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Assistive devices for the upper limb – Inserm, CNRS, IFRH, and ISPRM

CO073

Pre-clinical evaluation of a natural prosthetic elbow control strategy using residual limb motion and a model of healthy inter-joint coordinations

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Objective A gap has been growing between the mechanical features of newly commercialized prosthetic devices and the control strategies available to the users. The prosthetic joints are controlled sequentially via myoelectric control, and each actuation requires the user's attention. Because of a complex control scheme, transhumeral amputees are generally equipped with a 1-degree-of-freedom myoelectric hand, a myoelectric wrist rotator, and a manually locked elbow. The prosthetic forearm position, adjusted before the movement, is not involved in the overall upper limb movements, resulting in the development of compensatory strategies. A promising solution to improve prosthetic control utilizes the residual limb motions to control the elbow. Previous studies have shown that elbow motion could be predicted from measures of the residual limb movements and an inter-joint coordination model. This study is the first to report the utilization of an automatically driven prosthetic elbow by a transhumeral amputee.

Material/patients and methods The participant pointed at targets with a prosthesis prototype including a modified motorized elbow. The prosthetic elbow motion was derived from a generic model of inter-joint coordinations, and IMU-based residual limb measurements. The participant performed also the task with the prosthetic elbow implemented with his own myoelectric control strategy. Body movements were assessed with the data recorded with a motion capture system.

Results The patient achieved the pointing task with a better precision when the elbow was myoelectrically-driven. However, these movements required important trunk compensations. Trunk movements were smaller with residual limb motion-based elbow control, which enabled a more natural overall body behavior with synchronous shoulder and elbow motions. Due to socket impairment, but also to post-amputation body scheme modifications and discrepancies between healthy and artificial limbs, the participant's residual limb amplitudes were different of the ones of healthy shoulder movements for the same tasks.

Discussion – conclusion This work questions the paradigm whereby a prosthetic elbow can be intuitively and naturally used by an amputee while its motion is derived from healthy individual data. Although there is a need for novel modeling approaches to build an inter-joint coordination model adapted to each user, residual limb motion-driven prosthetic elbow enables simultaneous control of elbow and end-effector, and restores a more natural body behavior.

Keywords Upper limb prosthetics; Transhumeral amputation; Prosthetic elbow control; Inter-joint coordination; Compensatory strategies
Disclosure of interest The authors have not supplied their declaration of competing interest.

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CO074

Pre-clinical assessment of an intuitive prosthetic elbow control strategy using residual limb motion with osseo-integrated patients

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Objective Most transhumeral amputees deplore that their prosthesis lacks functionality due to control-related limitations. Externally powered prosthetic devices are commonly controlled via myoelectric control whereby biceps and triceps contractions drive sequentially the prosthetic joints. Because of a complex control scheme, transhumeral amputees are generally equipped with a 1-degree-of-freedom myoelectric hand, a myoelectric wrist rotator, and a manually locked elbow, despite the commercialization of more advanced devices. This results in the development of compensatory strategies to overcome the prosthesis' lack of mobility. An

alternative control strategy relates the residual limb motions to the prosthetic elbow motion using the natural coordination between shoulder and elbow observed in healthy movements. However, conventional external sockets tend to prevent the residual limb mobility, limiting the potentiality of this novel control strategy. Osseo-integration enables a stable attachment of the prosthetic device and frees the residual limb. This study focuses on the performance of three osseo-integrated patients using an automatically driven prosthesis.

Material/patients and methods A prosthesis prototype including a myoelectric hand, a wrist rotator, and a motorized elbow was mounted on the participants' abutment from the osseo-integrated implant system. The subjects were asked to point at targets while the motorized elbow was controlled by residual limb movements based on a model of healthy shoulder/elbow coordination. For comparison purposes, the task was also performed with conventional sequential myoelectric control. Body movements were assessed with the data recorded with a motion capture system.

Results Large trunk compensatory movements were measured during pointing gesture with a myoelectrically driven elbow. Automatic control of the elbow enabled a more natural body behavior whereby the trunk displacements were small, and the shoulder and the prosthetic elbow were moving synchronously.

Discussion – conclusion The study shows that osseo-integration made possible residual limb movements of large amplitudes, allowing the participants to achieve the pointing task with a prosthetic elbow driven by the residual limb motions. Moreover, simultaneous control of elbow and end-effector was achieved by one subject. Hence, this work highlights the interest of combining osseo-integration with an automatic control strategy for intermediate joints in terms of compensatory movement reduction and control intuitiveness gain.

Keywords Upper limb prosthetics; Transhumeral osseo-integration; Prosthetic elbow control; Inter-joint coordination; Compensatory strategies

Disclosure of interest The authors have not supplied their declaration of competing interest.

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CO092

Manual handling tasks performed with an upper limbs exoskeleton at the workplace

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Objective Exoskeletons for industrial applications were designed to physically assist the workers in performing tasks. These new technologies appear as an additional way to prevent work-related musculoskeletal disorders. Limited information is known about the potential benefits and risks of such exoskeletons during work tasks. This study aimed to assess the impact of the use of an upper limbs exoskeleton on the muscular activities, arm kinematic and cardiovascular adaptations during manual handling tasks.

Material/patients and methods Participants had to perform, with a bilateral passive exoskeleton (EXOS) versus without equipment (FREE), three handling tasks, consisting of load lifting in the sagittal plane (LIFT), walking with load carrying (WALK) and boxes stacking with a 90° rotation on the longitudinal axis (STACK). Electromyographic activity of the anterior deltoid (AD), triceps brachii (TB), erector spinae (ES) and tibialis anterior (TA) muscles, arm kinematic, and cardiac cost (CC) were recorded.

Results DA activity was lower for EXOS than for FREE during LIFT and STACK, whereas TB activity was higher. In contrast, TB activity was lower for EXOS during WALK. Furthermore, TA activity was greater for EXOS as compared to FREE during LIFT. No statistical difference in ES activity has been reported during the 3 tasks. Regarding arm kinematic, EXOS has induced an increase of the average angle of elbow flexion as compared to FREE for LIFT and WALK, and a diminution for STACK. Moreover, EXOS was accompanied by a diminution of the average angle of shoulder flexion and shoulder internal rotation for LIFT and by modifications of shoulder abduction angles for WALK and STACK. Finally, CC was similar between both conditions for WALK and STACK, but presented a strong trend to an increase for EXOS during LIFT.

Discussion – conclusion The use of an upper limbs exoskeleton seems to be beneficial to reduce the workload of shoulder flexor muscles. Nevertheless, the benefits do not appear without broader physiological consequences, as an increase of antagonist muscles activity, cardiovascular strain and changes in arm kinematic. Moreover, the advantages and disadvantages of this exoskeleton do not show themselves in the same manner, according to the movements realized by the workers.

Keywords Exoskeleton; Manual handling; Workload; Workplace

Disclosure of interest The author has not supplied his declaration of competing interest.

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