Gait and Posture Responses to backpack load

Mohamed A. Sayari [#], Amur Al Yahmedi[*] , and Neila Masmoudi [#]

[*] Mechanical & Industrial Engineering
College of Engineering
Sultan Qaboos University
P.O. Box 33, Al-Khod 123
Sultanate of Oman
amery@squ.edu.om

[#] Electromechanical Systems Laboratory (LASEM),
National Engineering School of Sfax
University of Sfax, BP 1173
3038, Sfax – Tunisia
neila.masmoudikhabou@enis.rnu.tn
sayariaminemm@gmail.com

Abstract

The role played by the trunk in gait is relatively unexplored in the literature. Considering that the upper body makes up two third of the body weight and to look at its role as being purely passive is a puzzling hypothesis. This paper investigates the postural strategies to adapt to walking with a backpack load. The aim of the current work is to explore the possibility of using simple models to study the role played by the upper body during specific tasks (in the present reported work walking up an inclined surface with a backpack).

The simple model used in this paper depict the body as being made up of a hip of mass m_H at a position (x_H,y_H) at time t, and a trunk of mass m_T at a position (x_T,y_T). The trunk is modulated via a torque τ between the stance leg and the trunk. It is assumed that the legs are massless. The fluctuations of the leg length $q(t)$ due to flexion of the lower joints, namely, hip, knee and ankle are incorporated in a single telescopic axial actuator that carries a compressive force $F(t)$. The leg has a maximum allowable leg extension, such that $\sqrt{x_H^2 + y_H^2} = R + q(t)$, where R is the nominal length of the leg. It is assumed that during the stance phase, the foot in contact with the ground does not slip, and at most one foot can be in contact with the ground at any given time, and that there is no flight phase. The left and right legs have identical force and length profiles.

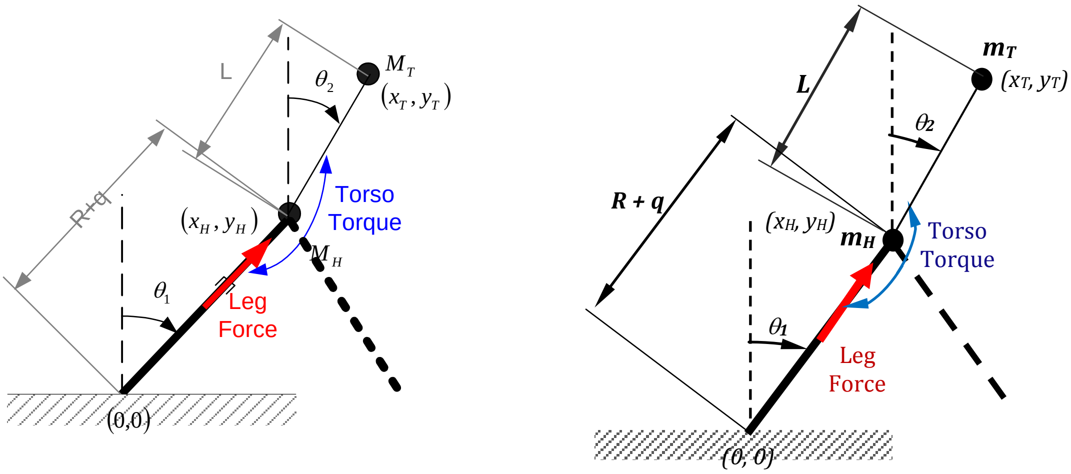

Figure 1: A Schematic of the model used

A gait is characterized by the position and velocity of the hip mass and trunk mass, by the step period and by $F(t)$ and the torque $\tau(t)$ and the maximum allowed leg extension. The equations of motion were derive using Lagrange formulation and yielded the following dynamic equations:

$$(R+q)^2(m_H+m_T)\ddot{\theta}_1 + (R+q)Lm_T\cos(\theta_1-\theta_2)\,\ddot{\theta}_2 + 2(m_H+m_T)(R+q)\dot{q}\dot{\theta}_1 + (R+q)Lm_T\sin(\theta_1-\theta_2)\,\dot{\theta}_2^2 - (R+q)g(m_H+m_T)\sin(\theta_1) = \tau \qquad (1.a)$$

