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MECHATRONIC AIDED WALK – A COMPARATIVE STUDY

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Abstract: *This work presents some differences and similarities, experimentally measured, between normal walking and mechatronically aided walking. A mechatronic system for the locomotory rehabilitation of disabled persons designed and realised by the authors was used. There are a lot of parameters to be considered, but the most important is to mechanically simulate a foot movement as close as possible to the natural one. In this respect, the intended work was to emphasize the "artificial noise" influence on normal gait. Goniometers were attached around the lower limb joints (hip, knee and ankle) and the angular displacement of each joint was recorded. The results were compared to depict the main differences between natural walk and the mechatronically assisted one. The authors propose a new, fast method of tracking locomotory disorders.*
Key words: *gait analysis, mechatronic, locomotion, human walking*

1. INTRODUCTION

Bipedal walking is one of the most important features of humans. The vital importance of the feet is obvious: no feet, no gait. The poorer the functional performance of the feet, the lower the functional performance of the gait. The feet's architectural design and its consequent biomechanical function is responsible for our distinctive erect manner of gait - walking on two feet with a stride (Font-Llagunes & Kövecses 2009; Lei et al. 2006).

The designing and assembling of the mechatronic system for assisting the rehabilitation of locomotory disabled patients (MS) was presented in several papers (Filipoiu et al., 2007; Seiciu et al., 2008; Seiciu et al., 2009). The experiments made on MS lead the authors to the conclusion that a more thorough study of the walking is needed in order to improve the MS functioning (Seiciu et al., 2008). The main goal is an improved design of the feet driving system, since this is the most complex feature of the MS, mainly due to the feet complex movement.

The present study shows the experimental measurements using the same subjects in normal walking (NW) and in mechanically aided walking (MAW). It is, emphasized that changes at the feet level have consequences far distal, from ankle to hip in all kinematic parameters.

2. MATERIALS AND METHODS

One male subject (age 24 years; height 183 cm; weight 80 Kg) took part in this experiment. The subject performed several walking trials. Two walking situations were studied: NW using a conventional treadmill and MAW using the MS. Each trial took 20 seconds.

Kinematic data were collected at 200Hz using Biometrics goniometers (Biometrics Ltd, Gwent, United Kingdom) placed at lower limb joints (ankle, knee and hip – see fig. 1). Raw kinematic data was filtered by applying a 50 Hz low-pass filter.

One angular displacement (Flexion-Extension) was recorded for the ankle and the knee and two angular displacements (Flexion-Extension and Abduction-Adduction) were recorded for the hip joint. Angular velocities and accelerations were derived from joint displacements (Seiciu, 2009; Hardy 1987). The knee abduction-adduction measurements were excepted because of lack of mobility while using the MS.

Fig. 1. Electro-goniometers layout

3. RESULTS

From the kinematic point of view there are many similarities and a few differences between NW and MAW.

The *similarities* between NW and MAW are:

- The knee flexion–extension measurements (fig. 2a) have almost the same amplitude and phase.
- The hip abduction–adduction measurements (fig. 2d) have almost the same amplitude and phase.

The *differences* between NW and MAW are:

- The hip flexion–extension measurements (fig. 2c) present a significant amplitude variation.
- The angular movement amplitude for flexion-extension is variable for all MAW measurements while, as expected, the NW angular amplitude is almost constant (fig. 2a, 2b and 2c).
- The ankle flexion-extension measurements (fig. 2b) present the largest variation both in amplitude and phase.

The authors propose *a new method* to assess the gait quality. This method implies the following:

- The differences between NW and MAW can be observed and measured.
- The differences are observable for all the leg joints. This paper concentrates on the gait differences at the hip joint (as seen in fig. 2d).
- The analyzed differences are defined by: *angle deviation* ($\delta\varphi$) and *pitch deviation* (δt). The angle deviation can have positive or negative values. The pitch deviation can be in advance or delay.

