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A public data set of human balance evaluations

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The goal of this study was to create a public data set with results of qualitative and quantitative evaluations related to human balance. Subject's balance was evaluated by posturography using a force platform and by the Mini Balance Evaluation Systems Tests. In the posturography test, we evaluated subjects during standing still for 60 s in four different conditions where vision and the standing surface were manipulated: on a rigid surface with eyes open; on a rigid surface with eyes closed; on an unstable surface with eyes open; on an unstable surface with eyes closed. Each condition was performed three times and the order of the conditions was randomized among subjects. In addition, the following tests were employed in order to better characterize each subject: Short Falls Efficacy Scale International; International Physical Activity Questionnaire Short Version; and Trail Making Test. The subjects were also interviewed to collect information about their socio-cultural, demographic, and health characteristics. The data set comprises signals from the force platform (raw data for the force, moments of forces, and centers of pressure) of 163 subjects plus one file with information about the subjects and balance conditions and the results of the other evaluations. All the data is available at PhysioNet (DOI: 10.13026/C2WW2W) and at Figshare (DOI: 10.6084/m9.figshare.3394432).

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2 **A public data set of human balance evaluations**

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13

14 **Abstract**

15

16 The goal of this study was to create a public data set with results of qualitative and quantitative

17 evaluations related to human balance. Subject's balance was evaluated by posturography using a

18 force platform and by the Mini Balance Evaluation Systems Tests. In the posturography test, we

19 evaluated subjects during standing still for 60 s in four different conditions where vision and the

20 standing surface were manipulated: on a rigid surface with eyes open; on a rigid surface with

21 eyes closed; on an unstable surface with eyes open; on an unstable surface with eyes closed.

22 Each condition was performed three times and the order of the conditions was randomized

23 among subjects. In addition, the following tests were employed in order to better characterize

24 each subject: Short Falls Efficacy Scale International; International Physical Activity

25 Questionnaire Short Version; and Trail Making Test. The subjects were also interviewed to

26 collect information about their socio-cultural, demographic, and health characteristics. The data

27 set comprises signals from the force platform (raw data for the force, moments of forces, and

28 centers of pressure) of 163 subjects plus one file with information about the subjects and balance

29 conditions and the results of the other evaluations. All the data is available at PhysioNet (DOI:

30 10.13026/C2WW2W) and at Figshare (DOI: 10.6084/m9.figshare.3394432).

31

1   Introduction

32

33   Age-related disabilities and certain illnesses affect body balance in humans and can

34   negatively influence their health and quality of life. There has been great effort by researchers

35   and clinicians for a greater understanding of this problem and postural control in humans has

36   been under intense scientific investigation over the past decades.

37   There is a large variety of tests to describe balance in humans (for a review see Duarte &

38   Freitas 2010; Paillard & Noe 2015; Scoppa et al. 2013; Shumway-Cook & Woollacott 2001;

39   Visser et al. 2008). The most common quantitative measurement to characterize body balance is

40   the displacement of the center of pressure (COP); the point of application of the resultant vertical

41   forces acting on the subject's surface of support. COP displacement is typically measured with a

42   force plate and presented as time-series of numerical data in the anterior-posterior (ap) and

43   medio-lateral (ml) directions in relation to the subject's orientation. The technique concerned

44   with the measurement of COP displacement in this context is commonly referred to as

45   stabilography or posturography.

46   In stabilography, there is no consensus yet on the best techniques to analyze COP

47   displacement in order to extract meaningful information about the subject's balance condition.

48   There are also numerous different protocols (which include the type of task the subject is

49   submitted, instructions to the subject, duration of the task, type of instrument for using, etc.) for

50   data collection, algorithms, and variables to process and characterize COP displacement (for a

51   review see Duarte & Freitas 2010; Paillard & Noe 2015; Scoppa et al. 2013; Visser et al. 2008).

52   Particularly on the plethora of algorithms and variables, part of the lack of consensus might be

53   because different researchers work with small sets of COP displacement data when investigating

54   balance. A related problem is that researchers propose and compare new methods of analysis

55   based on different sets of data across centers.

56 The deployment of a public data set of human balance evaluations would allow the access

57 of a normative reference for data comparison and testing analysis from different centers. In the

58 human movement science field there are few publicly available data sets (for example, see

59 Moore et al. 2015 and the references therein). However, none of the available data sets are about

60 human balance. Hence, the purpose of the present study is the implementation of such a public

61 data set of balance evaluations on young and elderly adults.

