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Evaluating the Baseline Characteristics of Static Balance in Young Adults

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***Abstract*—**The objectives of this study (baseline study, n = 20) were to implement Matlab procedures for quantifying selected static balance variables, establish baseline data of selected variables which characterize static balance activities in a population of healthy young adult males, and to examine any trial effects on these variables. The results indicated that the implementation of Matlab procedures for quantifying selected static balance variables was practical and enabled baseline data to be established for selected variables. There was no significant trial effect. Recommendations were made for suitable tests to be used in later studies. Specifically it was found that one foot-tiptoes tests either in static balance is too challenging for most participants in normal circumstances. A one foot-flat eyes open test was considered to be representative and challenging for static balance.

***Keywords*—**Static Balance, Base of support.Baseline Data.

I. Introduction

QUIET standing is widely considered by many researchers as a (static) task, an event involving no activity. In reality, the upright posture is a continuum of adjustments (correctional movements) that are made in response to a changing environment. Physiological activities are ongoing and internal and external forces that are present are constantly monitored and adjusted to prevent movement and maintain posture. These body adjustments in anterior-posterior (AP) and medio-lateral (ML) directions are dramatically increased in some circumstances, e.g. on a narrow Base of Support (BoS), a moving platform, with eyes closed, or in sport related activities such as landing from jumping or hopping.

External forces acting on the body include gravity and ground reaction forces while internal forces are generated from muscle contraction and/or passive tension in tendons, ligaments, joint capsules and other connective tissue structures. To remain stable, the forces must be in equilibrium, that is, all of the forces acting on the body and its segments must be equal to zero [1].

In quiet standing, the body undergoes a constant swaying motion or postural sway that can be considered as an indirect measurement of stability. In normal stance, such as standing on two feet flat eyes open, the amount of sway is small and plays a minimal role in altering the position of the body segments compared to harder conditions e.g. standing on one foot tip toes with eyes open. This sway, however, may become greater when the body is under unstable situations particularly, when the BoS gets smaller and whilst eyes are closed.

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The mechanical variables which are needed to evaluate static balance, such as Centre of Pressure (CoP), Centre of Mass (CoM), Friction Torque (Q) as well as the extrapolated Centre of Mass (XCoM), can be extended to evaluate. Moreover, evaluating these selected variables on a sufficiently large population (e.g. 20 healthy males) generates baseline data for future studies. In general, baseline studies help researchers to gain a deeper understanding of the phenomenon they are investigating and the values of the variables, which quantify that phenomenon.

Treating data from the output of analysis systems is complex. In this study, advanced analytical software scripts (MATLAB® 7.4.0, R2007a, The Math Works™) were necessary for analyzing numerous data files and creating informative plots as well as organizing structures which are useful in the current study and in future works.

A. Objectives

1. To implement Matlab procedures for quantifying selected static balance variables;
2. To establish baseline data of selected variables which characterize static balance activities in a population of healthy young adult males;
3. To examine the trial effect on selected variables which characterize static balance.

II. Method

A. Participants

The participants in this study were 20 healthy male students at Liverpool John Moores University (age 25.4±4.5 years, height 179±7.2 cm, and body mass 73.4±7.2 kg). They had no history of problems of postural instability, passed the stereovision test, (no gross problem with stereopsis and fine depth perception). The main requirement was to perform normal balance in a set of different balance tests. Each participant signed the consent form that complied with the testing information sheet.

B. Equipment

A force platform was used as detailed: the first was a Kistler 9281B11, Kistler, Switzerland (dimensions 400x 600mm) which was built-in and levelled with the floor of the laboratory. The force platform recorded ground reaction forces and the CoP at 1000 Hz (12 bit A/D conversion). Additional markers on the 5th metatarsal joints of the feet/foot were used for providing the BoS.

Whole-body kinematic analysis using 41 retro-reflective markers and eight cameras system (Vicon Peak® 512) was performed at 100 Hz wherein the CoM was defined by using a common, commercially available gait kinematic model was used (Plug-In-Gait, Vicon Peak®, Oxford, UK).

C. Procedures

Anthropometry: Measurements of stature and body mass were recorded using analogue Leicester height measure (Seca Ltd., Birmingham, UK). Participants were measured barefoot whilst wearing a stretch suit prior to starting balance testing.

1) Activities:

Balance variables were evaluated under the following conditions; standing with two feet flat, on one foot flat, on one foot and two feet tip-toes. The participant was given an opportunity to practice prior to the measurements. The subjects were required to stand with two feet flat, on one foot flat and on one and then two feet tiptoes (four conditions). A series of 3 trials of each activity were performed with eyes open as well as with eyes closed.

D. Data Collection

Data were recorded over 60s for two feet flat standing, 15s for two feet tiptoe and one foot flat for both conditions eyes open and eyes closed. The BoS was determined using the RSscan pressure mat which recorded the image of the area of contact between foot/feet and the mat.

Data analysis: The (AP) and (ML) coordinates of the CoP and the CoM were derived from recorded data and filtered using low pass Butterworth 10 Hz. The velocity of the CoM was calculated using a 3-point central difference differentiation algorithm [2]. The mean of the RMS values over the period of data collection of (F, CoM, XCoM and CoP in both ML and AP directions) for the three trials were calculated for each subject in each condition. Matlab scripts (Matlab 7.4.0, R2007a) were developed in conjunction with laboratory staff (setting the force platform accurately to minimize the shift between the CoP and CoM which was achieved by computing each mean of (CoP and CoM), and removing the difference and then replacing it with the calculated value. AlsoMatlab was used to create organized functions for analyzing data. These functions can be used with large volumes of data for creating informative organized structures including plots, and all treated output can be saved as SPSS compatible files.

