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Walking Speed: The Functional Vital Sign

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Abstract

Walking speed (WS) is a valid, reliable, sensitive measure appropriate for assessing and monitoring functional status and overall health in a wide range of populations. These capabilities have led to its designation as the "6th vital sign". By synthesizing the available evidence on WS, this scholarly review article provides clinicians with a reference tool regarding this robust measure. Recommendations on testing procedures for assessing WS, including optimal distance, inclusion of acceleration/deceleration phases, instructions, and instrumentation are given. After assessing an individual's WS, clinicians need to know what this value represents. Therefore, WS cut-off values and the corresponding predicted outcomes, as well as minimal detectable change values for specific populations and settings are provided.

Background

The *White Paper: "Walking Speed: the Sixth Vital Sign"* published in 2009 consolidated available evidence on a robust measure, walking speed (Adell, Wehmhorner, & Rydwik, 2013; Afilalo et al., 2010; Castell et al., 2013; Graham, Fisher, Berges, Kuo, & Ostir, 2010; Peters, Fritz, & Krotish, 2013; Quach et al., 2011; Rydwik, Bergland, Forsen, & Frandin, 2012; Shimada et al., 2013; Verghese, Wang, & Holtzer, 2011). Since publication of the original article, evidence has emerged regarding updated recommendations on testing protocols. Additional cut-off values and minimal detectable change values have also been reported in the interim. For this reason, the authors decided to follow-up the original white paper with recent evidence regarding this robust tool. As a valid (Rydwik et al., 2012; Verghese et al., 2011), reliable (Peters, Fritz, et al., 2013; Rydwik et al., 2012), and sensitive (Goldberg & Schepens, 2011; van Iersel, Munneke, Esselink, Benraad, & Olde Rikkert, 2008) measure, WS tests have found a home in both clinical (Peel, Kuys, & Klein, 2013) and research (Graham, Ostir, Fisher, & Ottenbacher, 2008) settings. Not only is WS indicative of an individual's functional capacity (Verghese et al., 2011) and general health status (Cesari et al., 2005; Studenski et al., 2011), the measure has been shown to be predictive of a range of outcomes, including response to rehabilitation (Goldie, Matyas, & Evans, 1996), functional dependence (Purser et al., 2005; Shimada et al., 2013; Shinkai et

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al., 2000), frailty (Castell et al., 2013), mobility disability (Cesari et al., 2005) (Rosano, Newman, Katz, Hirsch, & Kuller, 2008), cognitive decline (Alfaro-Acha, Al Snih, Raji, Markides, & Ottenbacher, 2007) (Inzitari et al., 2007), falls (Montero-Odasso et al., 2005) (Chu, Chi, & Chiu, 2005), institutionalization (Woo, Ho, & Yu, 1999), hospitalization (Montero-Odasso et al., 2005) (Cesari et al., 2005), cardiovascular-related events and mortality (Dumurgier et al., 2009; Matsuzawa et al., 2013), as well as all-cause mortality (Studenski et al., 2011) (Blain et al., 2010). An association has been observed between slow self-selected WS and lower quality of life (Ekstrom, Dahlin-Ivanoff, & Elmstahl, 2011), decreased participation (Ekstrom et al., 2011), and presence of depressive symptoms (Brandler, Wang, Oh-Park, Holtzer, & Verghese, 2012). Due to the measure's extensive predictive capabilities, as well as ease of administration, the original article proposed WS be considered the "sixth vital sign". Research findings continue to support this designation (Afilalo et al., 2010; Castell et al., 2013; Elbaz et al., 2013; Matsuzawa et al., 2013; Studenski et al., 2011).

Predictive Capabilities of Walking Speed

Just as with the other vital signs, WS has "cut-off" values that are indicative of specific outcomes. Figure 1 provides visual representation of the various cut-off values and the corresponding predicted outcomes from across the literature. The corresponding table (Table 1) provides details regarding the studies included in Figure 1.

Responsiveness of Walking Speed

Walking speed tests can be performed in a variety of settings (Adell et al., 2013; Barthuly, Bohannon, & Gorack, 2012; Bohannon, 2009; Braden, Hilgenberg, Bohannon, Ko, & Hasson, 2012; Fulk et al., 2011; Puthoff & Saskowski, 2013) and are appropriate for use with a wide range of diagnoses (Chrysagis, Skordilis, Stavrou, Grammatopoulou, & Koutsouki, 2012; Fulk et al., 2011; Hass et al., 2012; Hollman et al., 2008; Horemans, Beelen, Nollet, & Lankhorst, 2004; Kon et al., 2012; Motyl, Driban, McAdams, Price, & McAlindon, 2013; Nair, Hornby, & Behrman, 2012; Nogueira, Dos Santos, Sabino, Alvarenga, & Santos Thuler, 2013; Peel et al., 2013; Puthoff & Saskowski, 2013; Working Group on Health Outcomes for Older Persons with Multiple Chronic, 2012) making it a universal measure. Refer to Table 2 for further information regarding specific populations and settings. The breadth of information provided by this assessment tool is not limited to inferences made based on a single time point. As a responsive measure (Barthuly et al., 2012; Goldberg & Schepens, 2011; Puthoff & Saskowski, 2013), repeated WS tests can be used to monitor patients over time. For example, in a clinical setting a patient's WS at initial evaluation can be compared to their WS at reassessment and discharge; or in a research setting WS may be used to determine changes over the course of a study and maintenance at follow up. In order to be confident that true change in WS has occurred, the difference between testing sessions needs to exceed the measurement error and natural variability that can occur with repeated measurements. A value that reflects this is the measure's minimal detectable change value (MDC). If an individual's change in WS between testing sessions exceeds the MDC_{95}, we can be 95% confident that a true change in WS has occurred. MDC values for self-selected and fast WSs by diagnosis are presented in Table 2. As this is a scholarly, rather than systematic review, the selected studies represent the most recently published values not a consolidation of all high-quality evidence. Therefore, clinicians and researchers should exert caution when using the values to determine if true change has occurred. There may be more applicable values available in the literature for your specific patients or participants.

