Exoskeletons: taking off the strain?

Seen as somewhat futuristic, there is a certain amount of hype about (powered) exoskeletons in the media. On paper, these devices are seen as a way of making strenuous or repetitive tasks easier for their users. But is that really the case? What side effects do they have? A spotlight on these new-style devices.

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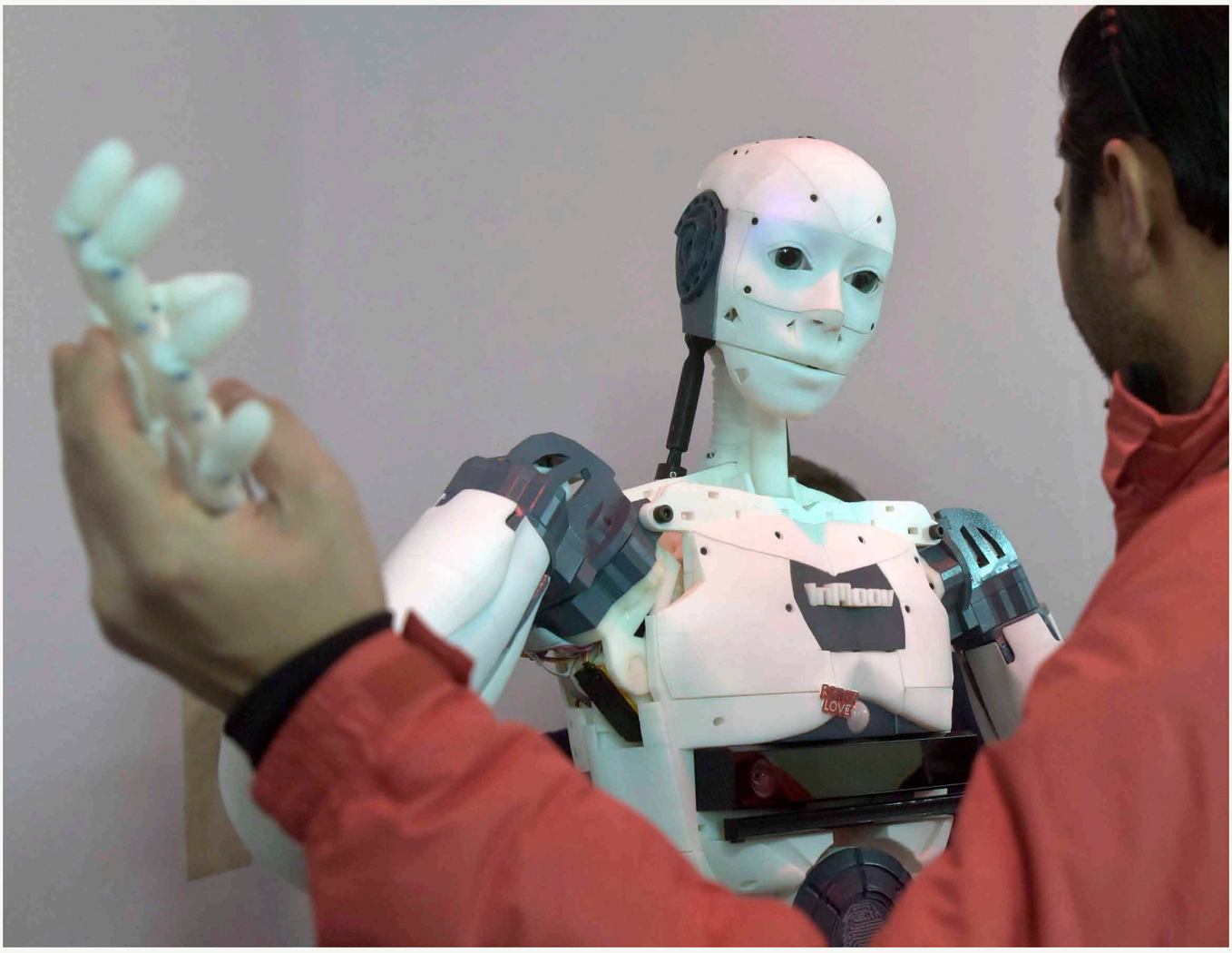
Will collaborative robots (cobots), exoskeletons and other physical assistance technologies succeed in stemming the "pandemic" of musculoskeletal disorders?
Image: © Belga



In the lobby of this splendid Haussmann building on the Champ-de-Mars in Paris, Aurélien Grilla, an employee of SOE Stuc & Staff, is preparing to climb up a small scaffold to sand the ceiling. In the building trade, this is not a much-liked task as it involves working overhead, keeping one's arms up in the air for long periods. "Though the sander weighs just 2 - 3 kilos, believe me, by the end of the day it feels it weighs a ton!", said Aurélien Grilla.