62

63 ## 2 Methods

64 This study was designed to create a public repository of data related to human balance,

65 employing quantitative and qualitative evaluations. The entire data collection for each subject

66 was performed in a single session, which lasted between one and two hours. Each subject was

67 assessed by the same experienced examiner (D.A.S.) in the Laboratory of Biomechanics and

68 Motor Control at the Federal University of ABC, Brazil. Prior to the evaluations that generated

69 this data set, we conducted pilot studies with five subjects for training with the equipment and

70 experimental protocol. The data of these subjects are not included in this data set. This study was

71 approved by the local ethics committee of the Federal University of ABC (#842529/2014).

72

73 ### 2.1 Subjects

74 We evaluated 163 subjects (116 females and 47 males) who voluntarily participated in

75 this study. The subjects were first interviewed to collect information about their socio-cultural,

76 demographic, and health characteristics. Their ages varied from 18 to 85 years, body masses

77 from 44.0 to 75.9 Kg, heights from 140.0 to 189.8 cm, and body-mass indexes (BMI) from 17.2

78 to 31.9 Kg/m^2. Of the 163 subjects, 16 of them were classified as having at least one severe

79 disability or more (eight with hearing and vestibular deficits; two with visual deficits; three with

80   musculoskeletal deficits, one with visual and musculoskeletal deficits, one with hearing and

81   visual deficits, and one with intellectual disability). All this information for each subject are

82   presented in the public data set (see later on how to obtain it).

83

84   **2.2   Stabilography**

85   The stabilography evaluation was based on the most common practices used in research

86   laboratories and the clinical environment (for a review see Duarte & Freitas 2010; Paillard &

87   Noe 2015; Scoppa et al. 2013; Visser et al. 2008).

88   We evaluated the subjects' balance during standing still with tasks lasting 60 s each in

89   four different conditions where vision and the standing surface were manipulated: on a rigid

90   surface with eyes open; on a rigid surface with eyes closed; on an unstable surface (a 6-cm foam

91   height block, Balance Pad, Airex, U.S.) with eyes open; on an unstable surface with eyes closed.

92   Each condition was performed three times and the order of the conditions was randomized

93   among subjects. In all conditions, the subjects were required to stand, barefoot and as still as

94   possible with their arms at their sides, and to look at a 5-cm round black target placed on the

95   subject's eye-height on a wall 3-m ahead. For the trials where the eyes were kept closed, subjects

96   were first instructed to look at the target with eyes open, find a stable and comfortable posture

97   given the requirements, and close their eyes. A few seconds later, the data acquisition started.

98   For all trials, the subject's feet were placed with an angle of 20 degrees between them and their

99   heels were kept 10-cm apart by requesting the subjects to stand on lines marked on the top of the

100   force platform (see Figure 1). The trials were acquired in an empty 4.5 x 2.8 m room with white

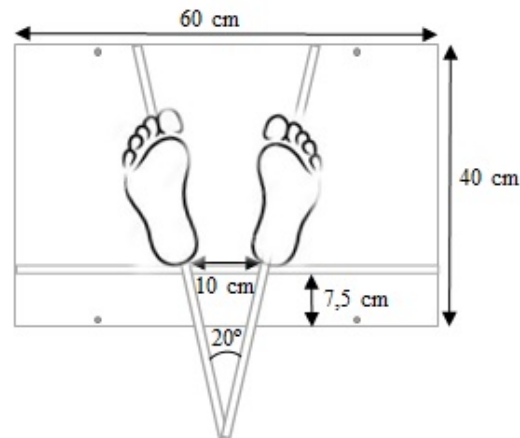101   walls and adequate illumination (see Figure 1).

Figure 1. Top: Marks for the subject's feet placement on the force platform. Bottom: Data

collection room for the stabilography (note the 5-cm black target at the wall 3-m ahead) and the

force platform with its coordinate system convention.

2.2.1 Protocol

We followed the following procedure for the stabilography:

1. The researcher explained to the subject about the data collection with the force plate. The

subject was also informed that during the data collection, he or she would be monitored,

there should not be any verbal communication during the trials, but he or she could interrupt

the data collection if desired and that assistance would be given if necessary;

112   2.   The researcher filled a form with the subject's name and identification number, the force

113   platform was zeroed and the subject was requested to stand on the force platform to record

114   her or his weight;

115   3.   The researcher gave instructions on how the subject should stand on the force platform

116   according to the task (open or closed eyes, firm or form surface). The subject's feet was

117   positioned on the marks at the force platform (see Figure 1);

118   4.   The researcher instructed the subject to maintain their arms along their body and to stand as

119   still as possible;

120   5.   During the trials with eyes open, the subjects were told to fixate their gaze at the round black

121   target placed on the wall ahead at the eye level;

122   6.   During the trials with eyes closed, the subjects were told to fixate their gaze at the target

123   placed ahead, close their eyes when they felt ready and only open them when the researcher

124   informed them of end of the trial;

125   7.   The researcher started the data collection around 5 s later when the subject said he or she was

126   ready;

127   8.   At the end of the trial, the subject was assisted to step from the force platform and he or she

128   could rest (and sit if desired) for about one minute before the next trial.

