



Research to Standards

EXO TECHNOLOGY

ASTM INTERNATIONAL  
Exo Technology Center of Excellence

# Exoskeleton Producer Survey Report

Perceptions and Opinions of Exoskeleton  
Producers in 2020

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**Data Collection Conducted 08/10/2020 to 09/21/2020**

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ASTM International Exo Technology Center of Excellence

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# Executive Summary

## ASTM International ET CoE

The ASTM International Exo Technology Center of Excellence (ET CoE) is a collaboration between ASTM (and its more than 30,000 members) and consumers, industry, government, healthcare, and academia whose focus is to accelerate safety, quality, and reliability standards for exoskeletons and their systems. The ET CoE has a vision of people of all ages able to pursue a high-quality life and fully participate in work and society thanks to safe and reliable exoskeletons. Its mission is to build, connect, and energize exo technology research, standards, and applications. The ET CoE accomplishes this mission by serving the exo community with initiatives that speed the development of high priority standards through:

- conducting strategic Research to Standards (R2S) projects,
- delivering education, training, and workforce development opportunities,
- connecting people and organizations to promote innovation and collaboration,
- providing a neutral venue for stakeholder groups to discuss consensus solutions for exo technologies,
- establishing a proficiency and conformity testing and certification service, and
- promoting exo technology through various outreach mechanisms.

## The Survey

The purpose of this survey is to collect input and feedback from exoskeleton producers in order to help the ASTM F48 Committee on Exoskeletons and Exosuits develop relevant standards to support and enhance the growth and success of the exoskeleton industry. A total of 55 exoskeleton producer representatives responded to the survey.

Among the general findings, the data shows that safety and reliability of their products is among the most pervasive concern for producers. On average, exoskeleton producers agreed that they have enough evidence to demonstrate that their products are effective. While producers have positive opinions about the safety and reliability of their products, on average the confidence in these two key areas is not as high as effectiveness. This finding leaves a topic for further analysis and meaningful discussions with producers in the future.

As for standards, on average exoskeleton producers agree that exoskeleton standards are important for the successful growth of the industry and for customers to adopt their products, but many are unsure of what the impact of their participation in the standards process could be. This allows for the ASTM Exo Technology Center of Excellence and F48 committee to consider increasing outreach and education for exoskeleton producers on the activities and work efforts of F48, why they should matter to producers, and what value producers will get from participating. But the outreach should not be limited to current producers, it is important to impact those newcomers and academics considering the production and sales of exoskeleton products and services.

Further discussions include a number of other topics: rate of exoskeleton adoption; the role of government in accelerating test method development and product adoption; data mining and sharing.

In general, there is a solid agreement about the importance of safety standards and certifications. The data also suggests the need for a data vault/knowledge base for data and resource storage and sharing across the exoskeleton industry, a need for education (such as educating producers about standards, and educating end users and/or potential consumers about exoskeletons), a need to recruit producers for standards development, and a need for exoskeleton industry, government and insurance industry collaboration.

## Recommendations

### Standards and Certifications

Focus on safety standards and certifications (F48.02 Safety Task Group currently focuses on practices and guides. Consideration should be given to begin to develop test methods that can be used to determine safety in a standardized manner that can lead to certifications)

### Outreach

- Consider standards, test methods, and certification outreach efforts that are directed towards engaging exoskeleton producers related to the activities and work efforts of F48, orienting the message towards “value added” - why these products should matter to exoskeleton producers, what value producers will get from participating in the F48 consensus building processes and the impact of such products on the consumer market
- ET CoE and F48 outreach efforts for exoskeleton producers can incorporate ASTM F48 and ET CoE’s overarching mission, vision, values and objectives in the context of the international standards, test methods and certification
- Design outreach products that will encourage recruiting exoskeleton producers for F48 participation

### Education, Data and Knowledge Sharing

- Consider developing a system to collect, catalog and avail material and data of interest to exoskeleton producers such as creation of a data vault, knowledge base, and resource library for exoskeleton producers, end users, insurance, government, and other interested parties
- Promote and facilitate the sharing of knowledge across the exoskeleton industry and interested parties as a committee or center aligned with the designated ASTM mission and/or in collaborations with other consensus building standard and test methods, communities of practice, societies, and academics
- Provide a platform or suite of products that serve to educate exoskeleton producers about standards, test method development and certification processes
- Provide a platform or suite of products that serve to educate exoskeleton end users and interested parties about exoskeletons and/or collaborate with producers, academics, industry members, societies, government and other organizations to achieve the goal of promoting exoskeleton knowledge growth

### Government and Insurance Collaboration

- Consider collaborative analysis of the interrelationships that impact the community as it relates to government policies and procedures as well as the impact of the insurance industry on the ability to cover cost of exoskeletons, implement exoskeletons in the workplace or address other insurance related information
- Promote and facilitate government-insurance-standards-exoskeleton industry collaboration

- Facilitate discussions around exoskeleton certifications, improving the rate of adoption, the role of government and insurance in accelerating development and adoption, device classification (e.g. as PPE), data mining and knowledge sharing

### The Team:

This survey was designed and conducted in collaboration with the ET CoE, by members of the ET CoE’s founding team of three recognized entities in the exoskeleton world, who are also members of the F48 Committee on Exoskeletons and Exosuits:

- Exoskeleton Report LLC ([exoskeletonreport.com](http://exoskeletonreport.com)), the first comprehensive on-line publication dedicated to exoskeleton and wearable technologies since 2015.
- Optimum Performance Services LLC ([www.linkedin.com/in/matthew-marino-26903997/](http://www.linkedin.com/in/matthew-marino-26903997/)), recognized for their work with occupational health and safety, ergonomics consulting, physical therapy, strength and conditioning services, standards and test methods, and exoskeleton design, testing and analysis, and implementation.
- New Stone Soup VT LLC ([www.newstonesoupvt.com](http://www.newstonesoupvt.com)), a woman owned consulting firm with over 20 years of Army exoskeleton RDT&E project management experience and strategy development support.

**For more information on this project, contact [etcoe@astm.org](mailto:etcoe@astm.org)**

# Survey Objectives, Participants, Methodology, and Data Collected

## Survey Objectives

The purpose of this survey is to collect input and feedback from exoskeleton producers in order to help the ASTM F48 Committee on Exoskeletons and Exosuits develop relevant standards to support and enhance the growth and success of the exoskeleton industry. Additionally, the input and feedback from exoskeleton producers will help the ASTM Exo Technology Center of Excellence prioritize and plan activities according to its charter. Decisions will include, but not limited to, allocating time, defining level of effort, and budgeting resources for supporting the F48 Committee and the broader exoskeleton industry. The broader exoskeleton industry includes, among others: current and upcoming producers, government, consumers, academics, occupational health and safety professionals, policy makers, purchasing officials, insurance industries and so on.

## Participants

The participants of the survey were employees and/or representatives from the international community of exoskeleton producers. ASTM F3323-20 Standard Terminology for Exoskeletons and Exosuits defines an exoskeleton as a “wearable device that augments, enables, assists, and/or enhances physical activity through mechanical interaction with the body.” Exoskeleton producers, for the purpose of this survey, were defined as companies that design, manufacture and make exoskeletons and exosuits available to customers.

## Methodology

The project began with a planning phase during which the survey scope, objectives, key results and timeline were developed. A draft list of survey categories and questions were then developed and sent to select active members of the ASTM F48 committee for their input. A combination of question types including open

ended, forced choice with a Likert scale of 0 to 5, multiple choice and yes or no were utilized. A final list of survey categories and questions were then entered into SurveyMonkey. The survey was designed to take less than 15 minutes to complete, and utilized plain English as much as possible to reach and be understood by the widest audience of producers possible. The ASTM ET CoE team launched the survey, notifying exoskeleton producers by email, article posted on the Exoskeleton Report website, ASTM ET CoE presentations, and via social media marketing. Data was collected using SurveyMonkey until the survey closed. The survey data was anonymized and analyzed, and a results report draft was produced. The views, opinions and recommendations presented and/or discussed are those of the authors, and do not necessarily represent the positions of the ASTM ET CoE or those of the entire F48 committee. The survey was open for six weeks, starting from Aug 10th, 2020 to Sept 21st, 2020.

