Characterization of the motor control of gait by measuring stability and rhythmicity from linear acceleration signals: A pilot study

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INTRODUCTION

The maintenance of stability during gait is a process which involves neural, kinetic and kinematic mechanisms for it to be effective [1-3]. One of the alternatives for the study of gait stability is by measuring the harmonics ratios and the variability of the accelerations of the head and pelvis [4-9]. The classic gait models allow us to understand a few aspects of gait, but are limited by either being incomplete or inapplicable [2]. Some of these limitations have been solved by the "Dynamic Walking Model", mainly by the proposed methods of gait stabilization [2]. The model states that a complete stride can be controlled by passive dynamics and that there may be active control before or during the double support phase.

However, the dynamic walking model doesn't incorporate the benefits of active control in other areas or limbs other than the inferior limbs [2]. There are studies that have shown a method to measure the rhythmicity and dynamic stability during gait, to help characterize the motor control during gait [4-11]. Studies of this nature have not been done in Chile, which in turn makes it difficult to obtain an objective parameter as to the effects of treatments which may affect the motor control of gait.

The objective is to give a first look at the characterization of the motor control during gait by using as parameters the rhythmicity and dynamic stability of the head and pelvis of young healthy Chilean adults.

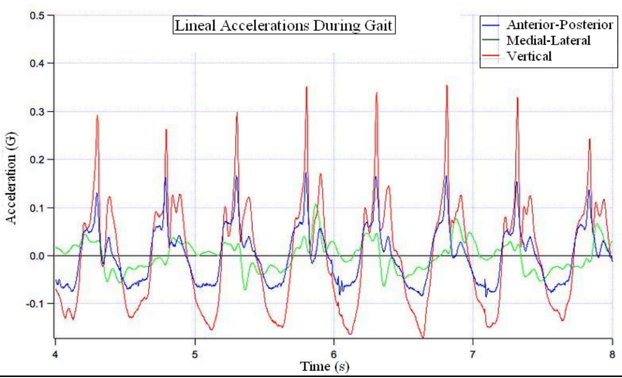
METHODS

A cross-sectional observational pilot study was performed, with a descriptive emphasis, where the harmonics ratio (rythmicity) and root mean square (stability) of gait are measured using lineal acceleration signals. An EMG Delsys Bagnoli with a ± 3.6g triaxial accelerometer was used. The signals were processed in IGOR PRO 6.2.

The Harmonics Ratio (HR) indicates the smoothness and rhythmicity of the acceleration patterns during gait. It is based on the premise that the unit of measurement is the stride. For gait to be considered rhythmic, it must consist of accelerations that occur in variables of two within any stride during gait, because these patterns must be competed before the beginning of a new stride. Acceleration patterns which don't repeat in multiples of two are problematic, given that these are accelerations that occur out of phase and don't complete within each stride, therefore these manifest irregular accelerations during gait [7]. It's measured on a continuous quantitative scale where a higher value indicates gait which is smoother and mot rhythmic.

Mathematically, the HR in the medial-lateral axis is calculated as the quotient between the summation of the power spectrum of the twenty first un-even harmonics and the summation of the power spectrum of the first twenty even harmonics. For the vertical and anterior-posterior axis, said quotient is inverted.

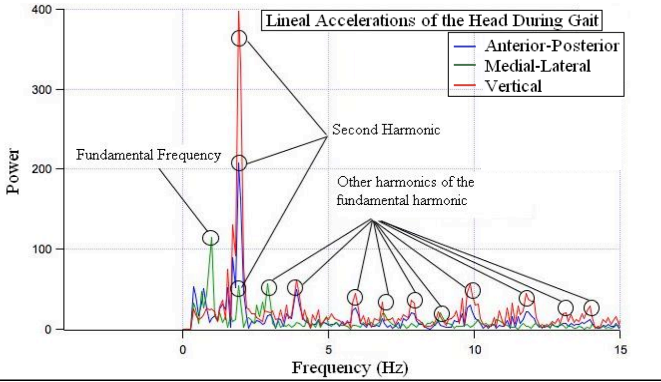
The Root Meat Square (RMS) is a measurement of the dispersion of the data with respect to zero, which opposes the standard deviation, which is the dispersion in relation to the mean. However, as the accelerations are transformed to give a mean of zero, in this case the RMS is an equivalent of the standard deviation [7]. It's measured on a continuous quantitative scale, where a value closer to zero indicates an acceleration of lesser magnitude, which in turn indicates a more stable gait.



