Safety and Performance Test Methods for Exoskeletons

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Exoskeletons\(^1\) are wearable devices that can assist the user with functional (i.e., perhaps below normal), normal, or amplified human capability. Recent research on exoskeletons has dramatically increased as seen in, for example, [1] and [2], and has driven the current global exoskeleton market to include over 60 manufacturers. However, these devices have yet to show long-term safety and performance impacts on humans.

International Organization for Standardization (ISO) 13482 [3] was developed over several years and published in 2014 to address the safety concerns for robots, including exoskeletons, used as personal care devices. However, no normative requirements on data collection and analysis is included in the safety standard to be used as a basis for understanding long-term effects. Test methods are therefore needed to allow manufacturers and users to replicate standard safety procedures allowing exoskeleton users to fully understand their potentially imposed ramifications.

Exoskeleton performance is interlaced with some safety considerations for these devices. For example, as a lower-extremity, an exoskeleton user stands up from a crouched position or walks for an entire day carrying heavy loads - does the device provide full lift, overdrive human joints, cause the wearer strain or chafed skin, or other harm and if so, how should the device instead be designed to be safe? Safety test methods can help provide this measured data for most any exoskeleton manufacturer for comparison of capability to the task. However, performance test methods may additionally provide task-specific measurements of how well the device can provide, for example, improved movement, increased or longer lift capability, or combined lift with precision positioning of a heavy load. Unfortunately, there are currently no performance standards or test method procedures to provide such exoskeleton measurement data to be included in either safety or performance standards when they are developed. In addition, there are no commonly agreed upon physiological measurements of the human user to provide baseline measurements of before and after long term use of exoskeletons.

The National Institute of Standards and Technology (NIST), Robotic Systems for Smart Manufacturing Program [4] develops test methods and measurement science for robot-human, robot-robot, and robot-robotic vehicle calibration, measurement, and collaboration. Advanced measurement tools and artifacts are being used at NIST to develop affordable and repeatable performance measurements and test methods for robots used in smart manufacturing – e.g., assembly. Lessons can be learned from industrial robot measurement methods, and even response robots, that can also apply to exoskeletons, such as navigation of an exoskeleton user (versus a mobile robot) within a complex test course or assembly of components while wearing an exoskeleton (versus using a robot to assemble components). Crossing again from manufacturing and response robotics to exoskeletons are performance metrics, such as: navigation, perception, management of tasks, and manipulation, as well as those that more specifically describe performance: duration, speed, acceleration/deceleration, pose uncertainty, back-drivability, vertical/horizontal maneuvering, ease-of-use. Even more specific to exoskeleton-use metrics are ergonomics and ingress/egress complexity. Towards ergonomics and many of the listed metrics, NIST is developing a test method that can determine the rotation axis of industrial-robot joints from outside the robot arm so that devices can properly adapt to robots. Again, this crosses from the manufacturing to the exoskeleton industries where human joint rotation axis measured from outside the body can perhaps determine the ideal fit of an exoskeleton to the user, as well as the misfit to the user.

This poster will show arm rotations as background, the physical simulator (robot arm) setup (see Figure 1), and initial results (see Figure 2) of joint axis rotation measurements of the physical simulator. The poster will also show recommended test method apparatus’ being designed for exoskeletons stemming from manufacturing and response robotics that are currently being developed and standardized (see Figure 3).

\(^1\) Disclaimer: Commercial equipment, software, and materials are identified in order to adequately specify certain procedures. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials, equipment, or software are necessarily the best available for the purpose.
Figure 1 – (a) Elbow extension through flexion angle. [5] (b) Rigid marker artifacts (RMA) posed on a robot arm for a circle measurement method for determining elbow joint rotation axis location. (c) Shoulder-to-elbow view of two illuminated (from camera flash) RMAs posed on the robot wrist-to-elbow link for measuring uncertainty of joint rotation axis location.

Figure 2 – (a) Plot of data points and calculated center joint rotation location after circle fit. (b) Histogram of data fit to a circle to find the uncertainty for the joint rotation axis location.

Figure 3 – Example exoskeleton test method apparatus: (a) recommended for load positioning and b) that combines autonomous vehicle ASTM F45.02 navigation-perpendicular aisle section (center) and constant radius curve sections (left and right) defined space navigation test methods leading to docking (exoskeleton load positioning) tests.
References


