☐	1 ☐	2 ☐	3 ☐	84.
*	85.	STD, HOLDING 1 RAIL: WALKS DOWN 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0 ☐	1 ☐	2 ☐	3 ☐	85.
*	86.	STD: WALKS UP 4 STEPS, ALTERNATING FEET	0 ☐	1 ☐	2 ☐	3 ☐	86.
*	87.	STD: WALKS DOWN 4 STEPS, ALTERNATING FEET	0 ☐	1 ☐	2 ☐	3 ☐	87.
*	88.	STD ON 15cm (6") STEP: JUMPS OFF, BOTH FEET SIMULTANEOUSLY	0 ☐	1 ☐	2 ☐	3 ☐	88.

TOTAL DIMENSION E ☐

Was this assessment indicative of this child's "regular" performance? YES ☐ NO ☐

COMMENTS:

GMFM RAW SUMMARY SCORE

DIMENSION	CALCULATION OF DIMENSION % SCORES	GOAL AREA (indicated with ✓ check)
A. Lying & Rolling	$\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$	A. ☐
B. Sitting	$\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$	B. ☐
C. Crawling & Kneeling	$\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$	C. ☐
D. Standing	$\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$	D. ☐
E. Walking, Running & Jumping	$\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$	E. ☐

TOTAL SCORE = $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

$= \frac{\quad + \quad + \quad + \quad + \quad}{5} = \frac{\quad}{5} = \quad\%$

GOAL TOTAL SCORE = $\frac{\text{Sum of \% scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \quad = \quad\%$

GMFM-66 Gross Motor Ability Estimator Score [1]

GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

previous GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

change in GMFM-66 = _____

[1] from the Gross Motor Ability Estimator (GMAE) Software

TESTING WITH AIDS/ORTHOSES

Indicate below with a check (✓) which aid/orthosis was used and what dimension it was first applied. (There may be more than one).

AID		DIMENSION	ORTHOSIS		DIMENSION
Rollator/Pusher	☐	____	Hip Control	☐	____
Walker	☐	____	Knee Control	☐	____
H Frame Crutches	☐	____	Ankle-Foot Control	☐	____
Crutches	☐	____	Foot Control	☐	____
Quad Cane	☐	____	Shoes	☐	____
Cane	☐	____	None	☐	____
None	☐	____	Other	☐	____
Other	☐	____	_____ (please specify)		

_____ (please specify)

RAW SUMMARY SCORE USING AIDS/ORTHOSES

DIMENSION	CALCULATION OF DIMENSION % SCORES	GOAL AREA (indicated with ✓ check)
F. Lying & Rolling	$\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$	A. ☐
G. Sitting	$\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$	B. ☐
H. Crawling & Kneeling	$\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$	C. ☐
I. Standing	$\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$	D. ☐
J. Walking, Running & Jumping	$\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$	E. ☐

TOTAL SCORE = $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

$= \frac{\quad + \quad + \quad + \quad + \quad}{5} = \frac{\quad}{5} = \quad\%$

GOAL TOTAL SCORE = $\frac{\text{Sum of \% scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \quad = \quad\%$

GMFM-66 Gross Motor Ability Estimator Score [1]

GMFM-66 Score = _____ _____ to _____
95% Confidence Intervals

previous GMFM-66 Score = _____ _____ to _____
95% Confidence Intervals

change in GMFM-66 = _____

[1] from the Gross Motor Ability Estimator (GMAE) Software

Appendix 4: EMG placement

Gluteus medius.

- Location: at 50% of the line of the iliac crest and the greater trochanter.
- Test contraction: While the subject is standing on one leg, palpate the muscle or when lying on one side, abduction of the hip (with knee extended) against resistance at the ankle.

Rectus femoris.

- Location: at 50% of the line of the ASIS and superior edge of the patella
- Test contraction: Lift the extended leg or extend the knee without rotation of the hip.

Vastus lateralis.

- Location: at 2/3 of the line of the ASIS and the lateral side of the patella
- Test contraction: Lift the extended leg or extend the knee without rotation of the hip.

back to protocol

Medial hamstrings/Semitendinosus.

- Location: at 1/3 of the line of the ischial tuberosity and the lateral epicondyle of the tibia.
- Test contraction: apply resisted pressure at the ankle and ask for knee flexion.