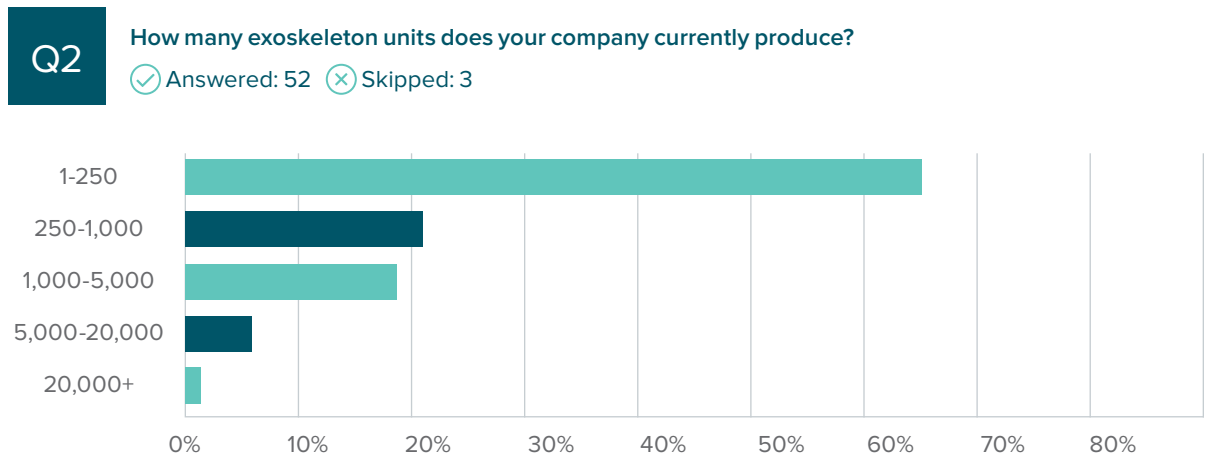
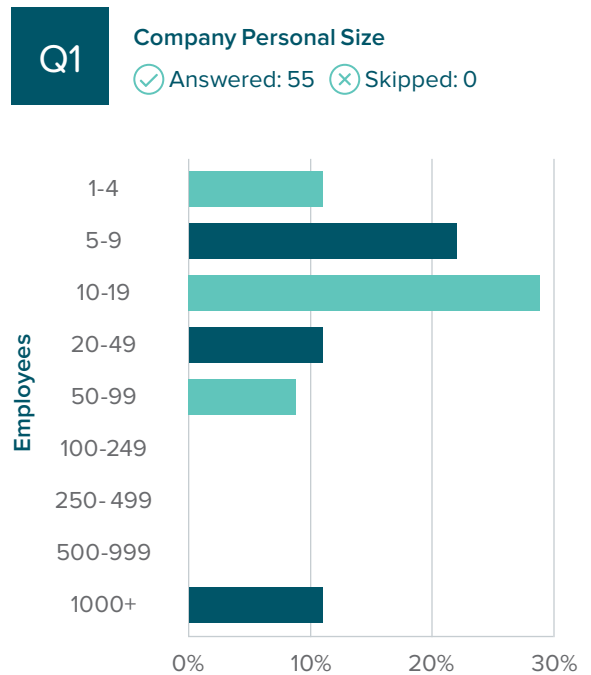
## Data Collected

[Appendix A](#) contains the complete list of survey questions.

# Results

The results are broken out by category and listed by question on pages 7-17. The survey platform’s data analysis and display functionality was utilized for certain demographics and yes or no question results. A 0 (strongly disagree) to 5 (strongly agree) point Likert scale was utilized for questions in a number of survey categories. For these 5 point Likert scale questions, the mean and standard deviation (SD) was calculated and the number of responses was listed for each question. In addition, multi-colored bar charts to visualize the Likert scale responses were created for each question. Word clouds were created for open ended questions by segmenting the responses based on the phrasing and overall context of each response. Each grouping was then represented with varying font size based on how often that thought was expressed in the responses.

## Exoskeleton Producer Demographics

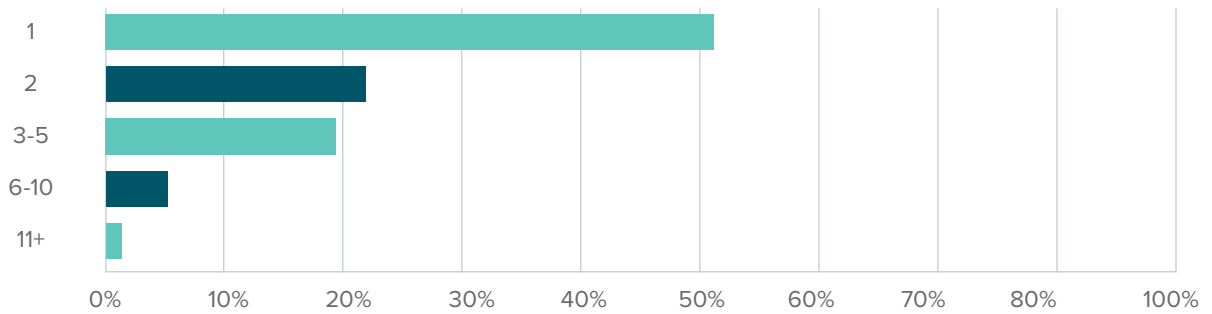


### Exoskeleton Producer Demographics

**Q3**

**How many exoskeleton products does your company currently produce?**

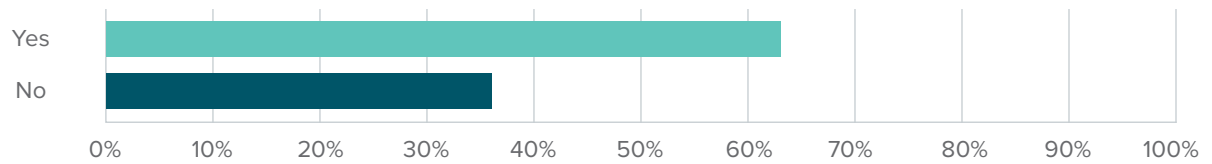
Answered: 53  Skipped: 2



**Q4**

**Are you or is someone else at your company a member of a standards committee doing work related to exoskeletons (i.e. ASTM International, ISO TC/299, etc.)?**

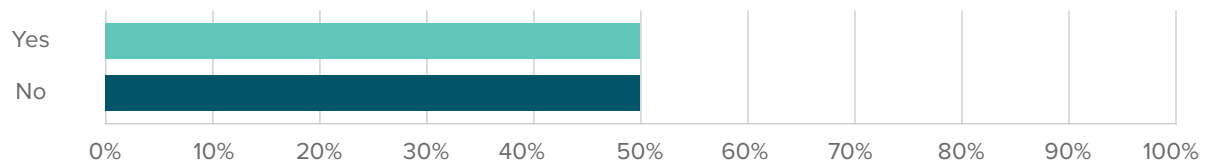
Answered: 53  Skipped: 2



**Q5**

**Are you or is someone else at your company a member of any trade associations or organizations that are focused on exoskeletons?**

Answered: 52  Skipped: 3



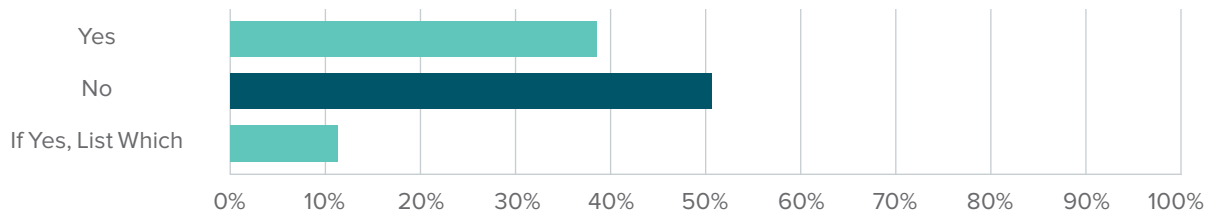


## Exoskeleton Producer Demographics

**Q6**

Are you or is someone else at your company participating in programs to evaluate exoskeletons

✔ Answered: 53 ✘ Skipped: 2



**Q7**

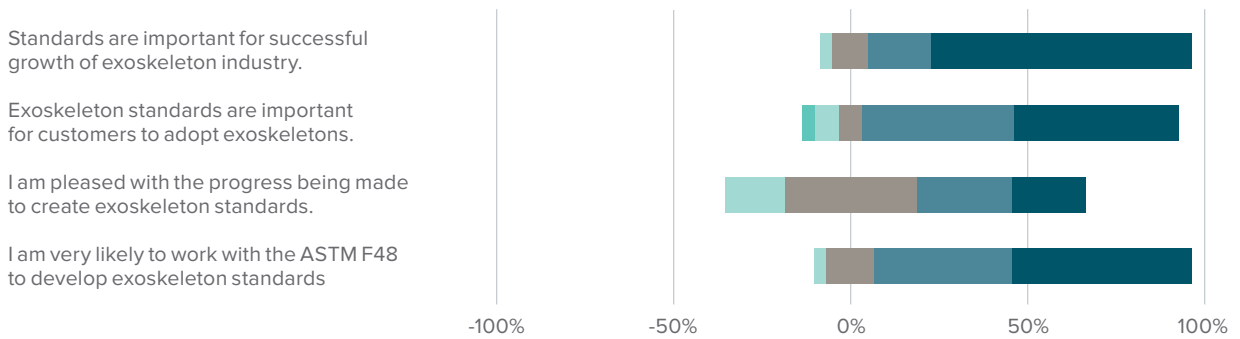
If yes, which ones?