E. Statistical Analysis

To analyze the postural balance parameters during static testing, each variable for each condition (static balance) was tested for normality of distribution. Repeated measures analyses of variance (SPSS GLM procedure) were used to test between trial differences in each condition to determine if there was a trial order effect (i.e. effect of learning). A contrast analysis was used to illustrate which levels of the factors are differed. The difference contrast was used between times (trials) to illustrate any learning effect. The (SPSS) version 20 (SPSS Inc, Chicago, IL) was used to manage and analyze data for statistical analyses. The alpha level was set a prior at .05 to indicate statistical significance. A Pearson Product moment correlation was used to test relationships between static balance tests.

III. Results

A. Base of Support (BoS):

The (BoS) is widely interpreted as the outer line of the outer edges of the feet or the area of contact between a body and support surface or surfaces [3]; [4].

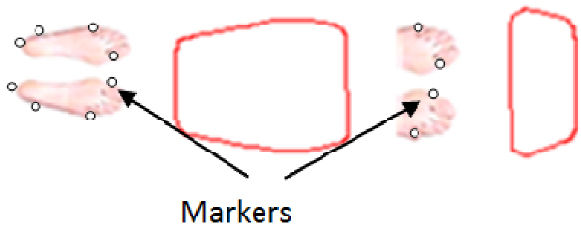

Fig. 1 An example of the BoS during static balance (two feet flat, eyes open) and the BoS during landing in dynamic balance (jumping on tiptoes), the markers are used as the BoS boundaries

The BoSwas simultaneously measured by using the feet/foot markers as references and so could be calculated dynamically throughout the movements. Although, the RSscan method gives a more detailed representation of the functional BoS, using, the anatomical plug-in gait feet/foot markers provide similar information about the BoS. This anatomical plug-in gait feet/foot markers method is useful to determine the BoS and its boundaries. All markers are representing the location of the boundary except the big toe markers which calculated based on their location plus a correction (based on the draw of outline of the feet/ foot in anterior directions).

B. Centre of Pressure (CoP), Centre of Mass (CoM) and the Extrapolated Centre of Mass (XCoM): For Static Balance

1) 2-Feet Flat, Eyes Open

Typical graphical displays are given in Fig. 2 for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML (x) and AP (y) during static balance (2-feet flat, eyes open) in relation to the functional BoS (straight dotted line).

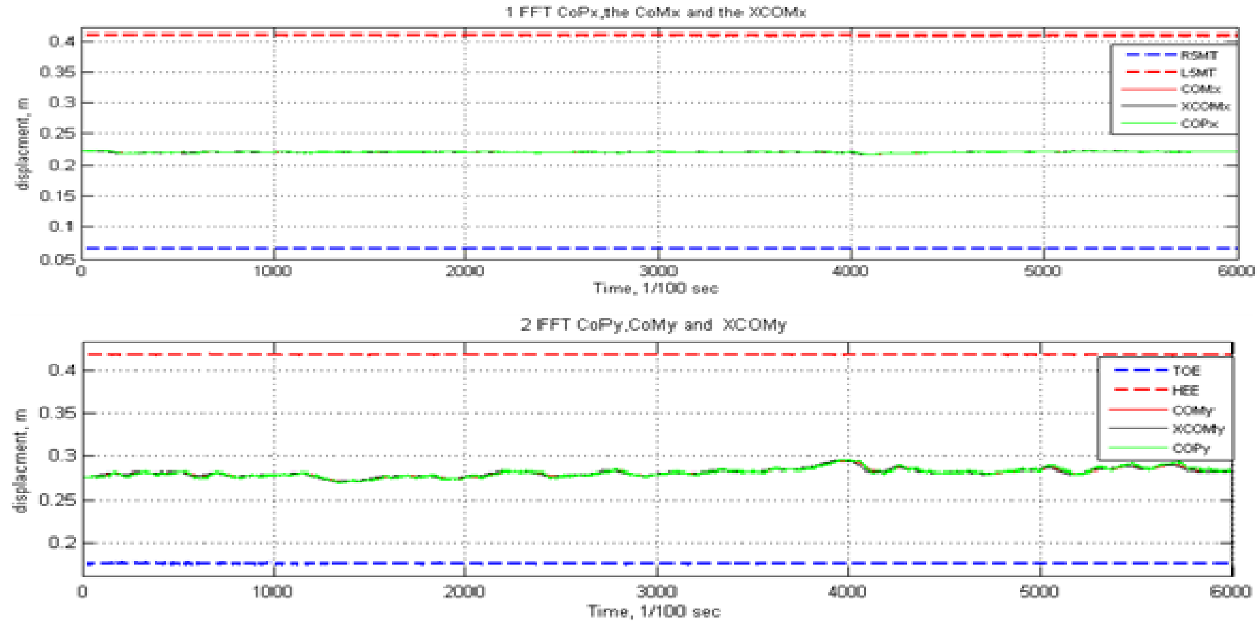

Fig. 2 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (2-feet flat eyes open) (Units = m)

These variables fluctuate around each other continuously which represent a state of equilibrium but are easily controlled within the BoS.

2) 2-Feet Flat, Eyes Closed

Typical graphical displays are given in Fig. 3 for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML(x) and AP (y) during static balance (2-feet flat, eyes closed) in relation to the functional BoS (dotted line).