129

130   **2.2.2   Data acquisition and processing**

131   The force platform signals were collected employing a commercial force platform (40x60

132   cm, OPT400600-1000, AMTI, U.S.) and amplifier (Optima Signal Conditioner, AMTI, U.S.) at a

133   sampling frequency of 100 Hz. The Optima force plate was factory-calibrated and presented an

134   average COP accuracy of 0.02 cm. The fluctuation of the COP displacement (an indication of the

135   measurement precision) was estimated as the standard-deviation value of the COP data when a

136   30-kg static load was placed on the force plate for 30 s and was equal to 0.005 cm. The data

137   acquisition was performed employing NetForce software (Version 3.5.3, AMTI, U.S.). The

138   NetForce software outputs the calibrated forces and moments of forces (Fx, Fy, Fz, Mx, My, Mz)

139   from the Optima platform to a file with a proprietary binary format. All subsequent steps,

140   reading these binary files, data processing, analysis and visualization, and exporting data to text

141   files, were implemented in Python language using the SciPy Stack (https://www.scipy.org/) and

142   are available as Jupyter Notebooks (http://jupyter.org/) in a GitHub repository

143   (https://github.com/demotu/datasets).

144   The force platform data were smoothed with a 10-Hz 4th order zero lag low-pass

145   Butterworth filter and the center of pressure in the anterior–posterior (x-positive is anterior) and

146   medio–lateral (y-positive is to the right) directions (see Figure 1) were calculated according to

147   the standard formulas (also described in the force platform manual):

148
$$COP_x = -\frac{M_y}{F_z}$$

149
$$COP_y = \frac{M_x}{F_z}$$

150   Note that the force platform data are expressed as forces and moments of forces in the

151   force platform co-ordinate system and they refer to the forces and moments of forces the subject

152   is applying on the force platform. This is the inverse of the ground reaction forces, where the

153   forces act on the subject (Newton's Third Law).

154

2.3   Mini Balance Evaluation Systems Tests

Each subject's balance was also evaluated by the Mini Balance Evaluation Systems Tests

(Mini-BESTest). The Mini-BESTest contains 14 items classified in four different domains of the

human balance: Anticipatory Postural Adjustment; Reactive Postural Response; Sensorial

Organization; and Gait Stability; its maximum score is 28 points and each item varies from 0

(abnormal performance) to 2 (normal performance) points (Franchignoni et al. 2010). The tasks

in the Mini BESTest requiring the subjects' gaze fixed at a target were performed with the target

placed 3 m ahead.

2.4   Other evaluations

The following tests were also employed: Short Falls Efficacy Scale International (Short

FES-I) (Kempen et al. 2008), International Physical Activity Questionnaire - Short Version

(IPAQ-SV) (Craig et al. 2003), and Trail Making Test (TMT) (Reitan 1958). These evaluations

were conducted with personal interviews performed in an empty 7.5 x 5.7 m room with adequate

illumination. We followed the instructions of each evaluation test. For the IPAQ-SV, the last

seven days prior to the interview were considered. For the TMT, we followed the orientations by

(Bowie & Harvey 2006) to administer parts A and B with the following details: the letter "K"

was excluded in the evaluation because it is less common to Brazilians and part B of the TMT

was composed by 24 circles with numbers from "1" to "12" and letters from "A" to "M".

3   Results

All the data is available at PhysioNet (DOI: 10.13026/C2WW2W) and at Figshare (DOI:

10.6084/m9.figshare.3394432). The data at PhysioNet (Goldberger et al. 2000) are stored in a

binary format that can be read using for example, the WFDB software package or online using

179   the physiobank ATM software and are made available under the ODC Public Domain Dedication

180   and License v1.0 (http://opendatacommons.org/licenses/pddl/1.0/). The data at Figshare are

181   stored in ASCII (text) format that can be downloaded as a single compressed file and are made

182   available under the CC-BY license (https://creativecommons.org/licenses/by/4.0/).

183   The data set comprises files with the force platform data of 163 subjects plus one file

184   named BDSinfo (in two different formats, .txt or .xlsx) with meta data about each file, subject

185   and the evaluation results. The data files and the BDSinfo.txt file are in ASCII format with tab-

186   separated columns. The files with the force platform data have the following columns: Time, Fx,

187   Fy, Fz, Mx, My, Mz, COPx, COPy, and contain the force platform signals (see Methods). Each

188   file has the following header: Time[s] Fx[N] Fy[N] Fz[N] Mx[Nm] My[Nm] Mz[Nm]

189   COPx[cm] COPy[cm], followed by 6000 rows by 9 columns of data with 6-digit numeric

190   precision (with the exception of the time column, which has a 3-digit numeric precision). These

191   files are named as BDSxxxxx.txt, where BDS stands for the project's name, Balance Data Set,

192   and xxxxx refers to the number of the trial; from 00001 to 01956. For each subject there are 12

193   trials and the numbers in the file names are grouped in sets of 12, e.g., the first subject has files

194   from 00001 to 00012 and the last subject (the 163rd), from 01945 to 01956. A total of 26 files

195   (trials) are missing for five subjects who were unable to complete the most challenging

196   conditions.

