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Inpatient Caregivers' Perceptions of the Use of Passive Exoskeletons in Daily Work – A Case Study

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ABSTRACT

Background: Nurses in inpatient care are affected by heavy physical activities in their daily recurring working tasks. This includes transferring persons or helping persons to stand up. Such tasks are the reason why caregivers often suffer from musculoskeletal disorders, such as back pain. Various robotic systems are already used to relieve the burden on caregivers. Passive exoskeletons have only recently been offered to provide physical relief. Research from other industries and among caregivers shows that objective physical relief can be achieved through the targeted use of passive exoskeletons. To date, however, there is no research on caregivers' subjective perceptions of wearing passive exoskeletons in their daily work.

Population and methods: This case study refers to the perception of four caregivers (m = 1; f = 3) in an inpatient long-term care facility. Two different passive exoskeletons were worn during the shift on different days for on average 5.75 hours. Subsequently, a self-developed questionnaire was completed by the caregivers after having worn both exoskeletons.

Results: All subjects perceived a subjective physical relief by wearing both exoskeletons. The exoskeletons were perceived as comfortable, especially in the lumbar spine region. In general, it can be stated that caregivers are so far hardly aware of the existence, the functionality, and the benefits of passive exoskeletons for care until they get the opportunity to wear and try one.

Discussion and conclusion: Structure and functioning of the exoskeletons seem to make a difference on the perception of the passive exoskeleton. Prior information could increase acceptance by the caregivers.

Hintergrund: Stationäre Pflegekräfte sind bei ihren täglich wiederkehrenden Arbeitsaufgaben von schweren körperlichen Tätigkeiten betroffen. Dazu gehört das Umlagern von Personen oder die Hilfe beim Aufstehen. Solche Aufgaben sind der Grund dafür, dass Pflegende häufig unter Muskel-Skelett-Erkrankungen leiden, wie z. B. Rückenschmerzen. Verschiedene robotische Systeme werden bereits eingesetzt, um Pflegekräfte zu entlasten. Passive Exoskelette werden erst seit kurzem zur körperlichen Entlastung angeboten. Forschung aus anderen Branchen und bei Pflegekräften zeigt, dass durch den gezielten Einsatz von passiven Exoskeletten eine objektive körperliche Entlastung erreicht werden kann. Bisher gibt es jedoch keine Untersuchungen über die subjektive Wahrnehmung des Tragens von passiven Exoskeletten bei der täglichen Arbeit durch die Pflegenden.

Population und Methoden: Diese Fallstudie bezieht sich auf die Wahrnehmung von vier Pflegekräften (m = 1; w = 3) in einer stationären Langzeitpflegeeinrichtung. Zwei

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verschiedene passive Exoskelette wurden während der Schicht an verschiedenen Tagen für durchschnittlich 5,75 Stunden getragen. Anschließend wurde ein selbstentwickelter Fragebogen durch die Pflegekräfte ausgefüllt, nachdem sie beide Exoskelette getragen hatten.

Ergebnisse: Alle Pflegenden empfanden eine subjektive körperliche Entlastung durch das Tragen beider Exoskelette. Die Exoskelette wurden als angenehm empfunden, insbesondere im Bereich der Lendenwirbelsäule. Generell kann festgestellt werden, dass die Existenz, die Funktionalität und die Vorteile von passiven Exoskeletten für die Pflegenden bisher kaum bekannt sind, bis sie die Gelegenheit bekommen, ein Exoskelett zu tragen und auszuprobieren.

Diskussion und Schlussfolgerung: Der Aufbau und die Funktionsweise eines Exoskeletts scheinen einen Unterschied in der Wahrnehmung des passiven Exoskeletts zu machen. Eine vorherige Information könnte die Akzeptanz durch die Pflegenden erhöhen.