- Several European Projects
- Exskallerate
- French Ministry of Defence
- Canadian Department of National Defence (DND/DRDC)
- SSOCOM TALOS Program
- University Studies
- Association of the Exoskeleton Industry – VDEI.org
- Australian Defence Forces (ADF) Diggerworks
- Singapore Armed Forces (SAF)
- Afnor – Association Française de Normalisation

## Exoskeleton Standards

Qs		Mean	SD	Responses
8	Exoskeleton standards are important for successful growth of the exoskeleton industry.	4.64	0.62	42
9	Exoskeleton standards are important for customers to adopt exoskeletons.	4.29	0.94	42
10	I am pleased with the progress being made to create exoskeleton standards.	3.54	0.98	41
11	I am very likely to work with the ASTM F48 Committee on Exoskeletons and Exosuits to develop exoskeleton standards.	4.33	0.75	42

STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE



### Exoskeleton Standards

**Q12**

In your opinion, what is the primary purpose of exoskeleton standards?



**Q13**

In your opinion, what are the three most important exoskeleton topics/areas in need of standards?



**Q14**

What are your biggest concerns about exoskeleton standards?



## Exoskeleton Validation and Certification

Qs		Mean	SD	Responses
15	My company has enough information, data, or other evidence to demonstrate that our exoskeleton is safe.	3.85	1.11	39
16	My company has enough information, data, or other evidence to demonstrate that our exoskeleton is reliable.	3.95	0.92	39
17	My company has enough information, data, or other evidence to demonstrate that our exoskeleton is effective.	4.08	1.04	39
18	Exoskeleton certifications through organizations like ASTM Int'l are important for the success of the exoskeleton industry.	3.92	0.98	39
19	Certifications specifically for exoskeleton performance should be required to sell exoskeletons.	3.21	1.32	39
20	Certifications specifically for exoskeleton quality should be required to sell exoskeletons.	3.74	1.07	39
21	Certifications specifically for exoskeleton safety should be required to sell exoskeletons.	4.21	0.83	39
22	Certifications specifically for exoskeleton reliability should be required to sell exoskeletons.	3.44	1.07	39

STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE

My company has enough information, data, or other evidence to demonstrate that our exoskeleton is safe.

My company has enough information, data, or other evidence to demonstrate that our exoskeleton is reliable.

My company has enough information, data, or other evidence to demonstrate that our exoskeleton is effective.

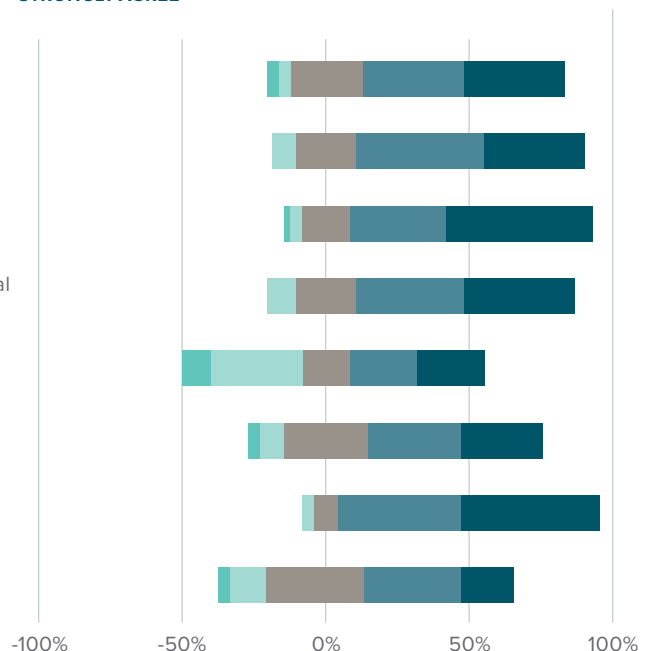
Exo certifications through organizations like ASTM International are important for the success of the exoskeleton industry.

Certifications specifically for exoskeleton performance should be required to sell exoskeletons.

Certifications specifically for exoskeleton quality should be required to sell exoskeletons.

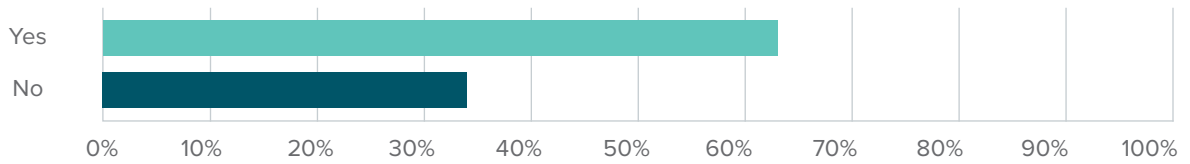
Certifications specifically for exoskeleton safety should be required to sell exoskeletons.

Certifications specifically for exoskeleton reliability should be required to sell exoskeletons.

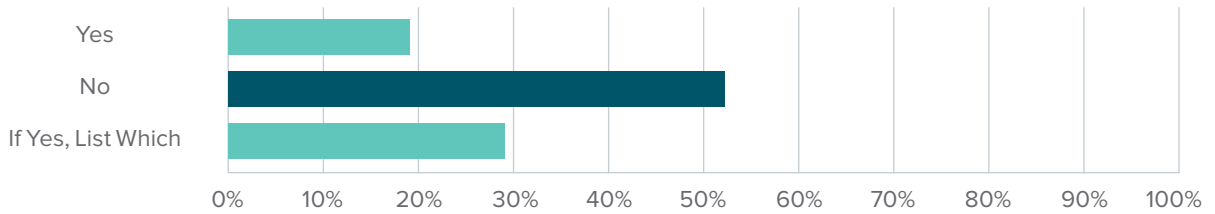


## Exoskeleton Producer Demographics

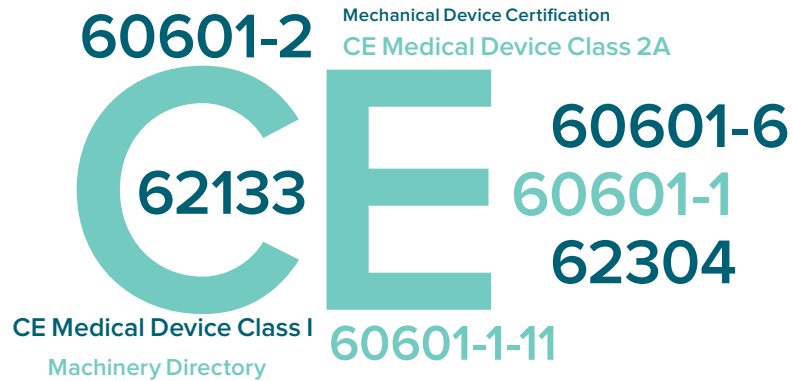
**Q23** Independent third-party researchers have performed research on our exoskeleton and published peer-reviewed studies about our device.  
 Answered: 39  Skipped: 16



**Q24** My company has received certifications for our exoskeletons.  
 Answered: 39  Skipped: 16



**Q25** If yes, which ones?



## Data, Education, and Knowledge Sharing

Qs		Mean	SD	Responses
26	I am happy with my company's understanding of our customer's needs.	4.05	0.84	38
27	I am happy with the amount of data that is shared with my company by its customers.	3.5	0.92	38
28	I am happy with how our customers are supporting and sustaining the use of our exoskeletons in their environments.	3.55	0.86	38
29	I am happy with the progress of longitudinal research (i.e., long term use) to demonstrate that our products are safe and effective.	3.21	1.07	38
30	I am happy with how the insurance industry is tracking the impacts of using exoskeletons in the environments which our products are being used.	2.79	1.19	38
31	I am happy with the amount and quality of government regulations and laws for our exoskeletons.	2.71	0.96	38

STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE

I am happy with the quantity of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.