The absolute change is not the only variable of interest; an individual's WS trajectory has health implications as well. Walking speed trajectories demonstrating rapid decline are associated more strongly with mortality than trajectories that are more stable (White et al., 2013). Therefore, determining rate of change, in addition to amount of change, of an individual's WS may be of value.

Recommendations on Assessment Procedures

A variety of testing protocols are available for assessing WS. Procedures differ in regards to distance (2 meters to 40 meters) (Rydwik et al., 2012), start (static versus dynamic) (Phan-Ba et al., 2012), path (straight versus turn) (van Herk, Arendzen, & Rispens, 1998), speed (self-selected versus maximal) (Rydwik et al., 2012), instruction (e.g. "walk at a comfortable pace" versus " walk as if you are taking a stroll through the park") (Nascimento et al., 2012), and timing instrument (e.g. stopwatch, automatic timer, instrumented walkway) (Peters, Fritz, et al., 2013; Youdas et al., 2010). Although a standardized protocol has not been adopted, there is evidence available to help guide WS test selection. Clinicians may want to consider administering WS tests of 10 meter distances and less as they are more clinically feasible than longer walkways. When selecting a distance within this range, the psychometric properties of the various tests must be taken into account. A study conducted by Ng, et al (2013) found no significant differences between WSs calculated via 5, 8, or 10 meter walkways in older adults (Ng et al., 2013) or individuals with stroke (Ng, Ng, Lee, Ng, & Tong, 2012). These results held for both self-selected and maximal WS tests (Ng et al., 2013). Since findings indicate that walkways ranging in length from 5 to 10 meters produce similar results, the distance in that range most suited to the environment can be used. Caution may need to be exercised, however, if considering a walkway shorter than 5 meters.

Although the original White paper indicated that distances as short as three meters (approximately 10′) could be used, recommendations have been revised based on recent evidence. Results from a study conducted by Peters, et al, indicate that while a 4 meter walk test is a reliable option for older adults, WSs calculated via this method do not demonstrate sufficient concurrent validity with the 10 meter walk test to be used interchangeably (Peters, Fritz, et al., 2013). Therefore, WSs calculated via the 4 meter walk test can be compared across testing sessions, but should not be compared to 10 meter walk test results for determining changes over time. Similar results were found in a study comparing a 3 meter walk test to the GAITRite® electronic walkway in individuals with chronic stroke (Peters, Middleton, Donley, Blanck, & Fritz, 2013). Lack of concurrent validity with longer WS tests is a potential limitation of 4 meter assessments and those of even shorter distances. To maximize clinical feasibility, while maintaining psychometric soundness, clinicians may want to select WS tests ranging from 5 to 10 meters in length.

The recommended 5 to 10 meter length refers to the timed distance. Clinicians may also want to incorporate acceleration and deceleration phases. Standardized acceleration and deceleration distances are not established and some uncertainty exists over whether or not these phases are necessary (Graham et al., 2008). However, allowing acceleration and deceleration to occur outside of the timed portion may allow for a more accurate assessment of self-selected and maximal WSs (Macfarlane & Looney, 2008). WSs calculated without an acceleration phase (static start) are slower than WSs calculated via dynamic start protocols (Phan-Ba et al., 2012). Exclusion of an acceleration phase may introduce greater variability into WS measurement, which hinders the ability for the test to capture true change (Macfarlane & Looney, 2008). Recommended acceleration phase distances range from 2.17 (healthy) (Macfarlane & Looney, 2008) to 2.5 (frail) (Lindemann et al., 2008) meters for older adults. A greater distance is required to achieve steady state maximal WS. For maximal tests, recommended acceleration phase distances are 3.23 meters (Macfarlane & Looney, 2008) for healthy older adults and 3 meters (Phan-Ba et al., 2012) for individuals with Multiple Sclerosis. As acceleration and deceleration during the timed portion of WS tests can increase variability, the use of a straight path protocol has advantages over a path that includes a turn (e.g. 10 meter path rather than 5 meter x 2 path) (Graham et al., 2008; van Herk et al., 1998). Turning not only requires adjustments in speed, it also increases the complexity of the test making it harder to standardize over multiple assessment sessions and between individuals.

