Dataset Description:

This dataset reports the lower-limb kinematics and kinetics of ten able-bodied participants walking at multiple inclines (± 0°, 5°, and 10°) and speeds (0.8 m/s, 1 m/s, and 1.2 m/s), running over level-ground at multiple speeds (1.8 m/s, 2 m/s, 2.2 m/s, and 2.4 m/s), walking and running with constant acceleration and deceleration (± 0.2 m/s^2, and 0.5 m/s^2), and stair ascent/descent with multiple stair inclines (± 20°, 25°, 30°, and 35°). This dataset also includes sit-stand transitions, walk-run transitions, and walk-stairs transitions. Data were recorded by a Vicon motion capture system and, for applicable tasks, a Bertec instrumented treadmill. This dataset can aid in the development of kinematic models of multi-activity human locomotion and the design and control of agile wearable robots.

Citation:

E. Reznick*, K. Embry*, R. Neuman, E. Bolívar, N. Fey, and R. Gregg, “Human lower-limb kinematics and kinetics during continuously varying locomotion,” *Scientific Data - Nature*

Size:

3.47 GB

Environment:
The file is of *.mat format and can be opened using MATLAB. To do so in your MATLAB workspace, use the load command and the full file extension

load(‘C: ... \example_folder_____);

This will load two variables to your workspace, Streaming.mat and Normalized.mat.

Major Component Description:

The experiment’s data is saved in two MATLAB structs, Streaming and Normalized. Streaming.mat is the continuous data from each trial, whereas Normalized.mat contains the same data parsed and normalized by stride. The Normalized dataset is interpolated for all strides (HS-HS) to have the same length, while the sampling rate for the Streaming structure by data type is as follows:

- Joint Angles, Forces, Moments, Powers - 100Hz
- Forceplate - 1000Hz

Streaming.mat:

y = Streaming.(participant).(ambulationMode).(trial).(dataType).(variable)

(participant) = ABXX: One of ten able-bodied individuals

(ambulationMode) = Wrt: Capturing the walk-to-run and run-to-walk transition through constant acceleration/deceleration trials

Run: Steady-state running trials over level ground

Run.(trial): each trial under running indicates a separate run. The name of the trial indicates the maximum speed achieved: e.g.: 's1x8' obtained a maximum running speed of 1.8 m/s

Sts: Participants rise from seated to standing, pause, and sit again. A backless stool was placed on the right force plate and participants feet were placed on the left.

Sts.(trial): the trial field indicates sequential sit-to-stand-to-sit events. 'Sts_1' occurred before 'Sts_2', and so on.

Tread: Participants progressing through a randomized protocol of steady-state walking and acceleration/deceleration tasks at a constant incline/decline.

Tread.(trial): indicates what incline the test was performed at. E.g.: d5 = 5 degrees decline, i5 = 5 degrees incline

Stair: Streaming data of the participant approaching, ascending/descending, and walking from the end of the stair set. Trials are sorted by incline, e.g., 'i25' is stairs at a self selected speed. The following number indicates the trial (odd: ascent; even: decent).

Stair.(trial): indicates the inclination of the stairs, which direction the person was walking (ascent or descent) and the sequence of trials. E.g.: s25dg_05: the stairs were set to 25 degrees, this was the 5th trial of 10, and all odd trials are ascent.

(dataType) = markers: Position of markers in global coordinates (unit: m)

jointAngles: Tracks the joint angle in three dimensions (unit: deg)

➔ Full documentation: https://docs.vicon.com/pages/viewpage.action?pageId=50888880

jointForces: Tracks the resultant force at each joint (unit: N/kg)

- ➔ Not available for stairs or sit-to-stand
- ➔ Full documentation: https://docs.vicon.com/display/Nexus25/Plug-in+Gait+lower+body+forces+and+moments

jointMoments: Tracks the moment (or Torque) about each joint (unit: N*m/kg)

- ➔ Corrected to reflect the internal moment of the joint
- ➔ Not available for stairs or sit-to-stand
- ➔ Full documentation: https://docs.vicon.com/display/Nexus25/Plug-in+Gait+lower+body+forces+and+moments

jointPowers: The power output by the joint (unit: W/kg)

- ➔ Not available for stairs or sit-to-stand
- ➔ Corrected to reflect the internal moment of the joint.

forceplates: Provides weight normalized force plate data from each leg; directions follow the local force plate frame.

