STEP RATE MONITOR FOR GAIT ANALYSIS

Carmen Coddington[1], Christa Wille[1]

Advisor: Mitchell Tyler[1] Client: Bryan Heiderscheit[2], PT, PhD

Departments of Biomedical Engineering[1] and Orthopedics & Rehabilitation[2],

University of Wisconsin - Madison

Abstract

With an increase in the popularity of running, an increase in the occurrence of running related injuries is also apparent[1]. Excessive knee joint loading has been recognized as one of the most common factor when predicting the outcome of injury[2]. A common outcome for altering joint loads during running is with an increased step rate (number of steps per minute). By achieving a reduction in joint loading, an injured runner may be enabled to continue running without aggravating symptoms, while receiving care for their injuries. Thus, it is important to monitor step rate during a running analysis. Fabrication of the device has resulted in a prototype that successfully calculates step rate in real time, while providing visual feedback to the clinician.

Motivation

- 56% of recreational runners will sustain a running related injury each year[3]
- Excessive joint loading is a common risk factor[4,5]
- Modifying applied load may be one injury prevention strategy
- Manipulating a runner's step rate can be used to achieve a reduction in applied loads
- Currently, there are no devices that calculate step rate
- **Aim**: To create a device that will identify a runner's step rate while on a treadmill with minimal setup time for use in a clinical setting.

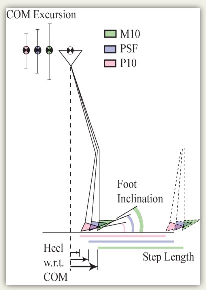


Figure 1 (left). Kinematic changes that occur due to a modification of step rate, a comparison between preferred stride frequency (PSF) and 10% above (P10) and 10% below (M10) PFS. With an increase in step rate a decrease in stride length, foot inclination angle, center of mass (COM) vertical excursion, and the distance from heel to COM at initial contact will be observed.

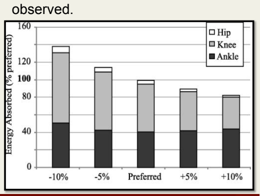


Figure 2 (right). Changes in energy absorbed as step rate is modified. An increase in step rate will result in a decrease in energy absorbed.

Methods

- Subjects ran with a digital audio metronome to ensure we could accurately identify their step rate
- Accuracy was based upon whether or not the step rate monitor had a sensitivity less than the average variability of a runner's step rate (3%)

Subject Characteristics	
Males:Females	5:6
Height (ft)	5.2-6.4 (±0.27)
Weight(lbs)	128–205 (±26.2)
Speed(min/mile)	7-10 (±1.04)
Preferred Step Rate (steps/min)	146-174 (±10.5)

Table 1 (left). Subject characteristics. Subjects with a wide variety of anthropometric data were chosen to ensure that our design works for all types of runners.

Final Design

Block Diagram

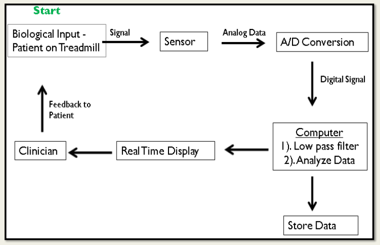


Figure 3 (above). Final design block diagram. The design needs to collect analog data, convert it to digital, and manipulate it to determine the step rate.

Data Processing

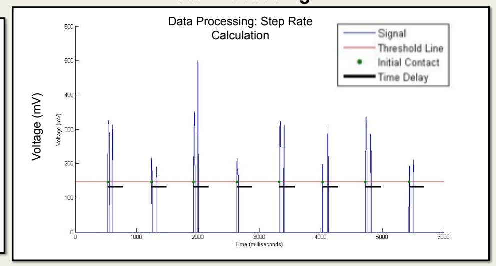


Figure 4 (above). Graphical representation of the key values to calculate step rate. A calibration period is used to identify key parameters such as threshold and the time delay. Data is then filtered and all values below the threshold are set to zero. Every time the signal crosses the threshold, a step is counted and the time delay begins to ensure that multiple vibrations are not counted for a single step.

User Interface

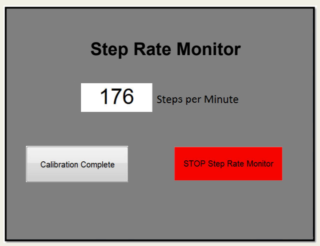


Figure 5 (above). User interface that is displayed to indicate the runner's step rate.

