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What is an Agricultural Exoskeleton?

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Introduction

Agriculture is a physically demanding way of life. One that requires a farmer to carry heavy loads, maintain awkward positions for prolonged periods of time, and engage in repetitive behavior. The nature of farming means that farmers more likely to experience back injuries, arthritis, and other work-related injuries (Upasani et al. 2019, 1). Unlike other industries, agriculture does not wait for injuries to heal. Regardless of how the farmer feels, feed needs to be moved, cows give birth, and tractors break down. This often can compound hazardous situations for farmers and result in greater injury (Upasani et al. 2019, 1). While the physically demanding and time-sensitive nature of agriculture cannot be avoided, we can make those tasks safer with assistive technology.

Assistive technology is any technology, simple or complex, that helps an individual carry out an activity or task. A prime example is an exoskeleton. An exoskeleton is a wearable device that mimics the structure of the human body to help reduce the strain on the user. Like the exoskeleton of an insect, the device can disperse the weight of the load, reducing the impact on the back and joints, as well as increasing a user's mobility (Upasani et al. 2019). While already adopted within other industries, agricultural exoskeletons are in their infancy. The potential benefit of agricultural exoskeletons is undeniable. However, the lack of agriculture-specific exoskeletons and the variety of uses may make purchasing one for the farm a confusing and costly investment. This publication aims to provide a concise breakdown of agricultural exoskeletons.

Passive vs. Active

Exoskeletons fall into two main categories: active and passive. Active and passive refers to the way the exoskeleton bends. A passive device does not need additional energy to assist the user. Rather, a passive exoskeleton uses springs or flexible beams to provide or disperse energy (Toxiri et al. 2019, 239; Olar, Leba, and Risteiu 2021). An active exoskeleton relies on actuators, a device that operates like a dimmer switch to open or close, and a power source to provide torque, rotational force used to help a person bend in this case, and resistance. The actuators can be hydraulic, pneumatic, electrical, or a combination of them (Olar, Leba, and Risteiu 2021; Tiboni et al. 2022, 21–26). The differences between the two varieties ensure that an appropriate exoskeleton is available for the user's needs.

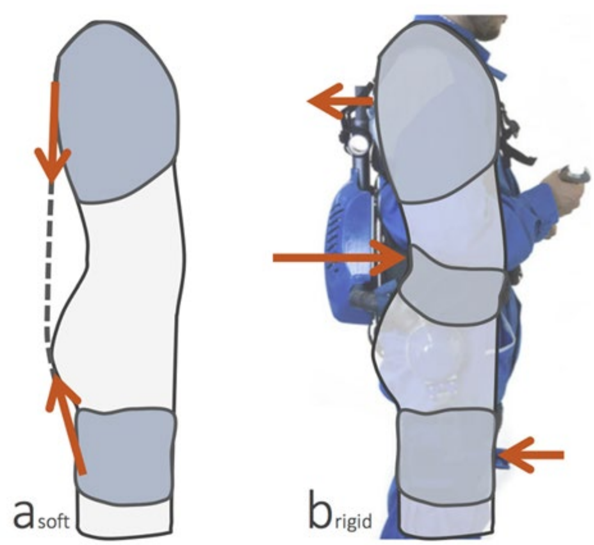

Figure 1: Illustration demonstrating a passive (a) and active (b) back exoskeleton. The arrows show the

direction of force the devices provide (Toxiri et al. 2019).

The actuators in an active exoskeleton allow it to assist with heavier loads and allow for a greater range of motion and use (Tiboni et al. 2022, 883–84). In many respects, this makes active exoskeletons more versatile (Toxiri et al. 2019, 239). While the versatility of an active exoskeleton makes it attractive for many situations, the increased areas of support and additional torque also mean that an active exoskeleton is heavier, more costly, and less suitable for some situations. Active exoskeletons may be preferred by a user who lifts heavy loads repeatedly or wants assistance managing involuntary movements such as tremors.

By contrast, a passive exoskeleton will have a smaller maximum load, but the lower profile of the spring system may make it more appropriate for everyday tasks (Toxiri et al. 2019). While the absence of actuators reduces the range of motion and limits the amount of torque provided, it also reduces the overall weight of the exoskeleton and eliminates the bulky battery and down time for recharging associated with active exoskeleton. A passive exoskeleton is ideal for a user that would like additional support with repetitive actions to avoid injury.

