A STUDY OF THE MECHANICAL ENERGY DIFFERENCES BETWEEN TREADMILL AND OVERGROUND WALKING

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The aim of this paper was to analyze the components of the mechanical energy of the body considering the differences between treadmill and overground walking. One subject was filmed while walking at 1.5 m/s on treadmill and overground. The results show that the patterns of the curves are very similar, but the change in the total energy, both in the upper as in the lower extremity were greater on overground (23.20J and 17.47J respectively for overground and treadmill and for the upper extremity 4.91J and 2.56J). The potential energy change of the trunk was also greater on overground (overground 45.97J; treadmill 24.88J). These findings, showing a lower measured mechanical cost on treadmill address the problem whether the treadmill can be used as a valid simulator for overground walking.

KEY WORDS: mechanical energy, walking, overground, treadmill, videography

INTRODUCTION: Several studies have been conducted about the differences between treadmill and overground walking, most of them based on the study of kinematic parameters in the sagital and frontal plane, including stride, angle (Isacson et al., 1986, Taves et al.,1985) and temporal patterns. Only several have searched the differences involved in the mechanical energy changes in both forms of locomotion (Frischberg ,1983; Milani et al., 1988) and even fewer brought numerical results. The approach based on mechanical energy differences between the two forms is usually based on the theoretical energy transfer between the subject and the belt.
The aim of this paper is to analyze the different components of the mechanical energy (potential, kinetic and rotational) of the segments considering the differences between walking overground and on treadmill.

METHODS: A stride from one male subject was filmed with two video cameras (Sony-50 Hz) while walking at 1.5 m/s on treadmill and overground. Treadmill speed and overground walking speed variability were measured with photo cells. The subject was accustomed to treadmill walking. The cameras were positioned so that the distance from the camera lens to the subject was 7 meters and their focal axis formed an angle of 90° for both conditions. Each trial was repeated at least 3 times on overground and on treadmill it was filmed for at least 30 second. From the kinematics we performed a 3D analysis after a manual digitizing process. For each case: a) overground walking (Wo), b) treadmill walking (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 (Drills & Contini, 1966), both as revised by Winter (1979). 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 Zatsiorsky 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) the average curves of the potential, kinetic and rotational energies with their mean values and standard deviations for the right and left side of the body. For each side we calculated: a) the total amount of energy divided in upper extremity – sum of energies of: hand, forearm and upper arm and lower extremity – sum of energies of: foot, leg and thigh; b) the energy of each segment including the trunk; c) kinetic, potential and total energy of the center of mass (C.M.). The values of energy change were calculated by summing the differences between the minimal and maximal values for each subject's walking phase. We describe a complete cycle, from right heel strike (RHS) to the next RHS.

RESULTS AND DISCUSSION: The patterns of the kinetic, potential and total energy of the C.M. in treadmill and overground walking can be seen in Figure 1a, b, c. (Corrêa,1996; Corrêa et al., 1996).