Lateral hamstrings/Biceps femoris[1].

[1] According to the Seniam guidelines, the location should be at 50% of the line between ischial tuberosity and the lateral epicondyle of the tibia. However, to avoid cross-talk, the electrodes for medial hamstrings are placed a little

- Location: at 2/3 of the line of the ischial tuberosity and the lateral epicondyle of the tibia.
- Test contraction: apply resisted pressure at the ankle and ask for knee flexion.

Tibialis anterior.

- Location: at 1/3 on the line between the tip of the fibula and the tip of the medial malleolus (as proximal as possible).
- Test contraction: apply resisted pressure and ask for dorsiflexion and inversion.

bit more proximal from the 50% and the electrodes for the lateral hamstrings are placed a little bit more distal than the 50%.

Gastronemicus (medial)

- Location: At 1/3 of the line between medial femur condyle and the heel (preferably a little bit more proximal).
- Test contraction: Ask plantar flexion of the foot under resistance while the knee is almost extended. .

Soleus.

- Location: at 2/3 of the line between the tip of the medial femur condyle and the tip of the medial malleolus.
- Test contraction: Move the foot passively in dorsiflexion and palpate the muscle. Or bend the knee and let the patient actively rise the heel and press their toes into the table. Examiner gives resistance against the knee.

Appendix 5: Marker placement

Marker placement is described in detail in the Marker Placement Protocol (MPP) of Task 6.1.2 of Deliverable 6.1 of the MD-Paedigree project.

Appendix 6: Physical examination.

A. Passive range of motion

Test positions

Hips

Flexion[2]	
Testing position	Supine with hips and knees in neutral rotation
Stabilization	Trunk stabilized by body position
Goniometer axis	Femoral greater trochanter
Proximal arm	Parallel to the table
Distal arm	Parallel to the longitudinal axis of the femur in line with the lateral femoral condyle
Movement	Hip flexion, knee flexion allowed
Expected ROM	120^0
Add. movement	Lumber spine flexion

Extension[3]	*Thomas test*
Testing position	Supine with the contralateral hip flexed
Stabilization	Pelvis is stabilized through manual fixation
Goniometer axis	Greater Trochanter
Proximal arm	Parallel to table
Distal arm	Parallel to longitudinal axis of femur in line with lateral femoral condyle
Movement	UL of the measured side flat on the table.
Expected ROM	0°
Add. movement	Lumbar spine extension

Extension	*Staheli test*
Testing position	Prone.
Stabilization	Pelvis is stabilized through manual fixation
Goniometer axis	Greater Trochanter
Proximal arm	Parallel to midaxillary line of the pelvi (line between ASIS and PSIS)
Distal arm	Parallel to longitudinal axis of femur in line with lateral femoral condyle
Movement	Tested leg is on the table or from the table if ROM is greater than 0°.
Expected ROM	0°
Add. movement	Lumbar spine extension

[2] When flexion seems normal, nl is noted instead of the amount of degrees.
[3] When the patient is able to keep his leg flat on the table, extension is graded with 0^0 (Thomas test)

Abduction (knee 0^0)

Testing position	Supine with hips and knees in neutral and pelvis level
Stabilization	By body weight
Goniometer axis	ASIS on measured side
Proximal arm	Perpendicular to the line between the two ASIS
Distal arm	Parallel to the long axis of the femur, middle of the patella
Movement	Abduction until motion is detected at the opposite anterior superior iliac spine
Expected ROM	45°
Add. movement	Hip external rotation, knee flexion/internal rotation, or lateral pelvic tilt

Abduction (knee 90^0)

Testing position	Supine with hips in 60^0 flexion and knees in 90^0 flexion, feet together
Stabilization	Manual fixation on pelvis
Goniometer axis	ASIS on measured side
Proximal arm	Perpendicular to the line between the two ASIS
Distal arm	Parallel to the long axis of the femur (inner side of the leg)
Movement	Abduction of both legs
Expected ROM	45°
Add. movement	Hip external rotation, knee flexion/internal rotation, or lateral pelvic tilt

Adduction[4]