KEYWORDS

Passive exoskeletons, nurses, testing, inpatient care, opinion

Passive Exoskelette, Pflegepersonal, Test, stationäre Pflege, Meinung

1. Background

The quest for new innovations is a driving factor in business, amongst others to keep pace with competing companies in the market. In the area of product innovations, a trend towards technical and digital assistance systems (e.g. head-up displays, wearables, cameras) can be identified, which also include various types of robots or so-called exoskeletons.

Exoskeletons are body-mounted mechanical structures (De Looze et al. 2016; Hensel & Keil 2018). Different classifications of exoskeletons exist, depending on the intended use, supported body region, and mechanism of action. The most common delineation distinguishes between active, passive, and semi-active exoskeletons. Active exoskeletons are powered, e.g., electrically, or pneumatically. Passive exoskeletons provide support by transferring power from the human to the exoskeleton and back again to the human, e.g., by springs without drive. Semi-active exoskeletons

can be a combination of both. This means that the exoskeleton primarily works purely mechanically without a drive (passive) but can provide additional support as needed through a drive with supplied electrical or pneumatic energy (active component) (De Looze et al. 2016; Stewart et al. 2017).

Furthermore, exoskeletons can also be distinguished in terms of whether they support the whole body or only parts, such as the trunk or extremities like the arms or legs.

Technical assistance systems, including robots and exoskeletons, are already being used in many sectors, such as manufacturing in industry. There, very high forces and loads often occur for the body of the workers, for example through carrying, lifting, or working overhead. Therefore, robots and active exoskeletons are often used in industrial manufacturing (e.g. the automotive industry), which can provide the person with physical support for the forces that occur (Pacifico et al. 2022). In their investigation of passive exoskeletons, Glitsch et al. (2020) demonstrated that exoskeletons can provide physical relief during activities such as lifting or carrying loads in industry. The more frequently the physically demanding activities are performed, the greater and therefore the more important, in terms of prevention, is the relief for the body. Many models of exoskeletons are aimed at relieving pressure in the areas of the lumbar spine. Little research has been conducted on the physical support on caregivers. However, since the passive exoskeletons for caregivers are sometimes hardly modified and function similarly to models used in industry, it can be assumed that passive exoskeletons can bring physical relief for caregivers as well (Dittrich 2019).

In the healthcare sector, robots and exoskeletons have so far been predominantly used in rehabilitation. Here, the application can relate to different types and severities of diseases and injuries as well as to different body regions (Gülke et al. 2018; Shore, de Eyto & O'Sullivan 2020). One example is assistive robotics for early mobilization of critically ill and intensive care patients. Reactive Robots (2022) indicate that their early mobilization by the robot VEMOTION, based on a patient-initiated movement therapy, minimizes secondary complications, and supports the recovery process. Research shows that self-initiation of the motor movement command is essential for functional improvement. In comparison, rehabilitation therapies were significantly less successful when patients were only passively moved (Donati et al. 2016). They state that without VEMOTION, multiple caregivers would otherwise be needed for an extended period to mobilize the person by hand.

Managers in the care sector consequently also recognized the benefits of exoskeletons for their employees. Therefore, passive exoskeletons for care were developed by some companies. For not too long, passive exoskeletons for caregivers are purchasable on the market. The technical functions of the manufacturers' existing models of passive exoskeletons are usually only slightly adapted. For example, grip options for the person in need of care are added on the exoskeleton. This facilitates the task of lifting the person in need of care by the caregiver (HUNIC GmbH 2022).

Research on the perception of exoskeletons in industry has already been conducted by Elprama, Vanderborght & Jacobs (2022), who identified various acceptance factors of persons when wearing the exoskeletons. These include perceived usability and comfort of wearing the exoskeleton. They conclude that consideration of these factors is important early in industrial development of exoskeletons. In general, research on the acceptance of technology use in care shows that aids for physical support, including lifting aids, are particularly well accepted insofar as they are also available for use (Zöllick 2020).