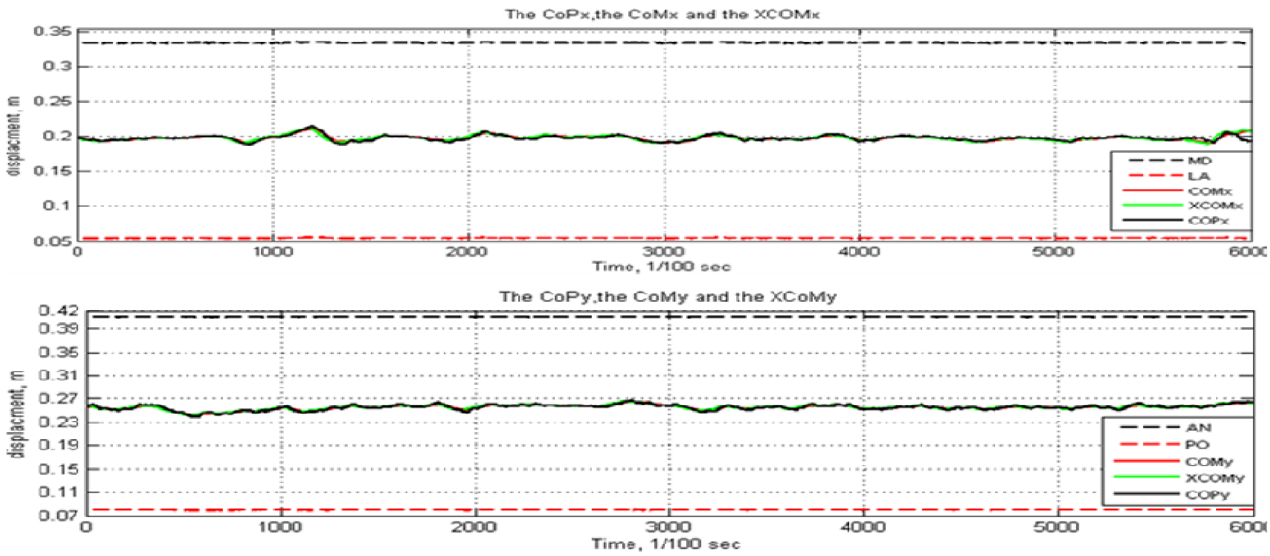

Fig. 3 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (2-feet flat, eyes closed) (Units = m)

3) 2-Feet Tiptoes, Eyes Open

Typical graphical displays are given in Fig. 4 for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML (x) and AP (y) during static balance (2-feet tiptoes, eyes open) in relation to the functional BoS (dotted line).

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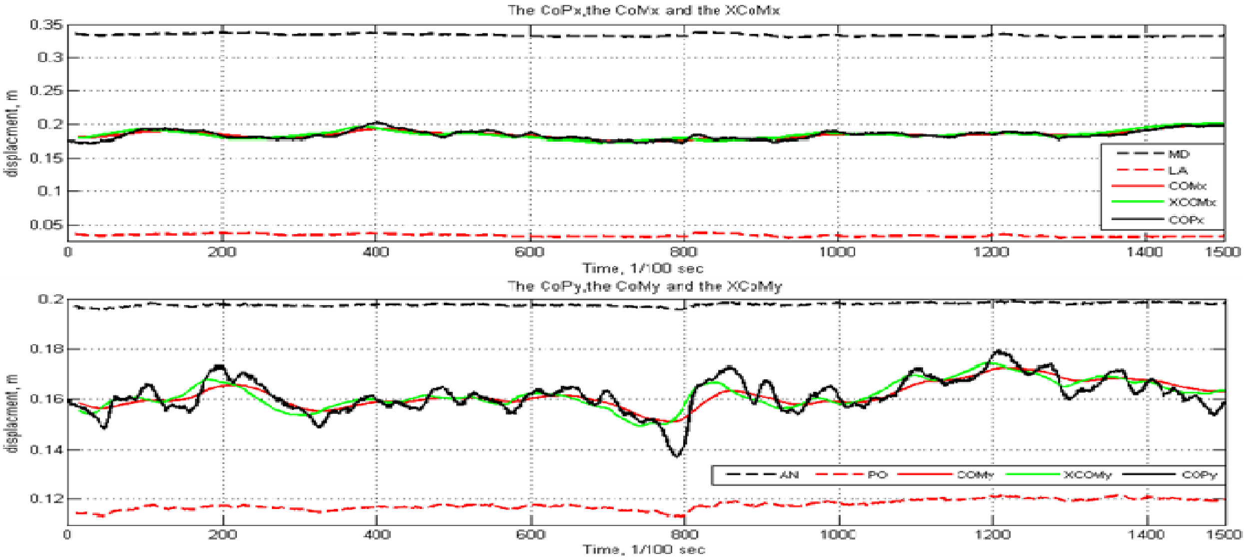

Fig. 4 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (2-feet tiptoes eyes open) (Units = m)

The charts above illustrate good stability in the (CoP), (CoM) and (XCoM) in the medio-lateral (ML) during static balance while the anterior-posterior (AP) shows large fluctuations due to the small available size of the BoS there are perturbations. These variables fluctuate around each other continuously which represent a state of equilibrium.

4) 2-Feet Tiptoes, Eyes Closed

Typical graphical displays are given in Fig. 5for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML (x) and AP (y) during static balance (2-feet tiptoes, eyes closed) in relation to the functional BoS (dotted line).