I am happy with the quality of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.

I am happy with how the data and results of exoskeleton research studies are shared across the industry.

I am happy with my company's understanding of our customer's needs.

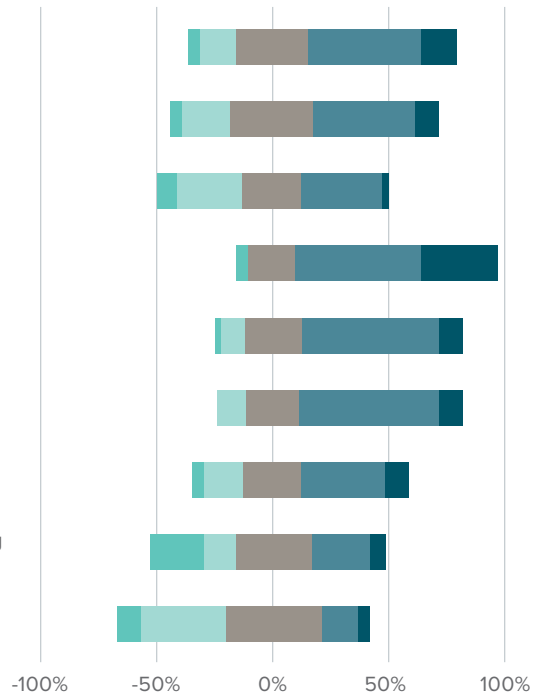
I am happy with the amount of data that is shared with my company by its customers.

I am happy with how our customers are supporting and sustaining the use of our exoskeletons in their environments.

I am happy with the progress of longitudinal research (i.e., long term use) to demonstrate that our products are safe and effective.

I am happy with how the insurance industry in tracking the impacts of using exoskeletons in the environments where our products are being used.

I am happy with the amount and quality of government regulations and laws for our exoskeletons.



## Exoskeleton Standards

**Q32** What are your thoughts about government and/or insurance oversight in your domain of exoskeletons (for example, how much or how little oversight should there be, and what should be done more or less)?



## Sales and Adoption

**Q33**

	Mean	SD	Responses
I am satisfied with the rate of adoption for our exoskeletons.	2.87	1.12	38

STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE



### Sales and Adoption

Q34

What do you think are the biggest challenges with widespread exoskeleton adoption?



### Exoskeleton Industry Needs

Q35

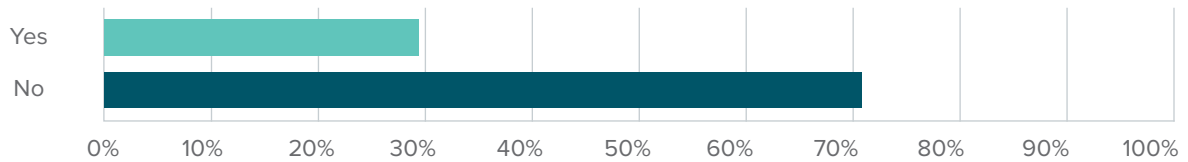
What do you think would be the most impactful approach to help increase the adoption of your exoskeletons in the marketplace?





### General Comments and Feedback

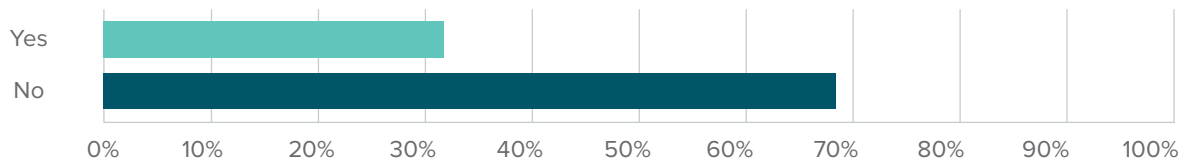
**Q36** Do you have anything you would like to share or discuss with the ASTM International Exo Technology Center of Excellence?  
 ✓ Answered: 38 ✗ Skipped: 17



**Q37** If yes, please share.

Create Regional Groups  
 What is the ET CoE's Mission?  
**Include More Producers**  
 What Standards Are WIP? Why Develop Standards? Medical Norms  
**Who is the ET CoE?**  
 Discuss Benefits of Standards  
 Learn More About ASTM  
 Access to ASTM Exo Standards  
 Who is the ET CoE Working With?  
 Discuss Adoption Acceleration

**Q38** If you answered yes, would you like to schedule a meeting with the ASTM International Exo Technology Center of Excellence?  
 ✓ Answered: 28 ✗ Skipped: 27



The list and contact information for those who requested a meeting with the ASTM ET CoE has been intentionally left out of this report. The ASTM ET CoE should communicate directly with these groups/individuals.

## Discussion and Recommendations

A total of 55 exoskeleton producer representatives responded to the survey. It's important to note that many (up to 17) skipped and chose not to answer certain questions. About 73% of those who responded work at companies with fewer than 50 employees. About 74% of respondents' companies produce 1-2 types of exoskeletons, and about 87% of these companies produce fewer than 1,000 exoskeletons per year. Taken together, exoskeleton producers are small companies, they focus mainly on 1-2 products, and would need to produce many more units per year to support large scale adoption.

About 64% of respondents report being members of an exoskeleton standards committee or working with others at their company who are members of standards committees like ASTM F48. Half of the respondents report participation by themselves or by someone at their company in exoskeleton trade associations. With standards taking shape to guide the exoskeleton industry, it's surprising that there are not more producers participating and developing the standards that will impact their businesses. This may be because they are more focused on evaluating their products and working to get them out into the marketplace and onto users. Almost 40% of producers indicated they were involved in programs to evaluate exoskeletons. Those that shared which programs these were indicated they were involved in university studies, military exoskeleton programs, and other industry programs and projects. Producers also may see standards as something that don't help or hinder them yet, and until they perceive standards impacting their business there isn't enough of the right type of motivation to trigger greater participation. The ET CoE and F48 committee should consider performing more outreach and education for exoskeleton producers on the activities and work efforts of F48, why they should matter to producers, and what value producers will get from participating.

On average exoskeleton producers agree that exoskeleton standards are important for the successful growth of the industry and for customers to adopt their products. Exoskeleton producers report being likely to work with exoskeleton standards organizations, but that they are more neutral in their opinion about the progress being made by standards committees. This again begs the question, if exoskeleton producers are not satisfied with the progress being made with

exoskeleton standards and they are willing to work with the committees developing them, then why are they not participating? In addition, what more can, or should committees like F48 and the ET CoE do to recruit producers to participate and accelerate the development of their standards?

Perhaps the rate of participation is related to the concerns that exoskeleton producers have about standards. Producers believe that standards have the potential to stifle innovation, that they are immature, overly complicated, and some went as far as saying they were useless. While more producers felt standards were too slow to publish, others indicated they were too fast to publish. One producer said, "...from a producer's perspective, it's not clear what standards are being developed or why. It's also not clear how all these committees work together. Is there overlap? Who owns what? I believe that some education is in order to help you all gain more support from the producers of exos." In order to recruit more producers to participate in the development of standards, the F48 committee and ET CoE will need to educate them on the value that standards have specifically for producers and address these concerns. According to one producer, standards organizations should, "Make sure to include as many producers as possible; the overall market needs many participants to grow and develop the market."

Based on the survey results, there are three major motivators for exo producers to be involved with standards development: increasing sales, increasing differentiation, and fear.

There is a minority of exoskeleton producers who hope that standards can be used to make exoskeletons mandatory, similar to hard hats or safety harnesses. The majority of producers are looking for safety standards that can alleviate consumers' fears that regardless of if their exoskeleton is effective or not, it is at the very least safe to trial.

A second motivator for exo producers to participate in standards development appears to stem from a desire to increase differentiation between their products and a competitor using performance standards. Without performance standards, decision-makers are forced

to choose based on which exo producer has a better marketing team, rather than on the more applicable device that meets their needs.

A third driver for participation stems from fear, or the desire to protect a producer's market position. Counterfeit devices that have been hastily produced with low-quality materials are of particular concern to this group of producers. Furthermore, producers are concerned that standards will be created with metrics that are not favorable to their product or are completely irrelevant from their point of view.

When it comes to exoskeleton validation, adoption and consumption, it's important to keep in mind that the general notion among end users regarding what an exoskeleton is (or isn't) is either limited to or highly influenced by science fiction or fictional literature. In essence, the general public is still unaware of what exoskeletons are, and a large majority of those rely on sources that do not portray exoskeletons as real technologies.