197   The BDSinfo file contains meta data describing the conditions of the stabilography trials,

198   the information from the anamnesis, and the results of the qualitative evaluations. Because a

199   subject has 12 files for the force platform data, there are 12 rows for each subject in this file. In

200   these 12 rows, the only column that has rows with different values is the column identifying the

201   trial (the file name). The content of all the other columns are simply repeated over the 12 rows.

202   As result, the BDSdata file has the header plus 1930 rows and 64 columns. Here is the coding for

203   the meta data (the first word identifies the name of the column in the header):

204   1. **Trial:** file name of the stabilography trial (BDSxxxxx, where xxxxx varies from 00001 to

205   01956).

206   2. **Subject:** number of the subject (from 1 to 163).

207   3. **Vision:** visual condition (Open or Closed).

208   4. **Surface:** surface support condition (Firm or Foam).

209   5. **Age:** subject's age in years.

210   6. **AgeGroup:** age group (Young: **Age** < 60; Old: **Age** ≥ 60).

211   7. **Gender:** gender (F or M).

212   8. **Height:** height in centimeters (measured with a calibrated stadiometer).

213   9. **Weight:** weight in kilograms (measured with a calibrated scale).

214   10. **BMI:** body mass index in kg/m^2.

215   11. **FootLen:** foot length in centimeters (average of the two feet, measured with a calibrated

216   paquimeter).

217   12. **Nationality:** country where the subject was born.

218   13. **SkinColor:** self-reported skin color.

219   14. **Ystudy:** years of regular study.

220   15. **Footwear:** most common type of footwear the subject wears daily.

221   16. **Illness:** whether the subject has any illness, as declared by themselves (Yes or No).

222   17. **Illness2:** type of illness of the subject ('No' if the subjects doesn't have any illness).

223   18. **Nmedication:** total number of medications the subject takes per day, if any.

224   19. **Medication:** name of the medication(s) the subject takes ('No' if the subject doesn't take any

225   medication).

226   20. **Ortho-Prosthesis:** whether the subject wears any type of orthosis of prosthesis, as declared

227   themselves (Yes or No).

228   21. **Ortho-Prosthesis2:** name of the orthosis or prosthesis the subject wears ('No' if the subject

229   doesn't take any orthosis or prosthesis).

230   22. **Disability:** whether the subject has any deficit, as declared by themselves (Yes or No).

231   23. **Disability2:** name of the disability of the subject ('No' if the subject doesn't take any

232   disability).

233   24. **Falls12m:** how many non-intentional falls the subject had in the last 12 months, as declared

234   by themselves (from 0 to …).

235   25. **FES_1:** answer for the first question of the Short Falls Efficacy Scale International test (FES-

236   I).

237   26. **FES_2:** answer for the second question of the FES-I.

238   27. **FES_3:** answer for the third question of the FES-I.

239   28. **FES_4:** answer for the fourth question of the FES-I.

240   29. **FES_5:** answer for the fifth question of the FES-I.

241   30. **FES_6:** answer for the sixth question of the FES-I.

242   31. **FES_7:** answer for the seventh question of the FES-I.

243   32. **FES_T:** answer for the total score question of the FES-I.

