DJSpresentation

January 24, 2019

1 Dynamic Joint Stiffness of the ankle in human gait: Reviewing and insights of the Data from literature and clinical Databases

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2.1 Highlights

- A methodological search was made to find and collect datasets suitable to perform a dynamical analysis in the ankle joint.
- A biomechanical analysis was performed for the ankle joint from childhood through adulthood in order to see differences in their dynamic patterns.
- An enhanced method for detecting instances in ankle DJS was proposed.
- Different gait genders were considered in the study.
- The information collected could be useful for prosthesis designers and control engineers.

2.2 State of the art.

2.2.1 Introduction

- Concept adopted by [?] in which they defined this concept as: The resistance that the muscle and other soft tissue structures that cross a joint offer during gait in response to an applied moment.

- The importance of the DJS for prosthetic application in the ankle joint was coined by [?]. There, important insights were revealed. Another studies such as [?] mention the same aspects. However, a proposed concept of quasi-stiffness in active prostheses was given by [?].

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<div class="column">
    <img src="./figures/fastQuasi.png" alt="Fast" style="width:40%">
</div>
<div class="column">
    <img src="./figures/NormalQuasi.png" alt="Normal" style="width:40%">
</div>
<div class="column">
    <img src="./figures/SlowQuasi.png" alt="Slow" style="width:40%">
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```

Later, [**?**] established a method for linearized the instances of the ankle DJS.

Where the Threshold 1 is set when the moment increased up to 5%, the Threshold 2 is set at 95% of the maximum moment, for the maximum limit of the Early Response Phase and the beginning of the Large Response Phase, they apply the following equation:

$$S_i = (M_{i+1} - Mi)/(\theta_{i+1} - \theta i) >= 1.7 \tag{1}$$

Now, applying the limits to the function we can obtain the coefficients with the form: $Y = a + bx$ on each method.

Also, they made the energetic analysis of this human joint, as the image shows.

To calculate the work along the x-axis, the Simpon's Rule was applied. Mathematically this rule is represented as:

$$Area = \int_a^b f(x)dx \approx \frac{\triangle x}{3}[y_0 + 4\sum odds + 2\sum even + y_n] \tag{2}$$

2.2.2 Types of Quasi-stiffness

- [**?**] proposed the identification of the key independent parameters needed to predict ankle quasi-stiffness and propulsive work and also the functional form of each correlation.

2.3 Motivation

- Dynamic Joint Stiffness can be used either for studying pathologic abnormalities and to develop prostheses and orthoses [**?**].
- Many studies support the DJS analysis as the primary input for any prosthetic or orthetic device (e.g. [**?**, **?**, **?**, **?**]).
- On the other hand, the DJS is use to contrast any pathological with non-pathological behavior (e.g. [**?**, **?**]) and predict irregular patterns in the ankle dynamics.
- The DJS of the human ankle has been studied to find dynamical patterns such that changes in gender [**?**], gender and age [**?**] , and anthropometrics [**?**].
- The importance of reusing the data is highly remarkable by [**?**] and for that reason would be helpful for the research community to show proof of homogeneity in the data.
- Many databases were created with the aim of collecting human gait data as [**?**, **?**, **?**], but they are not useful at all for dynamic analysis purposes.
- Mention the importance for AI.

2.4 Methods

2.4.1 Literature Search

2.4.2 Online Gait Database search

Criteria of the data to be processed in the study of the ankle DJS

ID
Requirement
1
It should be related with regular gait
2
Not older than 10 years ago.
3
Definitely, it must contain kinetic information.
4
The format given should be familiar with standard data in human gait, e.g., C3D, CSV, txt.
5
It should be well organized and unrestrictable
6
It must contain the methods of how it was measured.

2.4.3 Selection of the data

Clinical Databases found in the web.

1
2
3
4
5
6
1
Physiobank databases
<100
3D motion
.dat
X
-
-
O
O
O
0
2
Clinical Gait analysis
13
3D motion, EMG
.m .txt .xls
O

X
O
O
O
O
1
3
Koroibot
544
3D motion, pressure, EMG
mmm, c3d, csv
O
O
-
O
O
O
10
4
Motion Capture HDM05
< 50
3D Motion
c3d, amc
O
O
X
O
O
O
0
5
CMU Graphics Lab Motion Capture
< 50
3D motion
tvd, c3d, amc, mpg
O
-
X
O
O
-
0
6
MAREA Dataset
2
Acelerometers
.m
O

O
X
-
O
O
1
7
ENABL3S
1
EMG, GONIO, IMU
csv
O
O
X
O
O
O
1
8
Gaitabase
1
N.A.
N.A.
X
X
X
X
X
X
1

Note: The table represents the level of accomplishment in Table [table:Criteria], where (O) meets, (-) fulfill partially and (X) does not meet the requirement. [table:Databases]

2.5 Methodology

We implemented the python programming language because it integrates libraries that concerns with the PhD thesis, such as: Opensim for biomechanical modeling, numpy for numerical computing, SciPy for optimization techniques, bokeh for graphical representations, Scikit learn to get regression models, Pandas to manage DataSets and jupyter to present information in notebooks. In not all cases all the libraries were implemented.

In that order of ideas, we describe the activities done with every study found in the literature as well as in gait Databases, which are mentioned below:

- Selecting, filtering and cleaning the data.
- Obtaining physical variables and visualizing behaviors at the ankle joint.
    - Obtaining the integral as the area under a curve through Simpson's Rule of ankle power and ankle DJS.

