A STUDY OF THE VARIABILITY IN ENERGY CALCULATION RELATED TO THE VISIBILITY OF THE MANUALLY DIGITIZED MARKERS .

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INTRODUCTION

Starting with Fenn's study of sprint running (FENN,1930) there have been many studies on energetics of running and walking. Even so, there still remains room for discussion. CAVANAGH (1990) described a variation from 170 to 1700W in power output for the same movement (running at 3.6 $m.s^{-1}$) calculated by six different authors.

A general methodological problem in the energy calculation is related to contributions of the segments that are hidden for a certain time during the digitizing process. We have first studied the variability of a 3D reconstruction of the segment's link after a manual digitizing process, without relating it to an energy calculation (CORREA ET AL., 1995). This study showed that the hidden side, as already expected, presented a greater variability than the visible side for all segments. The standard deviation was around two times that showed by the other side and the mean value for the segment length also had a difference of around 1 cm. This study reinforced our idea that the variations in segment link would considerably affect the energy calculations.

The aim of this paper is to analyse the different components of the mechanical energy (potential, kinetic and rotational) of the segments considering the differences between the right side (visible) and left side (hidden). We will consider as variables that interfere in this variation: different movement conditions - treadmill and overground.

METHODOLOGY

A stride from one male subject was filmed with two video-cameras (Sony-50Hz) while walking at 1.5 m/s on the treadmill and overground.Each trial was repeated for at least 3 times on overground and on treadmill it was filmed for at least 30 seconds.From the kinematics we performed a 3D analysis after a manual digitizing process. For each case: a) walking overground (Wo), b) walking on treadmill (Wt), we digitized the same sequence three times and two other trials of the same case. The analysis was based on a 13 segment model, represented by 17 markers placed on: ear, and on right and left shoulder, elbow, wrist, hip, knee, ankle, heel and front foot extremity. Positions of segmental centers of gravity, segmental weights, and moments of inertia were estimated on the basis of tables devised by DEMPSTER (1955); the segmental lengths were estimated as a percent of body height (DRILLIS AND CONTINI, 1966), both as revised by WINTER (1979). We assumed for the calculation of the anthropometrical parameters that the segments' lengths are constant although the links' lengths were dependent from the estimation of the coordinates of joint centers.

From the different forms of mechanical energy, we have calculated the potential, kinetic and rotational energy at each instant of time for each segment, using basically the equations described by SAZIORSKI ET. AL (1987).The kinetic energy of each segment was calculated in relation to the center of mass of the subject.

We calculated for each case (n = 5), and for the right and left side the average curves of the potential, kinetic and rotational energies with their mean values and standard deviations. For each side: a) the total amount of each energy - the sum of energies of: hand, forearm, upper arm, foot, leg and thigh; b) the total amount divided in upper extremity - sum of energies of: hand, forearm and upper arm and lower extremity - sum of energies of: foot, leg and thigh; c) the energy of each segment. We describe a complete cycle, from right heel strike (RHS) to the next RHS.

RESULTS

It was not possible to identify differences between the average energy curves of the visible and hidden side considering the following cases : a) Wt and Wo - total kinetic and rotational energies .On the contrary, differences were easily to be noticed in the other cases : a) Wt and Wo - total potential energy (Figure 1a).There was no difference between the curves' patterns on treadmill and overground. In order to better determine where the differences really were, each of these energy curves for the whole side were divided into two parts : upper and lower extremity curves.We observe that for the potential energy the greatest lateral difference lies in the lower extremity curves. When we observe the potential energy curves from the three segments of the lower extremity, we observe that the curve that shows a great lateral difference is the thigh's curve (Figure 1b) with the curves for the leg and foot showing no lateral differences.

Potential Energy (Treadmill)

Sum of the segments　　　　Thigh

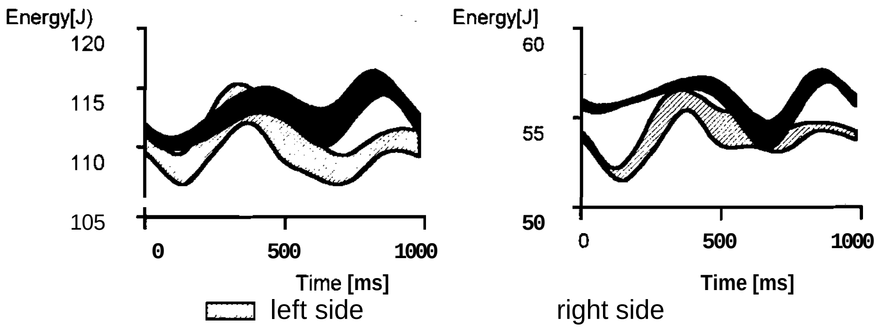

Figure 1 - a) Potential energy in walking on treadmill $(\bar{x} \pm sd)$ for the sum of the segments of the right and left side.b)Potential energy in walking on treadmill $(\bar{x} \pm sd)$ for thigh, of the right and left side.