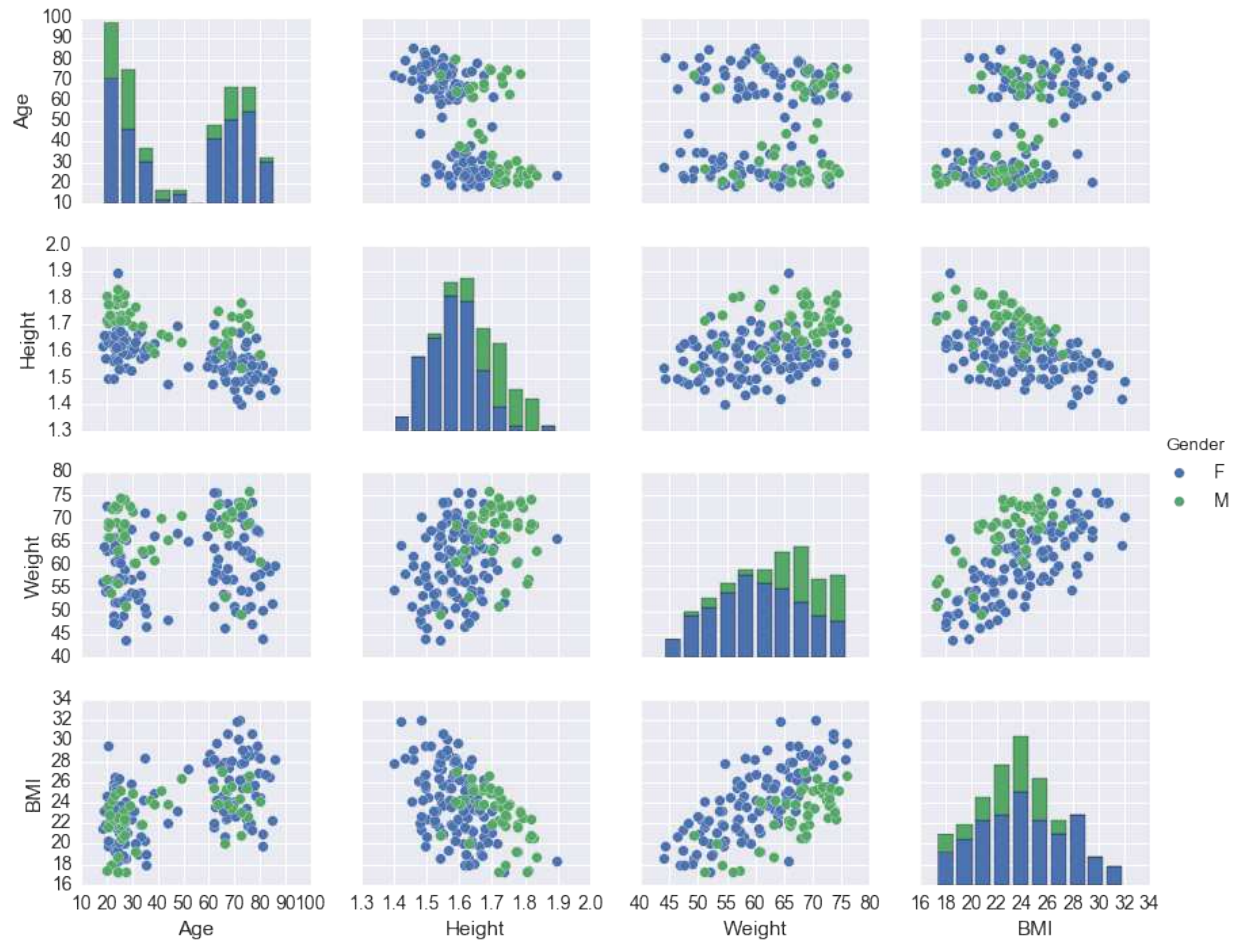244   33. **FES_S:** answer for the scoring question of the FES-I, see

245   http://www.profane.eu.org/fesi.html.

246   34. **IPAQ_1a:** answer for the 1a question of the International Physical Activity Questionnaire

247   Short Version test (IPAQ).

248   35. **IPAQ_1b:** answer for the 1b question of the IPAQ.

249   36. **IPAQ_2a:** answer for the 2a question of the IPAQ.

250   37. **IPAQ_2b:** answer for the 2b question of the IPAQ.

251   38. **IPAQ_3a:** answer for the 3a question of the IPAQ.

252   39. **IPAQ_3b:** answer for the 3b question of the IPAQ.

253   40. **IPAQ_4a:** answer for the 4a question of the IPAQ.

254   41. **IPAQ_4b:** answer for the 4b question of the IPAQ.

255   42. **IPAQ_S:** score in the IPAQ (Low, Moderate, or High), see

256   https://sites.google.com/site/theipaq/.

257   43. **TMT_timeA:** time in seconds taken to complete part A of the Trail Making Test (TMT). We

258   didn't measure times longer than 5 minutes (for these cases we report a time of 300 s).

259   44. **TMT_errorsA:** number of errors in part A of the TMT.

260   45. **TMT_timeB:** time in seconds taken to complete part B of the TMT. We did not measure

261   times longer than 5 minutes (for these cases we report a time of 300 s).

262   46. **TMT_errorsB:** number of errors in part B of the TMT.

263   47. **Best_1:** score for the first task of the Mini Balance Evaluation Systems Test (Mini-BESTest).

264   48. **Best_2:** score for the second task of the Mini-BESTest.

265   49. **Best_3l:** score for the third task (left side) of the Mini-BESTest.

266   50. **Best_3r:** score for the third task (right side) of the Mini-BESTest.

267   51. **Best_4:** score for the fourth task of the Mini-BESTest.