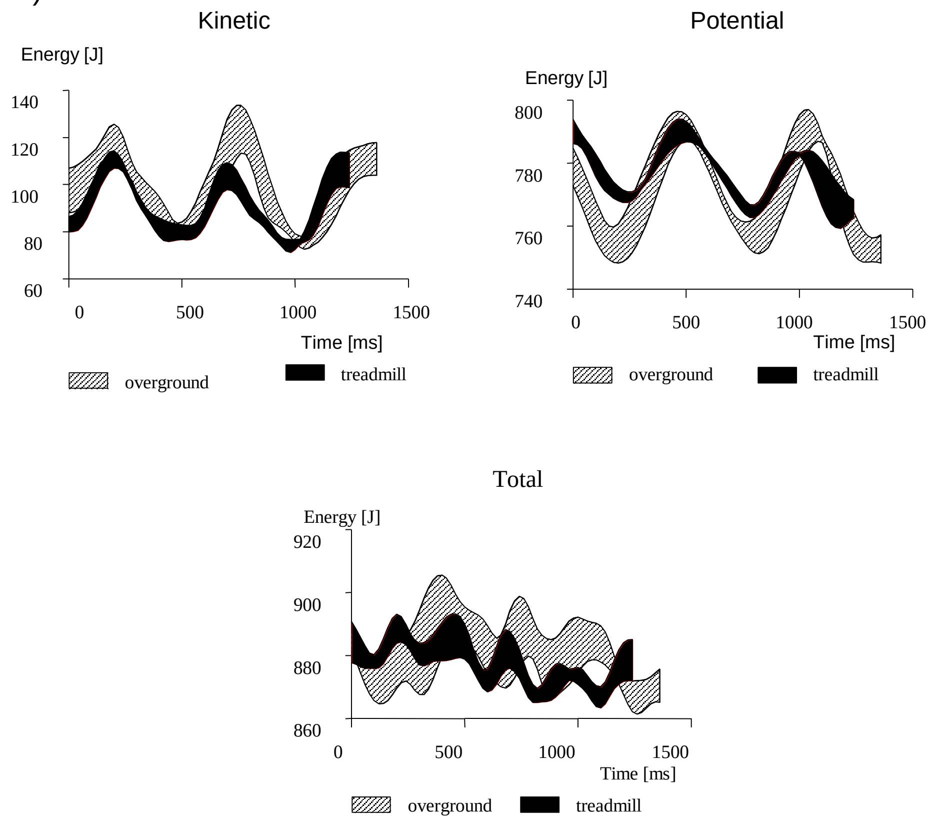

Figure1 - Average curves $(\bar{x} \pm sd)$ of kinetic, (a) potential (b) and total (c) energy for the C.M. of a subject walking at 1.5 m/s on treadmill and overground.

The similar patterns found for the energy curves in the two conditions – overground and treadmill – are to be expected because of the similarity of the movement in both conditions.
In Figure 2 a, b, c, d we can see the sum of the potential, kinetic and rotational energy for the upper and lower extremity in both conditions- treadmill and overground. Once more the patterns are very similar, but by examining the curves for both conditions, we observe that on treadmill the values show less amplitude, and for the lower extremity the values in the two phases of the curve show lower maximal values. The average values for the lower and upper extremities for both conditions are not considerably different, being for the lower extremity on overground 73.88 J and on treadmill 73.33J. However the change in the total energy, both in the upper as in the lower extremity were greater on overground (23.20 J and 17.47 J for overground and treadmill respectively and for the upper extremity 4.91 J and 2.56 J.)
In order to complete the study we compared the variability of the potential energy of the trunk on treadmill and overground, considering that the kinetic (in relation to C.M.) and the rotational were negligible. We can see in Figure 3 that, as observed for the lower extremity, the average values are very similar for both conditions (overground- 546,97 J; treadmill - 551,88 J) but the changes in energy were greater on overground (overground – 45,97J; treadmill – 24.88 J).

