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Aiming at the 'proper' body: How exoskeletons foster 'risky' bodies and conflicting knowledge regimes

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Abstract

Exoskeletal devices are new technologies that have been developed in the medical field to provide assistance and rehabilitation for persons with motor impairments. Among these impairments, spinal cord injury and stroke are the most common. Drawing on materials collected during multi-sited ethnography conducted in France, Germany and Switzerland from 2014 to 2019, I suggest that exoskeletons contribute to a more general process that I identify as 'aiming at the "proper" body'. As they materially craft motor impaired bodies but also are responsible for datafication and dataveillance, exoskeletons allow to categorise new aspects of 'risky' bodies. Simultaneously, they foster conflicts between experts' perspectives about rehabilitation practice and the users' phenomenological experiences that exoskeletons aim to transform. After describing how exoskeletons expand the realm of contemporary medical technologies in their purpose of 'aiming at "proper" bodies' while being 'miraculous', I identify two conceptions of 'risky' bodies: a first one related to materiality, a second one to processes of digitalisation to which exoskeletons actively participate. Finally, I investigate some conflicting levels between the regimes of expert knowledge and the phenomenological experiences of the users and reassess the latter's role in rehabilitation practice with exoskeletons.

KEYWORDS
exoskeletons, knowledge and phenomenological experience conflicts, 'risky' bodies, spinal cord injury, stroke

INTRODUCTION

Exoskeletal devices are relatively new technologies being used in the medical field. They have been developed and used equally in industry and the armed forces, their purpose being to provide assistance or rehabilitation for motor functions. With respect to rehabilitation, and thus regarding their medical use, exoskeletons are designed for persons with motor impairments, such as spinal cord injuries, cerebrovascular accidents (CVA) (more commonly known as strokes), some forms of cerebral palsy and muscular dystrophy. According to Anam and Al-Jumaily, an 'exoskeleton is an electromechanical structure worn by [an] operator and matching the shape and functions of [the] human body. It is able to augment the ability of human limb and/or to treat muscles, joints, or skeletal parts which are weak, ineffective or injured because of a disease or a neurological condition. [...] The exoskeleton works mechanically in parallel with [the] human body and can be actuated passively and or actively' (Anam & Al-Jumaily, 2012, p. 988).

In rehabilitation, as in the other two fields of application, exoskeletons may be either passive, functioning with springs or active, that is, functioning with electrical power. More often exoskeletons used in rehabilitation are active devices. In this case, they need to compensate for a variety of motor capacities that have been damaged in human bodies and are therefore lacking. They work with batteries, have motors and usually also have an integrated computer, which records and collects data from their users. Passive exoskeletons that work with springs are used for those cases where the patients' motor functions are not strongly damaged. Generally, these devices may be used to train walking, being designed for the legs, or to train arm and finger motor patterns, therefore being designed for the upper limbs.

Based on my empirical observations of two neurological deficiencies, namely spinal cord injury (SCI) and CVA, in the following I will explore some of the challenges of doing therapy with exoskeletons. In these two studied examples, exoskeletons either improve and ameliorate existing residual functions in the patient's body, or maintain and help those anatomical and physiological functions which can no longer be improved. In this process, it is instructive to understand the ambivalence exoskeletons introduce in providing 'objectivity' about how patients live their improvements during therapy sessions and how they contribute to the emergence of new conceptions of 'risky' bodies, as well as to specific political tensions that are materially and digitally defined around the users' bodies. In this article I propose the category of 'aiming at a "proper" body' to denote an 'ideal body' of healthy anatomical functions that is correlated with this quest for improvement and 'objectivity'. In this context, I understand the production of 'proper bodies' in terms of 'health work'.[1]

Training sessions with exoskeletons characterise emerging landscapes where two types of experience confront each other. The first is quantified, collected and recorded by exoskeletons and invokes the expert 'eye'. Often, this perspective is that of the physiotherapists, since they are most often in contact with the users; still, on another level medical doctors, and especially engineers who are the designers of these technologies, are also concerned. More specifically, engineers come to play an active role in shaping these new techno-imaginaries. Within these landscapes, the 'objective' stance of experts confronts the lived experience of the patient, who is the targeted user and beneficiary of these devices.

The users' phenomenological experience may sometimes oppose the views and practices of physiotherapists on how to train with the machine and reveal specific conflicts. This mismatch asks for a reassessment of the users' experience as expertise with regard to how current 'modes of watching' (Lupton, 2018, p. 54), body metrics and dataveillance practices operate in medical worlds shaped by exoskeletons. This confrontation fosters the numerous processes in medical techno-scapes that seek to reach what I earlier termed a 'proper' body. Also, because the passage from bodily materiality to bodily immateriality results in the production of novel corporeal forms—those of impaired bodies—this made me elaborate further the idea of impaired bodies as being engaged in a quest to become the 'proper' ones of health.

