XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

XV BRAZILIAN CONGRESS OF BIOMECHANICS

COMPARISON BETWEEN A SUBJECT-SPECIFIC MODEL TO ESTIMATE MOMENTS IN THE LOW BACK AND 3D-SSPP

[1,2]Geneviève Dumas, [2]Tara Diesbourg, [1]Ryan Budd, [1]Adam Labaj, [1]Florence Meyer

[1]Department of Mechanical and Materials Engineering, Queen's University, Kingston, Ontario
[2]School of Kinesiology and Health Studies, Queen's University, Kingston, Ontario, *dumas@me.queensu.ca*

INTRODUCTION

For several decades, there has been a strong interest in biomechanical research into estimating the demands placed on the low back during lifting tasks. As such, several models have been developed for that purpose. These models range in terms of complexity both in the model and within the analyzed task, depending on their purpose and intended use, e.g. field versus laboratory study. Inertial parameters of body segments are required, and these parameters may affect the accuracy of the results [1], particularly in the case of hands-down models that include the trunk. Researchers have established relationships to predict segment length and mass, position of segment centre of mass, based on total body height and mass [2, 3, 4]. Static models have been developed to determine the loads on the spine during a task based on postural information from video recordings taken in the field. Such models also use estimated anthropometric values (e.g. segment length) to approximate the moment arms required to calculate the load on the spine when these cannot be measured from the data recorded.

While this method is widely accepted in the field of biomechanical research, some limitations exist. The first of these is that the relationships were established based mostly on data from live and cadaveric North American subjects [3]. These relationships may not apply to subjects from other countries where genetics, nutrition and lifestyle may affect body parameters. The authors of the current study are interested in research involving the forces and moments in the lumbar spine of pregnant women when working. The anthropometric data that currently exist do not take into account the physical changes that occur throughout a pregnancy. The purpose of the current study, therefore, was to develop and test a static biomechanical model and assessment protocol that would estimate the forces and moments imposed upon the low back of pregnant women when lifting form video recordings and compare the results to those of the widely used University of Michigan 3D-SSPP model.

METHODS

The Model A two dimensional, hands-down, static biomechanical model was developed to estimate the forces and moments about the center of the L5 vertebra during symmetrical lifting tasks.

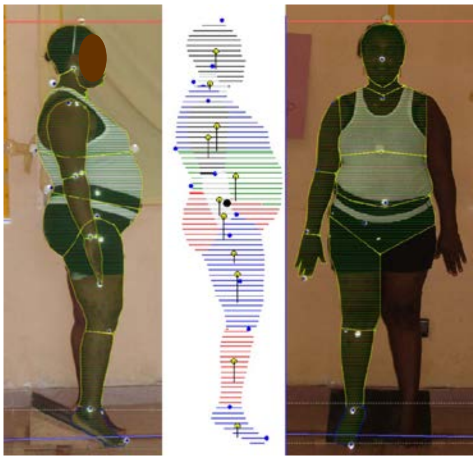

Figure 1: The digitizing of the contours of the segments and joint locations for the photogrammetric method of Jensen.

The largest difference between this model and previously-developed models is in the segment definitions and segment mass/centre of mass estimations. The anthropometric data for use in the current model are obtained from two photographs of the subject according to the photogrammetric method developed by Jensen [6] for 17 segments (Figure 1). This method (Slicer program) models the trunk as three separate segments, allowing for a more accurate representation of the change in mass distribution associated with pregnancy. The Slicer program also determines the lengths of the body segments from the digitized photographs and these values are used to calculate the moment arms in the model.

Starting at the hand, the program determines the joint reaction forces and moments from the wrists to L5 based on a recursive link-segment approach. As the task analyzed is considered a static task, $\Sigma F = 0$, thus the following equations were used to determine joint reaction forces and moments:

$$\begin{Bmatrix} \sum F_{ki} + m_i \times g = 0 \\ \sum (r_{ki} \times F_{ki}) + r_{ei} \times F_{ei} + r_i \times m_i g + \sum M_{ki} = 0 \end{Bmatrix} \quad (1)$$

For segment i, having a mass m_i, F_{ki} represents the inter-segmental forces at the distal (k= i-1) and proximal (k= i+1) joints, and M_{ki} represents the inter-segmental moments (at the proximal and distal joints) acting across the joint. F_{ei} and M_{ei} are the external force and moment applied on the segment (only to the hand segment in this case), while r_i and r_{ki} are the position vectors of the center of mass of the segment and points of application of forces F_{ki} and F_{ei} .