Graph 1: Lineal accelerations in relation to time. All accelerations are transformed to give a mean of zero.

RESULTS AND DISCUSSION

Statistical analysis: The distribution of the data was analyzed using the Kolomogorov – Smirnov test, which has an h = 0 where the distribution of the values is non-parametric. The data obtained after the calculation of the

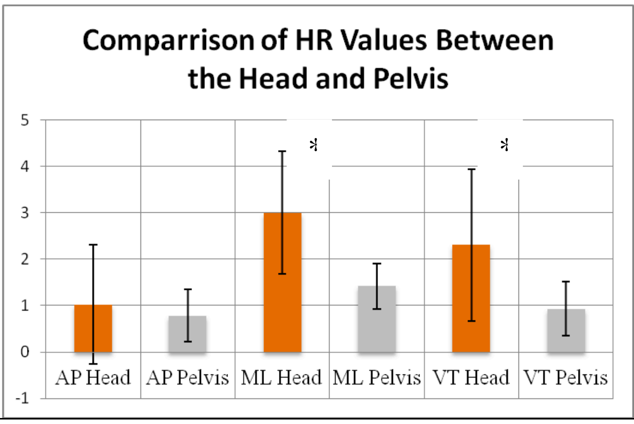


Graph 2: Analysis of the acceleration signals within the frequency domain, for the recognition of the harmonics of the fundamental frequency.

HR and RMS at the head and pelvis present a non-parametric distribution for all three axes at both the head and pelvis (p value < 0.01). As no sample had a parametric distribution, the median was used as the central tendency value to describe the samples, due to its low sensitivity to the extreme variations of the data.

In line with the non-parametric distribution of the samples from the head and pelvis, the differences of HR and RMS between the head and pelvis in the three axes were calculated using the Wilcoxon test.

The results show a tendency towards greater rhythmicity and stability at the head in the medial-lateral axis, greater rhythmicity in the vertical axis and greater stability in the anterior-posterior axis, compared to the values obtained at the pelvis (p value < 0.05).

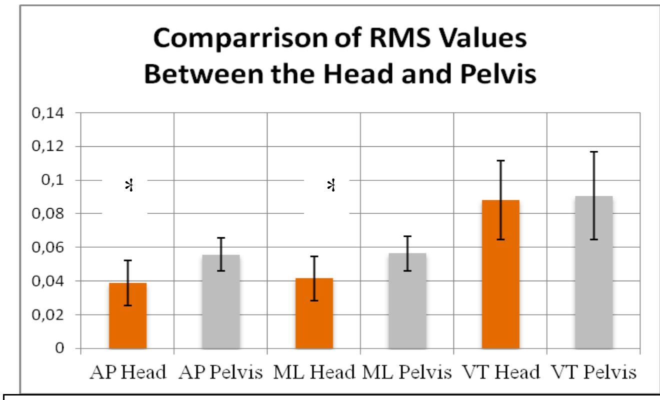


Graph 3: The values of the HR are greater in the ML and VT axes (* indicates a p value < 0.05), compared to the complementary axes in the pelvis.

These results are in line with other studies using the same method of analysis in young and healthy populations [4-9]. One important aspect of motor control during gait is the stabilization of the head, which can be attributed to the important sensorial systems in the head [12]. These results are useful to understand how the active control systems act and interact at and between the head and pelvis during gait.

CONCLUSIONS

The data obtained in this study complement the Dynamic Walking Model, given that active control tends to prefer



Graph 4: The values of the RMS are greater in the ML and AP axes (* indicates a p value < 0.05), compared to the complementary axes in the pelvis.

stabilizing the head, by giving it more rhythmic movements and by attenuating the effects of the collision during the initial contact and loading phases of the stride. The data obtained during this study could be useful for future studies using this method of gait analysis in Chile.

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