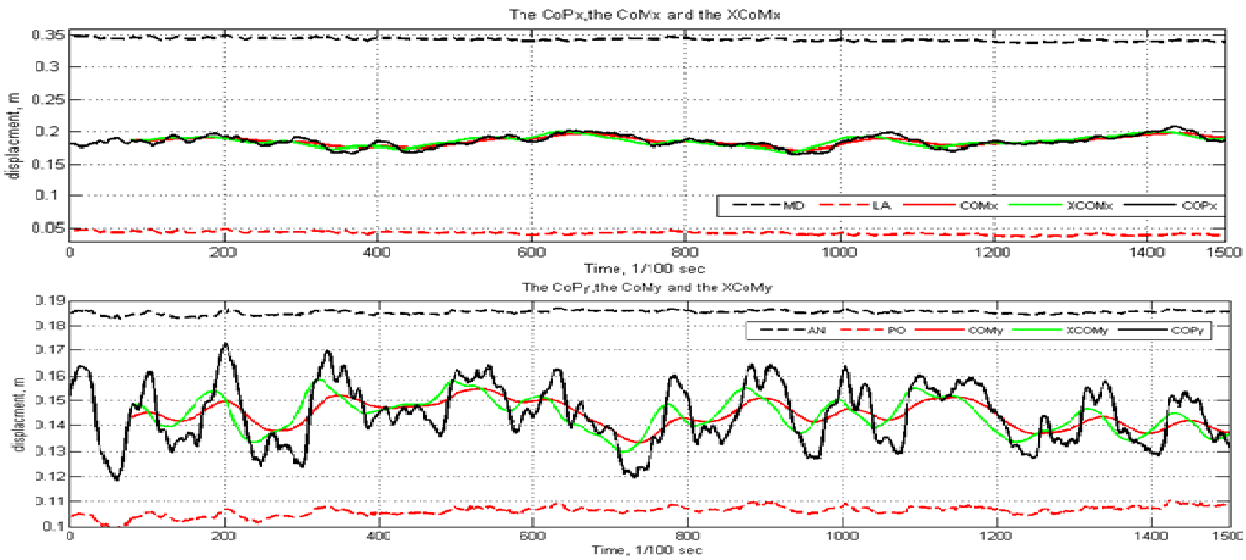

Fig. 5 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (2-feet tiptoes eyes closed) (Units = m)

There was small perturbation in the ML direction due to the nature of the event (eyes closed), whereas as a result of the small available size of the BoS in the AP direction these variables fluctuate widely around each other. Particularly the CoP_{AP} diverges to control the other variables.

5) 1-Foot Flat, Eyes Open

Typical graphical displays are given in Fig. 6 for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML (x) and AP (y) during static balance (1-foot flat, eyes open) in relation to the functional BoS (dotted line).

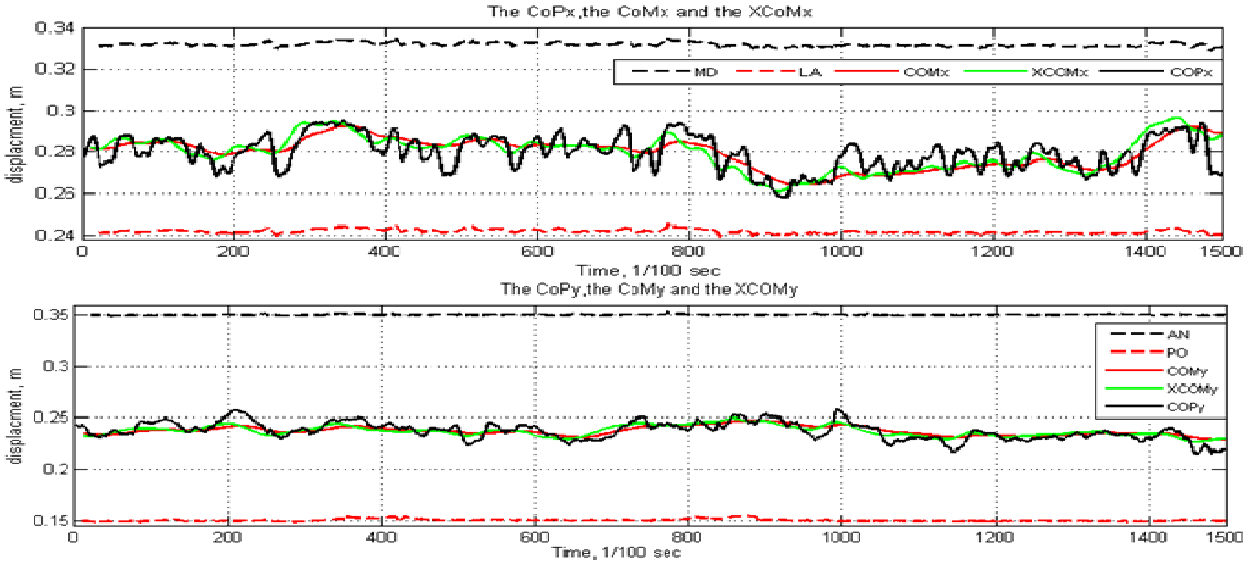

Fig. 6 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (1-foot flat eyes open) (Units = m)

As a result of the small available size of the BoS in the ML direction there were larger fluctuations. These variables fluctuate widely around each other particularly the CoP_{ML} diverges far away to control the other variables. There was smaller perturbation in the AP direction due to the available size of the BoS (one foot open).

6) 1-Foot Flat, Eyes Closed

Typical graphical displays are given in Fig. 7 for the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML (x) and AP (y) during static balance (1-foot flat, eyes closed) in relation to the functional BoS (dotted line).