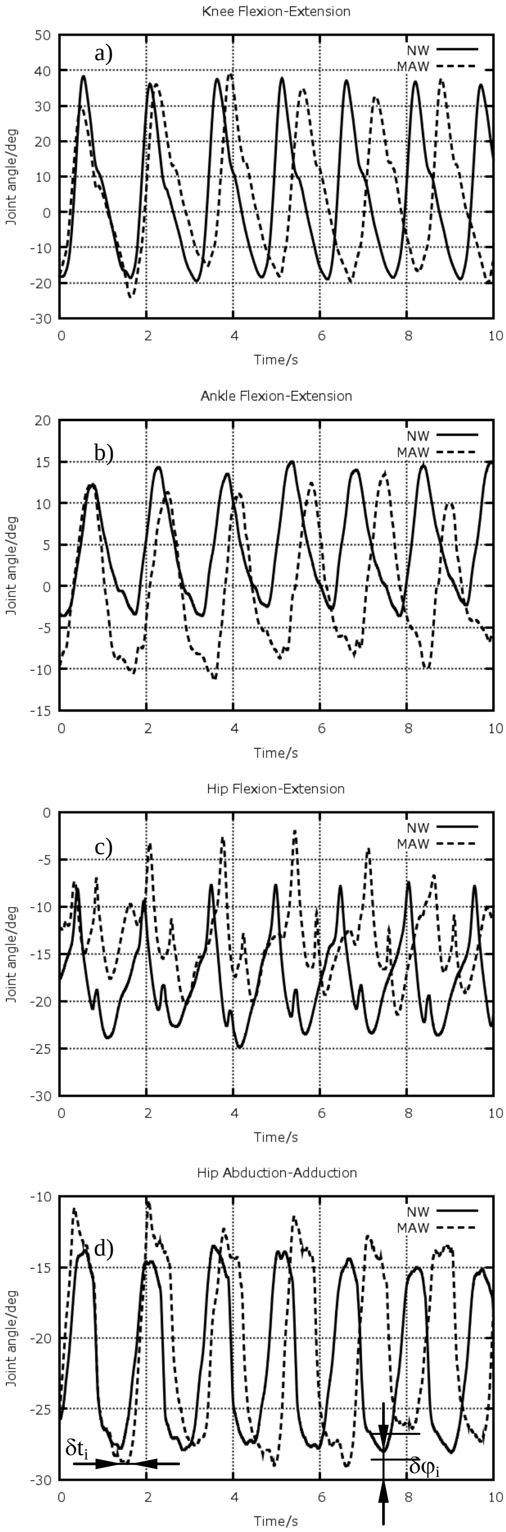

Fig. 2. Comparison of NW and MAW with respect to angular displacement for: a) ankle, b) knee, c) hip-FE and d) hip-AA

- For an accurate analysis these deviations are calculated for each step (denoted with index n). For improved accuracy the calculation can be done for a large number of steps.

With these values, we can determine the absolute deviations:

- *Absolute pitch deviation* (APD):

$$\Delta \mathrm{T} = \frac{\sum_{i=1}^{n} \delta t_i}{n} \tag{1}$$

- *Absolute angular deviation* (AAD):

$$\Delta \Phi = \frac{\sum_{i=1}^{n} \delta \varphi_i}{n \varphi_{\max}} \tag{2}$$

where n is the number of measured gait cycles and φ_{max} is the maximum angular amplitude of the joint.

APD is calculated by taking into account the pitch deviations for all gait cycles, while AAD is calculated by taking into account the angular deviation at the same moment relative to each gait cycle.

For a more profound analysis one can use the means of non-linear analysis such as the Lyapunov exponent or the system entropy. The most used method is the calculation of the Lyapunov exponent, which requires a large number of cycles and therefore being more time consuming.

The method presented in this paper implies the calculation of angular and pitch deviations and is a fast way of assessing locomotory disorders. The required data is obtained for two types of gait: normal walking (NW) and mechanical aided walk (MAW). This method does not require the use of a complicated mathematical model and is not time consuming.

4. CONCLUSION

The mechatronic system is fit for locomotory rehabilitation though several improvements have to be done in order to achieve a MAW similar to NW.

In NW measurements the variability of joint angular displacement amplitude was significantly greater than in MAW case. The lack of mobility at metatarsophalangeal articulations, in MAW, leads to increased amplitude in ankle flexion-extension.

Understanding how mechanical aided walk influences gait parameters and postural stability is helpful mainly in locomotory rehabilitation (gait disorder and joint degeneration prevention) but also in other connected domains such as high performance sport.

This method does not exclude the non-linear analysis which is necessary for more detailed studies.

This is only a preliminary study, further measurements performed on numerous subjects being intended for the future.

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