



Designation: F3584 – 22

Standard Test Method for Exoskeleton Use: Obstacle Avoidance: Walking¹

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1. Scope

1.1 Purpose:

1.1.1 The purpose of this test method, as a part of a suite of exoskeleton use test methods, is to quantitatively evaluate an exoskeleton's (see Terminology [F3323](#)) safety (see [1.4](#)) or performance, or both, when avoiding obstacles.

1.1.2 Exoskeletons shall possess a certain set of allowable exoskeleton user movement capabilities, including user-motion adaptability, to suit operations such as: industrial/occupational, military, response, medical, or recreational.

1.1.3 Environments in these typical sectors often pose constraints to exoskeleton user movement to various degrees. Being able to avoid obstacles while walking, as intended by the user or test requestor, while using an exoskeleton is essential for exoskeleton deployment for a variety of tasks (for example, ascending/descending stairs, crossing gaps and hurdles, balancing on a beam). This test method specifies test setup, procedure, and recording to standardize this obstacle avoidance task for testing exoskeleton user movement.

1.1.4 Exoskeletons need to function as intended, regardless of types of tasks and terrain complexities (for example, carpet, metal, masonry, rock, wood). Required movement capabilities may include, for example: walking, running, crawling, climbing; traversing gaps, hurdles, stairs, slopes; avoiding obstacles, on various types of floor surfaces or terrains, or within confined spaces, or combinations thereof. Standard test methods are required to evaluate whether or not exoskeletons meet these requirements while also allowing test repeatability.

1.1.5 ASTM Subcommittee F48.03 develops and maintains international standards for task performance and environmental considerations that include but are not limited to, standards for safety, quality, and efficiency. This subcommittee aims to develop standards for any exoskeleton application as exemplified as in [1.1.2](#). The F48.03 test suite consists of a set of test methods for evaluating exoskeleton capability requirements. This obstacle avoidance test method is a part of the test suite. The setup, procedure, and apparatuses associated with the test methods challenge specific exoskeleton capabilities in repeat-

able ways to facilitate comparison of different exoskeleton models or exoskeleton capabilities to tasks.

1.1.6 The test methods quantify elemental exoskeleton use capabilities necessary for sector applications listed in [1.1.2](#) and perhaps other applications. As such, users of this standard should use either the entire suite or a subset based on their particular requirements. Users are also allowed to weigh particular test methods or particular metrics within a test method differently, based on their specific requirements. The testing results should collectively represent an exoskeleton's overall safety or performance, or both, as required for the task. These performance data can be used: to guide procurement specifications, for acceptance testing, and for training to use exoskeletons intended for specified applications.

NOTE 1—Additional test methods within the suite are anticipated to be developed to address additional exoskeleton capability requirements, including newly identified requirements and for new application domains.

1.2 *Exoskeleton*—The exoskeleton shall be used as intended by the manufacturer to perform the test described in this test method. If the exoskeleton is not designed for obstacle avoidance while walking and the test requestor intends to use the exoskeleton to perform an obstacle avoidance test (for example, for research, development of obstacle avoidance-capable use by a manufacturer, training as in military applications), appropriate manufacturer approvals should be sought prior to performing the test method.

1.3 *Performing Location*—This test method shall be performed in a testing laboratory or the field where the specified apparatus and environmental conditions are implemented.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to inch-pound units. They are close approximate equivalents for the purpose of specifying material dimensions or quantities that are readily available to avoid excessive fabrication costs of test apparatuses while maintaining repeatability and reproducibility of the test method results. These values given in parentheses are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

¹ This test method is under the jurisdiction of ASTM Committee [F48](#) on Exoskeletons and Exosuits and is the direct responsibility of Subcommittee [F48.03](#) on Task Performance and Environmental Considerations.

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1.6 This international standard was developed in accordance with internationally recognized principles on standardization established in the *Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee*.