While reviewing existing open source material, the prevalence of comments made in articles for public consumption or marketing materials tend to make common associations between the exoskeleton products and those found in sci-fi films (Aliens, Iron Man, and so on). These associations create unrealistic expectations for a product (or products) of interest, which adversely impacts the producer's job of "selling" a product (to an investor or potential customer) more difficult. This has had an adverse impact on the exoskeletons industry's ability to influence the intended consumer base, and create a more cohesive industry message. As one producer stated, "The number one problem is a lack of education, and an overabundance of misinformation and inflated expectations. From there, there is very little organization or cohesion across the industry, there is too much negativity in marketing and communication between producers, gatekeepers and end users, there is poor visibility of exo technology for the general public, it's not on people's radar, exoskeletons are still a concept in a comic book movie rather than a real thing to most people. Real world success stories need to be told, people need to be educated with facts, misinformation needs to be eliminated, experts and leaders need to rise and begin to drive the industry forward."

The existing community vested in the exoskeleton industry (producers, academics, early adopters) understand that the current exoskeleton technology state of the art doesn't compare to these fictional sources. Thus, a gap between the technologies real

performance and consumer perception exists and is a detriment to the industry. This gap has a noticeable impact on the producer's ability to expand their market reach, overall product adoption and proliferation, and the ability to create an industry with a cohesive message and a recognizable every-day consumable product.

If we are to consider the existing state of the market vis-à-vis the existing data and studies, there is considerable literature to substantiate that in its early adoption phases, exoskeletons are achieving their desired results. These results, studied within living applied conditions (automotive industry, construction, logistics, healthcare), indicate that products such as shoulder-assist devices for reducing shoulder muscle activity, back-assist exoskeletons for reducing back muscle activity and medical devices designed for patient rehabilitation or mobility gain do exist. Studies also identify concerns, tradeoffs and areas for consideration. Given the existing products entering the marketplace, and existing data, it is relevant that expectations be managed within realistic contexts and not those molded by anecdotal or fictional information.

On average, exoskeleton producers agree that they have enough evidence to demonstrate that their products are effective. While producers have positive opinions about the safety and reliability of their products, on average the confidence in these two key areas is not as high as it is for effectiveness. This has potential to be a problem. If producers have more confidence in their devices' effectiveness than they do in their products' safety and reliability, consideration needs to be given on how to manage this trend. Exoskeleton producers agreed that safety certifications should be required to sell exoskeletons more than any other type of certification proposed in this survey (safety, performance, quality, and reliability). Because safety is something that producers seem to agree is important, it is safe to state that standards and certifications focused on this area will help boost producers' (and ultimately end users') confidence in their products' safety. This is a topic that should be of interest and focus for the ET CoE, standards

committees like F48 and certification organizations in prioritizing activities. This particular survey seems to indicate that these products will be of shorter-term interest as compared to standards and certifications for effectiveness or performance, which, based on the survey do not have as much support from exoskeleton producers at this time. However, it should be a consensus process by which goals and needs can be prioritized and address accordingly. Currently, the efforts of the F48.02 Safety Task Group are focused on practices and guides. Based on some of the results from this survey, this group could consider developing test methods that can be used to create the certifications that producers who participated in this survey indicated are important. The majority of survey respondents indicated that their products did not currently have any type of certification. The majority of those that did report having certifications listed the CE and/or a medical device certification, so safety is the best area to begin with to help producers test, and end users accept and adopt exoskeletons.

Exoskeleton producers agree that they have a good understanding of their customers' needs, but they are more neutral when it comes to how their customers are sustaining the use of their products and sharing data with them, the amount and quality of published data, and the progress of longitudinal research. On average exoskeleton producers are not happy with how data and results of exoskeleton research studies are shared across the industry. This is an area in need of improvement. There is a growing body of literature and data out there about exoskeletons, but there are no good resources or knowledge bases available for cataloging and sharing this information across the industry in a way that is searchable and easy to use. This is something the ET CoE may want to consider for a future project. The creation of a data vault, knowledge base and/or a resource library for everyone's benefit may help improve exoskeleton producer perceptions about the work being done by the ET CoE, and boost confidence and perceptions about data and knowledge sharing. Unbiased third-party groups like the ET CoE are in a good position to handle, manage, and own such as resource for the benefit of the entire exoskeleton industry. On this subject, one producer stated, "To standardize the exoskeleton understanding of both manufacturers and consumers to improve the quality of production and use." This standardized understanding will require everyone having equal access to the same information.

When it comes to insurance industry and government involvement in regulating and tracking the impacts of exoskeleton technology on society, exoskeleton producers are on average dissatisfied. Producers indicated that government and insurance stakeholders could be helpful to the exoskeleton industry, but that they are not aware of appropriate levels of oversight, legislation, and advocacy from these groups at this time. One producer stated, "Many insurers stand to benefit from exoskeletons but we see very little effort on their part to work with exoskeleton companies, perform testing/pilots, provide funding and reimbursement, yet they complain that they don't have enough data." While this constitutes the opinion of one producer, there seems to be a general consensus in the desire to see more resources put into supporting exoskeleton testing and validation. While exoskeletons seem to be proliferating in real-time use, they are not being used at a level of activity that would solidify confidence from government, insurance industry and other desired stakeholders. The most effective way of generating reliable and relevant data is by broader implementation of technology in their intended use-spaces. The Veterans Administration is a leader in the provision of exoskeleton technology for patient rehabilitation. The Washington State Department of Labor and Industries has an Exoskeleton Advisory Committee. The Ohio Bureau of Workers Compensation has a representative that is very involved in the ASTM F48 committee work efforts. CNA insurance company recently made an exoskeleton producer an "Allied Vendor" after vetting the product in construction environments. Liberty Mutual Insurance representatives have been getting more involved in the F48 committee work efforts. Other state and private insurance groups are also beginning to ramp up interest, investment, participation in the F48 committee, and activity in this area, but there is more work to be done. Coordination between the ET CoE, government and insurance stakeholders should be considered as near-term projects to address these issues.

Exoskeleton producers on average are dissatisfied with the rate of adoption of their products. They reported that return on investment studies, cost reductions, evaluation standards, formal classification (e.g. as PPE), education and exoskeleton awareness initiatives

would be the most impactful approaches for increasing user acceptance and adoption of exoskeletons in the marketplace. One producer stated, “More awareness of the technology among potential customers (not within the exoskeleton community, we are fine). Outreach programs outside the echo chamber.” The ET CoE should consider safety and evaluation standards, education, user experience studies, and government-insurance-standards-exoskeleton industry collaboration to help drive exoskeleton adoption and the long-term success of the industry.

It should be noted that while the majority of exoskeleton producers are in agreement that standards are important for the successful growth of the exoskeleton industry and long-term adoption of exoskeletons, those views are not mirrored in latter open-ended questions. When asked what the biggest challenges to widespread exoskeleton adoption are and what would be the most impactful approach to increase it, “more standards” is almost never the answer. It is likely that standards are a component of what producers see as the solution to growing the exoskeleton industry. For example, ROI studies are impossible without proof that the wearable devices involved are safe to use. There needs to be agreement on what metrics need to be collected for which classes of exoskeletons (also an agreement on which exoskeletons are in which class in the first place), and how this data would be reported and aggregated, which can only be addressed with standards. Similarly, exo technology acceptance by users and acquisition decision-makers will not happen without validation that the wearable devices are safe and a common framework to evaluate their capabilities, which again rely on standards. Tests and studies will continue to be done randomly without standards. Education and increasing awareness are also hampered without a uniform language that categorizes and binds this emerging exoskeleton technology field. Exoskeleton producers understand that standards are a tool that could increase and improve the collection of data (e.g. ROI, safety, reliability, and effectiveness), long-term testing, acceptance, and awareness, but they do not currently list standards as the answer to what they feel is the most impactful approach to achieving widespread exoskeleton adoption.

There are some limitations to consider for this project. The survey results are limited to the producer population who responded to the survey. Thus, the data represents a subset of the total target population. The number of responses from representatives of each exoskeleton producer was not limited, so there

may have been multiple respondents from certain producers, but only one or none from others. Many of those who responded skipped certain questions, so there was more data to consider for some questions than there was for others. While various methods were employed to make exoskeleton producers aware of the survey (e.g. ASTM member emails, social media, presentations, articles, word of mouth), it’s possible that not all producers knew about the opportunity to participate. Finally, while every effort was made by the authors to be unbiased in the data analysis and this report, the authors acknowledge the potential for bias as members of the ASTM F48 committee, founding partners of the ET CoE, and other potential conditions. It is to be understood that the recommendations provided herein represent the observations and considerations of the authors based on the data generated through the survey. The recommendations are provided for the consideration of the ET CoE as the funding authority and the F48 committee as a primary consumer of the data as presented. It does not represent the position of ASTM International, ASTM ET CoE or ASTM F48.