Testing position	Supine with the opposite extremity abducted
Stabilization	By body weight
Goniometer axis	ASIS on measured side
Proximal arm	Perpendicular to the line between the two ASIS
Distal arm	Parallel to the long axis of the femur
Movement	Adduction
Expected ROM	30°
Add. movement	Hip internal rotation and/or lateral pelvic tilt

Internal and external rotation prone

Testing position	Prone with knee flexed 90^0
Stabilization	Manual fixation of the pelvis
Goniometer axis	Mid-patella
Proximal arm	Perpendicular to the table
Distal arm	Parallel along the axis of the tibia, between both malleoli
Movement	Internal and external movement of the hip
Expected ROM	45^0
Add. movement	Thigh abduction/adduction and/or pelvis tilt

[4] This is set at 0^0 when the patient is in relaxed position and adduction is normal

Knee

Flexion supine

Testing position	Supine with the hip and knee in neutral position
Stabilization	Trunk and pelvis are stabilized by body weight
Goniometer axis	Lateral epicondyle of the femur
Proximal arm	Parallel along the axis of the femur, pointing at the greater trochanter
Distal arm	Parallel to the long axis of the fibula, pointing at the lateral malleolus
Movement	Knee flexion
Expected ROM	135^0
Add. movement	

Hyper(extension)

Testing position	Supine with hips and knees in neutral rotation
Stabilization	Trunk and pelvis stabilized by body weight and position
Goniometer axis	Lateral epicondyle of the femur
Proximal arm	Parallel to the long axis of the femur, pointing at the greater trochanter
Distal arm	Parallel to the long axis of the fibula, pointing at the lateral malleolus
Movement	Knee extension
Expected ROM	0^0. Hyperextension can go up to 10-15^0
Add. movement	

Knee flexion prone (rectus femoris length)

Testing position	Prone with the hips and knees in neutral position
Stabilization	Pelvis manually stabilized
Goniometer axis	Lateral epicondyle of the femur
Proximal arm	Parallel along the axis of the femur, pointing at the greater trochanter
Distal arm	Parallel to the long axis of the fibula, pointing at the lateral malleolus
Movement	Passive knee flexion

Popleteal angle unilateral

Testing position	Supine with the hip and knee in flexion, contralateral knee extended
Stabilization	Trunk and pelvis are stabilized by body weight
Goniometer axis	Lateral epicondyle of the femur
Proximal arm	Parallel along the axis of the femur, pointing at the greater trochanter
Distal arm	Parallel to the long axis of the fibula, pointing at the lateral malleolus
Movement	Knee extension, while the hip stays flexed in 90^0.
Expected ROM	
Add. movement	Pelvic lift or rotation

Ankle

Dorsiflexion (knee 0^0)

Testing position	Supine with the hip and knee in neutral rotation
Stabilization	Trunk and pelvis are stabilized by body weight
Goniometer axis	Lateral malleolus
Proximal arm	Parallel to the long axis of the fibula and pointing towards the fibular head
Distal arm	Parallel to the long axis of the 5th metatarsal
Movement	Dorsiflexion
Expected ROM	10^0
Add. movement	Varus/Valgus (note if varus/valgus happens)

Dorsiflexion (knee 90^0)

Testing position	Supine with the knee flexed in 90^0
Stabilization	Trunk and pelvis are stabilized by body weight
Goniometer axis	Lateral malleolus
Proximal arm	Parallel to the long axis of the fibula and pointing towards the fibular head
Distal arm	Parallel to the long axis of the 5th metatarsal
Movement	Dorsiflexion
Expected ROM	20^0
Add. movement	

Plantar flexion

Testing position	Supine with hip en knee flexed in 90^0. Ankle in neutral position
Stabilization	Therapist stabilizes lower leg
Goniometer axis	Lateral malleolus
Proximal arm	Parallel to the long axis of the fibula and pointing towards the fibular head
Distal arm	Parallel to the long axis of the 5th metatarsal
Movement	Plantar flexion
Expected ROM	20^0
Add movement	Inversion

Varus (calcaneus)

Testing position	Prone with the knee in 90^0 flexion.
Stabilization	Therapist stabilizes lower leg
Goniometer axis	Joint between talus and calcaneus
Proximal arm	Line in the middle of the dorsal part of the lower leg
Distal arm	Line in the middle of the dorsal part of the calcaneus
Movement	Varus calcaneus
Expected ROM	
Add movement	