268   52. **Best_5:** score for the fifth task of the Mini-BESTest.

269   53. **Best_6l:** score for the sixth task (left side) of the Mini-BESTest.

270   54. **Best_6r:** score for the sixth task (right side) of the Mini-BESTest.

271   55. **Best_7:** score for the seventh task of the Mini-BESTest.

272   56. **Best_8:** score for the eighth task of the Mini-BESTest.

273   57. **Best_9:** score for the ninth task of the Mini-BESTest.

274   58. **Best_10:** score for the tenth task of the Mini-BESTest.

275   59. **Best_11:** score for the eleventh task of the Mini-BESTest.

276   60. **Best_12:** score for the twelfth task of the Mini-BESTest.

277   61. **Best_13:** score for the thirteenth task of the Mini-BESTest.

278   62. **Best_14:** score for the fourteenth task of the Mini-BESTest.

279   63. **Best_T:** total score of the Mini-BESTest, see http://www.bestest.us/.

280   64. **Date:** date and time of the subject's evaluation (yyyy-mm-dd hh:mm:ss.sss 24-hour local

281   time format).

282

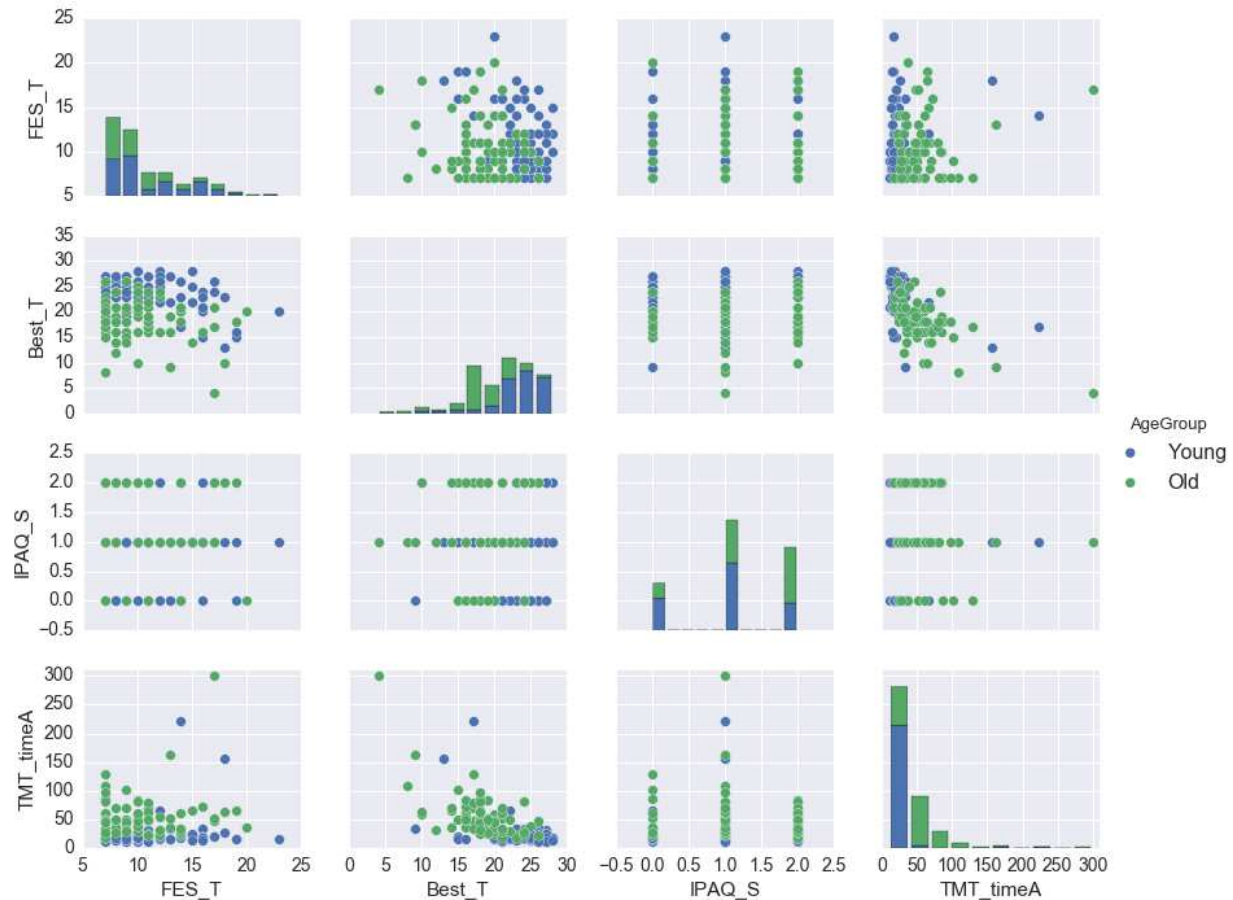283   **3.1   Data exploration**

284   To exemplify how these data can be explored, shown in Figure 2 are histograms and

285   scatter plots for the variables: age, body mass, height, and BMI, and in Figure 3 are similar plots