  - Visualizing the ankle powers and ankle DJS at different speeds, modes of walking, ages, etc.
  - Obtaining the work done (work absorbed, work produced and net work) through the integration of the power loop.

- Configuring Dynamic Joint Stiffness variables, such as sub-phases of gait and linear slopes.

  - Plotting the angle-moment loop at different speeds, modes and ages.
  - Determining the dorsi-flexion limit point, the bottom and the top threshold through two ways:
    * As mentioned by Crenna and Frigo [**?**].
    * As mentioned by Shamaei et al. [**?**].

- Making the linear regression at each sub-phase, doing these at different ways, such as:

  - Using Least Squared Methods with Scikit-learn tool.
  - Using Non-linear Least Squared Methods through SciPy Library.

2.6 Results

Year

Title

Authors

Subjects

Method

General Observations

Type of file

2006

Regression analysis of gait parameters with speed in normal children walking at self-selected speeds.

[**?**]

16

Ground reaction forces (Kistler Instruments, AG Winterthur, Switzerland) and motion analysis data (five camera stystem—Vicon, Oxford Metrics Group, Oxford, UK) were collected at 50 Hz. Inverse dynamics were calculated with Vicon Clinical Manager.

Children between the ages of 7 and 12 years (eight boys and eight girls) each year for 5 consecutive years. Children walked barefoot at self-selected normal velocities. GRF were calculated for approximately three sets of data for each leg for each child for each of the 5 consecutive years of the study (a total of 457 trials). Weight, height and leg length (greater trochanter to lateral malleolus) data were recorded.

.xls

2008

The effect of walking speed on the gait of typically developing children

[**?**]

83

12-camera Vicon MX system (Vicon,Oxford, UK) operating at 120 Hz. Ground reaction forces were recorded using four force plates (AMTI, Watertown, MA), sampled at 1080 Hz. Surface EMG signals were also measured.

Three-dimensional gait data was collected on 83 subjects who were given general instructions to walk at very slow, slow, self-selected comfortable (free), and fast walking speeds during a single testing session.

.xls

2011

A multiple-task gait analysis approach: Kinematic, kinetic and EMG reference data for healthy young and adult subjects

[?]

40

3D kinematics was measured using a 9-cameras SMART-E motion capture system (BTS). Two force plates (Kistler, Winterthur, Switzerland), at 960 Hz sampling frequency, provided ground reaction forces (GRFs)

20 subjects included in the adult group (aged from 22 to 72 years, mean 43.1 15.4; body mass 68.5 15.8 kg; height 1.71 0.10 m; 9 males, 11 females) and 20 in the young group (aged from 6 to 17 years, mean 10.8 3.2; body mass 41.4 15.5 kg; height 1.47 0.20 m; 9 males, 11 females).

.xls

2015

An elaborate data set on human gait and the effect of mechanical perturbations.

[?]

15

A R-Mill treadmill which has dual 6 degree of freedom force plates, independent belts for each foot, along with lateral translation and pitch rotation capabilities. A 10 Osprey camera motion capture system. Four ADXL330 Triple Axis Accelerometer Breakout boards attached to the treadmill.

Four females and eleven males with an average age of 244 years, height of 1.750.09 m, mass of 7413 kg participated in the study.

.txt

2018

Benchmark Datasets for Bilateral Lower-Limb Neuromechanical Signals from Wearable Sensors during Unassisted Locomotion in Able-Bodied Individuals

[?]

10

Subjects were instrumented with wearable sensors to measure bilateral lower limb muscle activity and joint and limb kinematics. EMG signals were recorded using bipolar surface electrodes (DE2.1; Delsys, Boston, MA, USA)

10 subjects (seven male, three female); 25.5 2 years; 174 12 cm; 70 14 kg without any gait impairments were recruited.

csv

2017

Evaluation of the performance of accelerometer-based gait event detection algorithms in different real-world scenarios using the MAREA gait database

[?]

20

Each subject had a 3-axes Shimmer3 (Shimmer Research, Dublin, Ireland) accelerometer (8 g) attached to their waist, left wrist and left and right ankles using elastic bands and velcro straps.

20 healthy adults:12 males and 8 females, average age: 33.4 7 years, average mass: 73.2 10.9 kg, average height: 172.6 9.5 cm.

.mat

2.7 Data

A multiple-task gait analysis approach: Kinematic, kinetic and EMG reference data for healthy young and adult subjects

Ankle DJS analyze in children at different velocities

2.8 Discussion

- Recent online databases for human gait need to be fed and could be focused on to human improvements, due to the search demonstrated that most of databases are oriented to other purposes as: motion, robotics, etc.
- Recent techniques showed to set the instances in the quasi-stiffness slope are inefficient for a wide range of speed, It is recommended to apply the curvature in those cases.
- Comparing data between similar subjects shows regularities in terms of the type of quasi-stiffness given.
- The DJS in children at lower speeds and irregular walking (e.g. toes, heel, and descending) showed a clockwise behavior.
- A narrow quasi-stiffness was seen in children at lower speed. On the other hand, at higher speed in children a rounded DJS was observed in them.

2.9 Future Work

- Conssidering the statistics in the overall data.
- A possible classifier for a pathological DJS can be done if more data is collected.
- A meta analysis for all types of data might be useful.
- Finishing the data analysis for the rest of the data.

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