Whether a new technology proves to be practical in use depends on other factors besides the health benefits. One decisive factor is the perception of the people using the technology, in this case the caregivers testing the passive exoskeletons in inpatient long-term care facilities, in their real-life working environment. So far, no research of caregivers testing passive exoskeletons in inpatient care facilities has been identified.

Aim: The aim of the case study is to present the perception of caregivers in inpatient long-term care on using passive exoskeletons in their real-life working environment.

Population: Four caregivers (n = 4) of an inpatient long-term care facility tested the passive exoskeletons. The demographic data of the nursing staff are shown in Table 1:

Participant	1	2	3	4	Mean
Age (years)	34	59	53	20	41.5
Gender (m/f/d)	m	f	f	f	m = 1; f = 3
Physical complaints	yes	yes	yes	NA	yes = 3; NA = 1

Table 1: Demographic data

Participants received use and safety instructions before wearing the two exoskeletons.

2. Methods

A self-developed questionnaire was set up and completed by the nurses after wearing the exoskeletons during work. It contained quantitative and qualitative questions. The questionnaire was divided into the following four sections: 1) CareExoLift, 2) Rakunie, 3) general questions about wearing both exoskeletons, 4) sociodemographic data. The complete questionnaire is shown in Appendix 1. Two models of passive exoskeletons were worn, the CareExoLift from Hunic GmbH (2022) and the Rakunie Back Support from awb Schraubtechnik- und Industriebedarf GmbH (2020).

The two models differ in terms of provided information from the manufacturers. The CareExoLift is a one-size-fits-all model, weighs 3.52 lbs (pounds) and covers the entire body from shoulders to ankles. It relieves pressure by up to 21 percent depending on the degree of adjustment. The Rakunie Back Support is no one-size-fits-all model and can be purchased in a variety of sizes. It weighs about 0.55 lbs and goes from the shoulders to the knees. According to the manufacturer, it relieves the spine by 20 percent during activities in forced bending postures. It can also be worn underneath clothing.

Three persons wore the exoskeleton on one day, one person on two days. The average total wearing time of the exoskeletons per person was 345 minutes (= 5.75 hours) each.

Figure 1: Rakunie Back Support (awb Schraubtechnik- und Industriebedarf GmbH, 2020)

Figure 2: CareExoLift (HUNIC GmbH, 2022)

3. Results

The exoskeletons were mainly worn for nursing care activities, among which the lifting and repositioning of persons from beds or chairs as well as personal hygiene activities were mentioned. When asked for which activities the exoskeletons helped the most, heavy lifting and bending activities were mostly mentioned.

All subjects felt a subjective physical relief by wearing both exoskeletons. The exoskeletons were perceived as comfortable on the back, especially in the lumbar spine region (n = 7 for both models). The CareExoLift was found to be irritating at the shoulders (n = 1), knees (n = 1) and legs (n = 1), the Rakunie Back Support nowhere. In none of the models did a dangerous situation occur caused by wearing the exoskeletons. In most cases, the exoskeletons did not negatively restrict the movements of the caregivers (n = 7 for both models).

The following adjectives were mentioned by the caregivers as descriptions for the CareExoLift: helpful, pleasant, relieving, supporting, back-saving, disturbing, irritating, different. For the Rakunie Back Support, the adjectives pleasant, helpful, good, easy, relieving, gentle on the back, not irritating were named.

The caregivers mentioned several suggestions for improving the design of the CareExoLift. One is a request for more legroom. Also, a one-size-fits-all model is not very suitable for people who are very small or tall. Another suggestion is to place the side straps differently to allow for a coat pocket handle, and to omit the side handles for care recipients, as these can cause demented individuals to fall if they do not let go of the handles.

If the employer would purchase one of these two exoskeletons, caregivers would wear both models regularly during daily work (n = 8 for both models).

The following table presents additional quantitatively collected results.