Using qualitative empirical material from a wider research project in which I conducted multi-sited ethnography in three countries (France, Germany and Switzerland) for several years, my paper focuses on how the use of exoskeletal devices in rehabilitation attempts to shape motor-impaired bodies into 'proper' ones while addressing specific conceptions of risks related to the development and application of this type of technology and knowledge tensions between users and experts. After describing why exoskeletons are understood as revolutionary technologies in rehabilitation, often being associated with a miraculous breakthrough, I will discuss how the users' bodies are challenged by the device both in their materiality and in their translations from being lived and felt into being monitored, surveilled and adjusted. This latter aspect highlights exoskeletons' role as 'archival artefacts' (Lupton & Maslen, 2018, p. 192) and specific risks related to digitalisation, as they produce users' profiles. In these shifts, both corporeal materialities and their correlated 'digitalities' expand, revise and recapture one another. Finally, I consider how the politics of impaired bodies develop with knowledge conflicts and stress the necessity to rehabilitate the role of phenomenologies of resistance that motor-impaired bodies display in the process of 'aiming at "proper" ones'.

EXOSKELETAL DEVICES: REHABILITATION MIRACLES?

Exoskeletal devices have a variety of shapes according to the fields (rehabilitation, industry or military) for which they are designed to be used. In rehabilitation, those I have seen, touched and also tried myself were either intended for the upper part of the body, and thus for exercising the motility of arms and fingers, or for the lower limbs to practice walking. The examples of devices I observed refer either to those used to train movements in the arms and fingers, such as grasping, or to train a walking gait. In the cases of both arms and legs, exoskeletons may either be worn or may be stationary and thus attached to a support. They are made of a variety of materials, including metal, carbon fibres and fabrics, and they aim to mimic clothing, as they are parallel to and placed over the limbs of the user. Usually, they are attached with straps to the human limbs and have pads to protect the skin from abrasions. If they are stationary structures, the user cannot move freely in the space with the device, and thus the device has more control over the user's intentionality. Conversely, mobile devices allow users to move freely in a determined space (the clinic, but also at home), a feature that many users express as essential because this allows them to engage with their motor intentionality more.

Unlike those models that have been developed for industry and the armed forces, rehabilitation exoskeletons are often stationary, being similar to fitness gadgets.[2] When the device is powered, it often includes a computer that measures and adjusts the force the user needs to walk with the device. The presence of the computer turns exoskeletons into 'body collectors' as they track the movements of their users. Therefore, they join the wider family of those medical gadgets that currently 'generate new forms of digital intimacy' (Henwood & Marent, 2019, p. 8).

Some of the devices in rehabilitation are bulky, especially those that are powered, because the materials they consist of make them relatively heavy. Therefore, wearing an exoskeleton may often be a challenge, since they lack the degrees of freedom that human bodies have, as well as the more general flexibility that defines biological movement. Another reason for their being heavy is that they need to stabilise the user's body. For people with a SCI in particular this is an important parameter because, as many engineers explained to me, those who are paralysed cannot feel if they are being hurt by the robot. Although users 'wear' exoskeletons like clothes, in return, the devices transport the user. Therefore, when designing the robot, experts need to consider whether the device is strong enough to carry the body of the user, be able to carry its own weight simultaneously and capable of protecting the user's body from being further damaged by improper fitting and use. In some cases when the users walk with them, some models have crutches to stabilise equilibrium[3] and the users' weight. They also make a specific noise during walking provoked by the motors. For reasons of stability during walking practice, in rehabilitation some exoskeleton models weigh from around 30 kg (those with crutches) up to 60 kg (models without crutches, such as the exoskeleton Atalante X® from the French company Wandercraft[4]). The interviewees who used mobile exoskeletons or who took part in teams designing exoskeletons for motor impairments described their special preparation for the users' training sessions and the difficulties they had to face when walking with such a heavy device. These difficulties encouraged teams of engineers to develop another category of exoskeletons called exosuits. These devices contain fewer metal parts, thus being less heavy and easier to wear (Georgarakis & Xiloyannis, et al., 2022). However, unlike the bulky models, these lighter devices can only be used by persons who have more undamaged residual functions in their bodies. For example, in cases of severe SCI, forms of severe stroke or severe cerebral palsy, soft exoskeletons may not help the patient's walking gait. Conversely, some models, such as stationary exoskeletons that are very strong, may even show contraindications if the patient's body is too weak to bear the effort. As I will further show, this feature is an acknowledged risk and has an essential impact on the rehabilitation practice.

The motor deficiencies I mainly observed during my fieldwork, namely SCI and stroke, which currently benefit from rehabilitation with exoskeletons are often associated with the use of a wheelchair, and implicitly with the inability to walk. Seeing people verticalised and walking with a robot challenges many views of what it means to have a motor impairment and how to live with it, which is why exoskeletons represent a revolutionary technology in the first place. Many patients, after having an accident leading to their paraplegia, affirm that they thought that they would never walk again. In this sense, exoskeletons are intriguing technological objects in the medical field precisely because they intervene in worlds of impairment that have been thought to be irremediable. The *miracle* they are responsible for is the '*walking again*'. Especially in the past 2 decades,[5] these devices have gradually entered medical worlds as active members (Riener, 2017, 2019) that challenge both the role of their users and the roles of the many experts who are responsible for their design and application. Unlike other wearable gadgets, such as insulin pumps (Jansky, 2019), smart watches or bellybands for pregnant women (Joyce, 2019), exoskeletons are a special technology because, besides being literally attached to the body of the user, they are very indiscrete technologies, imposing a controversial 'body image' (Butnaru, 2023) that blends ability with impairment.