$$(R+q)Lm_T\,cos(\theta_1-\theta_2)\,\ddot{\theta}_1 + L^2 m_T\ddot{\theta}_2 + Lm_T\,sin(\theta_1-\theta_2)\,\ddot{q} - Lm_T\,sin(\theta_1-\theta_2)\,(R+q)\dot{\theta}_1^2 + 2Lm_T\,cos(\theta_1-\theta_2)\,\dot{q}\dot{\theta}_1 - Lm_T g sin(\theta_2) = -\tau \tag{1.b}$$

$$Lm_T\,sin(\theta_1-\theta_2)\,\ddot{\theta}_2 + (m_H+m_T)\ddot{q} - (m_H+m_T)(R+q)\dot{\theta}_1^2 - Lm_T\,cos(\theta_1-\theta_2)\,\dot{\theta}_2^2(m_H+m_T)g\,cos(\theta_1) = F \tag{1.c}$$

Where, θ_1, θ_2 are as defined in Fig. 1, L is distance from hip to the center of mass of the torso, and g is the gravitational constant. To reduce the number of parameters scaling was used. Scaling shows its effectiveness in gait analysis and meant that the equations are not anymore belonging to any dimension thus the person could be treated as an ensemble of ratios.

After scaling the equation of the model using, $M = m_T + m_H$; R, g and $t_c = \sqrt{R/g}$, the only two free parameters remaining are m_T/M and L/R. The optimizer will seek solutions as three parameters are varied, namely, normalized speed V, and normalized step length D and m_T/M. The remaining parameter, namely L/R will be fixed.

References

[1]. Amur S. AlYahmedi, Mohamed A. Sayari, “Efficient Walking Of A Simple Biped With a Torso”, Middle East Conference on Biomedical Engineering, 17-20, February 2014, Doha, Qatar

[2]. K.M. Jackson, “Why the upper limbs move during motion”, J. Theor. Biol.(1983), 105, 311-315.

[3]. Małgorzata Syczewska, Tommy Öberg, Dan Karlsson, “Segmental movements of the spine during treadmill walking with normal speed, Clinical Biomechanics, Volume 14, Issue 6, July 1999, Pages 384-388, ISSN 0268-0033, http://dx.doi.org/10.1016/S0268-0033(99)00003-0.

[4]. Alain Leroux, Joyce Fung, Hugues Barbeau, “Postural adaptation to walking on inclined surfaces: I. Normal strategies”, Gait & Posture, Volume 15, Issue 1, February 2002, Pages 64-74, ISSN 0966-6362, http://dx.doi.org/10.1016/S0966-6362(01)00181-3.

[5]. Stephen D. Prentice, Erika N. Hasler, Jennifer J. Groves, James S. Frank(2004), “Locomotor adaptations for changes in the slope of the walking surface”, Gait & Posture, Volume 20, Issue 3, December 2004, Pages 255-265, ISSN 0966-6362, http://dx.doi.org/10.1016/j.gaitpost.2003.09.006.

[6]. Andrea N. Lay, Chris J. Hass, Robert J. Gregor(2006), “The effects of sloped surfaces on locomotion: A kinematic and kinetic analysis”, Journal of Biomechanics, Volume 39, Issue 9, 2006, Pages 1621-1628, ISSN 0021-9290, http://dx.doi.org/10.1016/j.jbiomech.2005.05.005.

[7]. Devjani Saha, Steven Gard, Stefania Fatone(2008), “The effect of trunk flexion on able-bodied gait”, Gait & Posture, Volume 27, Issue 4, May 2008, Pages 653-660, ISSN 0966-6362, http://dx.doi.org/10.1016/j.gaitpost.2007.08.009.

[8]. Serge Gracovetsky, “Is the lumbodorsal fascia necessary?”, Journal of Bodywork and Movement Therapies, Volume 12, Issue 3, July 2008, Pages 194-197, ISSN 1360-8592

[9]. S Gracovetsky, “An hypothesis for the role of the spine in human locomotion: a challenge to current thinking”. Journal of Biomedical Engineering 08/1985; 7(3):205-16. DOI:10.1016/0141-5425(85)90021-4