- ➔ Not available for stairs, use caution for sts
- ➔ Force - (x (side to side), y (propulsive/braking), z (normal to ground)) (unit: N/kg)
- ➔ Moment - moment (x/y/z) (unit: N*m/kg)
- ➔ CoP - center of pressure (x,y,z) (unit: m)

events: Heel strike for left and right side (by frame) and velocity profiles for randomized protocol

- ➔ LHS/RHS - heel strikes by frame (Walk, Wtr, Run, Stair)
- ➔ L/RStrideTime - stride time (heel strike to heel strike in frames (100Hz))
- ➔ CutPoints - Points delineating different tasks for each ambulation mode (by column: 1 - start frame, 2 - end frame, 3 - task)
- ➔ VelProf - velocity profile of treadmill: cvel - commanded velocity; l/rvel - experimental velocity of each stride

(variable) = The final field for all data types. In general, results are given as streams of data, where each row is a new sample of the signal at its sampling rate, and each column represents a new dimension of the data if applicable. Where applicable, Columns 1, 2, 3 = Dimension x,y,z

Normalized.mat:

y = Normalized.(participant).(ambulationMode).(speed/rate).(incline).(datatype).(variable)

(participant)= ABXX: One of ten able-bodied individuals.

(ambulationMode)= Run:Running trials at level ground, both at steady state and accelerations, including walk/run transitions.

SitStand: Participants perform either a sit-to-stand, or stand-to-sit task. Force plate data available.

Walk: Walking on Bertec treadmill. Force plate data available.

Stair:Walking up and down variable grade stairs.

ParticipantDetails: Participant measurements and details with units. Gender is listed as 1:Female or 2:Male.

(speed/rate)= Walk/Run: Steady-state walking speeds (s*), constant accelerations (a*) and decelerations (d*) indicate the speed and rate. Accelerations were performed starting from rest and going to 1.2 m/s at a constant acceleration. Following is the rate (in m/s for velocity and m/s^2 for acceleration), where ‘x’ is used as a decimal point, e.g., ‘1.2m/s’ is ‘s1x2’.

SitStand: The term ‘ss’ is used because the participant was instructed to rise and sit at a self-selected speed.

Stair: The terms are used to determine where the participant is in relation to the stair set when walking at a self-selected pace. (See fig. below) Note: ‘s3’ is the most periodic (steady-state) stride.

- ➔ s#: Stair strides
- ➔ w2s: The walk-to-stair transition
- ➔ s2w: The stair-to-walk transition
- ➔ b#: Strides taken before w2s transition- if two steps occur before transition, 'b1' is the first, 'b2' is the second, and so on.
- ➔ a#: Strides taken after s2w transition- if two steps occur after transition, 'a1' is the first step taken, 'a2' is the second, and so on.

(incline)=

Run: this field indicates the incline of the trial. All running trials were performed at level ground, called ‘i0’.

SitStand: the incline field indicates if the data was collected while standing up (sit2stand) or sitting down (stand2sit)

Walk: the incline field indicates the inclination of the treadmill in degrees. 'i' prefix indicates uphill, 'in' is downhill.

Stair: the incline of field indicates the inclination of the staircase in degrees. 'i' prefix indicates stair ascent, 'in' is stair descent.

(dataType)=

markers: Position of markers in global coordinates (unit: m)

- ➔ 3 Dimensional array:
  - ◆ Dimension 1: normalized percent gait over the stride/task
  - ◆ Dimension 2: x,y,z,e position. The logical operator e = 1 when the cameras are able to see this marker.
  - ◆ Dimension 3: each stride recorded for each marker

jointAngles: Tracks the joint angle in three dimensions (unit: deg)

- ➔ Full documentation: https://docs.vicon.com/pages/viewpage.action?pageId=50888880
- ➔ 3 Dimensional array:
  - ◆ Dimension 1: normalized percent gait over the stride/task
  - ◆ Dimension 2: x,y,z components of rotation
  - ◆ Dimension 3: each stride recorded, left and right leg have been concatenated

jointForces: Tracks the force felt at each joint (unit: N/kg)