As noted above, during walking, those devices that are mobile and powered produce a specific noise, which introduces another nuance of the 'miraculous' around exoskeletons. This is because they openly recall a well-known character in science-fiction movies and popular culture: Robocop, a figure often referred to in interviews with users. Robocop creates ambivalence with respect to an impaired body because it associates corporeal capabilities and skills with the possibility of enhanced ones, together with expectations and hopes. Doubtless exoskeletons work a concrete revolution in the lives of people with heavy motor impairments, which is another reason why they deserve once more their characterisation as 'miraculous'. Still, their association with science-fiction narratives and popular culture, in which they stamp super-heroes and their extra-powers, may be misleading.

Because of this common view and its correlated bias, exoskeletons are often related to enhancement technologies rather than rehabilitation. This is a view that, based on my empirical findings, I have openly criticised elsewhere (Butnaru, 2021a, 2023). It is true that, besides their medical use, exoskeletons have also been developed for people working in industry and the armed forces. In these fields, exoskeletons do 'augment' sequential motor functions and the ability to take on contextually defined tasks. Recently, also, some projects for exoskeleton development have addressed recreational purposes and assistance to aged individuals with motor difficulties (Sugar, 2019). Yet, in all these fields of application, exoskeletons assist motor functions to address a targeted contextual augmentation and not the general augmentation of a human body. This second case mostly concerns their non-medical uses (Kazerooni, 2008; Stirling et al., 2020). When exoskeletons are used by people with residual motor functions, which is what I have observed during my fieldwork, the prevalent category that experts in robotics use is 'assistance'. Thus, besides the science-fiction bias I mentioned previously, the categorical shift in use between the worlds of the able, expected and hoped for above-average-able, and the worlds of the impaired makes exoskeletons an ambivalent technology at first sight, adding to the sense that they are 'miraculous'.

RESEARCH METHODS

In order to observe how exoskeletons transform the bodies of their users and how they 'aim' or target at inventing what I categorise in this article as 'proper bodies', I conducted fieldwork in the form of multi-sited ethnography (Marcus, 1995, 1998) between 2014 and 2019 in three countries: France, Germany and Switzerland. The wider aim of this research was to understand how both able and impaired bodies shape and are in turn shaped by these mesmerising devices. I thus visited labs, clinics and research centres in which exoskeletons were designed, tested and sometimes used. Regarding exoskeletons for rehabilitation, I visited four sites in Switzerland, two in Germany and one in France. In France, in addition, I visited three sites working on the industrial development of exoskeletons and one site where exoskeletons for the armed forces were being tested. The ethnographic fieldwork was completed by 46 audio-recorded in-depth interviews with users, both able and impaired, and experts. Interviews were conducted in French, German and English. All the interviewed users (able and impaired) were male.

Regarding rehabilitation, I have conducted eleven in-depth interviews ($N = 11$) lasting from one to 4 h with male persons aged from their mid-twenties to their mid-sixties at the time of the interviews.

During all these journeys, one of the main outcomes I observed was that many devices were in progress. One of the openly assumed challenges in the view of engineers that creates this situation is that 'one size does not fit all' (Goffredo, 2020). Each and every user's body is different, and this exposes the bodywork that characterises ambulatory practice with exoskeletons to a variety of risks. Hence a first hypothesis regarding the contrast between the phenomenological lived reality and the injury history of a patient who is a potential user of exoskeletons and what the technological object currently allows in terms of responses to this phenomenological complexity was based initially on these observations.

Furthermore, whereas with respect to static exoskeletons, the technology is relatively advanced, mobile exoskeletons for paraplegics raise numerous questions, among which the most important concerns the users' autonomy and safety of use. The premises regarding my definition of the category of a risky 'body', which I will detail in the following, are in part justified by these observations. Although some devices functioning with crutches receive relatively good levels of acceptance, not all patients have access to them. By access, I refer specifically to the anatomical and physiological conditions of a person's body. This explains in part the almost exclusive male category of users, because in order to use an exoskeleton the patient needs to have a certain remaining muscular force to use the gadget, which female users often lack.

Additionally, the bone texture needs to be strong enough to support the exercise with the robot, as walking with an exoskeleton is relatively demanding. Here another restriction emerged: that of age. People who are older often have osteoporosis, which may constitute a counter indication for the use of the device. When I asked him about the 'restriction' procedures for the exoskeleton users, one of the interviewees who was regularly using a mobile device with crutches explained to me the following: 'What they [the company for which he was advertising exoskeletons at the time of the interview] wanted, was a young person. Available, dynamic and in good health. This means no complications, no scars, no problems. [...] It's a profile according to clearly established criteria' (RehaM9FR, 127–129, my translation from French).