In conclusion, the key problems that exoskeleton producers identified are a sluggish rate of exoskeleton adoption, lack of safety standards and certifications, suboptimal exoskeleton producer participation in standards development, lack of education for exoskeleton producers and end users, lack of a way to share data, knowledge and resources across the industry, and poor government-insurance-standards-exoskeleton industry collaboration. The key standards, research and certification gap is around exoskeleton safety, followed by reliability. These are the most needed and supported area of focus for committees like F48 and the Exo Technology Center of Excellence, along with outreach to and education for producers and end users, recruiting more producers to participate in standards development, and facilitation of discussions and collaboration between government, insurance, standards, and exoskeleton industry stakeholders.

# Exoskeleton Producer Survey Results

## Key Learnings

- Good agreement about the importance of safety standards and certifications
- Need for a data vault, knowledge base, resource library and sharing of resources across the exoskeleton industry
- Need for education (producers about standards, and end users about exoskeletons)
- Need to recruit producers for standards
- Need for exoskeleton industry, government and insurance industry collaboration.

## Key Problems

- Rate of exoskeleton adoption
- Lack of safety standards and certifications
- Lack of exoskeleton producer participation in standards
- Lack of F48 outreach and recruiting of exoskeleton producers
- Lack of a way to share data and information across the industry
- Lack of collaboration with insurance and government.

## Key Standards and Research Gaps

- Safety – specifically test methods that can lead to certifications
- Reliability

## Key ET CoE Efforts (beyond F48 standards) to Meet Producer Needs

- Producer recruiting
- Education
- Government and insurance collaboration.

## Recommendations

### Standards and Certifications

Focus on safety standards and certifications (F48.02 Safety Task Group currently focuses on practices and guides. Consideration should be given to begin to develop test methods that can be used to determine safety in a standardized manner that can lead to certifications)

### Outreach

- Consider standards, test methods, and certification outreach efforts that are directed towards engaging exoskeleton producers related to the activities and work efforts of F48, orienting the message towards “value added” - why these products should matter to exoskeleton producers, what value producers will get from participating in the F48 consensus building

processes and the impact of such products on the consumer market

- ET CoE and F48 outreach efforts for exoskeleton producers can incorporate ASTM F48 and ET CoE’s overarching mission, vision, values and objectives in the context of the international standards, test methods and certification
- Design outreach products that will encourage recruiting exoskeleton producers for F48 participation

## Education, Data and Knowledge Sharing

- Consider developing a system to collect, catalog and avail material and data of interest to exoskeleton producers such as creation of a data vault, knowledge base, and resource library for exoskeleton producers, end users, insurance, government, and other interested parties
- Promote and facilitate the sharing of knowledge across the exoskeleton industry and interested parties as a committee or center aligned with the designated ASTM mission and/or in collaborations with other consensus building standard and test methods, communities of practice, societies, and academics
- Provide a platform or suite of products that serve to educate exoskeleton producers about standards, test method development and certification processes
- Provide a platform or suite of products that serve to educate exoskeleton end users and interested parties about exoskeletons and/or collaborate with producers, academics, industry members, societies, government and other organizations to achieve the goal of promoting exoskeleton knowledge growth

## Government and Insurance Collaboration

- Consider collaborative analysis of the interrelationships that impact the community as it relates to government policies and procedures as well as the impact of the insurance industry on the ability to cover cost of exoskeletons, implement exoskeletons in the workplace or address other insurance related information
- Promote and facilitate government-insurance-standards-exoskeleton industry collaboration
- Facilitate discussions around exoskeleton certifications, improving the rate of adoption, the role of government and insurance in accelerating development and adoption, device classification (e.g. as PPE), data mining and knowledge sharing



## Appendix A – Exoskeleton Producer Survey Text

Welcome to the Exoskeleton Producer Survey brought to you by the ASTM International Exo Technology Center of Excellence (ET CoE) on behalf of the ASTM Committee F48 on Exoskeletons and Exosuits.

On behalf of the entire committee we would like to thank for taking the time from your busy schedule to help accelerate standards development and promote safety and reliability across all exoskeletons.

The purpose of this survey is to collect input and feedback from exoskeleton producers in order to help the ASTM F48 Committee on Exoskeletons and Exosuits develop relevant standards to support and enhance the growth and success of the exoskeleton industry. Additionally, the input and feedback from exoskeleton producers will help the ASTM Exo Technology Center of Excellence prioritize and plan how to allocate time, effort, and resources for supporting the F48 Committee and the exoskeleton industry. All data reported will be anonymized and reported in aggregate to protect the privacy of each responder and their responses.

### Exoskeleton Producer Demographics

- Company Personnel Size
- How many exoskeleton units does your company currently produce per year?
- How many different exoskeleton products does your company produce?
- Are you or is someone else at your company a member of a standards committee doing work related to exoskeletons (i.e. ASTM International, ISO TC/299, etc.)?
- Are you or is someone else at your company a member of any trade associations or organizations that are focused on exoskeletons?
- Are you or is someone else at your company participating in programs to evaluate exoskeletons?
  - If yes, please list which ones.

### Exoskeleton Standards

ASTM Committee F48 on Exoskeletons and Exosuits was formed in 2017 to develop voluntary consensus standards for exoskeletons and exosuits. Standards take many forms including best practices, guidance documents, performance specifications, test methods, and others. Test methods in particular help an industry set up a non-biased testing framework that leads to certification and a trusted marketplace. The following questions pertain to the development of exoskeleton standards.

**STRONGLY DISAGREE** | **DISAGREE** | **NEUTRAL** | **AGREE** | **STRONGLY AGREE**

Please answer the following questions using the above scale.

1. Exoskeletons standards are important for successful growth of the exoskeleton industry.
2. Exoskeleton standards are important for customers to adopt exoskeletons.
3. I am pleased with the progress being made to create exoskeleton standards.
4. I am very likely to work with the ASTM F48 Committee on Exoskeletons and Exosuits to develop exoskeleton standards.

*(End of Likert Scale Questions)*

5. In your opinion, what is the primary purpose of exoskeleton standards?
6. In your opinion, what are the 3 most important exoskeleton topics/areas in need of standards?
7. What are your biggest concerns about exoskeleton standards?

### Exoskeleton Validation and Certification

The following questions pertain to research, validation, and potential future certification for exoskeletons.

**STRONGLY DISAGREE** | **DISAGREE** | **NEUTRAL** | **AGREE** | **STRONGLY AGREE**

Please answer the following questions using the above scale.

1. My company has enough information, data, or other evidence to demonstrate that our exoskeleton is safe.
2. My company has enough information, data, or other evidence to demonstrate that our exoskeleton is reliable.
3. My company has enough information, data, or other evidence to demonstrate that our exoskeleton is effective.
4. Exoskeleton certifications through organizations like ASTM International are important for the success of the exoskeleton industry.
5. Certifications specifically for exoskeleton performance should be required to sell exoskeletons.
6. Certifications specifically for exoskeleton quality should be required to sell exoskeletons.
7. Certifications specifically for exoskeleton safety should be required to sell exoskeletons.
8. Certifications specifically for exoskeleton reliability should be required to sell exoskeletons.

*(End of Likert Scale Questions)*

9. Independent third-party researchers have performed research on our exoskeleton and published peer reviewed studies about our device.
10. My company has received certifications for our exoskeletons.
  - If yes, which ones?

### Data, Education and Knowledge Sharing

The following questions pertain to the available data (e.g. safety, reliability, effectiveness), education and global knowledge sharing for the exoskeleton industry.

**STRONGLY DISAGREE** | **DISAGREE** | **NEUTRAL** | **AGREE** | **STRONGLY AGREE**

Please answer the following questions using the above scale.

1. I am happy with the quantity (number) of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.
2. I am happy with the quality of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.
3. I am happy with how the data and results of exoskeleton research studies are shared across the industry.
4. I am happy with my company's understanding of our customer's needs.
5. I am happy with the amount of data that is shared with my company by its customers.
6. I am happy with how our customers are supporting and sustaining the use of our exoskeletons in their environments.
7. I am happy with the progress of longitudinal research (i.e., long term use) to demonstrate that our products are safe and effective.
8. I am happy with how the insurance industry is tracking the impacts of using exoskeletons in the environments which our products are being used.
9. I am happy with the amount and quality of government regulations and laws for our exoskeletons.