Valgus (calcaneus)

Testing position	Prone with the knee in 90^0 flexion.
Stabilization	Therapist stabilizes lower leg
Goniometer axis	Joint between talus and calcaneus
Proximal arm	Line in the middle of the dorsal part of the lower leg
Distal arm	Line in the middle of the dorsal part of the calcaneus
Movement	Valgus calcaneus
Expected ROM	
Add movement	

Supination

Testing position	Prone with the knee in 90^0 flexion.
Stabilization	Therapist stabilizes lower leg
Goniometer axis	Thirth metatarsal joint
Proximal arm	Perpendicular to the lower leg
Distal arm	Line though the distal metatarsal bones
Movement	Supination in the lower hock
Expected ROM	
Add movement	

Pronation

Testing position	Prone with the knee in 90^0 flexion.
Stabilization	Therapist stabilizes lower leg
Goniometer axis	Thirth metatarsal joint
Proximal arm	Perpendicular to the lower leg
Distal arm	Line though the distal metatarsal bones
Movement	Pronation in the lower hock
Expected ROM	
Add movement	

B. Strength.

Clinical strength test positions.

Hips

Flexion

Testing position	Sitting with the hanging from lower legs from the table
Movement	Lift the knee
Resistance	Apply pressure at the knee in the direction of hip extension
Ass. motion	Trunk movement, other

Extension

Testing position	Prone.
Movement	Lift the extended leg
Resistance	Apply pressure at the knee in the direction of hip flexion
Ass. motion	Lumbar extension, pelvis rotation

Abduction (knee 0^0)

Testing position	Lying on the heterolateral side with hips and knees in neutral and pelvis level or in supine
Movement	Abduction
Resistance	Apply pressure at the ankle in the direction of adduction
Ass. motion	Hip external rotation, knee flexion/internal rotation, or lateral pelvic tilt

Adduction (knee 90^0)

Testing position	Supine with hips and knees flexed
Movement	Adduction
Resistance	Apply pressure at the knee in the direction of abduction
Ass. motion	Pelvic movement

Adduction(knee 0^0)

Testing position	Supine with the opposite extremity abducted
Movement	Adduction
Resistance	Apply pressure at the ankle in the direction of abduction
Ass. motion	Hip internal rotation or lateral pelvic tilt

Adduction ((knee 0^0)

Testing position	Lying on the ipsilateral side with hips and knees in neutral and pelvis level. Heterolateral leg is lifted in abduction by tester
Movement	Adduction
Resistance	Apply pressujust above the kneein the direction of abduction
Ass. motion	Hip internal rotation or lateral pelvic tilt

Knee.

Flexion

Testing position	Prone, legs extended
Movement	Knee flexion
Resistance	Apply pressure at the ankle in the direction of knee extension
Ass. motion	Lumbar extension, pelvis rotation

Extension

Testing position	Sitting, with the lower legs hanging from the table
Movement	Knee extension
Resistance	Apply pressure at the ankle in the direction of knee flexion
Ass. motion	Trunk movements

Ankle

Dorsiflexion (knee 90^0)

Testing position	Sitting, with the lower legs hanging from the table
Movement	Dorsiflexion of the ankle (lift your toes)
Resistance	Apply pressure at the foot in the direction of plantar flexion.
Ass. motion	Abduction/adduction movement of the foot

Dorsiflexion (knee 0^0)

Testing position	Supine with the knees extended
Movement	Dorsiflexion of the ankle (lift your toes)
Resistance	Apply pressure at the foot in the direction of plantar flexion.
Ass. motion	Abduction/adduction movement of the foot

Inversion/eversion

Testing position	Sitting, with the lower legs hanging from the table
Movement	Inversion/eversion of the ankle
Resistance	Apply pressure at the foot in the direction of eversion resp. inversion.
Ass. motion	

Plantar flexion

Testing position	In stance, or in sit with the legs hanging from the table
Movement	Plantar flexion by standing on the toes of one leg or while sitting on the table and make plantar flexion movement
Resistance	Dorsiflexion
Ass.motion	

