OVERWEIGHT AND OBESITY IN POSTURE: A BIOMECHANICAL EVALUATION OF POSTURAL STABILITY

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INTRODUCTION

Obesity is one of the commonest pathologies of industrialized countries. Many studies have been published on this pathology and its consequences, but very few used a biomechanical approach on the problem. We are interested in the biomechanical analysis of postural stability and loading condition of the spine of normal – weight and obese subjects. In fact, due to the excessive fat mass, especially on the trunk and thighs, the loading condition of the spine in obese subjects results certainly different from normal. This condition is expected to lead to deep biomechanical modifications, which can give pathological alterations of the musculoskeletal system. A quantitative assessment of the postural stability during quiet standing in normal and overweight subjects provides useful biomechanical information about the effect of an anomalous body weight loading of the spine. Moreover, it permits to evaluate the stability of a selected patient. These findings can be useful in a clinical setting to structure new rehabilitative treatments and to give indications on their effectiveness.

The main aim of this study was to examine postural stability in obese subjects in comparison to normal subjects using a biomechanical approach.

METHODS

We analyzed a total number of 26 women (mean age 32.5 s.d. 5.91 years) divided into 4 subgroups in relation to BMI value (BMI: Body Mass Index defined as weight [kg] / height\(^2\) [m\(^2\)]):

1) underweight, mean BMI 19.81, s.d. 0.86
2) normal weight, mean BMI 22.33 s.d. 1.55
3) overweight, 26.21 s.d. 1.09
4) obese mean BMI 38.94 s.d. 8.99.

Selection criterion for all subjects was no suffering from any musculoskeletal pathology.

An optoelectronic motion measurement system (ELITE, bts\(^\circ\), IT) provided the 3D coordinates of reflective passive markers placed on the subjects as shown in Fig.1. A force platform (AMTI, Newton, MA) provided the ground reaction forces and the trajectory of the Centre of Pressure (COP). In particular, 11 markers were placed over the spinous processes every two vertebrae from c7 to sacrum. Two markers were placed bilaterally on right and left acromion, two markers were placed bilaterally on right and left ASIS, two more markers on right and left knee (on the lateral processes of the fibula), finally, two markers were positioned on right and left malleolus and two on right and left 5th metatarsal head to retrieve the position on the feet with respect to the force platform.

Each subject was asked to stand on the force platform in orthostatic indifferent position with eyes open for three successive acquisition trials. Each trial was 30 seconds long and time interval between two trials was fixed at 30 seconds. Kinematic indexes were extracted mainly taking into consideration the trajectory of COP in anterior – posterior (A/P) direction and medial – lateral direction (M/L). In Fig.2 an example of A/P (pink line) and M/L (green line) trajectory of COP is plotted vs. time and the first defined index is evidenced with black arrows. These indexes are mathematically defined as follows:

1) Total excursion index (\(E_{\text{tot}}\)) is the spatial difference between the absolute maximum and the absolute minimum of the COP trajectory vs. time \((E_{\text{tot}} = \max(COP)-\min(COP))\); it is calculated for both A/P and M/L direction.

2) Mean excursion velocity \((v_m)\); it is defined as the mean, calculated on the ratio between the difference between each oscillation \((E_i)\) maximum and each oscillation \((E_i)\) minimum and the time interval in which the oscillation occurs \((t_{i+1}-t_i)\)

\[
v_m = \frac{\sum_{n=1}^{N} \frac{E_i}{t_{i+1}-t_i}}{n-1}.
\]

To allow a comparison between different subjects, these parameters have been multiplied by a normalization factor (NF) that takes into account for the different body heights of the analysed subjects: NF=1000/height (mm).

Figure 1: marker positioning, frontal view
For statistical analysis of the selected parameters ANOVA test was applied for the comparison between the four different groups. Significance level was set at $p = 0.01$. For multiple comparison test a Dunn’s post test with significance level set at $p = 0.05$ was selected.

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**RESULTS AND DISCUSSION**

We found statistically significant correlations ($p<0.01$) between variations of the calculated parameters and variations of the BMI value. In particular, it is to observe that the control group of normal weight women shows the minimum value of $E_{tot}$ for both A/P and M/L direction as shown in Figure 3 and 4, where mean value and SD of COP total excursions for each group are shown. On the contrary, underweight women overweight and obese women show a higher value of these parameters (see Figure 3 for A/P direction and Figure 4 for M/L direction). Statistical post-test analysis confirmed the significant differences between groups if examined in pairs.

The same consideration can be done for $v_m$: underweight, overweight women and even more obese women show values of $v_m$ higher than normal-weight women. This result evidences that postural adjustments, related to the velocity of the excursions, $v_m$, are slower in normal subjects, who are able to compensate little postural displacements with less energy expenditure. In fact, energy is directly related to the mass and velocity of the subject. On the contrary, underweight, overweight and obese women need more energy to correctly react to little postural changes that normally occur during quiet standing. This again is a sign that postural stability is related to normal BMI values and that both being under or over this normal range can give balance problems and postural instability. Statistical significance for $v_m$ is shown in Table 1.

<table>
<thead>
<tr>
<th>Underweight vs. normal weight</th>
<th>Underweight vs. overweight</th>
<th>Underweight vs. obese</th>
<th>ANOVA all groups</th>
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<tr>
<td>2.11719E-09</td>
<td>0.28425</td>
<td>0.46827</td>
<td>p&lt;0.0001</td>
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<tr>
<td>Normal weight vs. overweight</td>
<td>Normal weight vs. obese</td>
<td>Overweight vs. obese</td>
<td></td>
</tr>
<tr>
<td>1.13353E-51</td>
<td>5.66724E-32</td>
<td>8.07E-03</td>
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</tr>
</tbody>
</table>

Table 1: Statistical analysis of the significance of $v_m$: the four groups are compared in pairs and all together. Results are always significative except for underweight vs. obese

In general, our results show a strong correlation between pathological BMI values and increasing imbalance during quiet standing in both anterior – posterior direction and medial – lateral direction, confirming that normal BMI range gives the highest stability to the subject.
SUMMARY

In conclusion, the postural analysis using a biomechanical approach gives further information on the role of weight in postural stability. A simple acquisition protocol, as the one we used in this study, could be very helpful in the assessment of postural imbalance due to underweight, overweight or obesity. We think that our experimental protocol could be used in a clinical setting as a control tool before and after an appropriate rehabilitation program.

Future developments of this first work include a different signal processing of platform data (using Fourier analysis) and the comparison between feet position on the platform and COP position, which is expected to be different in normal weight and over weight or underweight subjects, because of the different use and weakness of muscles.

REFERENCES