A problem that was observed for almost all segments in the three energies was the greater difference between the right and left side of the body in the energy curves on treadmill in relation to overground. We can better analyse this difference by comparing the average results for the sum of the potential, kinetic and rotational energies for the upper extremity and lower extremity in walking on treadmill and overgound.The curves for both conditions have similar patterns, showing the left side of upper extremity a greater variability than the right side. However, the curves for left side in the treadmill condition seem to be a little dislocated downwards (Figure 2, a - b).

Lower Extremity

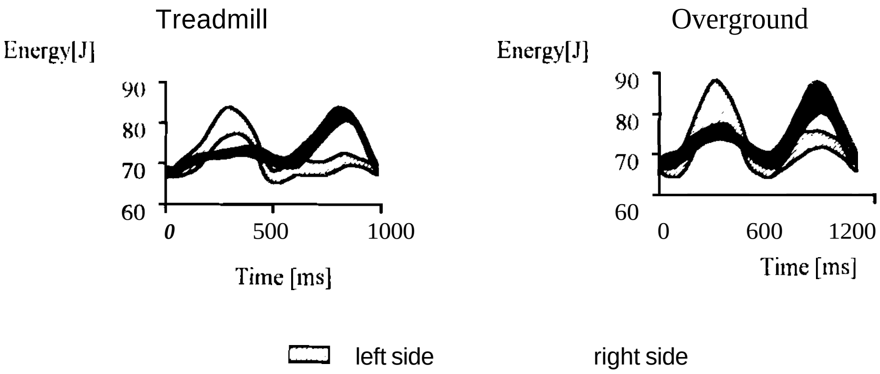

Figure 2 - Sum of the potential, kinetic and rotational energies ($\bar{x} \pm sd$) for : a) lower extremity in walking on treadmill and b) lower extremity in walking overground.

DISCUSSION

It was to be expected that the greatest lateral differences lay in the potential energy. Kinetic energy is not very influenced by the digitizing process as it does not have any input directly related to the length of the link. This happens for the potential and rotational energies. The rotational energy in walking shows this difference when we observe the different segments but it is still relatively little to be taken into consideration.

In respect to the potential energy, we can easily explain the greater difference in the thigh's curve. It has already been described (CORREA ET AL., 1995b), that after a manual digitizing process the difference between the average thigh's link for the visible and hidden side is around 25 mm, the standard deviation varying from 5 mm for the visible side to 18 mm for the hidden side.This variation in segment link was represented by the vector that connects two digitized points representing estimations of joint centers. The difference in the thigh's link could be derived from errors in the estimation of the joint center of the knee or of the hip. We described in this paper also the distance between the joint centers of the right and left side of hip (Dhip) and this distance varied by approximately the same amount as the thigh's link. So, undoubtedly the error is greater in the estimation of the thigh's joint center and this variation leads to the variability in the potential energy of the thigh.

LOOZE ET AL.(1992) described that the discrepancies they encountered within two different methods to estimate total power and its components (summed joint powers x rate of change of the summed segmental energy contents) during the performed lift testing were caused primarily by the variation in link lengths during motion. These discrepancies were reduced significantly using fixed link lengths.

The other variable to interfere in the lateral difference is the movement condition - treadmill x overground. It has already been noted (CORREA ET AL., 1995) that the segments' links on treadmill when compared to overground, showed greater variability. It was not however possible to establish a tendency for the individual comparisons between the conditions. We have observed in the energy curves also a greater difference between the right and left side on the treadmill condition, markedly for the lower extremity. These results suggest that the energy curves of the left side for walking on treadmill are more influenced by the lack of visibility of the markers than the curves obtained from walking overground.

CONCLUSIONS

According to our results the discrepancies in the energy calculation between the right and left side of the body are considerable, especially in relation to the potential energy of the thigh. We consider this is a parameter to be controlled when it is of interest to digitize the body landmarks for the whole body, having also an influence in the calculation of the total energy of the body. It is also important to stress that the variability between the energy curves of the sides appears to be different for overground and treadmill.

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