Hand-held dynanometry test positions

Hip

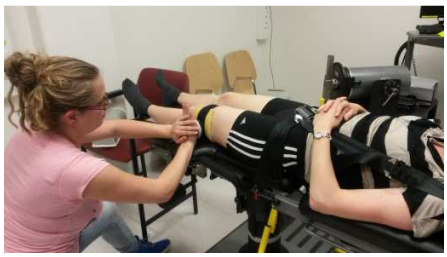
Flexion[6]–[8]

Testing position	Supine with the hip flexed in 90^0, knee relaxed (lower leg can lie on shoulder of assessor, a standardised knee angle is not possible but should be measured)
HHD position	Anterior side of the thigh at 75% (distally) of the distance between the trochantor major and the lateral epicondyle of the femur.
Fixation	Fixation of the pelvis
Resistance	Resistance at the knee in the direction of hip extension
Ass. motion	Trunk movement, other

Extension[6], [8]

Testing position	Supine with the hip flexed in 90^0, knee relaxed (to standardise knee angle, an extra assessor is required to keep knee angle in 90^0 . This assessor should only hold the leg up, not give any resistance to the hip extension moment.) Hands on belly.
HHD position	Posterior side of the thigh at 75% (distally) of the distance between the trochantor major and the lateral epicondyle of the femur.
Fixation	Fixation of the pelvis
Resistance	Resistance at the knee in the direction of hip flexion
Ass. motion	Trunk movement, other

Abduction[6]–[9]



Testing position	Supine, hips and knees in neutral position
HHD position	Lateral side of the thigh at 75% (distally) of the distance between the trochantor major and the lateral epicondyle of the femur.
Fixation	Fixation of the pelvis
Resistance	Resistance at the knee in the direction of hip adduction
Ass. Motion	Trunk movement, other

Knee

Flexion [6]–[10]

Testing position	Sitting, lower legs hanging from the table (90^0 flexion in hips and knees)
HHD position	Posterior side of the lower leg at 75% (distally) of the distance between the top of the fibula head and the lower side of the lateral malleolus.
Fixation	Fixation at the thigh and trunk
Resistance	Resistance at the shank in knee extension direction
Ass. motion	Lumbar extension, pelvis rotation

Extension[6]–[10]

Testing position	In sit, lower legs hanging from the table (90^0 flexion in hips and knees)
HHD position	Anterior side of the lower leg at 75% (distally) of the distance between the top of the fibula head and the lower side of the lateral malleolus.
Fixation	Fixation at the thigh (and trunk)
Resistance	Resistance at the shank in knee flexion direction
Ass. motion	Lumbar extension, pelvis rotation

Ankle.

Ankle plantarflexion (knee 0^0)

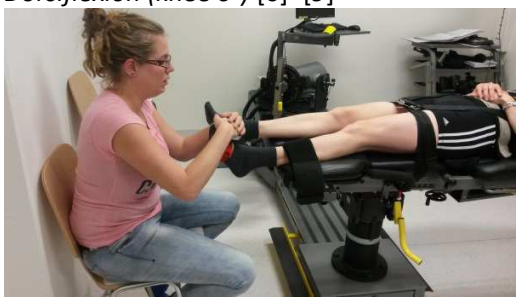
Testing position	Supine with the knees extended, foot is dorsiflexed $90^{0.}$, (first inversion, than dorsiflexion for 'pure'df movement) by positioning of the assessor if neccesary. If range of motion is restricted, measure ankle angel at which the test is done. Hands on the belly.
HHD position	On the plantair side of the foot at 75% (distally) of the distance between the lower side of the lateral malleolus and the head of MTP V.
Fixation	Upper and lower leg
Ass. Motion	Abductin/adduction movement of the foot.

Ankle plantarflexion (knee 90^0)

Picture will be added

Testing position	Seated with the knees 90^0 flexed, foot is dorsiflexed $90^{0.}$ (first inversion, than dorsiflexion for 'pure'df movement) by positioning of the assessor if neccesary. If range of motion is restricted, measure ankle angel at which the test is done. Hands on the belly.
HHD position	On the plantair side of the foot at 75% (distally) of the distance between the lower side of the lateral malleolus and the head of MTP V.
Fixation	Upper and lower leg
Ass. Motion	Abductin/adduction movement of the foot.