*(End of Likert Scale Questions)*

10. What are your thoughts about government and/or insurance oversight in your domain of exoskeletons (for example, how much or how little oversight should there be, and what should be done more or less)?



### Sales and Adoption

The following questions pertain to products sales and adoption of exoskeletons.

**STRONGLY DISAGREE** | **DISAGREE** | **NEUTRAL** | **AGREE** | **STRONGLY AGREE**

Please answer the following questions using the above scale.

1. I am satisfied with the rate of adoption for our exoskeletons.  
*(End of Likert Scale Questions)*
2. What do you think are the biggest challenges with widespread exoskeleton adoption?

### Exoskeleton Industry Needs

The following question pertains to the needs of the exoskeleton industry.

1. What do you think would be the most impactful approach to help increase the adoption of your exoskeletons in the marketplace?

### General Comments and Feedback

The following section is an opportunity for you to provide feedback and/or get in touch with the ASTM Exo Technology Center of Excellence.

1. Do you have anything you would like to share or discuss with the ASTM Exo Technology Center of Excellence?
  - If yes, please share.
2. If you answered yes, would you like to schedule a meeting with the ASTM ET CoE?
3. If you are interested in setting up a meeting, please leave your contact information.
  - Name
  - Company
  - Address
  - Email Address
  - Phone Number

Thank you for your time and feedback.

To learn more or get involved with ASTM F48 Committee on Exoskeletons and Exosuits please visit [www.astm.org/COMMITTEE/F48](http://www.astm.org/COMMITTEE/F48) and join.

### Additional Information

ASTM Committee F48 on Exoskeletons and Exosuits was formed in 2017 to develop voluntary consensus standards for exoskeletons, exosuits, wearable robotics and related technologies. Subcommittees will address safety, quality, performance, ergonomics and terminology for systems and components during the full life cycle of the product – from design, to use, to maintenance, to disposal – including, cleaning, sanitization, security and information technology considerations. The activities cover industrial, emergency response, medical, military and consumer applications covering passive and active systems, enhancing and decreasing effects systems, as well as systems with physical and cognitive integration. You will find more information on how you can get involved at the end of the survey.

### ASTM Exo Technology Center of Excellence (ET CoE) Introduction Page

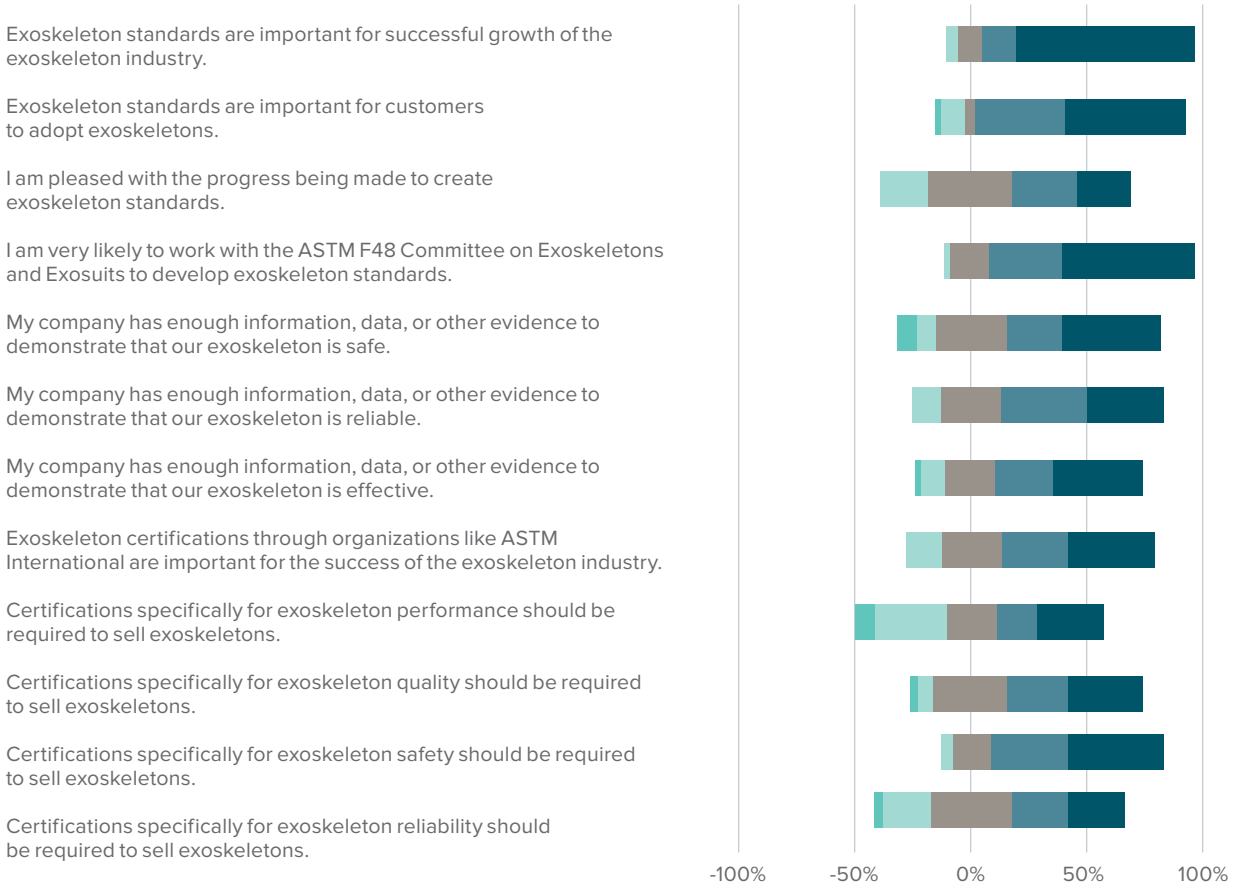
ASTM International's Exo Technology Center of Excellence (ET CoE) brings together industry, healthcare, academia, and government to accelerate safety and reliability standards for exoskeletons and their systems. The ET CoE's mission is to build, connect, and energize exo technology research, standards, and applications. Through research-to-standards, knowledge sharing, and education efforts, the ET CoE will ensure greater confidence in the baseline performance of exoskeletons and drive faster commercialization and adoption of the technology.

## Appendix B – Exoskeleton Producer Survey Likert Scale Questions and Results

Mean	Mean	SD	Responses
Exoskeleton standards are important for successful growth of the exoskeleton industry.	4.64	0.62	42
Exoskeleton standards are important for customers to adopt exoskeletons.	4.29	0.94	42
I am pleased with the progress being made to create exoskeleton standards.	3.54	0.98	41
I am very likely to work with the ASTM F48 Committee on Exoskeletons and Exosuits to develop exoskeleton standards.	4.33	0.75	42
My company has enough information, data, or other evidence to demonstrate that our exoskeleton is safe.	3.85	1.11	39
My company has enough information, data, or other evidence to demonstrate that our exoskeleton is reliable.	3.95	0.92	39
My company has enough information, data, or other evidence to demonstrate that our exoskeleton is effective.	4.08	1.04	39
Exoskeleton certifications through organizations like ASTM International are important for the success of the exoskeleton industry.	3.92	0.98	39
Certifications specifically for exoskeleton performance should be required to sell exoskeletons.	3.21	1.32	39
Certifications specifically for exoskeleton quality should be required to sell exoskeletons.	3.74	1.07	39
Certifications specifically for exoskeleton safety should be required to sell exoskeletons.	4.21	0.83	39
Certifications specifically for exoskeleton reliability should be required to sell exoskeletons.	3.44	1.07	39
I am happy with the quantity (number) of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.	3.42	0.92	38
I am happy with the quality of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.	3.24	0.88	38
I am happy with how the data and results of exoskeleton research studies are shared across the industry.	2.89	1.07	37
I am happy with my company's understanding of our customer's needs.	4.05	0.84	38

Mean	Mean	SD	Responses
I am happy with the amount of data that is shared with my company by its customers.	3.5	0.92	38
I am happy with how our customers are supporting and sustaining the use of our exoskeletons in their environments.	3.55	0.86	38
I am happy with the progress of longitudinal research (i.e., long term use) to demonstrate that our products are safe and effective.	3.21	1.07	38
I am happy with how the insurance industry is tracking the impacts of using exoskeletons in the environments which our products are being used.	2.79	1.19	38
I am happy with the amount and quality of government regulations and laws for our exoskeletons.	2.71	0.96	38
I am satisfied with the rate of adoption for our exoskeletons.	2.87	1.12	38

STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE



**STRONGLY DISAGREE** | **DISAGREE** | **NEUTRAL** | **AGREE** | **STRONGLY AGREE**

I am happy with the quantity (number) of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.