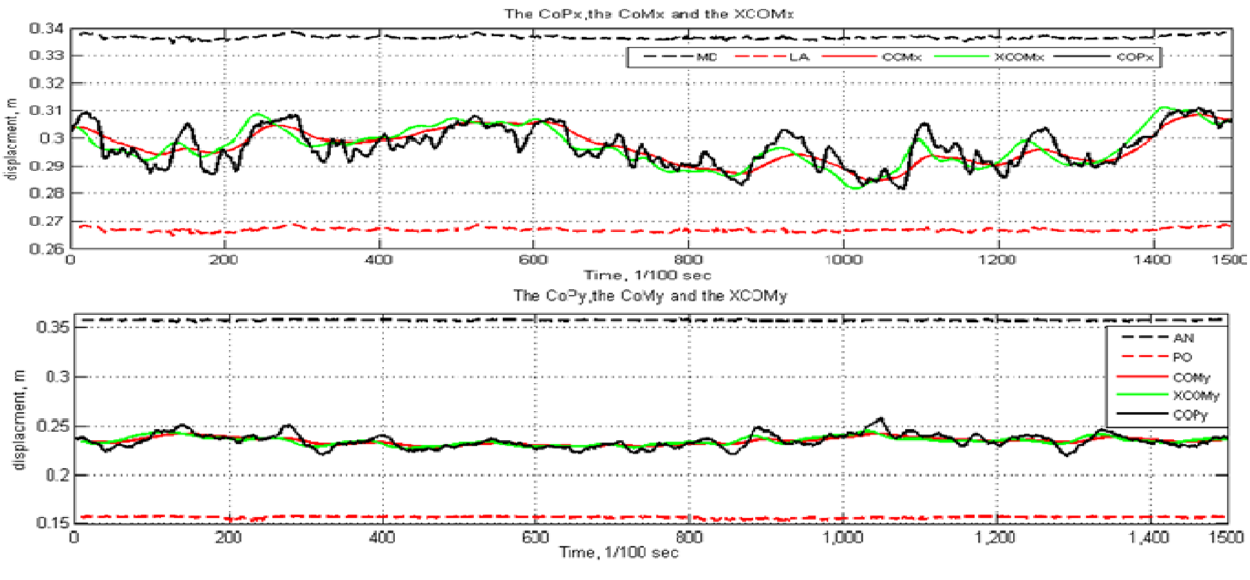

Fig. 7 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (1-foot-tiptoes eyes closed) (Units = m)

As a result of the small available size of the BoS in the ML direction there were larger fluctuations. These variables fluctuate widely around each other particularly the CoP_{ML} diverges far away to control the other variables. There was smaller perturbation in the AP direction due to the available size of the BoS (one foot).

7) Static Balance (1-Foot-Tiptoes, Eyes Open)

Typical graphical displays are given in Fig. 8. For the Centre of Pressure (CoP), Centre of Mass (CoM) and the extrapolated Centre of Mass (XCoM) in both directions ML *(x)* and AP *(y)* during static balance (1-foot-tiptoes, eyes open) in relation to the functional BoS (dotted line).

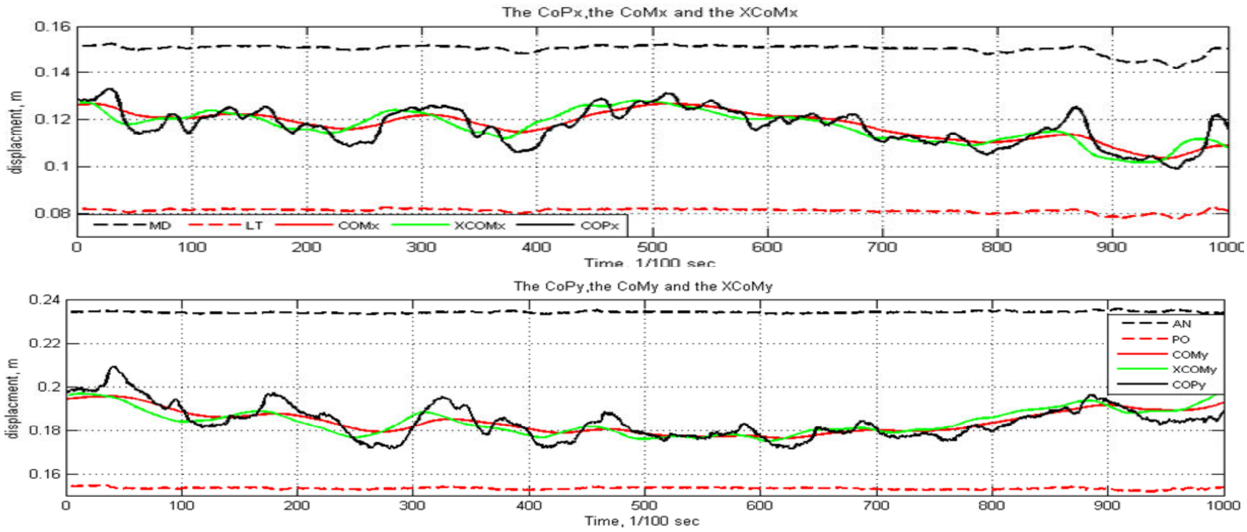

Fig. 8 The variables: (CoP), (CoM) and (XCoM) in both medio-lateral (ML) and anterior-posterior (AP) directions: static balance (1-foot-tiptoes, eyes open) (Units = m)

As a result of the small available size of the BoS in both the ML and AP directions there were large fluctuations. These variables fluctuate widely around each other and the CoP diverges far away to control and other variables.