"Most people find changing a bulb in a ceiling fixture strenuous, but that's something that only takes a couple of minutes. Here, you have to work overhead the whole day", said Bruno Rondet, head of this specialist plastering company. However, Aurélien Grilla does not seem too apprehensive about this afternoon's work, as he is now equipped with an innovative device specially designed for such tiring and strenuous work: an exoskeleton, a sort of overall with mobile "armrests", somewhat like the stirrups found in hospital labour wards. Resting on a tripod, this strange contraption is hoisted up onto the scaffold. All that Aurélien Grilla has to do is to put it on, in a way similar to putting on a backpack. This takes just a few minutes, as the exoskeleton has been previously adjusted to his body shape.

Aurélien Grilla then picks up his sander and starts working. "The armrests mean that the sander's weight is distributed over the whole body", he explained. Aurélien has already used the exoskeleton for other large surfaces, such as the ceilings of the Peninsular Paris Hotel. Sensitive to health and safety considerations after having experienced back problems as a young worker working for less scrupulous employers, Bruno Rondet reckons that the hardship and fatigue associated with sanding ceilings is reduced by 80%. The introduction of the device has also changed the image of sanding work within the company.

"Before, sanding was considered as a chore, something you gave to either the youngest or the heftiest, but not to those most skilled for the job, one of the company's specialties. But now we can give the work to our most experienced workers, without them batting an eyelid", Bruno Rondet went on to say.

"The augmented worker"

Sanding ceilings is just one of the many applications for exoskeletons, a device that has recently received growing attention in the health and safety arena. But the principle is by no means new. First experiments in this field date back to the 1950s/1960s, but were only short-lived due to the technology not being sufficiently mature (see box, p. 30). But over the last few years the miniaturisation of electronic components and batteries has revived interest in these futuristic assistant devices. Some of them, for instance, can boost an employee's strength, enabling him to carry things weighing 10 kilos as if they just weighed one.

This revival is also being driven by all the discussions around Industry 4.0 and the factory of the future, workplaces that could become full of "augmented workers", and by such demographic factors as population ageing. A number of companies have already taken the jump, or are showing great interest. The world leader in road construction, Colas, together with the company RB3D, has developed a model designed to make the work of its asphalt rakers easier. "Tasked with spreading hot asphalt straight from the lorry, rakers can shift up to 70 kilos with their rakes", explained Serge Grygorowitcz, head of RB3D. Following lots of trials and tests, the model developed by the French SME enables the workers to put part of the pressure on their legs, thereby relieving their backs.

Several Japanese banks are already providing their employees with exoskeletons to help them carry heavy loads such as wads of notes, reduced their felt weight by 40%. DHL is studying the possibility of equipping its sorting centre staff with exoskeletons allowing them to effortlessly handle packets weighing up to 25 kilos (see also the article on p. 22). In short, the spotlight is again on exoskeletons. They obviously have great potential for preventing musculoskeletal disorders (MSDs), numbers of which have increased 60% in the last ten years and which "now account for 87% of work-related diseases in France", stated Jean-Jacques Atain-Kouadio, an ergonomist working for INRS, a French health and safety body.

According to the Work Foundation Alliance, some 44 million workers suffer from MSDs in the EU alone. In certain sectors, workers have to lift around 10 tonnes a year. But "when an exoskeleton is well designed, it can reduce muscular activity, i.e. relieving the muscles used". "Effort can be reduced by 10 – 40% for certain tasks, reducing fatigue or limiting spinal cord compression", added Jean Theurel, head of research at the INRS lab for physiology and ergonomics.

Though these findings are encouraging, such devices are not to be seen as a simple one-size-fits-all response to posture problems or problems associated with manual work. An exoskeleton is no ordinary and by no means simple tool: worn by its user, it is a device providing physical assistance, but whose design and development require a great amount of attention and care. Many issues remain open. One of the main risks

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> Jean Theurel (INRS)

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involves shifting physical stress and strain from one part of the body to another, without this being initially felt. There is as yet little data available on this subject.

"Reducing physical stress and strain locally can lead to it being shifted elsewhere or induce a user to make unaccustomed movements, risking for instance muscle wasting or neuromotor mismatch," explained Jean Theurel.

Bruno Rondet remains cautious: "We need more feedback, as our system is still in its infancy. Like any medicine, we need time to make sure that it doesn't produce any side-effects."

"We've got to keep our feet on the ground. In the field of exoskeletons, there are still many things we don't know and little research has been conducted into device-assisted movement. We still don't know exactly how stress is distributed throughout the body and whether, when providing relief to a certain muscle or joint, we might end up over-compensating via another muscle or joint", added Jean-Jacques Atain-Kouadio.

Moreover, putting on such an "overall" can cause discomfort or even embarrassment. In the above-mentioned exoskeleton used for sanding for example, the first model's metal "spine" ended up hurting workers' backs. At their request, the manufacturer installed a small inflatable pocket along this spine, which the employee can inflate using a rubber bulb, easily accessible at the back of the suit. Also potentially undesirable is the "straitjacket" effect: as the exoskeleton works so closely with

Questions put to Bruno Rondet, head of SOE Stuc&Staff

What made your company buy an exoskeleton for sanding ceilings?

