Whole body gait kinematics in patients with bilateral and chronic unilateral vestibulopathy – DATASET v4

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This dataset contains whole body kinematics and 3D ground reaction forces and moments *from 30 subjects (10 with bilateral vestibulopathy, 10 with unilateral vestibulopathy, and 10 healthy subjects) during gait at three different walking speed: slow, comfortable, and fast. Three repetitions of these gait were performed by each subject. They were instrumented with 35 reflective placed on the whole body according to the Convention Gait Model 1.0. A 12-camera motion capture system (Oqus 7+, Qualisys, Göteborg, Sweden), set at a 100 Hz sampling frequency, was used to track cutaneous reflective markers. The marker trajectories were labeled using Qualisys Tracking Manager software (QTM 2019.3, Qualisys, Göteborg, Sweden) and exported in the C3D file format. Three force plates sampled at 1000 Hz (AMTI Accugait, Watertown, MA, USA) were used to record 3D ground reaction forces and moments. Results of gait standard deviation (GaitSD) and anchoring index (AI), as well as the kinematics data, are included in this dataset in csv file format.*

Version	Date	Update(s)
v1	2023.08.03	First upload of the dataset
v2	2024.11.18	- Update of the metadata in c3d files - Virtual markers added to define segment coordinate systems in c3ds - Update of the static file per session
v3	/	Not available
v4	2024.11.28	Correction of marker data filtering on some files – Gait Standard Deviation and Head Anchoring Index were not recalculated (please refer to v1 or v2)

1. Participants

Ten bilateral vestibulopathy (BV) patients and 10 unilateral vestibulopathy (UV) patients were recruited at the Service of Otorhinolaryngology and Head and Neck Surgery of a tertiary university hospital and compose this dataset. BV patients was diagnosed according to the guidelines of the Classification

Committee of the Bárány Society [1] (unsteadiness when walking or standing, oscillopsia and/or worsening of imbalance in darkness/uneven ground. No symptoms while sitting or lying down under static unsteadiness, bilaterally reduced or absent vestibulo-ocular reflex documented by a caloric test, video-head impulse test (vHIT), or torsion swing test, and finally not better accounted for by another disease). UV patients had to meet clinical vHIT requirements, with gain values below 0.6 for at least one of the lateral semicircular canals of the affected ear. The unilateral vestibular disorder had to be present for at least 3 months (to have a chronic deficit). Moreover, UV patients needed to have normal vestibular function in the other ear (vHIT gain values above 0.6). Ten healthy participants were included in this dataset in the HS group. They had no history of vestibular symptoms (i.e., imbalance, vertigo, dizziness). All HS met a criterion of normal vHIT gain values for all semicircular canals (vHIT gain values above 0.6). All study participants were over 18 years of age and provided their written informed consent. The study was designed and conducted in accordance with the guidelines of the Declaration of Helsinki and was approved by the local ethics committee (Commission Cantonale d'Ethique de la Recherche).

The following table defines each subjects that compose this dataset.

Patient	**Gender**	**Affected side**	**Age (yrs)**	**Height (m)**	**Body mass (kg)**	**Aetiology**	**Score DHI** [2]
BV							
1	Female	NR	79	1.51	53	Ototoxic	48
2	Female	NR	54	1.60	66	Genetic	46
3	Male	NR	64	1.81	74	Idiopathic	12
4	Female	NR	65	1.66	59	Idiopathic	34
5	Female	NR	64	1.61	70	Idiopathic	20
6	Female	NR	56	1.61	88	Hydrops	74
7	Male	NR	59	1.71	84	Schwannoma	2
8	Male	NR	59	1.70	78	Idiopathic	40
9	Male	NR	71	1.71	72	Idiopathic	48
10	Female	NR	83	1.54	70	Idiopathic	NA
UV							
1	Female	Left	78	1.57	60	Idiopathic	68
2	Male	Left	63	1.87	91	Idiopathic	6
3	Male	Left	71	1.82	102	Post- labyrinthectomy	64
4	Female	Right	62	1.48	54	Idiopathic	NA
5	Male	Left	60	1.83	100	Schwannoma	20
6	Male	Right	61	1.82	91	Idiopathic	8
7	Female	Right	57	1.58	77	Idiopathic	NA
8	Male	Right	65	1.79	89	Traumatic	11
9	Female	Right	67	1.54	70	Schwannoma	52
10	Female	Right	60	1.52	62	Idiopathic	14
HS							
1	Female	NR	55	1.65	59	NR	NR
2	Female	NR	59	1.67	58	NR	NR
3	Male	NR	76	1.76	71	NR	NR
4	Male	NR	61	1.72	83	NR	NR
5	Female	NR	71	1.69	56	NR	NR
6	Female	NR	59	1.64	78	NR	NR
7	Male	NR	73	1.79	76	NR	NR

