



NUS
National University
of Singapore

A Biomechanical Study of Arm Sling Design for People with Brachial Plexus Injury

By:
Mr Yap Hong Kai
Dr Raye Yeow Chen Hua

Department of Biomedical Engineering
Faculty of Engineering
National University of Singapore

ABSTRACT

Current commercial arm slings serve as a device that supports the weight of the forearm of the injured arm. However, commercial arm slings have several limitations. They do not provide adequate immobilization pertaining to the injured arm, which will then lead to excessive movement at the wrist joint as well as shoulder subluxation. A customized arm sling was designed to address the limitations. In this report, we examined the differences between a commercial arm sling and the customized arm sling in terms of stride characteristics such as speed, cadence and stride length as well as joint kinematics such as wrist angles, elbow angles, thorax angles and pelvis angles during walking and running trials. The preliminary results showed that the customized arm sling allowed the subject to adopt a more normal and efficient gait with less undesirable hand-wrist movement during ambulation.

INTRODUCTION

The brachial plexus is a set of nerves that run from the spinal cord to the shoulder and arm. Brachial plexus injuries can cause paralysis of the arm and shoulder muscles. It will further lead to shoulder subluxation due to muscles atrophy [1, 2]. In order to stabilize the arm and prevent shoulder subluxation, many brachial plexus patients must rely on shoulder and arm supporting slings. Arm slings have various purposes, including realigning scapular symmetry and supporting the weight of the forearm in a flexed arm position [3].

However, current commercial arm slings do not provide holistic immobilization pertaining to the injured arm. The design of the arm slings does not adequately prevent movement of the arm, especially for the wrist joint. During ambulation, especially during running, excessive movements at the wrist were observed. Moreover, commercial arm slings typically do not provide sufficient support for the shoulder and the elbow, and this inadequacy may lead to shoulder subluxation. Furthermore, they normally cater for temporary use as a support device, as opposed to being integrated into the lifestyle of a user that has a chronic or permanent injury.

Based on the limitations of the current commercial arm slings, there is a need to design a customized arm sling that is able to prevent shoulder subluxation and excessive movement at the wrist and arm. Additionally, the customized arm sling should be more integrated to the human body in order to allow the wearer to remain active with a better ambulation performance.

The aim of this experiment was to examine the differences between the commercial arm sling and the customized arm sling in terms of stride characteristics such as speed, cadence and stride length as well as joint kinematics such as wrist angles, elbow angles, thorax angles and pelvis angles during walking and running trials. We hypothesized that the subject with the customized arm sling would have an improvement in stride characteristics and a more stabilized arm during both walking and running trials.

METHODS

A subject with right brachial plexus injury was recruited. The subject's age, height, weight and anthropometric data were measured prior to the gait analysis. The subject was instructed to complete 5 normal walking trials and 5 running trials, across a 9m walkway. Kinematic data was synchronously collected at 100 Hz using an 8-camera Vicon motion analysis system (Nexus 1.8, Vicon, UK). Passive reflective markers were secured to the upper and lower extremities, according to the Plug-In-Gait marker set (Nexus 1.8, Vicon, UK).



Figure 1: (a) Subject with a commercial arm sling, (b) Subject with the customized arm sling. Reflective markers were attached on the joints according to the VICON Plug-In Gait model.

Joint kinematics (wrist angles, elbow angles, thorax angles and pelvis angles) were processed and analyzed. The data was normalized to 100% gait cycle (heel strike to heel strike). Stride characteristics were also determined from the subject during walking and running.

RESULTS

Compared to commercial arm sling, the subject with the customized arm sling has:

- An increase in walking and running speed, cadence and stride length (Table 1)
- A higher thorax and pelvis peak internal (counter-clockwise) rotation angle during walking and running (Table 2, Figure 2)
- A lower wrist flexion/extension and pronation/supination range of motion (i.e. more stabilized) during walking and running (Table 3)

Table 1. Stride characteristics during walking and running.

Stride Characteristics		Commercial	Customized
		Mean±SD	Mean±SD
Speed (m/s)	Walking	1.34±0.05	1.51±0.03
	Running	2.44±0.10	2.58±0.19
Stride length (m)	Walking	1.46±0.04	1.51±0.06
	Running	1.88±0.07	1.95±0.07
Cadence (steps/min)	Walking	110.3±2.6	120.3±3.6
	Running	156.0±6.1	158.5±6.1

Table 2. Peak thorax and pelvis internal rotation angles during walking and running.

Joint Kinematics		Commercial	Customized
		Mean±SD	Mean±SD
Thorax peak internal rotation angle	Walking	8.91±0.22	12.62±1.36
	Running	12.35±1.58	20.55±1.44
Pelvic peak internal rotation angle	Walking	0.80±0.61	1.61±0.95
	Running	<i>Only external rotation observed</i>	5.01±0.83

Table 3. Wrist joint range of motion.

