Conceptual design of a lower limb exoskeleton for gait rehabilitation

B. STAŃCZYK[1], O. SZYMANOWSKA[2], W. KUNIKOWSKI[3], D. GRZELCZYK[4], J. MROZOWSKI[5], J. AWREJCEWICZ[6]

Key words: *exoskeleton, gait, rehabilitation*

1. Introduction

Impairment of locomotion is a global and serious problem resulting from various diseases, ageing or accidents. To improve gait rehabilitation, lower limb exoskeletons (LLEs) can be employed to accompany or replace the intensive work of physiotherapists. Such devices have become a focus of many studies and have been proven to successfully fulfil their purpose [1, 2]. However, still much needs to be done to make exoskeletons broadly accessible to the disabled.

The main aim of this study was to develop a mechanical construction of a simple but effective lower limb exoskeleton that would be failure-free, patient customizable, and inexpensive in manufacturing. Simplifications had to be introduced to the mechanical design of the exoskeleton in order to achieve of all the above-mentioned goals. The device is intended to be used for gait rehabilitation and assistance of patients suffering from different types of gait abnormality. The main distinctive feature of the developed design is a novel back support module for improved posture.

3. Results

The prototype of the designed LLE has a total number of 11 degrees of freedom (DoFs) accompanied by the capability of performing motion in the back and feet. It allows the patient to perform fundamental movements of the lower limb such as hip extension/flexion, hip abduction and adduction, knee flexion/extension, foot dorsi- and plantarflexion, and foot inversion/eversion, which make a total of 5 DoFs per side. These movements have been supplemented by the capability of rotating the upper body and performing its flexion/extension as well as performing flexion/extension of toes. Depending on the specific treatment strategy, actuation of particular movements (DoFs) can be modified, i.e. abled/disabled. A 3D render of the described exoskeleton is shown in Fig. 1.

By design, mobility in particular joints has been mechanically limited to the range expected during normal gait as well as a sit-to-stand (and stand-to-sit) movements [3]. The main purpose of limitation of the range of motion is to avoid knee hyperextension in the event of a power failure. However, as many patients may have the range of motion reduced, the mobility of joints can be also modified by the control system.

It is believed that extension of the upper body can improve posture of patients suffering from postural impairments, which often accompany diseases such as cerebral palsy or other conditions when the patient are not used to maintain the vertical position. The main aim of facilitation of extension of the upper body is to increase stability of the patient by means of correcting the inclination of their pelvis. Assistance of spine flexion/extension has been also considered in [4,5]. In the developed device,

[1]Bartosz Stańczyk, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, bartosz.stanczyk@p.lodz.pl
[2]Olga Szymanowska, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, olga.szymanowska@edu.p.lodz.pl
[3]Wojciech Kunikowski, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, wojciech.kunikowski@edu.p.lodz.pl
[4]Dariusz Grzelczyk, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, dariusz.grzelczyk@p.lodz.pl
[5]Jerzy Mrozowski, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, jerzy.mrozowski@p.lodz.pl
[6]Jan Awrejcewicz, Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, 1/15 Stefanowskiego Str., 90-924 Lodz, Poland, jan.awrejcewicz@p.lodz.pl

the back support element was inspired by a back protector for sports such as snowboard. It has been supplemented by rollers attached to each segment of the element and connected via a cable to an additional electric motor, the role of which is to manage tension so as to keep the patient's upper body properly extended.

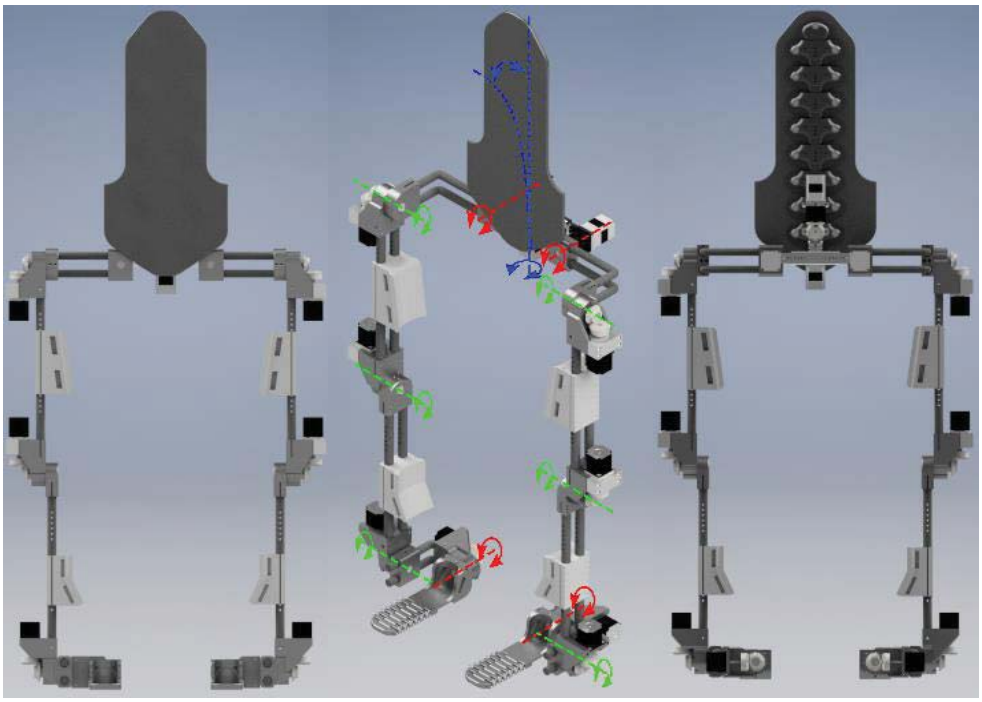

Fig. 1. Snapshots of the 3D model of the developed exoskeleton.

Acknowledgments: The work has been supported by the National Science Centre of Poland under the grant OPUS 9 no. 2015/17/B/ST8/01700 for years 2016-2018.

References

[1] AGRAWAL S., BANALA S., FATTAH A., KRISHNAMOORTHY V., SCHOLZ J., WEI-LI H., *Assessment of motion of a swing leg and gait rehabilitation with a gravity balancing exoskeleton.* IEEE Transactions on Neural Systems and Rehabilitation, 2017, 15, 410 – 420.

[2] PETRARCA M., PATANÈ F., ROSSI S., CARNIEL S., CAPPA P., CASTELLI E., A *new robotic exoskeleton for gait recovery.* Gait Posture, 2014, 40, 26 – 27.

[3] NOVACHECK T.F. *The biomechanics of running: Review Paper.* Gait Posture, 1998, 7, 77–95.

[4] TAAL S.R., SANKAI Y., *Exoskeletal Spine and Shoulders for Full Body Exoskeletons in Health Care.* Advances in Applied Science Research, 2011, 2, 270–286.

[5] ZHANG H., KADROLKAR A., SUP F.C., *Design and Preliminary Evaluation of a Passive Spine Exoskeleton.* Journal of Medical Devices 2015, 10, 11002.