- ➔ Full documentation: https://docs.vicon.com/display/Nexus25/Plug-in+Gait+lower+body+forces+and+moments
- ➔ 3 Dimensional array:
  - ◆ Dimension 1: normalized percent gait over the stride/task
  - ◆ Dimension 2: x,y,z components of force
  - ◆ Dimension 3: each stride recorded, left and right leg have been concatenated

jointMoments: Tracks the moment (or Torque) about each joint (unit: N*m/kg)

- ➔ Corrected to reflect the internal moment of the joint
- ➔ Full documentation: https://docs.vicon.com/display/Nexus25/Plug-in+Gait+lower+body+forces+and+moments
- ➔ 3 Dimensional array:
  - ◆ Dimension 1: normalized percent gait over the stride/task
  - ◆ Dimension 2: x,y,z components of moment
  - ◆ Dimension 3: each stride recorded, left and right leg have been concatenated

jointPowers: The power output by the joint (unit: W/kg)

- ➔ Corrected to reflect the internal moment of the joint.
- ➔ 3 Dimensional array:
  - ◆ Dimension 1: normalized percent gait over the stride/task
  - ◆ Dimension 2: x,y,z components of power
  - ◆ Dimension 3: each stride recorded, left and right leg have been concatenated

forceplates: Provides weight normalized force plate data from each leg; directions follow the local, force plate coordinate frame.

- ➔ F - force (x (side to side), y (propulsive/braking, z (GRF)) (unit: N/kg)
- ➔ M - moment (x/y/z) (unit: N*m/kg)
- ➔ C - center of pressure (x,y,z) (unit: m)

events: Provides details about the strides.

- ➔ StrideDetails - 2 Dimensional array:
  - ◆ Dimension 1: stride number
  - ◆ Dimension 2: [initial frame, final frame, stride duration (100Hz), leg (Left = 1, Right = 2)]

(variable)=

Markers: Broken down into each marker by name. See marker diagram.

JointAngles:Gives all lower body joint angles: ankle, knee, hip, pelvis, foot. Foot and pelvis are absolute angles, hip, knee, and ankle are relative. See marker diagram.

jointForces: Forces in ankle, knee, and hip.

jointMoment: Moments in ankle, knee, and hip.

jointPowers: Power in ankle, knee, and hip.

Known Issues:

- Walk: AB08 is missing ‘a/d0x5’ at ‘i10’, AB10 is missing ‘a/d0x5’ at ‘i0’
- Wtr: AB10 oped to not perform trial -- no Wtr or Running ‘s2x2’
- Run: AB08 and AB10 opted out of running ‘s2x4’
- Sts: AB01, AB03, and AB08 have one extra Sts trial
- Stairs: Based on quality of data, sometimes an extra ascent and descent were captured
- Transitions: Empty fields in Normalized.mat are caused by outlier detection or task transitions (i.e., no full strides were captured during the transition) were removed--please see Streaming.mat for full transitions

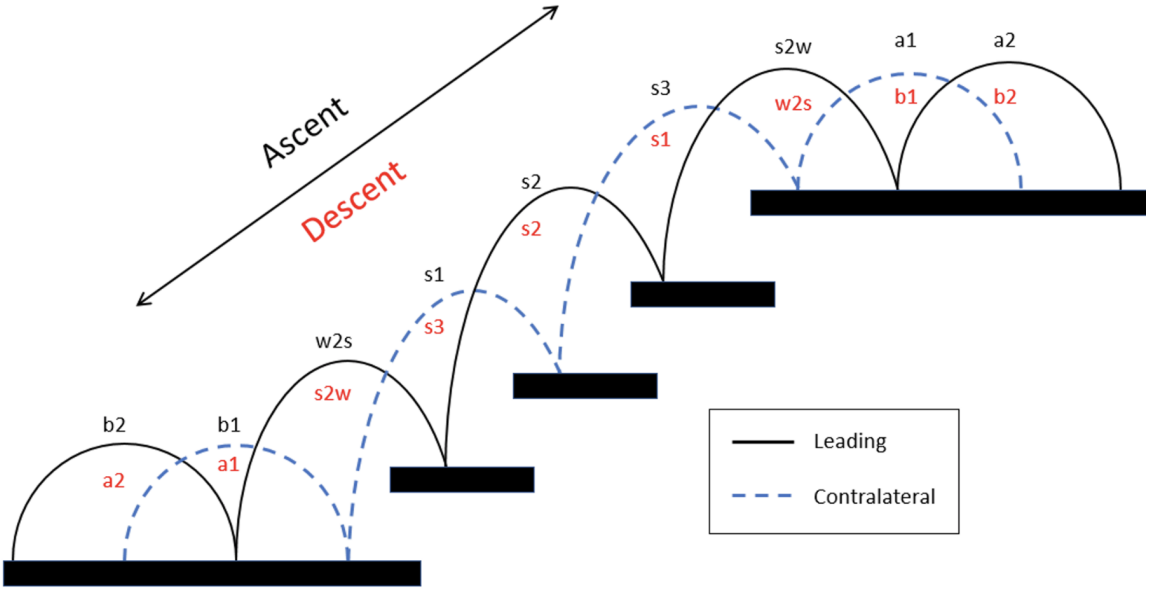
Corresponding Author Information:

Robert D. Gregg IV, Ph.D.
Associate Professor
Robotics Institute
Department of Electrical and Computer Science
University of Michigan - Ann Arbor
rgregg@ieee.org

STAIRCASE DETAILS

Incline	Riser Height	Tread Depth
20º	97mm (3.81”)	315mm
25º	120mm (4.72”)	305mm
30º	146mm (5.75”)	295mm
35º	162mm (6.38”)	285mm

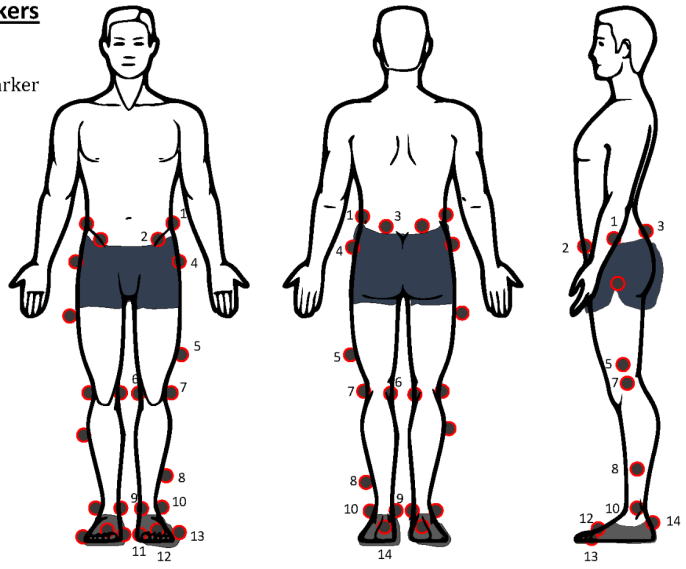
STAIR NAMING CONVENTION



Marker Diagram: Only the left side markers are labeled for clarity. It is symmetrical, so the right side markers begin with ‘R’ instead of an ‘L’. Markers noted with a ‘*’ are used in the conventional gait model.