Range of Motion		Commercial	Customized
		Mean±SD	Mean±SD
Flexion/Extension	Walking	3.17±0.35	2.01±0.17
	Running	45.50±5.67	10.74±1.22
Pronation/Supination	Walking	4.79±1.12	3.93±0.10
	Running	32.99±3.23	6.35±2.24

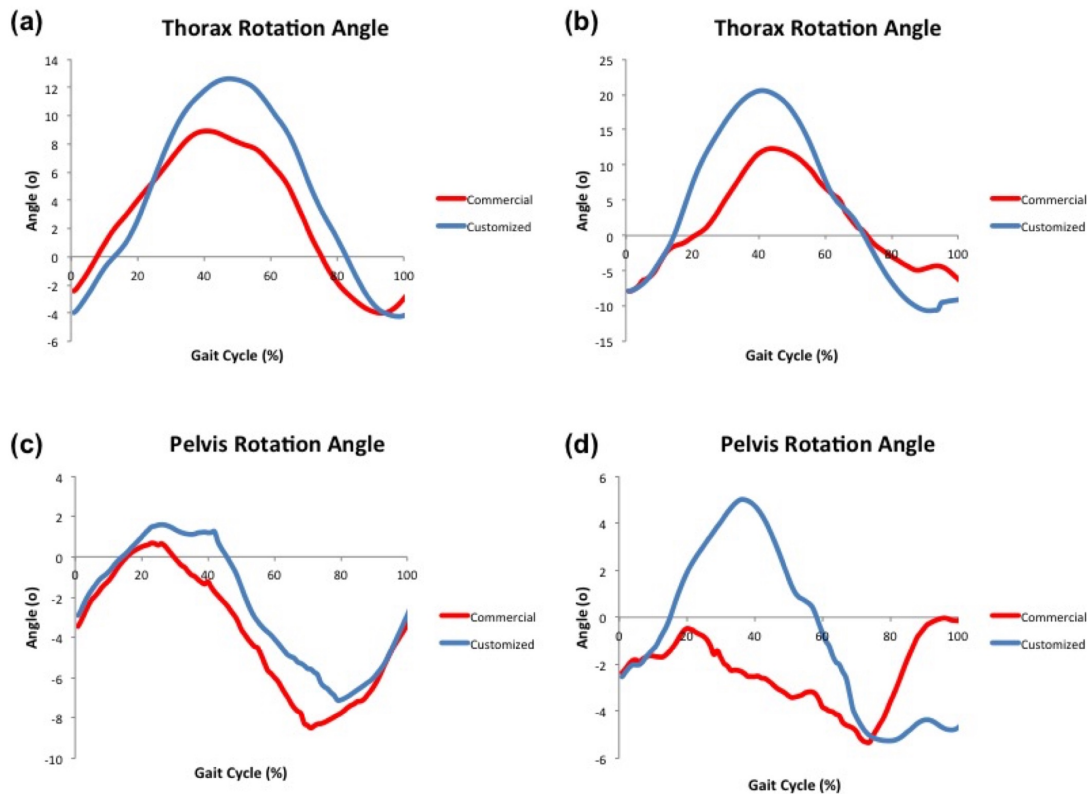


Figure 2: Thorax rotations during (a) walking, (b) running and pelvis rotations during (c) walking, (d) running. Positive angles of thorax and pelvis are internal rotations i.e. rotations to the left (counter-clockwise).

INTEPRETATION

Our preliminary results showed that the subject with the customized arm sling had an improvement in stride characteristics, specifically the walking/running speed, cadence and stride length. In addition, his wrist joint was more stabilized as the ranges of motion of wrist flexion/extension and pronation/supination were smaller with the customized arm sling than with the commercial arm sling. Furthermore, with the

customized arm sling, his thorax and pelvic rotated more during walking and running. Higher thorax and pelvic rotations are desirable as they are associated with gait efficiency [4, 5].

Collectively, the customized arm sling allowed the subject to adopt a more “normal” and efficient gait with noticeably less undesirable hand-wrist movement during walking and running. This study demonstrated a highly stable arm sling design that brings biomechanical benefits to the user. Future works will look into the refining the arm sling design and testing across a larger sample size.

REFERENCES

- [1] E. B. Hershman, "Brachial plexus injuries," *Clinics in sports medicine*, vol. 9, pp. 311-329, 1990/04// 1990.
- [2] W. Faraj and A. Zaghal, "Brachial Plexus Injury," in *Totally Implantable Venous Access Devices*, I. Di Carlo and R. Biffi, Eds., ed: Springer Milan, 2012, pp. 141-143.
- [3] S. H. Han, T. Kim, S. H. Jang, M. J. Kim, S. B. Park, S. I. Yoon, *et al.*, "The effect of an arm sling on energy consumption while walking in hemiplegic patients: a randomized comparison," *Clin Rehabil*, vol. 25, pp. 36-42, Jan 2011.
- [4] T. F. Novacheck, "The biomechanics of running," *Gait & posture*, vol. 7, pp. 77-95, 1998.
- [5] A. G. Schache, K. L. Bennell, P. D. Blanch, and T. V. Wrigley, "The coordinated movement of the lumbo-pelvic-hip complex during running: a literature review," *Gait Posture*, vol. 10, pp. 30-47, Sep 1999.