286   for the variables: FES_T, Best_T, IPAQ_S, TMT_timeA, and TMT_timeB. A representative

287   example of the force platform data is shown in Figure 4 and plots for the variables: COP area,

288   COP velocity, and COP mean frequency for each subject and standing condition are shown in

289   Figure 5 (see Duarte 2015; Duarte & Freitas 2010 for the algorithms to calculate these variables).

290   The programming scripts to generate these figures, as well as other examples on how to work

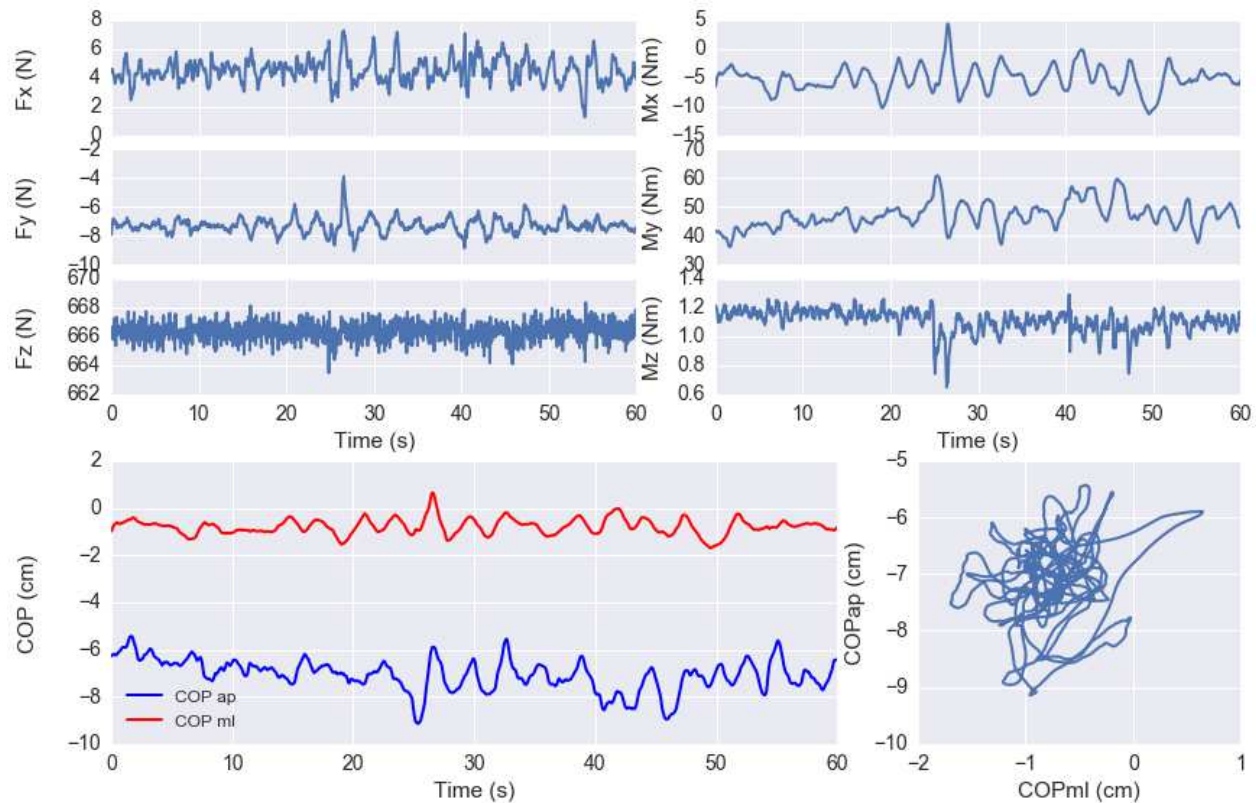291   with these data, are available in a GitHub repository (https://github.com/demotu/datasets).

292

Figure 2. Histograms and scatter plots of the variables: age (years), body mass (Kg), height (m), and BMI (Kg/m^2) for each subject, color-coded by gender (116 females and 47 males).

295

Figure 3. Histograms and scatter plots of the variables: FES_T, Best_T, IPAQ_S, and the

TMT_timeA for each subject, color-coded by age group (87 young adults and 76 older adults).

298

299 Figure 4: Top: exemplary forces and moments of forces at the horizontal and vertical anterior-

300 posterior (x or ap), medio-lateral (y or ml), and vertical (z) directions versus time. Bottom-left:

301 correspondent center of pressure (COP) displacements at the ap and ml directions versus time.