The category of interviewed experts, which is greater in number than the users, comprised engineers specialising in robotics, physiotherapists, one psychologist, one neuroscientist, sports scientists and sales managers, some with backgrounds in engineering science. The greatest number of interviews were with experts in the engineering sciences ($N = 21$). I have deliberately excluded interviews with medical doctors, since my focus during this research was on the design of these devices: I wanted to understand the 'objective' stance behind the technical choices of these objects. Hence, I gave the priority to engineers, although the exoskeleton design teams also included neuroscientists, psychologists, physiotherapists and ergonomists. The experts came not only from Germany, France and Switzerland, but also from the Netherlands, the United States and Canada.

To obtain interviews I used the snowballing technique, as well as direct contact with labs or companies designing and selling exoskeletons. I also visited trade shows where exoskeletons were advertised. During these shows, I conducted interviews and expanded my fieldwork contacts. In addition, I took part in conferences in robotics, where I conducted further expert interviews and gained extensive knowledge about the (im)possibilities that exoskeletons offer to the 'corporeal worlds' (Butnaru, 2023) for which they are currently designed. All interviews were transcribed. Having used Maxqda[6] software to code my interviews, I will give the number of the paragraph which I quote after the code designating the interviewee. To guard against conflicts of interest between labs and companies, all sites and all interviewees have been pseudonymised.[7]

AIMING AT 'PROPER' BODIES WHILE STRUGGLING WITH 'RISKY' ONES

I understand 'proper' bodies to be a form of 'ideal type' (Weber, 1978), which de facto is almost never attained. Globally, medical worlds are built on this quest and exoskeletons come in to join a wider instrumentarium of gadgets and drugs that 'aim at "proper" bodies'. Being very recent, rehabilitative robotics and wearables open up new interrogations about how rehabilitation as a field of risk and body-based conflicts is newly defined. However, regardless of whether they are related to such recent developments as robotics, nanotechnologies or genetics, 'proper' bodies remain the ultimate target in rehabilitation worlds. Based on my empirical fieldwork, I use the category of 'proper' bodies as an umbrella term to describe a wider and more complex process involving many levels of expertise and experience. As the quest for 'proper' bodies literally shapes the complex landscapes in which impairments meet technological advances, patients and experts are engaged in novel conflicting knowledge regimes that invite to rethink phenomenological potentials of resistance. In my observed cases of motor impairments, the process of 'aiming at a "proper" body' refers to recovering a person's motor abilities as much as possible after the occurrence of the impairment. It is in this complex articulation that exoskeletons interfere.

As exoskeletons forge motor habits by moulding phenomenological 'body schemas' (Gallagher, 2017, p. 108), they strongly impact on deep aspects of subjective experience. During this process, the devices rematerialise the bodies of their users by regularly confronting them with sets of healthy motor patterns. This confrontation considers first the conception of exoskeletons, during which healthy persons are invited to participate in the tests leading to the elaboration of the device. More specifically the algorithm embedded in the device is based on a collection of healthy motor patterns. With respect to the fieldwork situations I experienced, this process is based on a constant negotiation between levels of expertise, spaces and places, times and contexts, as well as on a variety of corporeality parameters correlated to contemporary cultures of rehabilitation shaped by digitalisation.

I came to think of an indispensable category related to the use of these devices, namely the risks[8] associated with their effective use, after witnessing a particular incident. The very first time I saw a person with a SCI walking with an exoskeleton was in 2016 at a trade fair for medical technologies in Freiburg, Germany. In his mid-forties, he had been injured in a motorcycle accident. Besides his paraplegia, he had also lost part of his leg, and thus had a below-the-knee prosthesis. After conducting a short interview with him, during which he was sitting in a wheelchair, he got inside the robot and started walking slowly with it in the space of the exhibition, as he was employed by the company advertising the exoskeleton. At one point, he wanted to go outside the building in order to show the visitors that he could also walk on less even ground. However, although he was walking slowly, when he attempted to go over the threshold of the entrance, the robot did not follow his movement and blocked him, which caused him to fall to the ground. Suddenly, the myth of the miracle-robot that would solve such complex problems as those resulting from heavy neurological injuries started to shake.

As the related episode showed, a first level of risk concerns the concrete material use of the device: in short, the user’s skills, but also the remaining bodily functions that allow the person to exercise and efficiently interact with the device. Exoskeletons may be a challenge for the users’ micro-corporeal resources and their correlated materialities, that is, the proper anatomical reality of the person’s neurologically affected body. This aspect is crucial because a deficient or improper use of the device may do even more damage to the body than help it. Moreover, since walking is categorised in some views as a fundamental ‘social practice’ (Harries & Rettie, 2016), failing to walk is harshly sanctioned. Failing it with a promissory device in a world of health and illness that requires more and more from devices and less and less from human protagonists is even more strongly sanctioned.