2. Referenced Documents

2.1 ASTM Standards:²

- F3200** Terminology for Robotics, Automation, and Autonomous Systems
- F3323** Terminology for Exoskeletons and Exosuits
- F3427** Practice for Documenting Environmental Conditions for Utilization with Exoskeleton Test Methods
- F3443** Practice for Load Handling When Using an Exoskeleton
- F3444/F3444M** Practice for Training Exoskeleton Users
- F3474** Practice for Establishing Exoskeleton Functional Ergonomic Parameters and Test Metrics
- F3517** Practice for Movement Tests When Using an Exoskeleton
- F3523** Test Method for Exoskeleton Use: Confined Space: Horizontal Movement
- F3527** Guide for Assessing Risks Related to Implementation of Exoskeletons in Task-Specific Environments
- F3528** Test Method for Exoskeleton Use: Gait
- F3613** Practice for Recording the Exoskeleton Fit to the User
- F3614** Practice for Recording the Exoskeleton User Information

2.2 ISO Standards:³

- ISO 13482** Robots and robotic devices — Safety requirements for personal care robots

3. Terminology

3.1 General terminology for ASTM F48 standards is available in Terminology **F3323**. Terminology specific to this standard are shown in this section.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *apparatus, n*—a structure, object, test component, or artifact thereof, found or placed in an environment and used for a test.

3.2.2 *obstacle, n*—static or moving object that obstructs the intended movement. **[F3200]**

3.2.3 *test suite, n*—designed collection of test methods that are used, collectively, to evaluate an exoskeleton’s safety and/or performance.

4. Summary of Test Method

4.1 The task for this test method, “exoskeleton use: obstacle avoidance: walking,” is defined as the exoskeleton-user per-

forming an obstacle avoidance test, including a number of repetitions as set by the test requestor. The test includes only stationary objects to avoid and covers all forms of obstacle avoidance while walking: agility, step-over, side-step, walk-around, and duck-under. Guidance on number of repetitions for the test is shown in **Appendix X1**. In-situ obstacles (for example, boxes, trees, logs) can be used for this test method. For ideal test replication, standard obstacle avoidance test apparatuses (for example, foam blocks, 2 by 2 nominal wooden bars, cloth and post crowd control) can be used for this test method. See **Fig. 1** for an illustration.

4.2 The test is described as follows:

4.2.1 This test can be used to assess aerobic function, endurance, obstacle avoidance capability and speed, balance, or other parameters, or combinations thereof, as required by the test requestor.

4.2.2 The test metrics can include, for example, the following:

- 4.2.2.1 Completion of the full or phased test;
- 4.2.2.2 Number of obstacles avoided;
- 4.2.2.3 Completion time;
- 4.2.2.4 Change(s) in user (for example, heart rate, fatigue, toe drag) by a specified amount;
- 4.2.2.5 Balance, stability, missed steps, near falls/falls (measures of dynamic balance can include, for example, Lyapunov exponents, center-of-mass displacement, multivariate multi-scale entropy, normalized jerk, and peak-to-peak angular torso momentum);
- 4.2.2.6 Contact with obstacles;
- 4.2.2.7 Changes between the baseline (that is, called No-EXO when no exoskeleton is used) versus while using the exoskeleton (that is, called EXO when an exoskeleton is used);
- 4.2.2.8 Clearance from obstacle; and
- 4.2.2.9 Variability in the distribution of minimal clearance.

4.3 For all tests, the specified START point to the END point and TURN point shall be defined by the test requestor prior to the test. This test method can be combined with other test methods, for example, Test Method **F3528**. The required apparatuses are described in Section 6.

4.4 A full obstacle avoidance: walking test is defined as: the user begins by standing behind a start marker, walks while avoiding obstacles in the agility apparatus, turns around 180° after passing a turn marker, walks while avoiding obstacles in the agility apparatus again, walks to the continue/end marker, traverses the step-over apparatuses, continues to the barriers and side-steps through the left side of the barriers, walks around the barriers, walks while ducking under the height bar past the turn marker, again ducks under the height bar, walks around and side-steps again through the right side of the barriers, walks around and continues to traverse again through the step-over apparatuses, and crosses the end line to complete the test. A phased test includes portions of the full test as follows:

Phased Obstacle Avoidance Test

4.4.1 *Phase 1*—The user begins by standing behind a start marker, walks while avoiding obstacles in the agility apparatus,

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.