Dorsiflexion (knee 0^0) [6]–[9]



Testing position	Supine with the knees extended. Patient wears socks. The foot is in passive neutral position. Hands are on the belly.
HHD position	On the dorsal side of the foot, at 75% (distally) of the distance between the lower side of the lateral malleolus and the head of MTP V.
Fixation	Upper and lower leg.
Resistance	Resistance at the foot in the direction of plantar flexion.

Appendix 7: North start ambulatory assessment.

North Star Ambulatory Assessment

We have attempted to give clear explanations of the methods employed to achieve motor goals, but it is not possible to be exhaustive in the descriptions, particularly of modifications to activity. Whilst DMD children may generally present with recognizable adaptations to activity due to the underlying progressive muscular weakness, they may modify their activity to achieve functional goals in slightly differing ways. Generally, activities are graded in the following manner:

2 – 'Normal' – no obvious modification of activity
1 - Modified method but achieves goal independent of physical assistance from another
0 - Unable to achieve independently

Gowers' Manoeuvre:

Figure: Gowers' Manoeuvre (from W.R. Gowers' *Pseudohypertrophic muscular paralysis*, 1879)

Definition of Gowers' manoeuvre:
The child turns towards the floor (generally into a four-point kneeling position) to place hands on the floor to assist rising, walks hands back in towards him then uses arms to 'climb' up legs to achieve upright standing. A wide base of support is often assumed through the phases of rising from the floor.

Stair Climb
As it is not possible to ensure standardisation, or availability, of flights of stairs, we are asking that a box step (approximately 15cm high) is used to assess single step climb and descend. A plinth or other immovable object may need to be available to provide support.

The following two pages give test details and instructions for the patient and a scoring sheet with details for grading. They should be used in conjunction. Please familiarize yourself with the test detail before starting to evaluate patients.

The **North Star Ambulatory Assessment** has been developed by the Physiotherapy Assessment and Evaluation Group of the North Star Clinical Network.
The North Star Project is supported by
Muscular Dystrophy Campaign

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Test Detail and Instructions to Patient

Activity	Instructions to patient	Start position/test detail	Comments
1. Stand	Can you stand up tall for me for as long as you can and as still as you can	Feet should be close together and heels on the ground if possible. Arms by sides. NO shoes should be worn.	Best done on the floor rather than on a mat. Whichever is chosen maintain consistency through repeated testing sessions. Minimum count of 3 seconds to score 2.
2. Walk	Can you walk from A to B (state to and where from) for me.	Walk without shoes/socks on. Should be enough of a distance to observe 'normal gait' for that subject	A value judgement needs to be made in scoring – if the patient generally toe walks but occasionally gets heels flat, or can on request but doesn't usually, they should score 1
3. Stand up from chair	Stand up from the chair keeping your arms folded if you can	Starting position 90° hips and knees, feet on floor/supported on a box step.	A size-appropriate chair or height adjustable plinth should be used. Arms should be kept crossed throughout the activity to score 2.
4. Stand on one leg - Right	Can you stand on your right leg for as long as you can?	Minimum count of 3 seconds to score 2. NO shoes should be worn.	Best done on the floor rather than on a mat. Whichever is chosen maintain consistency through repeated testing sessions.
5. Stand on one leg - Left	Can you stand on your left leg for as long as you can?	Minimum count of 3 seconds to score 2. NO shoes should be worn.	Best done on the floor rather than on a mat. Whichever is chosen maintain consistency through repeated testing sessions.
6. Climb box step - right	Can you step onto the top of the box using your right leg first?	Stands facing the box step. Step should be approximately 15cm high	Support may be provided by the use of a height adjustable plinth, or, if not available a 'neutral' hand from the therapist.
7. Climb box step - left	Can you step onto the top of the box using your left leg first?	Stands facing the box step. Step should be approximately 15cm high	Support may be provided by the use of a height adjustable plinth, or, if not available a 'neutral' hand from the therapist.
8. Descend box step - Right	Can you step down from the box using your right leg first?	Stands on top of the box step facing forwards. Step should be approximately 15cm high	Support may be provided by the use of a height adjustable plinth, or, if not available a 'neutral' hand from the therapist.
9. Descend box step - Left	Can you step down from the box using your left leg first?	Stands on top of the box step facing forwards. Step should be approximately 15cm high	Support may be provided by the use of a height adjustable plinth, or, if not available a 'neutral' hand from the therapist.
10. Gets to sitting	Can you get from lying to sitting?	Starting position supine on a mat. No pillow should be used under head	If patient turns into prone or towards the floor to work their way into sitting 1 should be scored
11. Rise from floor	Get up from the floor using as little support as possible and as fast as you can (from supine)	Starting position supine with arms by sides, legs straight. No pillow to be used	Activity should be attempted without use of furniture in the first instance. Do not note time if a chair has to be used.
12. Lifts head	Lift your head to look at your toes keeping your arms folded	Supine on a mat. No pillow should be used.	Ask patient to keep arms crossed over chest during the activity to avoid self-assist. Also ask to look at toes to ensure neck is flexed – should be a chin to chest manoeuvre.
13. Stands on heels	Can you stand on your heels?	Standing on the floor. No shoes to be worn.	Watch for inversion. If substantial inversion but forefeet are still lifted – score 1. If only inversion with lateral border of foot still on the ground score 0.
14. Jump	How high can you jump?	Standing on the floor, feet fairly close together.	Want height, not forward movement. Small amount of forward movement acceptable
15. Hop right leg	Can you hop on your right leg?	Starting position standing on floor on right leg. No shoes should be worn.	Needs obvious floor clearance to score 2
16. Hop left leg	Can you hop on your left leg?	Starting position standing on floor on right leg. No shoes should be worn.	Needs obvious floor clearance to score 2
17. Run (10m)	Run as fast you can to……(give point)	A straight 10m walkway should be clearly marked in a quiet department or corridor. A stopwatch should be used to time the walk. Be consistent as to whether shoes are worn or not. Ensure safety of patient. They should self select speed after being asked to go 'as fast as they can'.	'Duchenne jog' - not a true run (there probably IS a double support phase), but more than a walk. Typically characterized by excessive use of arms, trunk rotation, substantial 'waddle'. No real 'push-off'