Question	Model	Answers Participant				Mean
		1	2	3	4	
How practical did you find the donning and doffing of the exoskeleton?	CareExoLift	3	3	2	4	3
	Rakunie Back Support	1	2	1	2	1.5
How have care recipients responded to the exoskeleton?	CareExoLift	3	3	1	1	2
	Rakunie Back Support	3	3	1	1	2
How were your attitudes toward the exoskeleton prior to first use?	CareExoLift	1	2	1	1	1.25
	Rakunie Back Support	1	2	1	1	1.25
In general, how would you rate the benefits of using the exoskeleton in your everyday work?	CareExoLift	1	2	2	2	1.75
	Rakunie Back Support	3	3	1	1	2
How does wearing the exoskeleton on the body feel in general?	CareExoLift	2	3	2	3	2.5
	Rakunie Back Support	1	2	1	2	1.5

Table 2: Results of questions concerning the use of both passive exoskeleton models. *Please tick the most applicable answer for each question: 1 (good/positive), 2 (rather good/positive), 3 (medium), 4 (rather poor/negative), 5 (poor/negative)

The results show that there are differences between both models in terms of different dimensions. The attitudes toward the exoskeleton prior to first use were positive (m = 1.25 for both models). Furthermore, the care recipients responded rather positive to the exoskeleton (m = 2 for both models). Whereas the CareExoLift was more complicated in donning and doffing (m=3) compared to the Rakunie Back Support (m=1.5), there was hardly any difference in the rated benefits when wearing in everyday work. The participants rated the models differently with respect to how it felt to wear them on the body (CareExoLift m = 2.5; Rakunie Back Support m = 1.5).

In addition, general questions were asked about the knowledge of passive exoskeletons prior to the initial contact with the exoskeletons. Only one person knew before testing that passive exoskeletons for caregivers are already produced and offered. Also, only one other person knew before testing how a worn, passive exoskeleton works and that such a passive exoskeleton can provide physical relief in everyday work.

4. Discussion and conclusion

One limitation of this study is the small case number. Therefore, it is referred to as a case study. Thus, the external validity is limited, but allows first indications on the perception of caregivers on the use of passive exoskeletons during daily work.

In addition, most participants (n = 3; 75 %) reported physical complaints. The quest on physical complaints in the questionnaire was not defined more precisely but kept open. Logically, technical assistance systems are perceived as more helpful for people with physical complaints since the perceived benefit is higher. Therefore, it cannot be excluded that passive exoskeletons are considered less helpful by people without physical complaints (Kozinc, Babič & Šarabon 2021). Such a population could be constituted by younger people. A survey by von der Lippe et al. (2021) shows that in Germany, older people are more frequently affected by neck and back pain attacks than younger people.

The last question in Table 2 shows that both models felt rather good to wear on the body in general, but there was a difference between the models. It indicates that construction makes a difference on the acceptance and exoskeletons need to be adjusted to the work of caregivers to be better accepted.

Caregivers seem to have little knowledge about the existence, functionality, and benefits of passive exoskeletons in caregiving. It is possible that providing information could reduce reservations towards technical assistance systems. The investigated population seems to have a positive attitude about testing passive exoskeletons and feel a positive effect on their physical exertion when wearing them. The case study supports previous research showing that wearing comfort and ease of use, such as donning and doffing, should be a given (Schwerha et al. 2022). Furthermore, the case study indicates that the structure and functioning of the exoskeletons seems to make a difference on perception by the caregivers (Elprama et al. 2022).

In this pilot study, the acceptance factors perceived safe use of exoskeletons, perceived usefulness of exoskeletons, general attitude towards exoskeletons, existing knowledge about exoskeletons (psycho-socio factors), personal history of physical complaints, wearing comfort of exoskeletons (physiological factors) and ease of using an exoskeleton (implementation-related factors) were addressed. These acceptance factors in caregivers are consistent with findings of Elprama et al. (2022). In their framework of exoskeletons acceptance in industry, they showed that the factors identified in this pilot study and other factors are critical for exoskeleton acceptance. The factors can be classified in the dimensions psycho-socio, physiological, implementation-related, work-related, and policy-related.