I am happy with the quality of exoskeleton research studies that are available by traditional means such as PubMed, Google Scholar, etc.

I am happy with how the data and results of exoskeleton research studies are shared across the industry.

I am happy with my company's understanding of our customer's needs.

I am happy with the amount of data that is shared with my company by its customers.

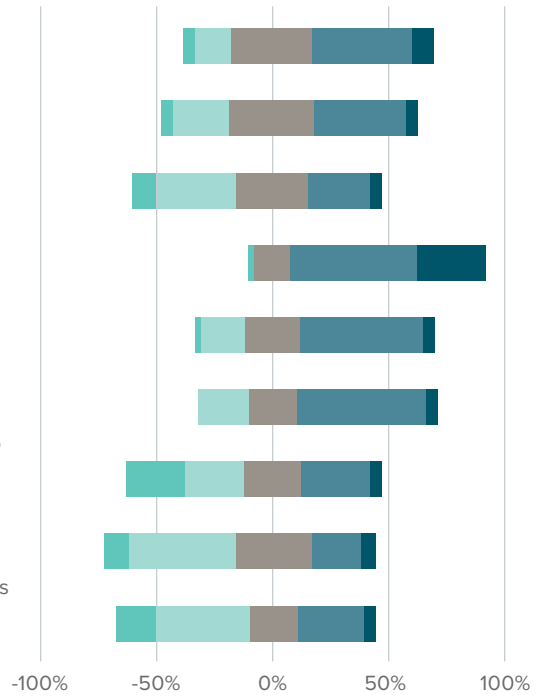
I am happy with how our customers are supporting and sustaining the use of our exoskeletons in their environments.

I am happy with the progress of longitudinal research (i.e., long term use) to demonstrate that our products are safe and effective.

I am happy with how the insurance industry is tracking the impacts of using exoskeletons in the environments which our products are being used.

I am happy with the amount and quality of government regulations and laws for our exoskeletons.

I am satisfied with the rate of adoption for our exoskeletons.



## Appendix C – Exoskeleton Producer Survey Word Cloud Questions Code

### In your opinion, what is the primary purpose of exoskeleton standards?

17	Safety	3	Consistency
10	Evaluation	3	Reduce Risk
6	Marketplace	2	Restrict
5	Common Practices	1	Ergonomics
5	Mainstream Adoption	1	Communication
4	Performance	1	Accelerate
3	Design	1	Guidance
3	Quality		

### In your opinion, what are the 3 most important exoskeleton topics/areas in need of standards?

10	Testing	3	Reliability
20	Safety	6	Usage
11	Evaluation	2	Compatibility
6	Design	1	Sizing
5	Ergonomics	6	Efficacy
5	Classification	2	Security
4	Comparison	1	Power
1	Describing	1	Acceptance
2	Range	4	Quality
2	Guides	2	Production
4	Application	2	Integration
2	No-Opinion	1	Modularity
6	Performance	1	Scalability
4	Side Effects		

### What are your biggest concerns about exoskeleton standards?

14	Stifle Innovation	2	Inconsistent
5	Wide Variety	2	Unclear Position
5	Low Maturation	2	Uninformed
4	Slow to Publish	2	Regionally Incompatible
4	Too Complicated	2	Useless
3	Poor Risk Assessment	1	Low Adoption
3	Unreasonable	1	Easy to Work Around
3	Missing Participation	1	Reliability
3	Safety	1	Too Fast to Publish
2	Side Effects	1	Flexible

### What are your thoughts about government and/or insurance oversight in your domain of exoskeletons (for example, how much or how little oversight should there be, and what should be done more or less)?

6	Insurance Doing Little	1	Military Exo Oversight By Government
4	Insurance Need ROI	1	Need More Favorable Standards
4	Government Is Doing Little	1	Insurance Need Safety Data
3	No Additional Government Oversight Needed	1	Recreational Exo Should Have Government Safety Oversight
3	Government Oversight Is Key	1	Too Many Regions
2	Industrial Exo Should Have Government Safety Oversight	1	Oversight Organization Must Understand The Technology
2	Government Should Set Goals	1	Fear of Exoskeletons
1	Need More Guidance	1	Lack of Awareness

### What do you think are the biggest challenges with widespread exoskeleton adoption?

9	ROI	1	Standards
7	Acceptance	1	Safety
5	Testing & Studies	1	Reimbursement
5	Education	1	Quality
5	Awareness	1	Novelty
4	Cost	1	Misinformation
3	Disjointed Industry	1	Lack of Guidelines
2	Low Maturity	1	Integration
2	Expectations	1	DOD Requirement Not Shown to Developers
2	Culture	1	Customization
1	Wrong Stakeholders	1	Certification
1	Trash Talking	1	Comfort
1	Sustained Implementation		

### What do you think would be the most impactful approach to help increase the adoption of your exoskeletons in the marketplace?

9	ROI Studies	1	Government Support
5	Marketing	1	Unknown
4	Acceptance	1	Safety Standards
3	Insurance Endorsement	1	3rd Party Testing
3	Categorize As PPE	1	Guidelines
2	Evaluation Standards	1	Gov Funding
2	Requirements	1	International Standards
2	Awareness	1	Programs
2	Better Exo Companies		

### Do you have anything you would like to share or discuss with the ASTM International Exo Technology Center of Excellence?

2	Who is the ET CoE?	1	Not Sure
2	Include More Producers	1	Create Regional Groups
1	Discussing Benefits of Standards	1	Discuss Adoption Acceleration
1	Learn More About ASTM International	1	Medical Norms
1	Access to ASTM Exo Standards	1	What Standards Are WIP?
1	What Is CoE Mission?	1	Why Develop Standards?
1	Who Is CoE Working With?	1	How Are Committees Working together?

### Certification

7	CE CERTIFICATION	1	CE Medical Device Class I
1	60601-1	1	CE Medical Device Class 2a
1	60601-1-2	1	Machinery directory
1	60601-1-6	1	Mechanical device certification
1	60601-1-11	1	62304
1	62133		



## Appendix D – Exoskeleton Producer Survey Project Plan

### Activity

#### Objective 1: Project Planning

- Develop OKRs
- Develop SOW's
- Develop Project Plan
- Develop Project Timeline
- Virtual meeting and communication to review and revise all of the above, define survey scope, develop data management plan
- Finalize above planning
- Kick off meeting
- ASTM signs off on all of the above and issues a press release

#### Objective 2: F48 collaboration

- Identify 5-10 F48 members to interview
- Schedule phone or virtual meetings with above contacts
- Get survey questions from F48 collaborators
- ExR/NSS team brainstorm session

#### Objective 3: Producer Inputs

- Randomly select producers
- Schedule phone or virtual meetings with above contacts

#### Objective 4: Draft Producer Survey

- Identify target number of questions
- Identify target survey duration
- Reach out to COST CA16116, AExG for results, reports, what they wish they had done differently.
- Compile data from producers and F48 collaborators
- Compile list of exoskeleton producers
- Draft questions
- Team review of questions
- Delivery and approval of questions

#### Objective 5: SurveyMonkey

- ASTM staff to create survey in SurveyMonkey
- Team review of survey
- Delivery and approval of survey

#### Objective 6: Producer and Exo Community Outreach

- Outreach and marketing to developers, F48 community, and global exo community via ExR, social media, direct email and press release notifying them in advance of survey

#### Objective 7: Data Collection

- Launch survey
- Collect data
- Ongoing outreach and marketing via ExR, social media, direct email and press release to developers and F48 community
- Close survey

#### Objective 8: Data Analysis

- Leverage ASTM staff for all data analysis and below key results
- Identify trends
- Identify key learnings
- Identify key problems for developers
- Identify key standards and research gaps and needs for developers to reach the market, compete on a level playing field and grow
- Identify key standards related work efforts, research, etc. to address problems

#### Objective 9: Reporting

- Produce a draft report in collaboration with ASTM staff

#### Objective 10: Delivery

- Deliver final report draft to ASTM
- ASTM staff to develop and deliver a summary to F48
- ASTM staff to determine if, when and how to share the survey results, summary, and report with the larger exo community
- ASTM to determine if, when and how to make the full report available to F48



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