Attachment

Figure 6 (above). Method of attachment. Aluminum angle bracket is used to position accelerometer in the correct orientation. Neodymium magnets are used to secure to treadmill.

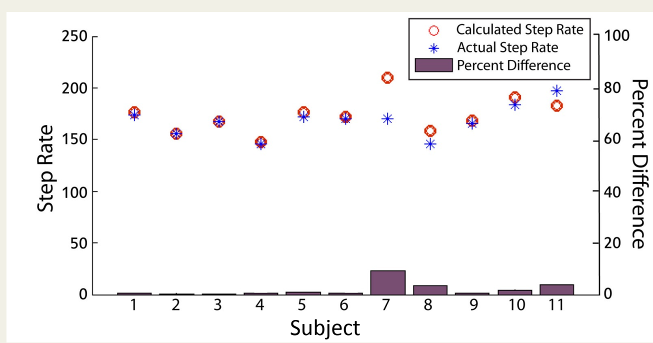
Cost Analysis

Item	Price
Accelerometer (1)	$275
Magnets (4)	$8.00
MatLab (1)	$500
Signal Conditioner (1)	$495
DAQ System (1)	$1,479
Total Cost	$2,757

Table 2 (above). Total cost of materials in a single prototype: $2,757. These calculations assume the facility will have a access to a computer.

Testing

Figure 7 (right). Plot comparing the step rate identified with our step rate monitor to the actual step rate of the runner. **Average percent difference was 4.7%.**



Criteria and Specifications

Specifications:

- Uniaxial accelerometer (PCB Piezotronics, model U353B16)
- Attachment method: 4 neodymium magnets
- Placement: Front, center on support beam below treadmill belt
- DAQ System: NI USB-6212 , MatLab DAQ Toolbox

Criteria:

- Compatible with clinical treadmill created by Standard Industries
- Must not compromise the infrastructure of the treadmill
- Must not interfere with the runner on the treadmill
- Accurately identify step rate of an individual (within 3%)
- Feedback of runner's step rate updated frequently
- Identified step rate must be displayed in real time

Future Work

SmartPhone App

- Move interface to an application on SmartPhones
- Can be used in fitness centers by connecting to pre-instrumented treadmills
- Improve accessibility and marketability

Reduce Cost

- Use a different method of programming to eliminate cost of a MatLab license
- Determine the effectiveness and accuracy of a microcontroller to identify step rate

Improve Signal Filtering

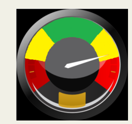
- Reduce noise while retaining biologically relevant data
- Increase magnitude of relevant data to improve signal to noise ratio

Further Testing

- Make algorithms more robust to improve accuracy with diverse body types and running styles
- Determine the effectiveness of the device on different clinical treadmills

Device Interface with Runner

- Provide visual relevant feedback for runner in the form of a graph of step rate versus time or speedometer
- Displaying a "green zone"
- This will facilitate altering step rate



Acknowledgements

- UW – Madison
  - Mitchell Tyler
  - Gerhard van Baalen
  - Amit Nimunkar
  - James Madsen
  - Carrie Frances
- Aldo Arizmendi, National Instruments
- Deborah Yagow, National Instruments
- Chiung-Yi Tseng, Mathworks
- Former teammates:
  - Bryan Jepson, Joel Schmocker
- Peter Erskine, National Instruments

References

[1] USA Track and Field Road Running Information Center. State of the sport report [online]. Available from URL: http://runningusa.org/node/57770#58008 [Accessed 2010 Nov 28].

[2] Messier SP, Legault C, Schoenlank CR, Newman JJ, Martin DF, DeVita P. Risk factors and mechanisms of knee injury in runners. *Med Sci Sports Ecerc*. 2008 Nov;40(11):1873-9.

[3] Dierks, T.A., K.T. Manal, J. Hamill, and I.S. Davis. Proximal and distal influences on hip and knee kinematics in runners with patellofemoral pain during a prolonged run. *J Orthop Sports Phys Ther*. 38:448-456, 2008.

[4] Buff, H., L. Jones, and D. Hungerford. Experimental determination of forces transmitted through the patello-femoral joint. *J Biomech*. 21:17-23, 1998.

[5] de Leva, P. Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics*. 29:1223-1230, 1996.

[5] Heiderscheit et al. Effects of step rate manipulation on joint mechanics while running. *MSSE*. 2011 Feb;43(2):296-302.