Chapter 2
A Current Review of Human Factors and Ergonomic Intervention With Exoskeletons

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ABSTRACT

Research and development of exoskeletons began as early as the 1960s. Recent advancement in technology has spurred a further research into the field specifically at rehabilitation and human performance augmentation. Human performance augmenting exoskeletons find use in the military, emergency services, industrial and space applications, and training. Rehabilitation exoskeletons assist in posture support and replacing lost function. Exoskeleton research is broadly broken up in this chapter by anthropometry: lower body, upper body, and extremities. The development for various anthropometry has their own unique set of challenges. This chapter provides a brief history, discusses current trends in research, looks at some of the technology involved in development, the potential benefits of using exoskeletons, and looks at the possible future improvements in research.

INTRODUCTION

This chapter provides a brief history of exoskeleton development from a human factors and ergonomic intervention standpoint. It discusses the current research with respect to the innate human-machine interface and the incorporation of exoskeletons for ergonomic intervention. Some novel exoskeletons based on their anatomical categories of lower body, upper body, extremities (hands/feet), and full body exoskeletons will be discussed. The chapter will conclude by covering the benefits of exoskeletons in

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rehabilitation, industrial applications, and military applications, as well as discuss some of the issues faced when designing exoskeletons.

It is imperative when performing research with exoskeletons to clearly define the difference between an exoskeleton and an orthotic because the two terms often overlap in the media as well as in the scientific literature. The term orthotic, or orthosis (plural orthoses) is generally a mechanical device applied externally to the body.

Similarly, an exoskeleton is also a mechanical device applied externally to the body but whose external mechanical structure has joints that anatomically match the human body. Typically, this mechanical structure will share physical contact with the user, will enable a direct or indirect transfer of mechanical power, and has either active or passive actuation (Pons, J.L., Moreno, J.C., Brunetti, F.J., and Rocon, E., 2007). A prosthetic is a device that substitutes a missing body part (Sansoni, S., Wodehouse, A., and Buis, A., 2014).

Hugh Herr defines exoskeletons and orthoses as follows: “The term ‘exoskeleton’ is used to describe a device that augments the performance of an able-bodied wearer, whereas the term ‘orthosis’ is typically used to describe a device that is used to assist a person with a limb pathology” (Herr, H., 2009).

OVERVIEW OF EXOSKELETONS

The field of exoskeleton research, design, and manufacturing is broad and expansive. The earliest work began in the early 1960’s with the Defense Department’s interest in a man-amplifier. This man-amplifier was a “powered suit of armor” that can augment a soldier’s lifting and carrying ability (Kazerooni, H., Steger, R., and Huang, L., 2006).

General Electric’s Hardiman, developed by Ralph Mosher from the early1960s to 1971, is widely considered the first exoskeleton device. This hydraulic and electrical body suit made carrying 250-pound seem as light as lifting 10-pounds. Ultimately, the concept of the Hardiman was well received but determined too heavy and bulky for standard military use. Not only was the exoskeleton heavy (weighing in at 1500 pounds), but it was also extremely slow (2.5ft/sec) and had uncontrolled, violent movements (Ali, H., 2014).

The United States Air Force commissioned the study of a man-amplifier from the Cornell Aeronautical Laboratory in 1962. The results of their study on this master-slave robotic system showed that exoskeletons, even those with fewer degrees of freedom (DoF) than the human body, was capable of completing most desired tasks (Mizen, 1965). However, the master-slave systems currently being used were deemed impractical. The devices were overly complex and had difficulty sensing human intent making many tasks difficult to complete (Kazerooni, H., Steger, R., and Huang, L., 2006).

Throughout the 1960’s and 1970’s, the University of Belgrade developed several types of exoskeletons that had limited predefined motion to aid paraplegics. They were met with limited success but the balancing algorithms that were developed are still in use in many current day bipedal robots (Vukobratovic, M., Ciric, V., and Hristic, D., 1972).