302 Bottom-right: correspondent plot of COP ap versus COP ml. Subject: 61-year-old male adult

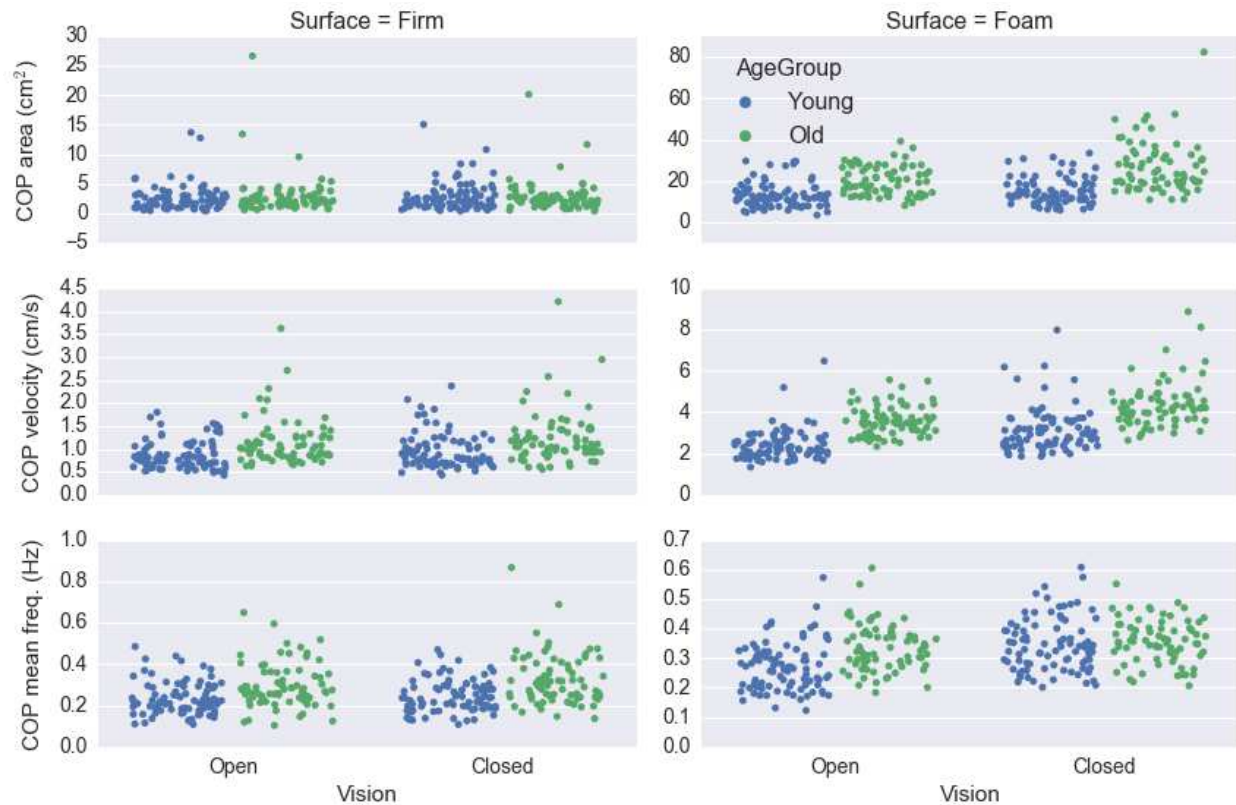303 during quiet standing on a rigid surface with open eyes.

Figure 5. Plot of the median value across trials of the variables: COP area, resultant COP velocity, and resultant COP mean frequency for each subject at the different visual and support surface conditions color-coded by age group (87 young adults and 76 older adults).

4 Conclusion

This study implemented a public data set with results of qualitative and quantitative evaluations related to the balance of young and elderly adults (a total of 163 subjects).

A limitation of this study is that we did not perform quantitative evaluations of the subjects' health conditions, particularly of their motor and sensory integrity. However, through the careful anamnesis we performed by interview, we were able to determine the history and current status of the subjects' health, and together with the different qualitative evaluations

316   performed, we believe the subjects are relatively well characterized. Nevertheless, the potential

317   user of this data set should bear this limitation in mind.

318   The Balance Data Set is the first public repository containing data of quantitative and

319   qualitative evaluations of human balance. Possible applications of this data set include: to test

320   new variables to describe the center of pressure displacement in methodological studies; to serve

321   as reference (normative) data for a new sample of subjects in a research of clinics context; for

322   training and education regarding the analysis of balance data, among others. Examples on how to

323   work with this data set are publicly available in a GitHub repository

324   (https://github.com/demotu/datasets).

325

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