Furthermore, walking with exoskeletons is sanctioned because the external and lay spectators of this emerging techno-corporeal world have little knowledge of the difficulties that both experts and users need to confront during the conception, design and end-use of this technological object. For example, little is known about the fact that not each and every person with severe motor deficiencies such as SCI and strokes is allowed to practice motor patterns with exoskeletons. Since the users’ bodies are already fragile, and hence inherently ‘risky’, working with the device may sometimes prove itself a counter-indication. It is in this context that I speak of a *first* dimension in describing exoskeletons’ users’ bodies as ‘risky’ during practice with the device. One of the interviewed engineers explained some limitations encountered in this wider process of ‘aiming’ at the ‘proper’ body to me:

> There are some classical risks regarding exoskeletons. For example, people who have been immobile for long periods of time. They have fragile bones. And medical doctors recounted to us that sometimes these people would break their legs only because they wanted to put socks on. A patient can take her or his leg like this [showing me the movement]; they will pull up the leg to put the sock on, and the leg is so fragile that they can break a bone. So one really needs to pay a lot of attention to the condition of the person’s bones. So we exclude [from our lab], for example, people who have already bone fractures.
>
> (Eng16FR, 68, my translation from French)

Confronting such radical uncertainties that users’ bodies contain is part of the wider project of rehabilitating bodies with exoskeletons. Still, if materialities engage both users and experts in risk negotiations, so are the ‘digitalities’ fostered by exoskeletons, an aspect that I will discuss in the next section.

DIGITAL PRODUCTIONS OF ‘RISKY’ BODIES: EXTRACTING, ARCHIVING, SHARING

Besides allowing new forms of material risks to be theorised, the process of ‘aiming’ at a proper body that characterises rehabilitation practices with exoskeletons involves harvesting data from the users’ own bodies. In this *second* case, the risks are of immaterial or digital nature. This aspect has led me to include exoskeletons with the category of what Lupton and Maslen call ‘archival artefacts’ and add them to the wider panoply of recent technologies associated with the production of what has been termed the ‘quantified self’ (Lupton, 2016). Recorded data serves the creation of a digital profile of the patient’s body here. As Lupton and Maslen note, ‘archival artefacts' are 'multi-sensory, and not only embodied, but intercorporeal, entangled with and distributed across other human bodies, other living organisms and nonliving things' (Lupton & Maslen, 2018, p. 192). Regarding recording and the possibility of creating a digital profile for users, one of the engineers I interviewed mentioned:

> We record with quite good resolution everything that the person is doing. And the idea is that the device should adjust to what the person is doing. So, we try to understand … You know, from a rehabilitation context: are they improving, are they not improving? So that we can better tailor the assistance that we give them.
>
> (Eng14CH, 148)

In a similar vein, a physiotherapist said:

> There are various exercise types for a device. Therefore, we need to create a patient's file. The training sessions are recorded in her or his file. Because this is how we can better monitor the patient's progression. We will know whether it is all right or better, or if the patient is stable.
>
> (Physio2CH, 13–17, my translation from French)

Like smartphones or insulin pumps, exoskeletons are a 'junction' technology that on the one hand collaborates with minimal experiential aspects of the users' bodies—in short, with their phenomenologies. On the other hand, though, exoskeletons contribute to forms of dataveillence. Yet, unlike other situations, dataveillance, monitoring and quantification are necessary supports for rehabilitation sessions with exoskeletons. Thus, digitalisation proves itself to be a necessary tool for the progress of a person's training. One may compare this situation with healthy people who seek to improve a variety of functions and skills in their bodies and who voluntarily monitor activities and their correlated anatomical functions. And as experts reveal, as with healthy people, this situation may contribute to forms of 'disloyalty' (Nafus, 2014) towards the users, and reinforce current forms of control enabled by digitalisation.

Because they collect data and establish data profiles from one therapy session to another, exoskeletons can be placed in the category of those devices I call 'extraction technologies', following a term coined by Stark and Campbell (2018). These authors, who, with respect to research in psychiatry, discuss a typology of methods that are used 'to know the interiority of others and to represent experiences that they regarded as beyond representation', evoke two types of method: methods of extraction and methods of ingression (Stark & Campbell, 2018, p. 790). Exoskeletons engage in a specific type of access to the user's interiority by means of their sensors because they collect information from their users' bodies, contributing to reinforce current practices related to the 'extraction imperative' (Zuboff, 2019, p. 87) in rehabilitation worlds; hence, my categorising them as 'extraction technologies'. Some projects, however, like one being conducted at CLINATEC[9] in Grenoble, France, aim to connect the device directly to the brain and thus to create a form of ingression. In line with the empirical data I observed, I argue that these correlated aspects of 'extraction' and 'information reading' forge further forms of 'risky' bodies in rehabilitation, while legitimating the association of exoskeletons with those technologies that contribute to the emergence of the 'quantified self'. As Deborah Lupton notes,