Agricultural Applications

The variety of tasks a farmer must be able to do makes the agricultural industry unique when designing assistive technology. Farmers must be able to have the strength, flexibility, and dexterity to perform a variety of tasks from feeding livestock, tending to row crops, and doing mechanical repairs or electrical work. The amount of squatting, twisting, and gripping means an assistive technology must target all the areas a farmer needs. While full exoskeletons are available, users may find it more comfortable and convenient to support the areas in most dire need. In a survey conducted by Virginia Tech researchers, the back, knees, and hands were identified as the most in need of support (Upasani et al. 2019). In the study, 94% of participants said they would use back and knee exoskeletons and 81% said they would use a hand exoskeleton. Shoulder and full-body exoskeletons were not far behind with 75% and 63% respectively (Upasani et al. 2019, 4).

Back Support

The lower back is a constant area for sore muscles and potential injury. An exoskeleton worn during periods of work reduces the amount of strain the lower back feels. Like a spotter in a gym, back exoskeletons accomplish this by providing additional strength when needed. While bulky, active back exoskeletons are more widely available today, there are more ‘soft’ options being developed. Ideally, these soft passive exoskeletons will be able to be worn under work clothes and provide enough support to avoid injury (Toxiri et al. 2019).

Figure 3: Front and back view of Virginia Tech and Lowe’s passive Exoskeleton (Alemi et al. 2019).

Knee Support

Lower-limb and knee support is one of the most heavily researched areas of exoskeletons (Tiboni et al. 2022, 13). In agriculture, actions like squatting or getting down from a tractor or other equipment provide the potential for knee injury. Knee-specific exoskeletons can provide support in all directions; side-to-side, as well as flexing the knee (e.g., getting up from a squat). Exoskeletons for the knees use sensors to detect when to provide support or rely on resistance to help with everyday movements.

Figure 4: An active knee exoskeleton (Wevolver 2022).

Hand Support

Exoskeletons for the upper limbs can be separated by the joint the device supports; wrist, elbow, and shoulder (Olar, Leba, and Risteiu 2021). Because the human hand has such a broad range of motions, hand exoskeletons are very unique. There are twelve joints in the hand, excluding the palm, that work together to provide complex mobility (Sarac, Solazzi, and Frisoli 2019). This necessitates a multitude of options for hand exoskeletons that focus on different areas for assistance.

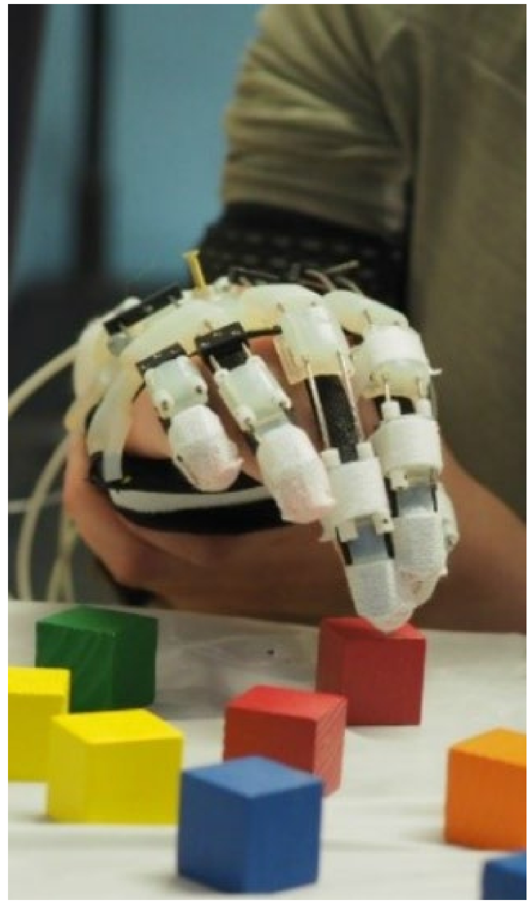

Figure 5. An active hand exoskeleton stabilizing fine motor function in an individual with a brain injury. Modified from (Fischer et al. 2022)

While farmers identified shoulder support as a need in the Virginia Tech survey, a device that supports the hand could be paired with further arm or shoulder support. Depending on the user's needs, the hand support could be passive or active and have a range of mobility specific to different tasks. This subset of exoskeletons can provide additional strength, support, and mobility in the hand.