Walking – Total energy of the segments

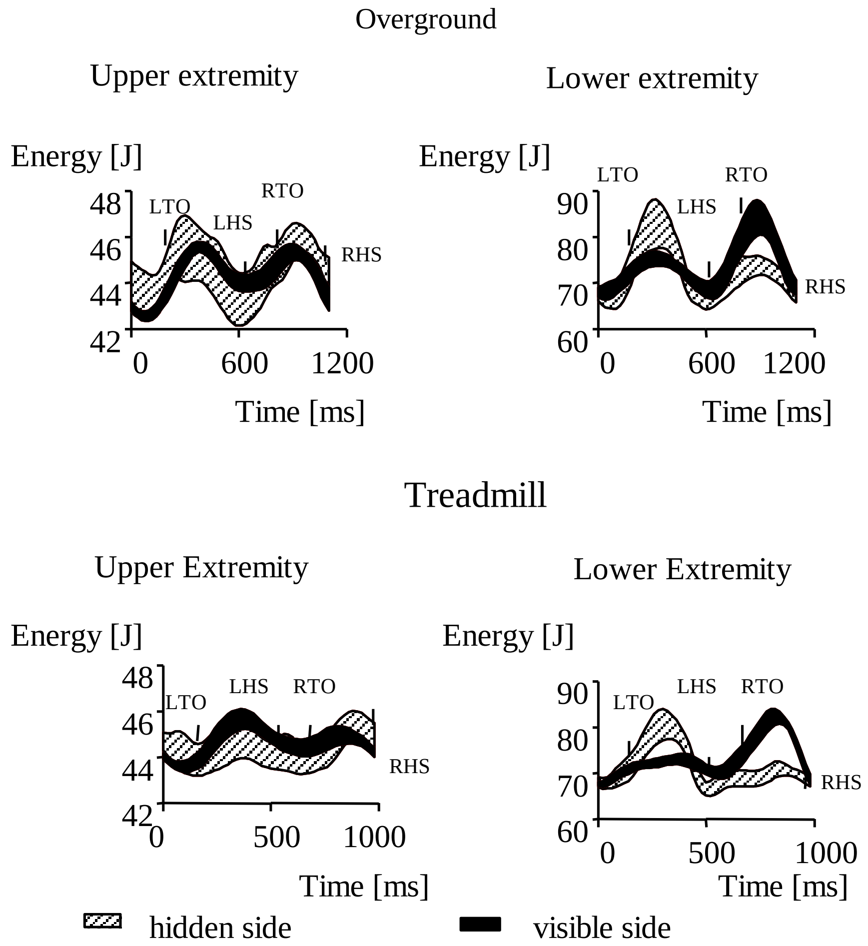

Figure 2 – Sum of the potential, kinetic and rotational energies for $(\bar{x} \pm sd)$: a) upper extremity in overground walking, b) lower extremity in overground walking, c) upper extremity in treadmill walking, d) lower extremity in treadmill walking.

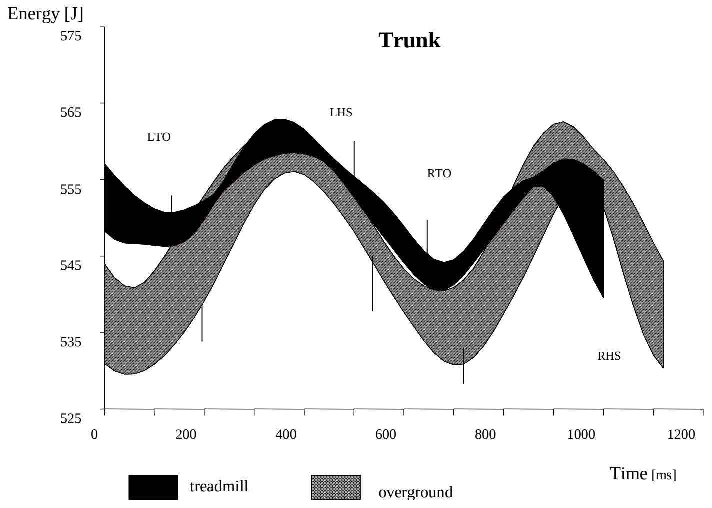

Figure 3 – Potential energy of the trunk for treadmill and overground walking. $(\bar{x} \pm sd)$

In order to better understand the reasons for these differences we compared some kinematic parameters in both conditions. On treadmill the subject showed: shorter stride length and faster stride rate, less range of motion in knee and ankle joints (respectively 5º and 10º) and less variability in the horizontal and vertical velocity of C.M.

These parameters and others together are responsible for the differences found in the calculated mechanical energy. The great advantage of using the mechanical energy as a tool for the comparison between the two conditions is that in one value we can examine the influence of several kinematic parameters. It's even more important when each variable by itself is not enough to show a significant difference between the two conditions.

CONCLUSION: According to our results there is a reduction in the mechanical energy costs on treadmill walking when compared to overground walking specially at the trunk and lower limbs. Generally speaking, analyses of several steps from one subject is not sufficient for universal application but we consider that as mechanical energy is a result of the combination of different kinematic parameters it is a tool that can be used to study the movement patterns in the two conditions and can bring a valuable contribution to the discussion whether a treadmill can be used as a valid instrument to simulate the kinematics of human locomotion during overground walking.

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