North Star Ambulatory Assessment – Score Sheet

Activity	2	1	0	Comments
1. Stand	Stands upright, still and symmetrically, without compensation (with heels flat and legs in neutral) for minimum count of 3 seconds	Stands still but with some degree of compensation (e.g. on toes or with legs abducted or with bottom stuck out) for minimum count of 3 seconds	Cannot stand still or independently, needs support (even minimal)	
2. Walk	Walks with heel-toe or flat-footed gait pattern	Persistent or habitual toe walker, unable to heel-toe consistently	Loss of independent ambulation – may use KAFOs or walk short distances with assistance	
3. Stand up from chair	Keeping arms folded Starting position 90° hips and knees, feet on floor/supported on a box step.	With help from thighs or push on chair or prone turn	Unable	
4. Stand on one leg - right	Able to stand in a relaxed manner (no fixation) for count of 3 seconds	Stands but either momentarily or needs a lot of fixation e.g. by knees tightly adducted or other trick	Unable	
5. Stand on one leg - left	Able to stand in a relaxed manner (no fixation) for count of 3 seconds	Stands but either momentarily or needs a lot of fixation e.g. by knees tightly adducted or other trick	Unable	
6. Climb box step - right	Faces step – no support needed	Goes up sideways or needs support	Unable	
7. Climb box step - left	Faces step – no support needed	Goes up sideways or needs support	Unable	
8. Descend box step - right	Faces forward, climbs down controlling weight bearing leg. No support needed	Sideways, skips down or needs support	Unable	
9. Descend box step -left	Faces forward, climbs down controlling weight bearing leg. No support needed	Sideways, skips down or needs support	Unable	
10. Gets to sitting	Starts in supine – may use one hand to assist	Self assistance e.g. – pulls on legs or uses head-on-hands or head flexed to floor	Unable	
11. Rise from floor	From supine – no evidence of Gowers' manoeuvre*	Gowers' evident	(a) NEEDS to use external support object e.g. chair OR (b) Unable	Time (00.0s).....
12. Lifts head	In supine, head must be lifted in mid-line. Chin moves towards chest	Head is lifted but through side flexion or with no neck flexion	Unable	
13. Stands on heels	Both feet at the same time, clearly standing on heels only (acceptable to move a few steps to keep balance) for count of 3	Flexes hip and only raises forefoot	Unable	
14. Jump	Both feet at the same time, clear the ground simultaneously	One foot after the other (skip)	Unable	
15. Hop right leg	Clears forefoot and heel off floor	Able bend knee and raise heel, no floor clearance	Unable	
16. Hop left leg	Clears forefoot and heel off floor	Able bend knee and raise heel, no floor clearance	Unable	
17. Run (10m)	Both feet off the ground (no double stance phase during running)	'Duchenne jog'	Walk	Time (00.0s).....
				TOTAL= /34