8) Ground Reaction Force (GRF) for Static Balance

Typical graphical displays are given in Fig. 9 for the shear force in both F_{ML} (F*x*) and F_{AP}(F*y*) directions during static balance. These forces fluctuate around a constant level (nominally zero) which represents a state of equilibrium. In static balance, the ranges (double arrow) of the forces F_{ML} and F_{AP} are shown.

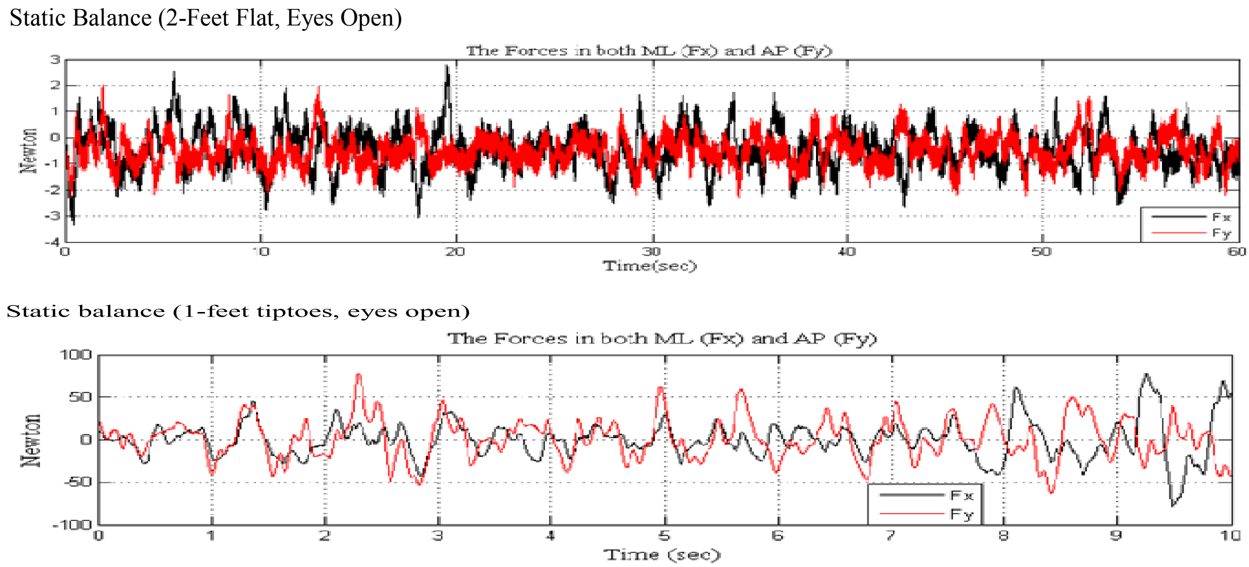

Fig. 9 The applied forces in both the F_{ML} and F_{AP} directions in static balance (Romberg 2-feet flat) and (Romberg 1-foot-tiptoes) (Units = N)

The applied forces in F_{ML} and F_{AP} values were small, (range < 10 Newton) during 2-feet flat standing, while the applied forces in F_{ML} and F_{AP} values were larger (range ≥ 100 Newton) during 1-foot-tiptoes standing.

C. Numerical Data

The mean and standard deviations of the RMS of the CoM, XCoM, CoP and F are given in Table I.

TABLE I
THE MEAN AND THE SD OF THE RMS OF THE COM, XCOM, COP AND F IN BOTH MEDIO-LATERAL (ML) AND ANTERIOR-POSTERIOR (AP) DIRECTIONS IN STATIC BALANCE (MEAN OF 20 SUBJECTS AND 3 TRIALS)

Tests	CoM_{ML}Mean (SD) (m)	$XCoM_{ML}$Mean (SD) (m)	CoP_{ML}Mean (SD) (m)	F_{ML} Mean (SD) (N)	CoM_{AP}Mean (SD) (m)	$XCoM_{AP}$Mean (SD) (m)	CoP_{AP}Mean (SD) (m)	F_{AP} Mean (SD) (N)
2FFT (EO)	0.008	0.009	0.011	3.750	0.010	0.011	0.012	6.152
	0.001	0.001	0.001	1.118	0.001	0.001	0.002	4.080
2FFT (EC)	0.0093	0.010	0.012	4.916	0.011	0.012	0.013	7.498
	0.0003	0.001	0.001	2.512	0.001	0.002	0.001	5.100
2FTtip	0.013	0.014	0.015	7.993	0.011	0.014	0.015	11.94
(EO)	0.002	0.002	0.002	2.979	0.001	0.002	0.001	5.850
2FTtip (EC)	0.014	0.015	0.016	10.02	0.013	0.015	0.017	18.26
	0.002	0.002	0.002	4.289	0.001	0.001	0.002	16.81
1FFT (EO)	0.011	0.012	0.014	13.56	0.016	0.018	0.020	11.22
	0.001	0.001	0.001	8.339	0.001	0.001	0.002	4.459
1FFT (EC)	0.012	0.013	0.015	26.89	0.018	0.019	0.021	17.65
	0.001	0.001	0.001	20.47	0.001	0.001	0.002	10.69
1FTtip	0.009	0.010	0.011	32.50	0.035	0.037	0.039	27.08
(EO)	0.001	0.001	0.001	17.22	0.001	0.002	0.002	14.87
1FTtip (EC)	**	**	**	**	**	**	**	**

** Most participants lost balance.
Legend: 2FFT = (2 feet flat), 2FTtip = (2 feet tiptoes), 1FFT = (2 foot flat), 1FFT = (2 foot-tiptoes), and EO = (eyes open), EC = (eyes closed)

D. Trial Effects

Centre of Mass;

The results in Table II for a one way repeated measures ANOVA with one within subject factor (TRIAL, 3 levels) showed that there was no significant main effect of trials neither in eyes open nor eyes closed conditions for the medio-lateral (ML) and anterior-posterior (AP) directions. Specific trial-by-trial comparisons are displayed in Fig. 9.

