Measurement of Spinal Rotation In Gait

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Abstract—**This project determined the spinal rotation during gait walking and compared an experimental group of subjects trained in the Core Integration Method to a control group. The angle of the spine was measured using a potentiometer which calculated the movement of the back at the T12 vertebra in the transverse plane. The average angles of the experimental group were 37.1% higher than the control group. Other parameters such as angular velocity, angular acceleration, stride rate and stride length were also compared.**

I. Introduction

One of the main components in human gait is spinal rotation. This aspect of gait has not been well researched, and is still poorly understood. This study further reveals its significance in gait efficiency. Axial rotation of the spine is observed during human gait because the spine is a segmented rod with various articulations between these segments. Earlier studies have proved that the resultant forces (both vertical and rotational) on lumbar discs and facet joints during walking reach 2.5 times the body weight. Another study has also demonstrated that the absence of (restricted) spinal movement results in shorter stride length, slower velocity and higher energy consumption in walking.. Spinal rotation is involved during various daily routine activities we do such as running, turning, lifting, as well as recreational activities like squash and tennis. However, the extent to which this rotation plays a role in these activities varies. It is also documented that excessive rotation of the spine among industrial workers involving torquing, or stressing spinal joints is directly linked to 60% of major back injuries.(Kumar).

To do this study, we fabricated a device which measured spinal rotation during walking gait. The project involved the recordings of data of two groups of people: a] the control group which consisted of 15 subjects. b] the experimental group of people trained by Dr. Josef DellaGrotte in walking gait and posture based on the method of Core Integration and principles of Feldenkrais. The hypothesis being tested was whether the experimental group would show a significant difference (with possible implications of benefits from walking more efficiently to joints and tissues) from the control group: mostly age- based between 18-22 years, exercise and athletically active and not. Testing revealed that the experimental group did show a marked statistically supported difference in angle of rotation when compared to the control group. The two groups were compared based on their angles of rotation, velocity of rotation, strides and stride length.

II. Methodology

A. String Potentiometer

A string potentiometer resembles a 'yo-yo'; its resistance changes on pulling the string. The string potentiometer was set up such that the string stretched outward as the body moved forward while taking a stride. The length of the string pulled out varied linearly with its resistance. The potentiometer is powered by a fixed voltage source such as a battery and as its resistance changed; a change in output voltage was recorded. The output voltage formed the basis of our experiment and acted as an input signal to a data acquisition card and the data was analyzed on a computer using LabVIEW.

Figure 1: A String Potentiometer

B. Setup

The setup involved a simple elastic belt which was attached to a light long piece of wood. Rotation of the spine was measured at the twelfth thoracic vertebra (T12) where maximum rotation was expected to be seen. The string potentiometer was attached at the end of the wooden strip, enclosed in a case. This case also helped in putting the potentiometer at the right place so that the potentiometer is closer to the skin and the T12. The case could slide up and down of the wooden piece so as to accommodate people with different heights. Thus, as the subject walked, the T12 moved, which pulled out the string of the potentiometer, thereby changing the output voltage and the signal was generated.

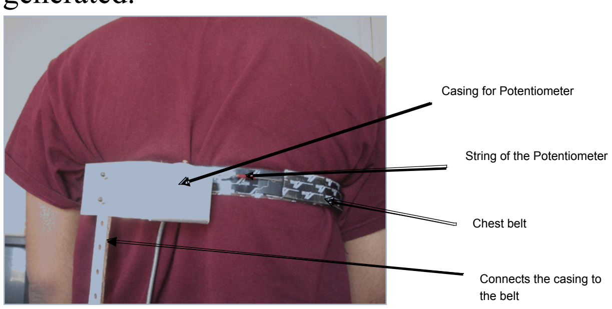


Figure 2: Positioning of the device on the back

C. Calibration

For using simple calibration techniques, the string was pulled out of the potentiometer and the readings were taken for voltage change for different lengths. The derived equation from these values was:

y = (x*4.35-2.644)/0.5*width of the back

y is the angle of rotation in radians

x is the length of the pot which is extended

D. LABVIEW

The LabVIEW program designed included several components for analyzing the data. The potentiometer was calibrated and the potentiometer specs were used to calculate the distance moved by the string in the transverse plane. Before the readings were recorded, the width of the back of each subject was recorded (as described in protocol and user guide). Using the width of the back and the distance moved by the back in the transverse plane, the angular rotation of the spine was calculated by the formula:

$$\_ = l/r$$

Where, l is the distance moved by the back in transverse plane

r is half the width of the back

In addition to this, a trigger counter counted the peaks in the signals corresponding to the largest angle in each stride and gave the number of strides in the period when the data was being recorded. The LabVIEW program also calculated the maximum angle taken by a subject. The LabVIEW program yielded out an excel spread sheet of data with continuous measurement of the angle of rotation where it was further analyzed. Also, MATLAB is used to analyze the data to calculate the angular velocity and the angular acceleration of the spine by differentiating the signal.

III. Results and Discussion

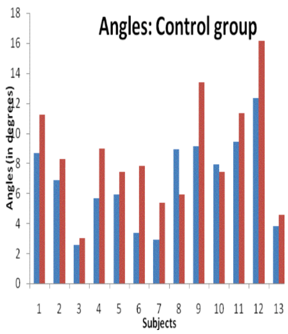
The measurements were made at three different speeds of the treadmill, namely, 1.5 mph, 2.5 mph and 3.5 mph and the angle of rotation, angular velocity, angular acceleration, strides per minute and stride length were calculated and compared at all the speeds. On an average, the angles of rotation and strides per length increased as the speed of the treadmill increased in both the groups. In the control group, the stride length did not seem to have a significant dependence on gait velocity. This could be accounted for by the fact that, while some subjects took longer strides as the velocity increased, others took more steps of shorter stride length. However, the stride length was seen to increase with gait velocity in the experimental group as all the subjects in this group has a similar gait as they were trained under the Core Integration method.

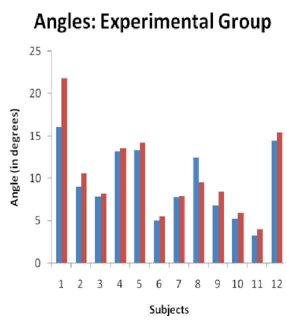
The angular velocity and acceleration were also seen to increase with gait velocity, and their dependence was tested by doing a regression analysis. Although, the test showed that there is a relationship, this outcome was not significant enough to establish a definite relationship as the readings were taken at three different speeds only.

The table below summarizes our findings.

	Control Group		Experimental	
Gait Velocity	2.5 mph	3.5 mph	2.5 mph	3.5 mph
_ (in degrees)	6.3	8.5	9.6	10.4
_' (Angular Velocity)	2.4	4.3	6.5	7.3
_'' (Angular Acceleration)	2.4	5.0	8.9	10.2
Stride rate (stride/minute)	112	151	126	141
Stride Length (in meters)	0.6	0.6	0.5	0.7

Paired t-tests were done to account for statistical difference in angles, angular velocity, angular acceleration, stride rate and stride length. It was observed that the experimental group had higher angles, angular velocity, angular acceleration, stride rate than the control group. Having a higher angle of rotation did not imply higher angular velocity and angular acceleration; this statistical difference probably arose because the experimental group had an altogether different gait





The device designed was sensitive up to a percentage error of 4.1% and was consistent in its measurements. It was also determined that there was no statistical difference in the data recorded in men and women.

IV. Conclusion

The results obtained proved the hypothesis as the control group had an average angle of 6.9^0 as opposed to 9.6^0 of the experimental group (39.1% higher). Higher stride rate, angular velocity and angular acceleration were recorded for the experimental group when compared to the control group. It was not possible to establish a definite relationship between efficient gait and spinal rotation based on the current design. However, a future modification can be made in the device to measure rotation at other thoracic vertebra which could establish a possible relation.

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References

[1] Kumar, Shrawan. "Ergonomics and biology of spinal rotation." The Ergonomics Society. Edmonton, 2003. 370-415