Subject Markers

● Reflective Marker



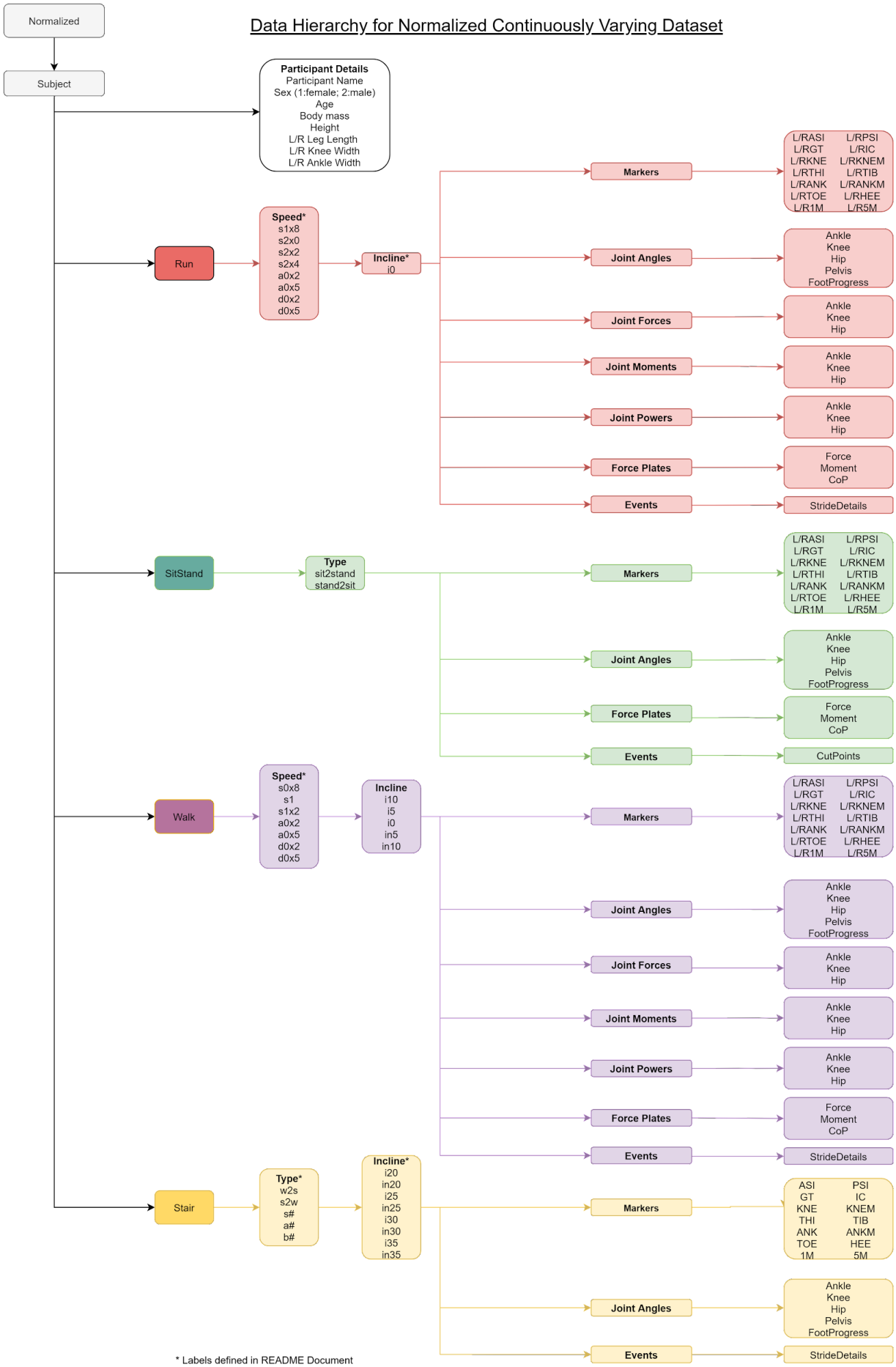
#	Anatomical Description	Code
1	Iliac Spine	LIC
2	*Anterior Superior Iliac Spine	LASI*
3	*Posterior Superior Iliac Spine	LPSI*
4	Greater Trochanter	LGT
5	*Thigh	LTHI*
6	Medial Knee	LKNEM
7	*Knee	LKNE*
8	*Tibia	LTIB*
9	Medial Ankle	LANKM
10	*Ankle	LANK*
11	First Metatarsal	L1M
12	*Toe	LTOE*
13	Fifth Metatarsal	L5M
14	*Heel	LHEE*

* Used to Derive Kinematics

Normalized Velocities: Commanded velocities after normalizing by leg length (m/s).

