Towards Standard Specifications for Back-Support Exoskeletons

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7 authors, including:

Stefano Toxiri
Istituto Italiano di Tecnologia

Matteo Sposito
Istituto Italiano di Tecnologia

Maria Lazzaroni
Istituto Italiano di Tecnologia

Jesus Ortiz
Istituto Italiano di Tecnologia

Towards standard specifications for back-support exoskeletons

Stefano Toxiri[1], Matteo Sposito[1,2], Maria Lazzaroni[1,2], Lorenza Mancini[1],
Massimo Di Pardo[3], Darwin G. Caldwell[1], Jesús Ortiz[1]

***Abstract*— Back-support exoskeletons have shown the potential to improve workplace ergonomics by reducing the risk of low-back injury. To support the rapidly expanding landscape and to correspondingly promote correct adoption, standard specifications for back-support exoskeletons are desirable. We propose a list of properties and discuss their relevance to industrial applications.**

I. INTRODUCTION

The large prevalence of occupational low-back pain and injury highlights the need for technical solutions to improve workplace ergonomics. A growing number of exoskeletons for this application have been developed in the past few years, including many research prototypes and, most recently, commercially available products. These devices are known as "back support", "lift assist", "lumbar support", "hip orthosis". They are wearable devices that produce forces between the user's torso and thighs. Their effect is to reduce compressive loading on the lumbar spine, which is believed to reduce the ergonomic risk [1]. Lists of prototypes and products in this category can be found in [2], [3].

As exoskeletons are still a relatively new class of devices, a challenge associated to the rapidly expanding landscape is to keep track of the different types of devices and their intended function in a standard way. The authors believe that a standard description will positively contribute by facilitating the communication between stakeholders, ultimately promoting adoption in industry. A secondary but important impact of clearer communication will be to provide valuable feedback for developers to improve their devices based on real needs. The interest in standard descriptions of exoskeletons is supported in the recent literature. In [4], a framework to describe and compare different models of lower-limb exoskeletons is proposed, as organized in categories. The study in [5] is specific to back-support exoskeletons. It describes an experimental setup and procedure to estimate the physical effectiveness of a device. The setup consists of a grounded articulated robot that replicates the shape and movements of the human body during the target lifting tasks. The outcome of the experiment on the HAL Lumbar Support is also reported.

This contribution proposes a set of properties to define back-support exoskeletons. The goal is to promote a common, standardized language to describe and compare devices belonging to this class.

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[1]Department of Advanced Robotics, Istituto Italiano di Tecnologia, Genoa, Italy. [2]Department of Electronics, Information and Bioengineering, Politecnico di Milano, Italy. [3]Centro Ricerche Fiat, Orbassano, Italy.

II. METHODS

The proposed properties of interest are grouped in different categories (see Table I). The physical properties include overall information on the fit of the device on the wearer. The second category provides technical information such as actuation technology, power autonomy and functionality. The usage properties describe the operator interface and related information that affect the use in a factory scenario. For the sake of illustration and to foster discussion, Table I is populated with sample information describing different devices known to the authors.

III. DISCUSSION

A number of properties influence the success and fit for a given application. Clearly, its total weight has a direct effect on user comfort and acceptance. However, its weight should be considered in relation with the physical assistance it provides. In particular, the physical effectiveness of a device is determined by (a) the forces that it can provide and (b) how these are modulated during operation. Since forces are typically generated on a joint by springs or motors, we chose to represent them in Table I as joint torques. The larger the torque capability, the greater the extent to which a device can contribute to the task and thereby reduce the risk of injury. However, this value alone does not directly determine the physical effectiveness of a device. Indeed, the actuation principle (i.e. the physical component that generates torque) can make a substantial difference. The assistance provided by a passive device (i.e. only using mechanical elements such as springs or dampers) is determined at design stage and cannot be modulated during operation. On the other hand, active devices employing powered actuators can potentially adjust automatically. The key to exploiting this potential is the assistive function, or strategy. A strategy should reflect what the user needs during the different phases of the target task. Different strategies are possible on active exoskeletons, and they may be modulated in real time to match different needs. Additionally, a strategy should operate automatically, requiring no or minimal user intervention so as to reduce the cognitive burden to a minimum. With the goal of promoting effectiveness while adapting to different users, we refer to the operator interface as the way the function of a device may be adjusted (e.g. tuning parameters such as thresholds). On an active device, this may be possible by "digitally" interacting with the computer program that determines the strategy. On a passive device, set screws or switches may for instance determine the pretension or offset of a mechanical spring.

Device	Robo-Mate Trunk Mk2b [6]	HAL Lumbar Support [7]	Laevo [8]
Physical properties			
Weight	$10kg$	$3kg$ (incl. battery)	$2.8kg$ (incl. battery)
Attachment points	shoulders, abdomen, thighs	abdomen, thighs	chest, waist, thighs
Lateral footprint	$62cm$	$45cm$	adjustable
Accomodated user height	$165 - 190cm$	$140 - 180cm$	$172 - 188cm$
Technical properties			
Assistive function	assistive forces increase with both (i) torso inclination and (ii) weight of held object (via forearm sEMG) [6]	combination of torso inclination and sEMG from spinal muscles [9]	elastic behavior contrasting back and hip flexion
Max. assistive torque	(2x) $20Nm$	*not available*	(2x) $20Nm$
Actuation principle	(active) geared BLDC motors	(active) electric motors	(passive) gas springs
Operating voltage	$24V$	*not available*	*not applicable*
Power autonomy (estimated)	n.a. *(ext. supply via cable)*	$3h$	*not applicable*
Joint range of motion	unrestricted	*not available*	unrestricted
Usage properties			
Time to don/setup/doff	$< 5min$	*not available*	$< 3min$
Operator interface	console-based via Wi-Fi	buttons to adjust level of assistance	mechanical switch to disengage springs
Standards	-	IP54	*not available*
Availability	research prototype	product (Japan only)	product

TABLE I

PROPOSED LIST OF SPECIFICATIONS. FOR THE SAKE OF ILLUSTRATION, INFORMATION IS PROVIDED FOR A FEW EXISTING DEVICES.

Accommodating different user sizes is a beneficial feature that promotes adoption in real-life cases. In the same direction, the lateral footprint should be kept to a minimum in order not to introduce space constraints that may exclude application in tight spaces (e.g. inside a car frame). Furthermore, the necessary time to don/setup/doff a device is also central to its adoption. Any cumbersome or lengthy procedure may compromise the ability to integrate with a specific working schedule. While long power autonomy is certainly a positive feature, it may not have high priority in factory settings where frequent battery replacement and recharge is facilitated. However, this may not be the case in different scenarios such as outdoor construction sites.

IV. CONCLUSION

The availability of standard specifications for back-support exoskeletons is expected to support adoption in industry by helping to critically evaluate and compare the fit of the different available options in a given application. In general terms, it is important to weigh the assistance that a device can provide against the limitations it imposes on a given operation.

Standard specifications will impact the different stakeholders. Potential adopters will have a clearer picture of the different options and the advantages and drawbacks associated to them. They will therefore be encouraged to test available devices. On the other hand, exoskeleton developers including researchers and manufacturers will benefit from extended valuable feedback as more field tests are carried out and solutions are adopted.

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