TABLE II
THE F VALUES ASSOCIATED WITH TRIAL EFFECTS OF THE CENTRE OF MASS VARIABLE IN ALL STATIC BALANCE TEST IN BOTH EYES OPEN AND EYES CLOSED CONDITIONS AND IN BOTH MEDIO-LATERAL (ML) AND ANTERIOR-POSTERIOR (AP) DIRECTIONS

Conditions	CoM_{ML}	CoM_{AP}
2FFT (EO)	$F_{(1.998, 37.956)} = 1.349$, $p > .05$	$F_{(1.884, 35.789)} = 1.483$, $p > .05$
2FFT (EC)	$F_{(1.855, 35.244)} = 1.316$, $p > .05$	$F_{(1.792, 34.041)} = 1.915$, $p > .05$
2FTtip (EO)	$F_{(1.910, 36.290)} = 1.355$, $p > .05$	$F_{(1.841, 34.976)} = 1.088$, $p > .05$
2FTtip (EC)	$F_{(1.862, 35.378)} = 1.293$, $p > .05$	$F_{(1.978, 37.582)} = 1.142$, $p > .05$
1FFT (EO)	$F_{(1.966, 37.362)} = 1.593$, $p > .05$	$F_{(1.905, 36.196)} = 1.957$, $p > .05$
1FFT (EC)	$F_{(1.982, 37.655)} = 1.302$, $p > .05$	$F_{(1.750, 33.251)} = 1.814$, $p > .05$
1FTtip (EO)	$F_{(1.596, 30.325)} = 2.158$, $p > .05$	$F_{(1.632, 31.015)} = 1.186$, $p > .05$

Legend: 2FFT = (2 feet flat), 2FTtip = (2 feet tiptoes), 1FFT = (2 foot flat), 1FFT = (2 foot-tiptoes), and EO = (eyes open), EC = (eyes closed)

1) The Correlations between Static Balance Tests:

Fundamentally, this study was designed to select a reliable test that represents the static balance. Therefore, establishing the correlation between tests was essential to clarify the relationship between the static tests on the main variables.

These are presented in Tables III-X and show a variable degree of correlation. The condition producing the most correlations is the 1-Foot flat-eyes open (1FTF_EO). This produced a total of 19 correlations across all tables.

TABLE III
MATRIX OF THE CoM_{ML} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.517*					
2FTP_EO	-0.230	-0.129				
2FTP_EC	-0.271	-0.162	0.802**			
1FTF_EO	-0.119	0.139	0.897**	0.446		
1FTF_EC	-0.152	0.075	0.715**	0.466	0.697**	
1FPT_EO	0.248	0.136	0.017	-0.081	0.008	0.011

TABLE IV
MATRIX OF THE CoM_{AP} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.743**					
2FTP_EO	-0.213	0.144				
2FTP_EC	-0.184	0.175	0.752**			
1FTF_EO	-0.458*	-0.325	0.733**	0.750**		
1FTF_EC	-0.453*	-0.277	0.693**	0.632**	0.671**	
1FPT_EO	0.719**	0.735**	0.021	0.083	-0.134	-0.094

TABLE V
MATRIX OF THE CoM_{AP} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.303					
2FTP_EO	-0.322	0.134				
2FTP_EC	-0.113	0.159	0.267			
1FTF_EO	-0.186	-0.171	0.488*	0.266		
1FTF_EC	0.003	-0.434	-0.121	-0.496*	0.408	
1FPT_EO	0.256	-0.016	0.083	-0.174	0.368	0.017

TABLE VI
MATRIX OF THE $XCoM_{AP}$ FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.141					
2FTP_EO	0.014	-0.323				
2FTP_EC	-0.163	0.029	-0.059			
1FTF_EO	-0.123	-0.391	0.553*	0.243		
1FTF_EC	-0.188	-0.346	0.186	0.733**	0.452	
1FPT_EO	0.541*	0.263	-0.084	0.072	-0.417	-0.125

*. Correlation is significant at the 0.05 level (2-tailed).**. Significant at the 0.01 level (2-tailed).

TABLE VII
MATRIX OF THE CoP_{ML} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.425					
2FTP_EO	-0.273	0.218				
2FTP_EC	-0.217	0.079	0.926**			
1FTF_EO	0.047	-0.250	-0.447*	-0.483*		
1FTF_EC	0.003	-0.473*	-0.189	-0.055	0.401	
1FPT_EO	0.246	0.052	-0.205	-0.229	0.235	0.121

TABLE VIII
MATRIX OF THE CoP_{AP}FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.203					
2FTP_EO	-0.029	-0.217				
2FTP_EC	-0.086	-0.083	0.619**			
1FTF_EO	-0.128	-0.236	0.742**	0.539*		
1FTF_EC	-0.199	-0.378	0.566**	0.124	0.508*	
1FPT_EO	0.395	0.323	0.011	0.075	-0.334	-0.121

TABLE IX
MATRIX OF THE F_{ML} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.522*					
2FTP_EO	0.487*	0.275				
2FTP_EC	0.526*	0.507*	0.363			
1FTF_EO	-0.108	-0.023	0.650**	0.260		
1FTF_EC	-0.237	0.351	0.087	0.301	0.270	
1FPT_EO	-0.455*	0.113	-0.141	-0.070	0.315	0.355

TABLE X
MATRIX OF THE F_{AP} FOR STATIC BALANCE TESTS

	2FTF_EO	2FTF_EC	2FTP_EO	2FTP_EC	1FTF_EO	1FTF_EC
2FTF_EC	0.432					
2FTP_EO	-0.014	0.441				
2FTP_EC	0.173	0.689**	0.328			
1FTF_EO	0.522*	0.564**	0.540*	0.216		
1FTF_EC	0.343	0.455*	0.254	0.329	0.486*	
1FPT_EO	0.474*	0.410	0.181	0.584**	0.765**	0.423

*. Correlation is significant at the 0.05 level (2-tailed).**. Significant at the 0.01 level (2-tailed).