8	Female	NR	53	1.62	56	NR	NR
9	Male	NR	57	1.84	90	NR	NR
10	Male	NR	82	1.70	82	NR	NR

2. Data analysis

2.1 Kinematics

Joint kinematics were calculated from the raw data of the marker trajectories. A custom-made software developed by Moveck® was used to compute the Conventional Gait Model 1.0 (CGM 1.0) [3], [4]. Then, each trial was divided into gait cycles (foot strike to foot strike) to calculate all the parameters of this study. Kinematic angles were calculated for the three anatomical reference planes (sagittal, frontal, and transverse) and for the joints and segments of the upper and lower limbs. Thus, angles for the head, neck, shoulder, elbow, wrist, trunk, spine, pelvis, hip, knee, ankle, and foot were calculated for all each participant of the three studied groups. The elbow ab-adduction, the elbow rotation and the wrist rotation were not considered in the selection of trials because of their low angle amplitude. For lower limb angles, knee rotation, ankle ab-adduction and ankle rotation were not included either in the analysis, as done in the clinical gait analysis because of the low reliability of the calculations. A minimum of 2 cycles was available per participant and per condition.

2.2 Gait Standard Deviation

The GaitSD [5] was defined as the square root of the average variance of 9 kinematic variables in degrees (pelvic tilt, pelvic obliquity, pelvic rotation, hip flexion, hip abduction, rotation, knee flexion, ankle dorsiflexion, and foot progression angles. A minimum of 5 cycles per subject was chosen to avoid losing too many subjects due to the low number of trials. However, Sangeux et al. required to select a minimum of 6 cycles to calculate a GaitSD with a relative precision superior to 90 %. Missing data information are available in a following section. For the GaitSD analysis, the left side of the BV and HS groups was randomly selected, while the affected side was chosen for the UV group.

2.3 Anchoring Index

AI [6] was based on the standard deviation of the head orientation in the global (laboratory) coordinate system and on the standard deviation of the head orientation relative to the trunk movement. A positive AI value indicated a head stabilization strategy in space and a negative value a stabilization strategy on the trunk. As done in the GaitSD analysis, a minimum of 5 cycles per subject was needed to compute the AI. Missing data information are available in a following section. For the AI analysis, the left side of the BV and HS groups was randomly selected, while the affected side was chosen for the UV group.

3. Recordings

To record the 3D motions, subjects were equipped with 35 anatomical markers (14 mm diameter) fixed with double-sided tape and placed on the whole body according to the Conventional Gait Model 1.0 (see marker details in the following table). A 12-camera motion capture system (Oqus 7+, Qualisys, Göteborg, Sweden), set at a 100 Hz sampling frequency, was used to track cutaneous reflective markers. Fourteen calculated virtual markers related to joint centers were also added to the dataset.

To record the 3D ground reaction forces and moments, three force plates sampled at 1000 Hz (AMTI Accugait, Watertown, MA, USA) were used. These data were not used in in the study and have therefore not been verified. However, they are present in the c3d files.
The measurement started with a 10-second recording of the participant standing upright (T-pose). Then, participants were asked to walk barefoot back and forth on a 10-meter walkway at three different self-selected speeds: comfortable, slow, and fast. Walking trials at each speed were repeated three times.