> the 'quantified self' has become a popular term to describe self-tracking […] involving online interactions and face-to-face meetings and conferences. Once the

> data are collected, self-tracking practices typically incorporate organization, analysis, interpretation and representation of the data (such as producing statistics or graphs and other data visualizations) to make sense of them, and efforts to determine how these data can offer insights for the user's life.
>
> (2016, 102)

Due to their data-harvesting properties, exoskeletons come to join these novel social practices based on digitisation. Obviously, unlike users who consciously acknowledge monitoring their bodies, exoskeletons are devices that may be controlled by users especially where home use is involved. Still, unlike those 'archival artefacts' that are explicitly related to the phenomenon of the 'quantified self' (Lupton, 2016, 2017, 2019; Nafus, 2016; Sharon, 2017), exoskeletons aim to form 'proper' bodies most often through control exercised by trained professionals. The data they gather belongs from the beginning to a medical institution. When I explicitly asked him about the risks of accessing the data collected from therapy sessions with a stationary arm exoskeleton that he was working to improve at the time of the interview, one of the engineers said:

> This is always the problem with data. When you have data stored somewhere, you always have security problems. When you have your bank account online and you do online banking, for example. Everywhere where data gets saved, somebody can steal the data or somebody can get access to the data somehow. This is a problem that is everywhere you have data. And the sharing process … well, I heard several times from patients that they did multiple X-rays because a certain doctor didn't know that they'd already had one. And he also forgot that. And then he needed to go for an X-ray again. The radiation is dangerous, so if the other doctor had had the information he actually had, it would have prevented the patient having an unnecessary treatment which has negative effects, as well as money. So, I would say, on the one hand, a life idea because this is the time in which we are going … this optimization, and also this connection of multiple things together. On the other hand, I also fear that we're getting more and more transparent for companies and other people having our data whom we don't want to have our data. And maybe fear. No, I want to correct myself. Fear is not the right word, but [to] insist that there is sufficient security for personal data. I hope and insist that there is a public and also a political discussion about data and that our data is also to a certain extent safely stored. I support every discussion about this, that this topic is in the foreground, because I think a lot of people, also with Facebook at the moment, or other uses, don't realize how much of their data is used for purposes that probably they don't want to be it used for.
>
> (Eng11CH, 235)

As this extract shows, exoskeletons demonstrate that 'aiming' at proper bodies crosses other boundaries than bone structure and flesh. What they do is 'extract', 'archive' and offer the possibility to 'share' corporeal values of patients, strengthening current practices of 'transducing' (Schüll, 2019, p. 28). Surprisingly, although they are designed to transform the user's phenomenological 'sense of agency', and partly their 'sense of ownership',[10] these devices potentially contribute to digital extensions of the contemporary biopolitical gaze (Lupton, 2012). In doing so, exoskeletons recapture divergent materialities of motor impairment, thus legitimising the emergence of 'smart' body borders in rehabilitation landscapes and expanding further conceptions of 'risk' around them.

CONFLICTUAL CORPOREAL REPERTOIRES: EXOSKELETONS BETWEEN 'OBJECTIVE' BODIES AND 'LIVED' ONES

As I have shown, while extracting it, exoskeletons are collectors of information. They address the aim of bringing the gait of people with motor impairments in line with the forms and values that characterise unimpaired walking, or to train the motor habits of arm and finger use. They thus forge impaired bodies both materially and digitally. Yet, in these many steps in attempting to aim at a 'proper' body, many actors representing the 'objective' expert gaze and thus the 'objective' body (*Körper*) come together. This situation sometimes creates conflicts with the corporeally felt realities of the users' bodies, namely with their body phenomenologies,[11] but also with an imagined body that they are attempting to recover, and displays further levels in unravelling risky aspects.

While some user-interviewees explicitly noted the positive effects they experience during training along with steady progress, others expressed dissatisfaction with how decisions about their bodies and how their responses to exoskeleton practice are actually lived. For example, during a test with a light exoskeleton in which I was allowed to participate, I could directly observe a contextual conflict between what experts planned to achieve (and aimed for) and what the user experienced and felt. The test person was a man in his late forties who had a condition known as transverse myelitis. Shortly after entering the test room, he was 'harnessed' in the device by the physiotherapist together with the engineer who was supervising the training sequence. The exercise the user was then asked to perform first implied walking with the device while simultaneously holding his arms on parallel bars intended for gait training. As I remarked in my field notes, 'soon his [the patient's] enthusiasm fell because he saw that he couldn't walk again as he thought. One could see on his face that he was straining. The physiotherapist explained to him that he needs to get used to the exoskeleton [...]. But the patient continued to complain of a bad communication between the device and his body. He said that the device always answered to his body later than his movement (or his intention of movement). [...] In the end, the patient broke a piece off the device because he turned to sit down and almost fell off the chair. Much of the control of his body was done with his arms, and he seemed to be tired after a few tours of walking' (field notes May 2019, 897, 900). Talking to him later on about this experience, he still insisted on the difference in perception between what he felt during the exercise and what the experts expected from him and his use of the device.