Each year we define a challenge for improving working conditions. Just one, but one that we always end up overcoming. In 2012, we decided to take on the challenge of sanding, with the idea of providing relief to workers having to hold the sander the whole day above their heads. We looked at what was available on the market, for example for decorators, and purchased a device like a giraffe – i.e. a long neck attached to a wheeled undercarriage. But we quickly realised that, as the "giraffe" didn't have a firm grip of the sander on starting, we ended up with unsightly rings on the ceilings, incompatible with our quality standards. So that was the end of the "giraffe".

What was your next step?

We contacted a manufacturer of film-making accessories, one which produced "steadicams", systems allowing a movie camera to be held and manoeuvred fluidly. We requested the company to adapt their system to hold a sander. But again, this turned out to be a failure, for similar reasons: attached to the end of a long arm, the sander again produced rings when starting. But flipping through the manufacturer's product catalogue, we came across an exoskeleton which allowed a person to work overhead without fatigue. We tried it out at one of our sites, and found the results encouraging. But we needed to make a few modifications to give users more freedom of movement and to improve their overall comfort. At the end of the day, it took two years to arrive at an operational exoskeleton fully satisfying all users and the company.

A (powered) exoskeleton modifies a person's habitual physical and ergonomic movements, making it easier for example to lift heavy weights but more difficult to make simple movements.

Hardiman, the origin of exoskeletons

The first serious attempt to make an exoskeleton dates back to the 1960s, when General Electric wanted to develop a model able to help people carry heavy loads without overdue strain. The first applications targeted were in the military field, for instance enabling people to lift bombs in an aircraft carrier; other applications involved handling weights in such field as underwater construction, nuclear power stations or in space. Going under the name of Hardiman, the prototype greatly increased a user's strength, enabling him to carry weights of up to 680 kilos. Unfortunately, the project soon came up against major technical obstacles: the machine itself weighed three-quarters of a ton and suffered from uncontrollable movements when it was turned on. We had to wait until the 2010's and the miniaturisation of the components for exoskeletons to get back into the spotlight.

the body, users may feel hampered in their freedom of movement, possibly experiencing a restraining effect in the long run.

In a certain way, an exoskeleton modifies a person's habitual physical and ergonomic movements, making it easier for example to lift heavy weights but more difficult to make simple movements like lifting one's arms. There are also several reasons why wearing such a "harness" can increase the risk of accidents, such as colliding with another operator or a third party, damage to joints (due to exceeding physiological limits), friction or abrasion, system failure... In the first prototype designed for Stuc & Staff, the operator had both hands tied to the system, as if handcuffed.

"In the case of a fall, the operator would not have been able to cushion it at all. And especially in a building site environment, so many unexpected things can happen. We therefore requested the manufacturer to modify the device to give the operator's hands a certain freedom, though without sacrificing safety for comfort", added Bruno Rondet. And then there is the aspect of social acceptance: an exoskeleton can change the way colleagues view the wearer or even how the operator views his role vis-à-vis the set task, making him feel he is worth less or even substituted by the "machine" – aspects likely to reduce certain users' acceptance.

Companies may also be tempted to demand that their employees become more productive, given the fact that their tasks have been made easier. Productivity improvements may in turn lead to job cuts, with one employee now able to carry out the tasks previously performed by several workers.

A "Swiss army knife" exoskeleton

"You don't buy an exoskeleton like you'd buy a screwdriver or a power saw. You need to know in advance what it's for and what requirements it has to fulfil. Otherwise there is a great risk that it will be unsuitable and thus quickly abandoned or, worse, that it will cause side-effects impacting health in the long term instead of improving it", summarised Jean Theurel.

"What we are seeing is that these devices provide specific assistance for a given task. However, only a few tasks are that specific, and in many cases a worker needs to do several different things. This means that it is essential to adopt an approach allowing users to assess the real value of exoskeletons and to make sure they meet up to expectations", added Jean-Jacques Atain-Kouadio.

Interested in their potential, management of SNCF's maintenance division has initiated just such an approach, developing an exoskeleton model adapted to its requirements. In their daily work, its employees find themselves confronted with a wide range of situations at work, requiring them to work in carriages, on ceilings, in maintenance pits, or to handle heavy items such as brake shoes.

"We would therefore like to develop a 'Swiss army knife' exoskeleton capable of adjusting to work in this variety of situations. But we are also aware of how complex such an undertaking is. This is the reason why it is being conducted by a multi-discipline project team made up of ergonomists, methods engineers, representatives from our maintenance depots and from the trade unions. Moreover, the project is being conducted as an 'open innovation' project together with the manufacturer", stated Yonnel Giovanelli, in charge of the department responsible for ergonomics and organisational and human factors in the SNCF maintenance division.

Aware of the need for proper reflection before purchasing an exoskeleton, the French standards organisation AFNOR (*Association française de normalisation*) recently published a "tool-box"[1] helping companies wanting to purchase such devices to ask the right questions and make the right choices. It contains tools and guidelines for assessing their use and their interaction with humans. The bottom line: a well-designed exoskeleton suited to a specific task can help improve working conditions. ●

1. AC Z68-800, Dispositifs d'assistance physique à contention de type exosquelettes robotisés ou non – Outils et repères méthodologiques pour l'évaluation de l'interaction humain-dispositif, mars 2017.