The above Tables III-X show correlation matrixes of the main variables (CoM, XCoM, CoP and F) in both in both medio-lateral (ML) medio-lateral and anterior-posterior (AP) directions in static balance tests (standing on two feet flat, two feet tiptoes, one feet flat and one foot tiptoes) in both conditions eyes open and eyes closed tests.

IV. Discussion

The purpose of this study was to implement Matlab procedures for quantifying static balance variables, establish baseline data of selected variables that characterize static balance activities in a population of healthy young adult males and to examine the trial effect baseline data of selected variables that characterize static balance.

Calculating the CoM was based on a commercially available method (Plug-in Gait marker set, Vicon, UK). The trajectory of the CoM was computed based on a video-based system combined with anthropometric information of the human body [2]. Individual body segments can be different depending on individual subject's anthropometric information. The Plug-in Gait model is widely accepted as a biomechanical model in both clinical and research settings for evaluating gait dynamics [5] as well as static balance [6]. Although, The CoM displacement based on the Plug-in-Gait model has been analysed recently in many studies [7], [8]; it does not consider the asymmetry of the human body particularly in the anterior-posterior direction. Talbott [1] avoided this issue by representing a plot of the CoMand matching them by displaying the CoP displacement data on a secondary axis. Consequently, in this study a Matlab script was used to shift mathematically the CoM toward the CoP to provide assured agreement between the CoP and CoM data.

A novel method of computing the BoS dynamically was established by adding markers to the subjects' feet/foot, which were tracked during the tests in static conditions. This provided a convenient way of establishing the BoS without the need for additional equipment and data processing.

Basically, this study was designed to implement Matlab procedures for quantifying selected static balance variables. The developed Matlab code can treat numerous files at once and creates figures in a standardised way. Many individual and generic Matlab functions were written for processing data and to create SPSS output which can be then statistically treated.

To establish baseline data of selected variables which characterize static balance activities in a population of healthy young adult males, it was fundamental to test many static conditions but necessary to reduce these for further studies. Vision is a very important factor in sport activities and testing with eyes open is essential. Therefore, the eyes closed tests will not be undertaken in future tests. Standing on two feet flat is an easy task while standing on one foot tiptoes is very difficult. Standing on one foot flat is challenging enough and commonly used in testing postural balance. Therefore, standing on one foot flat can be used as a representative test for static balance that is supported and clarified by establishing a correlation between static tests on the main variables (e.g. CoM, XCoM, CoP and F).

This is supported by the fact that this test condition had the highest number of correlations with other tests. Therefore, the one foot flat, eyes open test can be used to represent static balance in the forthcoming study.

For testing dynamic balance the existing horizontal jumping tests are useful for establishing baseline data of selected variables which characterize dynamic balance activities in a population of healthy young adult males. Due to the complexity of jumping on tiptoes and most subjects found this difficult and therefore failed to execute it successfully, the two feet tiptoe horizontal jump will not be used in the forthcoming study. instead vertical jumps (e.g. 2 feet flat vertical jump and one foot flat vertical hop) will be used which will widen the investigating into dynamic balance. An interesting pattern emerged when generally comparing jumping (two feet flat) and hopping (one foot flat). In one foot flat horizontal jump, the excursions of CoM, XCoM, and CoP were larger than in two feet flat horizontal jump, suggesting that the one foot flat condition is a less stable condition. However, shear forces and Q were smaller in one foot flat compared to two feet flat, suggesting that in one foot flat mechanism two (counter rotating segments) is utilized to a lesser extent to recover balance. This indicates interesting differential effects of condition (one foot flat versus two feet flat) related to the different balance mechanisms.

The trial effect (baseline data) of selected variables (CoM, CoP, XCoM, F) which characterize static balance was established by testing the differences between the trials. The results show clearly that there was no significant main effect of trials neither in eyes open, eyes closed conditions nor in medio-lateral (ML) and anterior-posterior (AP) directions. In other words, participants replicate similarly in each trial which means the mean of the trials can be used for analysis.

V. Conclusion

The main finding can be summarized as following:

- Using Matlab procedures for quantifying selected static balance is practical for handling such large data (e.g. analysis, plotting and producing SPSS output)
- Baseline data of selected variables which characterize static balance activities was established for a population of healthy young adult males.
- No significant trial effect was found between repetitions on selected variables which characterize static balance.
- The functional BoScan be measured by using additional markers to the feet/ foot.
- Testing with eyes open is related to sport activity. Furthermore, one foot flat is a representative test of static balance.
- Tiptoes tests, either in static balance are too challenging for most participants in normal circumstances.
- An interesting differential effect of condition (one foot flat versus two feet flat) was observed related to the utilization of different balance mechanisms.

The results of this study can be used for the comparative purpose in the forthcoming studies.

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