Further in-depth qualitative research is needed to identify the comprehensive range of acceptance factors of exoskeletons among caregivers.

Conflict of interest statement

The author declares that no conflict of interest exists with respect to the publication of this work.

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Appendix 1:
Eingesetzter Fragebogen

1) HUNIC GmbH

An wie vielen Tagen haben Sie das Exoskelett getragen? ___

Wie viele Minuten haben Sie das Exoskelett ca. pro Tag getragen? ___

Empfanden Sie eine körperliche Entlastung beim Tragen des Exoskelettes? Ja □ nein □

Empfanden Sie das Exoskelett an einer bestimmten Stelle des Körpers als angenehm? Ja □ nein □
Wenn ja, an welcher/n Stellen? ___

Empfanden Sie das Exoskelett an einer bestimmten Stelle des Körpers als störend? Ja □ nein □
Wenn ja, an welcher/n Stellen? ___

Kam es durch das Tragen des Exoskelettes während der Schicht zu einer gefährlichen Situation?
Ja □ nein □
Wenn ja, wie bzw. warum? ___

Hat Sie das Exoskelett in Ihren Bewegungsabläufen negativ beeinträchtigt? Ja □ nein □
Wenn ja, inwiefern? ___

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 1]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 2]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 3]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 4]

Wie fühlte sich das Tragen des Exoskelettes an? (Bitte nennen Sie nur Adjektive; z.B. angenehm, hilfreich, störend, irritierend) [Adjektiv 5]

Welche Verbesserungsvorschläge haben Sie für die Konstruktion des Exoskelettes? ___

Im Falle eines Erwerbes eines Exoskelettes durch Ihren Arbeitgeber, würden Sie das Exoskelett regelmäßig nutzen wollen? Ja □ nein □

Bitte kreuzen Sie für jede Frage die zutreffendste Antwort an:
1 (gut/positiv), 2 (eher gut/positiv), 3 (mittel), 4 (eher schlecht/negativ), 5 (schlecht/negativ):

- Wie praktikabel empfanden Sie das An- und Ausziehen des Exoskelettes?
- Wie haben die Pflegebedürftigen auf das Exoskelett reagiert?
- Wie waren Sie vor der ersten Nutzung gegenüber dem Exoskelett eingestellt?
- Wie würden Sie allgemein den Nutzen des Einsatzes des Exoskelettes in Ihrem Arbeitsalltag bewerten?
- Wie fühlt sich das Tragen des Exoskelettes am Körper im Allgemeinen an?

Wie praktikabel empfanden Sie das An- und Ausziehen des Exoskelettes? Schildern Sie bitte kurz Ihren Eindruck. ___

2) Rakunie

(selbe Fragen wie für HUNIC GmbH)

3) Allgemeine Fragen zum Tragen beider Exoskelette

Bei welchen Tätigkeiten haben Sie das Exoskelett getragen? ___

Bei welchen Tätigkeiten während der Arbeit half Ihnen das Exoskelett am meisten? ___

Sehen Sie eine Gefahr für sich oder die pflegebedürftige Person durch das Tragen des Exoskelettes?
Ja □ nein □
Wenn ja, welche Gefahr/en?

Wussten Sie bereits zuvor, dass Exoskelette für Pflegende entwickelt werden? Ja □ nein □

Wissen Sie in etwa, wie ein von Ihnen getragenes, passives Exoskelett funktioniert? Ja □ nein □

Wussten Sie bereits zuvor, dass Sie ein passives Exoskelett körperlich entlasten kann? Ja □ nein □

Haben Sie körperliche Einschränkungen oder Beschwerden? Ja □ nein □

4) Soziodemografische Daten

Alter? ___Jahre

Geschlecht? männlich □ weiblich □ divers □

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