* See definition page 1

Muscular Dystrophy Campaign
NorthStar Clinical Network

Appendix 8 CMTPedS

Final version of the 11-item CMTPedS data form

cmtpediatricscale

Initial Evaluation ☐ Re-Evaluation ☐ Date:

Patient Profile					
ID:		D.O.B:	Age (yrs):	Gender: Boy ☐ Girl ☐	
Height (m):	Weight (kg):	Dominant Hand: L ☐ R ☐	Dominant Foot: L ☐ R ☐	Diagnosis:	
Symptoms:	Foot pain ☐	Leg cramps ☐	Unsteady ankles ☐	Daily trips and/or falls ☐	Hand pain ☐
	Hand weakness ☐	Hand tremor ☐	Sensory symptoms (e.g. pins and needles, tingling, numbness, prickling) ☐		

Lunge test (degrees)		Left:	Right:
Foot Posture Index	Talar head palpation		
	Curves above and below lateral malleolus		
	Inversion/eversion of the calcaneus		
	Bulge in the region of the talonavicular joint		
	Congruence of the medial longitudinal arch		
	Abd/adduction of forefoot on rearfoot (too-many-toes)		
	Total (-12 to 12)		

Hand Dexterity			
1. Functional Dexterity Test (sec)		2. Nine-hole peg test (sec)	

Strength	Trial 1	Trial 2	Trial 3	Average
3. Hand grip (N)				÷2:
4. Foot plantarflexion (N)				
5. Foot dorsiflexion (N)				

Sensation	0	1	2	3	4	Score
6. Pinprick	Normal	Decreased below or at ankle bones	Decreased at or below midline of calf	Decreased above calf midline up to and including knee	Decreased above knee (above top of patella)	
7. Vibration	Normal	Reduced at first metatarsal bone	Reduced at ankle	Reduced at knee (tibial tuberosity)	Absent at knee and ankle	

Balance	Assistive device required (e.g. AFO) Y/N. Describe device and footwear:										
8. Bruininks Oseretsky Test	Raw Score Trial 1	Raw Score Trial 2	*Conduct second trial only if examinee does not earn the maximum score on the first trial*								Point score
Standing with feet apart on a line-eyes open			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Walking forward on a line			Raw	0	1-2	3-4	5	6			
			Point	0	1	2	3	4			
Standing on one leg on a line-eyes open			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Standing with feet apart on a line-eyes closed			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Walking forward heel-to-toe on a line			Raw	0	1-2	3-4	5	6			
			Point	0	1	2	3	4			
Standing on one leg on a line-eyes closed			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Standing on one leg on a beam-eyes open			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Standing heel-to-toe on a balance beam			Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10			
			Point	0	1	2	3	4			
Standing on one leg on a beam-eyes closed			Raw	0.0-0.9	1.0-2.9	3.0-4.9	5.0-7.9	8.0-9.9	10		
			Point	0	1	2	3	4	5		
Balance Subscale from the Bruininks Oseretsky Test of Motor Proficiency, Second Edition (BOT-2). Copyright© 2005 NCS Pearson, Inc. Adapted and reproduced with permission. All rights reserved.									Total		

Motor Function	Assistive device required (e.g. AFO) Y/N. Describe device and footwear:		
9. Gait	Foot drop: No ☐ Some ☐ Yes ☐	Difficulty heel walking: No ☐ Some ☐ Yes ☐	Difficulty toe walking: No ☐ Some ☐ Yes ☐
10. Long jump (cm)		11. Six-minute walk test (m)	

Item Scores (0-4)											Total Score (0-44)
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	

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