This is one example that led me to envisage a situation in which, besides the conflicting forms of materiality and immateriality I previously described, exoskeletons may sometimes prove to be complex conflictual arenas of expertise, as multiple regimes of 'expert' knowledge may oppose regimes of subjective experience and feeling. Although medical doctors *do* prescribe training sessions for people impaired by spinal cord injuries and strokes, many crucial decisions about what motor exercises should be practised with the device and how long they should last are taken by physiotherapists. Thus exoskeletons may strengthen a specific mode of watching, as they split the 'medical gaze' (Foucault, 1963).

One of the interviewees with a paraplegia resulting from SCI told me that rehabilitation with exoskeletons can sometimes generate very strong conflicts. He said:

> They [physiotherapists] are not trained that way [to support the patient] because they are trained to work inside an institution where they have certain limited amounts of resources that they can allocate to their patients. And it's not necessarily their fault—it's the system. But, if you only have those limited resources, then I'd also say to a patient: "Hey, maybe you'd better focus there [on this aspect, n.n., D.B.] because that will help you more." But that's not what a patient wants to hear. A patient wants to say: "Hey, yeah, I'm going to try it because potentially… "Especially in a field where there is no statistics. Because all of those physiotherapists are also just guessing. […] In my case they said: "Yeah, we think the [mobile] exoskeleton is better for you than [Exoskeleton A], which is stationary". And I was like: "Why?"—"Uh, we think that the active movement might be better." "Do you have some proof?" "No, we don't have any proof at all. This is just some… gut feeling." That's great [ironically]! So, I'm not allowed to work with the [stationary Exoskeleton A] because you have a gut feeling. Fantastic [ironically]!"
>
> (RehaM5CH, 580)

Based on the previous excerpt and in line with my earlier discussion of how forms of 'risky' bodies emerge, I conceive of the felt reality of the impaired body as being hardly measurable and quantifiable because it is unpredictable. Hence bodies in their specific phenomenologies of being injured may resist devices, as well as expert gazes and decisions. Besides the confrontation with a variety of levels of knowledge, rehabilitation practice with exoskeletons involves a steady challenge coming from subjective levels of experience (Carel, 2016). Some of these levels, specifically those that make individuals what they are, namely their own living corporeal histories with a defined type of impairment, oppose the regularity and natural law-like generality which (at least up to the present) characterises how exoskeletons have been designed and imagined to function. The phenomenological potential needs to be stressed at this stage because it is precisely basic experiential characteristics such as the 'body schema' and 'motor intentionality' (Merleau-Ponty, 2012 [1945]) that exoskeletons attempt to transform.

Whereas 'archiving bodies' by means of sensors opens up corporeal conflicts related to quantification and potentially to data leakage, the concrete material practice with the robot engages complex phenomenological articulations into specific politics of the body. Following my empirical observations, people with spinal cord injuries or strokes may obviously contribute to refining the expertise and conception of the technological gadgets that are intended for them while repurposing the understanding of 'cultures of expertise' (Holmes & Marcus, 2005) in current medical projects involving robotics. Remarkably, including the fine-grained differences of injuries and their critical narratives in the rehabilitation work with exoskeletons helps in revising the phenomenological universalism of subjectivity advanced by classic approaches in this epistemic tradition. In this regard, the subjectivity's contingency, as acknowledged in my case studies by the peculiarity of injury profiles, reveals itself to be a resource that is needed in the production of these contemporary media devices. In building up expertise with one's own body and thus *from within*, users confirm that phenomenological levels of experience *do* matter, while simultaneously forging the reality of these technological contexts and their knowledge negotiations. Moreover, they also acknowledge that entering these novel 'technological artefacts' and being 'archived' for the purpose of getting closer to the 'proper' body of health traverses many conflicts and forms of risk, and requires a reinvestment of those motor impairment phenomenologies that shape the reality of current health-scapes in which exoskeletons aim to be active participants.

CONCLUSION

In this article, I have shown that such novel rehabilitation devices as exoskeletons traverse a variety of conflictual imaginaries and body representations while resetting medical practices of rehabilitation. In their attempts to accompany impaired motor bodies on their journeys towards what I categorised as 'proper' ones, exoskeletons become dynamic instances in the expansion of growing worlds of datafication and dataveillance (Lupton, 2018). In this move, they simultaneously engage all the parties involved in their design and actual use in specific forms of corporeal risk. The ones I identified above describe current conflictual realities that are shaped especially during the concrete practice of rehabilitating bodies with these novel technologies, which have come to populate the emerging field of medical robotics.