User Considerations

The decreased risk of injury and the prolonged health of the farmer make an exoskeleton an investment in personal safety and an asset for the farm business. However, most exoskeletons on the market are targeted toward industrial, military, or medical uses. While agricultural-specific exoskeletons are still on the way, the occupational utility of many exoskeletons can still be helpful to farmers. To make sure you get the most out of your investment consider reaching out to AgrAbility for assistance with identifying potential suppliers, potential sources of funding, and the right exoskeleton for your needs. While not a complete list, the following recommendations can help guide your search.

Durability

Farming is a strenuous activity. It takes a toll on the body and will take a toll on the exoskeleton as well. The exoskeleton should be able to keep up with the farmer with minimal downtime. Consider the type of exoskeleton, number of sensors, and manufacturer specifications. Ensure the level of complexity is something you are comfortable with, and the exoskeleton is rated for the type of work you want it to do.

Additionally, the ease of repair should be considered. Does the exoskeleton need to be sent away for repairs or can the owner make repairs? The amount and frequency of downtime needed to recharge batteries, adjust settings, or make repairs to an exoskeleton may vary from model to model. This downtime and maintenance will need to be factored into farmers' schedules to ensure the exoskeleton is available during the growing season or whenever the farmer will be using it.

Compatibility

The last thing anyone wants is a disruptive device. An exoskeleton should be beneficial without getting in the way of a normal routine. Consider the number of exposed cords, battery packs that jut out, and the added bulk and weight of the exoskeleton. Consider those factors in the context of your farm operation and the activities you generally perform.

Crops like berries or field crops may require more stooping and bending than wheat or corn. Raising cattle may justify powered leg support. The type of tasks, repetition, and frequency shifting between them, may make some exoskeletons more compatible with your work than others. Lastly consider personal safety around your equipment. An exoskeleton with wires or loose fabric may provide potential snags when working with a lot of heavy machinery and could be dangerous around a PTO. The ability to wear the exoskeleton under your clothes may be of help in some of these regards.

Versatility

Unlike many industries, the tasks in agriculture change with the growing season, day to day, or hour to hour. While an exoskeleton can focus on a particular part of the body, the range of motion should be versatile enough to allow you to complete any task you may need. While an active full-body exoskeleton may be excellent for loading haybales, it could be limiting and cumbersome if your livestock needed attention right away. Additionally, it should be comfortable to wear for the duration of the task you need it for.

Consider the range of motion an exoskeleton provides and the design elements for comfort, padding, breathability, etc. These factors can improve the user experience and improve the ability to switch tasks. Compare these considerations to the type of work you need an exoskeleton for and the frequency you'll need the exoskeleton throughout your day.

Affordability

Exoskeletons, in general, are still a new technology and are just starting to take hold. As such, they can be relatively expensive—anywhere between a few hundred dollars and tens of thousands. The factors that influence the cost are the power source, whether they are active or passive, the range of support, and whether they are for a specific area of the body or support the full body. As technology improves, the cost of exoskeletons is projected to drop, but in the short term, consider reaching out to AgrAbility to help you look for potential funding sources and lessen the cost.

Conclusion

Agricultural exoskeletons are an exciting technology with a bright future. As the technology becomes readily available and specifically designed for agricultural tasks, it has the potential to help farmers avoid injury and recover faster (de Looze et al. 2016). Until the industry catches up with agricultural demand, you may use the information in this factsheet to narrow your search, but you may also consider consulting with your healthcare provider, an occupational or physical therapist, or staff at AgrAbility Virginia (for Virginians) or the National AgrAbility Project (for those outside of Virginia) for guidance. Knowing what tasks, you encounter frequently and where you feel you need support is a great starting point.

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Additional Resources

The following resources provide links to companies that are producing exoskeletons for industrial and medical uses. This is not an endorsement of these products, but they provide more fine details about options that are available.

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Acknowledgements

AgrAbility Virginia is funded by AgrAbility Project, USDA/NIFA Special Project 2019- 2022 (41590-22326)

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2023 ALCE-303NP