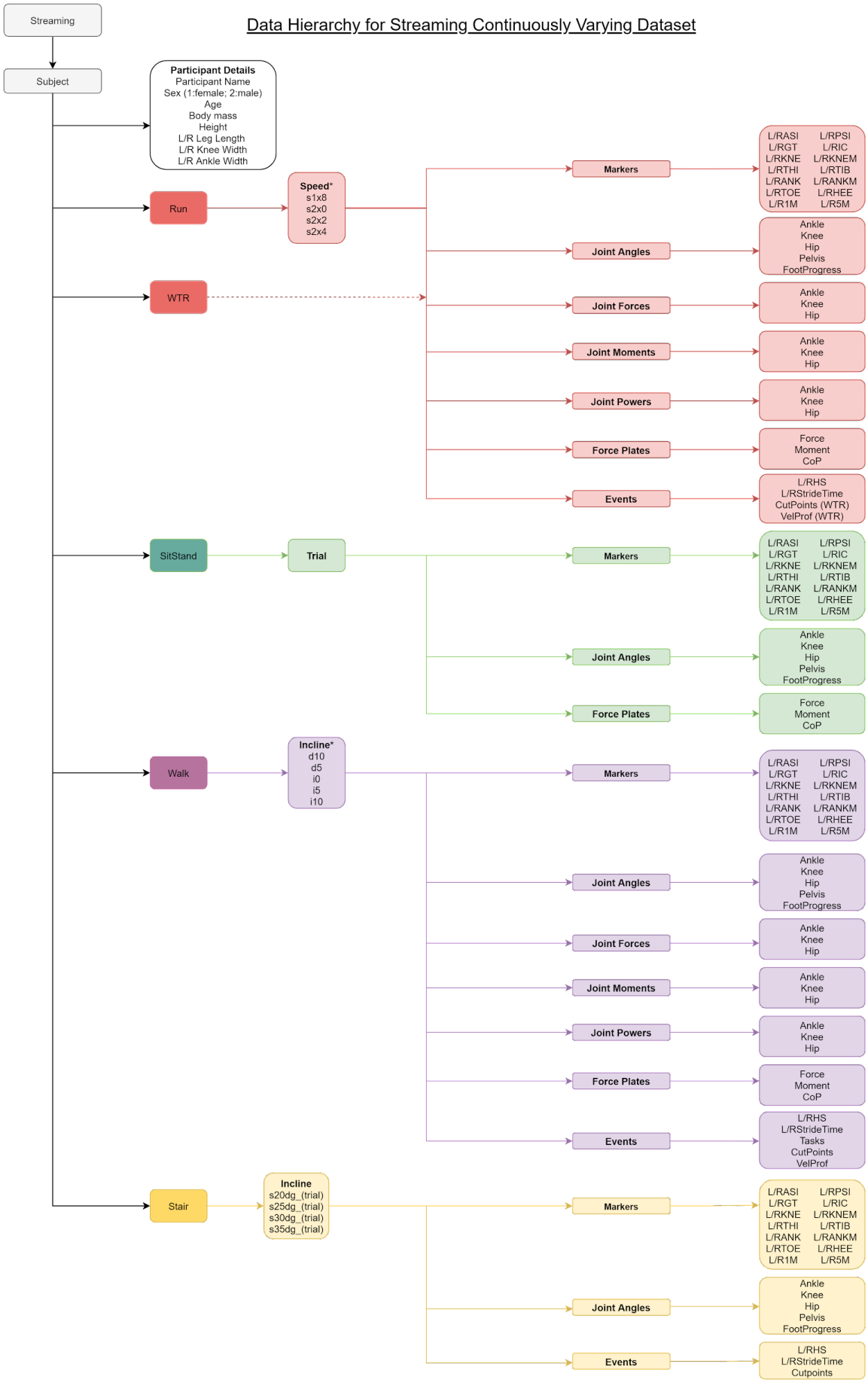
	AB01	AB02	AB03	AB04	AB05	AB06	AB07	AB08	AB09	AB10
0.8	0.824322	0.790062	0.779997	0.8	0.779997	0.815649	0.806884	0.830053	0.809816	0.772362
1.9	1.030402	0.987577	0.974996	1	0.974996	1.019562	1.008605	1.037566	1.01227	0.965453
1.2	1.236482	1.185093	1.169995	1.2	1.169995	1.223474	1.210326	1.245079	1.214724	1.158543
1.8	1.854724	1.777639	1.754993	1.8	1.754993	1.835211	1.815489	1.867619	1.822087	1.737815
2	2.060804	1.975154	1.949992	2	1.949992	2.039124	2.01721	2.075132	2.024541	1.930905
2.2	2.266885	2.17267	2.144991	2.2	2.144991	2.243036	2.218931	2.282645	2.226995	2.123996
2.4	2.472965	2.370185	2.339991	2.4	2.339991	2.446948	2.420652	2.490158	2.429449	2.317086

Data Hierarchy for Normalized Continuously Varying Dataset



* Labels defined in README Document

Data Hierarchy for Streaming Continuously Varying Dataset



* Labels defined in README Document