The fact that digitalisation and its correlated projects in robotics invite us to reflect on how the 'society of algorithms' (Burrell & Fourcade, 2021) spreads into medical worlds is a matter of concern in which exoskeletons participate both directly and indirectly. In doing so, they expand the conception of how bodies are forged through their being watched, recorded, monitored, transacted and compared. Relying greatly on sensors, these devices capture responses while also themselves responding. While transmitting this information, they concretely impact on phenomenologies of motor impairment. Due to this digital but also material technological intimacy, the risks involved in how they shape phenomenological 'own bodies' into 'proper' ones are higher.

As often noted by my interlocutors, both experts and users, in order to achieve and maintain visible effects, steady work and practice with exoskeletons is needed. Sometimes, however, steady work achievements are still fragile. Exercising with exoskeletons means constantly learning new perceptions of one's own body in the case of the users, and sometimes perceptions of new environments, depending on whether exercises are practised inside a closed space or outside. It also requires an understanding of how one's body responds to the device and thus develops a form of technological literacy. As decisions regarding how this rehabilitation work should be carried out are often taken by physiotherapists, some users may manifest disagreement, a situation that shows the potential of exoskeletons to reveal a novel politics of the body. Legitimate expertise associated with levels of the 'objective stance' and subjective experience may therefore sometimes enter into forms of conflict, as spinal cord injuries and strokes are highly subjective conditions. It is precisely the specificity of these neurological disorders that impacts on the process of 'aiming at the "proper" body', as exoskeletons are sometimes not flexible enough for the requirements of their users' conditions. Hence, the necessity to consider the peculiar subjective potential related to this type of rehabilitation practice and to reassess its role.

In their attempts to configure current realities of 'body crafting' (Merit Müller, 2018, p. 872) in both contemporary and prospective medical worlds, exoskeletons reveal themselves to be further 'risk' technologies, due to their material use restrictions and contribution to the datafication of motility impairment. Having examined the ways in which these types of wearables challenge rehabilitation practices and the impairment phenomenologies of the users, the analysis I have developed has implications beyond the explicit example of exoskeletons. Their contribution in 'aiming at "proper" bodies' and in shaping novel health-scapes needs to be understood along with other technologies that are engaged in similar trajectories and that redraw bodies in medical worlds as visible, but also as invisible and dataveilled.

AUTHOR CONTRIBUTION

Denisa Butnaru: Data collection; analysis and interpretation.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not publicly available due to privacy or ethical restrictions.

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ENDNOTES

[1] I understand 'health work' in this context as a type of work done to and on the human body. I therefore associate it to the category of 'body work' that I elaborated elsewhere and by which I mean the possibility that exoskeletons allow to rearrange and enact (although temporarily) capabilities, skills and a variety of forms of expertise during rehabilitation sessions (Butnaru, 2021b, p. 100).

[2] One of the exoskeletons marketed by Hocoma, namely Lokomat®, is an example of a stationary exoskeleton.

[3] An example of an exoskeleton with crutches is that produced by the company Rewalk: https://rewalk.com/rewalk-personal-3/ (accessed 25.08.2022).

[4] https://www.wandercraft.eu/ (accessed 30.12.2022).

[5] See, for example, the products developed by the Swiss company Hocoma, among which exoskeletal devices play a prominent role in the field of robotic rehabilitation: https://www.hocoma.com/de (accessed 25.08.2022). The Lokomat®, which is broadly used for gait rehabilitation, had already been designed in the 1990s (Riener, 2017).

[6] My analysis followed the principles of grounded theory, and more specifically the approach developed by Kathy Charmaz (2014). I first identified codes, then broader themes and finally established relations in order to explain how experiences and various forms of knowledge of users' bodies and the knowledge of the many experts involved in designing exoskeletal devices are interrelated in order to sustain the broader process of what I termed 'aiming at "proper" bodies' in this article.

[7] When quoting informants who have been pseudonymised, I will use codes which refer to the following criteria: type of expertise, an ordinal numeral, indicating the place of the interview in the series to which it belongs, and the country from which the expert comes. For example, the code 'Eng3GE' refers to the third engineer that I interviewed, who comes from Germany. The code 'RehaM2USA' refers to the second interviewee with motor impairment, who comes from the United States and is male.

[8] Medical worlds and health related practices are inherently populated with 'risky' bodies (Fox, 2002; Lupton, 2013, 2023). However, what may be surprising about how risks are understood with respect to rehabilitation with exoskeletal devices is a binary dimension: the restrictions that the bodies of users impose and data leakage.

[9] See the project's website: https://www.clinatec.fr/en/research/projects/bci-project/ (accessed 01.09.2022).

[10] According to the philosopher Shaun Gallagher, the 'sense of agency' refers to 'the pre-reflective experience that I am the one who is causing or generating a movement or action or thought process', whereas the 'sense of self-ownership' designates 'the pre-reflective experience that I am the one who is moving or undergoing an experience' (Gallagher, 2012, p. 132).

[11] The distinction between an 'objective' body that represents the perspective of the natural sciences and that of a 'lived' body that refers to the subjective reality of lived experience is a classic theme in phenomenology (Husserl, 1960, §50, Merleau-Ponty, 2012 [1945], p. 75 ff).

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