Labels	Format	Dim.	Unit	Description
LFHD	Real	n x 3	mm	Left front head trajectories
LBHD	Real	n x 3	mm	Left back head trajectories
RFHD	Real	n x 3	mm	Right front head trajectories
RBHD	Real	n x 3	mm	Right back head trajectories
CLAV	Real	n x 3	mm	Suprasternal notch trajectories
STRN	Real	n x 3	mm	Xiphoid process trajectories
C7	Real	n x 3	mm	7^{th} cervical vertebra trajectories
T10	Real	n x 3	mm	10^{th} thoracic vertebrae trajectories
RBAK	Real	n x 3	mm	Right scapula root spine trajectories
LSHO	Real	n x 3	mm	Left acromial edge trajectories
LSJC*	Real	n x 3	mm	Left shoulder joint center trajectories
LELB	Real	n x 3	mm	Left lateral humerus epicondyle trajectories
LEJC*	Real	n x 3	mm	Left elbow joint center trajectories
LWRA	Real	n x 3	mm	Left radius styloid process trajectories
LWRB	Real	n x 3	mm	Left ulnar styloid process trajectories
LWJC*	Real	n x 3	mm	Left wrist joint center trajectories
LFIN	Real	n x 3	mm	Left head of the 3^{rd} metacarpus trajectories
RSHO	Real	n x 3	mm	Right acromial edge trajectories
RSJC*	Real	n x 3	mm	Right shoulder joint center trajectories
RELB	Real	n x 3	mm	Right lateral humerus epicondyle trajectories
REJC*	Real	n x 3	mm	Right elbow joint center trajectories
RWRA	Real	n x 3	mm	Right radius styloid process trajectories
RWRB	Real	n x 3	mm	Right ulnar styloid process trajectories
RWJC*	Real	n x 3	mm	Right wrist joint center trajectories
RFIN	Real	n x 3	mm	Right head of the 3^{rd} metacarpus trajectories
LASI	Real	n x 3	mm	Left anterior-superior iliac spine trajectories
LPSI	Real	n x 3	mm	Left posterior-superior iliac spine trajectories
RASI	Real	n x 3	mm	Right anterior-superior iliac spine trajectories
RPSI	Real	n x 3	mm	Right posterior-superior iliac spine trajectories
SACR*	Real	n x 3	mm	Middle of the PSI distance trajectories
midASIS*	Real	n x 3	mm	Middle of the ASI distance trajectories
LTHI	Real	n x 3	mm	Left lateral femur wand trajectories
LHJC*	Real	n x 3	mm	Left hip joint center trajectories
LKNE	Real	n x 3	mm	Left lateral femoral epicondyle trajectories
LKJC*	Real	n x 3	mm	Left knee joint center trajectories
LTIB	Real	n x 3	mm	Left lateral tibia wand trajectories
LANK	Real	n x 3	mm	Left lateral tibial malleolus trajectories
LAJC*	Real	n x 3	mm	Left ankle joint center trajectories
LTOE	Real	n x 3	mm	Left 2^{nd} metatarsal calcaneus trajectories
LHEE	Real	n x 3	mm	Left posterior calcaneus trajectories
RTHI	Real	n x 3	mm	Right lateral femur wand trajectories

RHJC*	Real	n x 3	mm	Right hip joint center trajectories
RKNE	Real	n x 3	mm	Right lateral femoral epicondyle trajectories
RKJC*	Real	n x 3	mm	Right knee joint center trajectories
RTIB	Real	n x 3	mm	Right lateral tibia wand trajectories
RANK	Real	n x 3	mm	Right lateral tibial malleolus trajectories
RAJC*	Real	n x 3	mm	Right ankle joint center trajectories
RTOE	Real	n x 3	mm	2nd Right 2nd metatarsal head trajectories
RHEE	Real	n x 3	mm	Right posterior calcaneus trajectories
LUPPERARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the left upper arm coordinate system defined according to CGM 1.0 (same convention for all subsequent markers)
LUPPERARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the left upper arm coordinate system
LUPPERARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the left upper arm coordinate system
LFOREARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the left fore arm coordinate system
LFOREARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the left fore arm coordinate system
LFOREARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the left fore arm coordinate system
LHANDARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the left hand coordinate system
LHANDARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the left hand coordinate system
LHANDARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the left hand coordinate system
RUPPERARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the left upper arm coordinate system
RUPPERARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the right upper arm coordinate system
RUPPERARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the right upper arm coordinate system
RFOREARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the right fore arm coordinate system
RFOREARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the right fore arm coordinate system
RFOREARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the right fore arm coordinate system
RHANDARM_x	Real	n x 3	mm	Virtual marker for the x-axis of the right hand coordinate system
RHANDARM_y	Real	n x 3	mm	Virtual marker for the y-axis of the right hand coordinate system
RHANDARM_z	Real	n x 3	mm	Virtual marker for the z-axis of the right hand coordinate system
THORAX_x	Real	n x 3	mm	Virtual marker for the x-axis of the thorax coordinate system
THORAX_y	Real	n x 3	mm	Virtual marker for the y-axis of the thorax coordinate system
THORAX_z	Real	n x 3	mm	Virtual marker for the z-axis of the thorax coordinate system
PELVIS_x	Real	n x 3	mm	Virtual marker for the x-axis of the pelvis coordinate system
PELVIS_y	Real	n x 3	mm	Virtual marker for the y-axis of the pelvis coordinate system
PELVIS_z	Real	n x 3	mm	Virtual marker for the z-axis of the pelvis coordinate system
LFEMUR_x	Real	n x 3	mm	Virtual marker for the x-axis of the left femur coordinate system
LFEMUR_y	Real	n x 3	mm	Virtual marker for the y-axis of the left femur coordinate system
LFEMUR_z	Real	n x 3	mm	Virtual marker for the z-axis of the left femur coordinate system
LTIBIAPROX_x	Real	n x 3	mm	Virtual marker for the x-axis of the left tibia coordinate system
LTIBIAPROX_y	Real	n x 3	mm	Virtual marker for the y-axis of the left tibia coordinate system
LTIBIAPROX_z	Real	n x 3	mm	Virtual marker for the z-axis of the left tibia coordinate system
LFOOT_x	Real	n x 3	mm	Virtual marker for the x-axis of the left foot coordinate system
LFOOT_y	Real	n x 3	mm	Virtual marker for the y-axis of the left foot coordinate system
LFOOT_z	Real	n x 3	mm	Virtual marker for the z-axis of the left foot coordinate system
RFEMUR_x	Real	n x 3	mm	Virtual marker for the x-axis of the right femur coordinate system
RFEMUR_y	Real	n x 3	mm	Virtual marker for the y-axis of the right femur coordinate system
RFEMUR_z	Real	n x 3	mm	Virtual marker for the z-axis of the right femur coordinate system
RTIBIAPROX_x	Real	n x 3	mm	Virtual marker for the x-axis of the right tibia coordinate system
RTIBIAPROX_y	Real	n x 3	mm	Virtual marker for the y-axis of the right tibia coordinate system
RTIBIAPROX_z	Real	n x 3	mm	Virtual marker for the z-axis of the right tibia coordinate system