Model Validation

A subset of 20 women, 10 in their 7th to 9th month of pregnancy (mass 73 ± 19 kg, height 161 ± 3 cm) and 10 non-pregnant (mass 61± 13 kg, height 158 ± 6 cm) from Porto Novo, Benin, Africa was sampled from a larger dataset collected previously. The task analyzed consisted of a head load-carriage task whereby each participant was asked to pick-up a load weighing 20% of their body weight from a stool, place it atop their head, walk for 6 meters, and return the load to the stool. Video data were collected throughout the task from two orthogonal positions.

The frame of video data that was used in this analysis represented the subject in her most flexed position when picking up the load. The joint angles required for the model inputs were digitized using Dartfish software for the head, upper back, lower back, shoulder, elbow, and wrist joints. Segment lengths and centre of mass horizontal position were computed as described above using Slicer.

These angles and videos were used with two biomechanical models: the custom model developed above, and Michigan 3D-SSPP modeling software. Body mass and height were entered into the software and posture was determined by overlying a mannequin over the subject image in the selected video frame according to the instructions.

The outputs obtained from the two models were compared using Student t-tests and linear correlation.

RESULTS AND DISCUSSION

The results from the two models are presented in Table 1. There was an excellent correlation between the moments from the two models for both groups (NP: R>0.97 P: R>0.91) but the t-tests showed that the results from the 3D-SSPP model were significantly smaller than those from the custom model p<0.001 for the non-pregnant group while there was no difference for the pregnant group.

Table 1: Mean (SD) moments from the custom and 3D-SSPP models and mean (SD) difference between the custom model and 3D-SSPP results for both groups.

	NON-PREGNANT	PREGNANT
Custom model (Nm)	194(51)	221 (57)
3D-SSPP L5/S1(Nm)	157 (40)	219(63)
Difference (%)	23.8 (8)	2.0 (12.0)[1]

[1] Average absolute difference 9 %(7%)

The differences between the two models may be attributed to their evaluations of body mass distribution and of posture. Indeed a t-test comparison of the two models revealed that the upper body masses evaluated by 3D-SSPP (NP: 27.2kg, P: 32.2kg) were significantly lower than those determined the photogrammetric method from Jensen [6] (NP: 28.9, P: 37.1 kg, p<0.001). This may reflect the differences between the population studied and the populations on which data the 3D-SSPP model are based on, and it may also affect location of segment centers of mass and therefore moment arms. Both posture measurement methods are prone to errors. In addition, 3D-SSPP models the trunk as a single segment versus three for the custom model. As a result, it does not take into account the curvature of the back during flexion (figure 2), which may affect the moment arms of the upper body segments and load to L5.

Figure 2: Overlay of the mannequin from the 3D-SSPP software on the still picture from the video recording.

CONCLUSIONS

There was a good correlation between the moments calculated by a new custom model and the widely used 3D-SSPP model for both subject groups. However, for the non-pregnant group, the moments determined by the 3D-SSPP were significantly lower by 23% on average. This difference between the results may be due to the anthropometric assumptions made in both models and to the evaluation of posture. It was shown that upper body mass was underestimated by 3D-SSPP for both groups compared to the photogrammetric method used by the custom model. Further research should aim to clarify the origin of the discrepancies.

REFERENCES

[1] Lariviere C, Gagnon D, (1999) *Clin Biomech* **14** 449-461
[2] Zatsiorsky, V.M. & Seluyanov, V.N. (1983) In: *The mass and inertia characteristics of the main segments of the human body.* Human Kinetics: Illinois, USA. p. 1152-1159
[3] Jensen, R.K. (1986). *J Biomech.* P. 359-368
[4] de Leva, P. (1996). *J Biomech.* p.1223-1230
[5] Chaffin, D.B. (1997) *Hum Factor Ergon Man.*p. 305-322
[6] Jensen, R.K. (1978) *J Biomech.* p. 349-358