RFOOT_x	Real	n x 3	mm	Virtual marker for the x-axis of the right foot coordinate system
RFOOT_y	Real	n x 3	mm	Virtual marker for the y-axis of the right foot coordinate system
RFOOT_z	Real	n x 3	mm	Virtual marker for the z-axis of the right foot coordinate system

4. Data processing

The marker trajectories were labeled using Qualisys Tracking Manager software (QTM 2019.3, Qualisys, Göteborg, Sweden) and exported in the C3D file format[1]. All processing was performed using Matlab (R2021b, The MathWorks, Natick, MA, USA) with the C3D parser from the Biomechanics Toolkit[2] (BTK) [7]. The marker trajectories were interpolated to fill gaps using a reconstruction method that relies on marker inter-correlations [8]. Marker trajectories were filtered using a 4th order low-pass Butterworth filter (cut-off frequency 6 Hz). In each trial file, joint centers of the upper and lower limbs and the center of the posterior and anterior iliac spines were calculated and included as virtual markers. The hip joint centers were computed using Hara's regression equations [9], while other joint centers were determined using a chord function. Lower limb segment coordinate systems were also included in the c3d data as markers. Gait events, such as foot strikes and foot offs, were automatically detected in relation to gait using custom-made algorithm[3] developed in Matlab of self-selection among different methods [10]. To prevent detection errors, each event was visually verified by an operator.
3D ground reaction forces and moment data were not processed.

5. Missing data

There are only 2 trials for BV_01 at fast walking speed, BV_02 at slow and fast walking speeds, BV_06 at slow walking speed, BV_10 at slow walking speed, UV_08 at slow walking speed, and HS_09 at comfortable walking speed because of a too poor raw data quality before processing. In kinematic data (present in c3d or csv files), cycles for certain angles may contain NaN. This is usually because the corresponding segments have an insufficient number of markers, making kinematics calculations impossible.
In addition, for the GaitSD and AI analyses, the following subject's conditions were removed because the number of cycles was less than 5: BV03 at fast walking speed, HS9 at comfortable walking speed, HS1 at fast walking speed, HS7 at fast walking speed, HS3 at fast walking speed, HS1 at comfortable walking speed, UV2 at fast walking speed, UV4 at fast waking speed, and UV10 at comfortable and fast walking speed.

6. Folder structure

The dataset is organized in two folders. The first one contains all the raw data provided in c3d files per subject and condition. The file name consists of the patient type (i.e., BV, UV, HS), patient number (i.e., 01, 02, …), walking speed condition (i.e., slow, comfortable, fast), and trial number (i.e., 01, 02, 03). For example, BV_01_ComfortableGait_01.c3d. The second folder contains the processed kinematic, GaitSD, and AI results. They are provided in csv files format. One file contains all the results for all the subjects and conditions.

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[1] https://www.c3d.org
[2] http://biomechanical-toolkit.github.io/
[3] https://gitlab.unige.ch/KLab/gaitevent_autoselection

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