Administering both self-selected and maximal WS tests may provide a more complete picture of a patient than either test in isolation (Dobkin, 2006). While an individual’s self-selected or usual WS is indicative of current functional status (Verghese et al., 2011) and numerous health outcomes (Abellan van Kan et al., 2009; Castell et al., 2013; Dumurgier et al., 2009), maximal WS provides information regarding an individual’s capabilities in the community (Dobkin, 2006; Salbach et al., 2013). For example, in the United States WSs of 1.32 m/s or greater are required to ensure safe street crossing (Salbach et al., 2013). During testing, method of instruction to achieve actual maximum speed may need to be taken into account. In individuals with chronic stroke, instructions including the addition of a “real life” example (e.g. “reach a bus that is about to pull out”) or demonstration by the clinician were found to result in greater maximal WSs compared to traditional simple instructions (e.g. “walk as fast as possible and safely, but without running”) (Nascimento et al., 2012). These results may hold for other populations as well. Regardless of approach decided upon, instructions should be consistent across testing sessions as differing methods have been shown to produce significantly different results (Nascimento et al., 2012). Being able to increase WS in response to environmental demands is an important aspect of functional mobility and safety. Therefore, maximal WS should be assessed in addition to self-selected WS as part of a comprehensive evaluation (Nascimento et al., 2012).

A variety of instruments are available for measurement of self-selected and maximal WSs including stop watches, automatic timers, and instrumented walkways. While use of a stopwatch requires the assessor to start/stop the stopwatch as a patient crosses into and out of the timed section, automatic timers are electronic devices triggered to start/stop timing as an individual walks by. Another electronic option is an instrument walkway. Evidence suggests that WSs captured via instrumented walkways are less variable than those calculated using a stopwatch and marked walkway (Youdas et al., 2010). However, the expense of instrumented walkways limits their clinical feasibility. Use of a stopwatch and a marked walkway remains a valid (Shimada et al., 2013) and reliable (Adell et al., 2013; Phan-Ba et al., 2012; Puthoff & Saskowski, 2013) option. Not only is this option more clinically feasible, it has been shown to be as reliable as automatic timers for assessing WS in older adults (Peters, Fritz, et al., 2013).

Clinical Message

Consolidation of evidence supports the use of WS tests to assess and monitor a wide range of populations (Chrysagis et al., 2012; Fulk et al., 2011; Hass et al., 2012; Hollman et al., 2008; Horemans et al., 2004; Kon et al., 2012; Motyl et al., 2013; Nair et al., 2012; Nogueira et al., 2013; Puthoff & Saskowski, 2013; Working Group on Health Outcomes for Older Persons with Multiple Chronic, 2012). Clinicians should consider administering tests with timed distances of 5 to 10 meters (Ng et al., 2012; Ng et al., 2013) and acceleration phases of approximately 2.5 meters for self-selected speeds (Lindemann et al., 2008; Macfarlane & Looney, 2008) and 3.25 meters for maximal WSs (Macfarlane & Looney, 2008). A straight path should be used in order to capture steady state WS rather than including a turn (van Herk et al., 1998). Hand held stopwatches can be used for timing (Peters, Fritz, et al., 2013) and the path can be marked with tape. If working in an environment where tape cannot be applied to surfaces, another easy option is for clinicians to carry a thin rope that is the length of the entire distance (including acceleration/deceleration phases) and clearly marked with the timed section. The rope can then be temporarily laid out during performance of the test. This easily transportable option allows for testing anywhere within the setting, so may be useful in home health, acute care, skilled nursing, or long term care facilities where clinicians perform evaluations and treatments in multiple areas. For maximal WS tests, addition of “real life” examples or demonstration to simple instructions may result in greater, and therefore more accurate, speeds. The recommendations regarding WS assessment presented in this review are provided as a guide for clinicians to help them select the most appropriate protocol for their specific patient and environment. Regardless of protocol chosen, the important take home message is that consistency across testing sessions must be maintained in order for accurate conclusions to be drawn.

Assessment of a patient’s WS can be used to guide clinical decision-making. As a screening tool, WS can identify those at-risk of adverse outcomes or in need of intervention (Cesari et al., 2005; Montero-Odasso et al., 2005). Walking speed is the result of a complex interplay of multiple body structures and functions; proactive and reactive postural control (Woollacott & Tang, 1997), lower extremity strength (Bohannon, 1997) (Clark, Manini, Fielding, & Patten, 2013), aerobic capacity (Fiser et al., 2010), proprioception (Park, Kim, & Lee, 2013), and vision (Aartolahti et al., 2013) all contribute to WS. Therefore, patients who present with WSs indicative of impairment warrant further testing to determine the cause(s) of their decreased speed. Depending on the assessors’ scope of practice, the results can then be used as targets of intervention or reasons for referral to appropriate healthcare professionals.

Evidence continues to validate the prognostic and predictive values of WS, and accordingly, the measure's popularity as the "sixth vital sign" has not waned over time. As with any other vital sign, WS is a simple assessment that provides a wealth of information about underlying physiological processes. The value far out ways the cost, and clinicians should consider incorporating this vital sign into all comprehensive evaluations.

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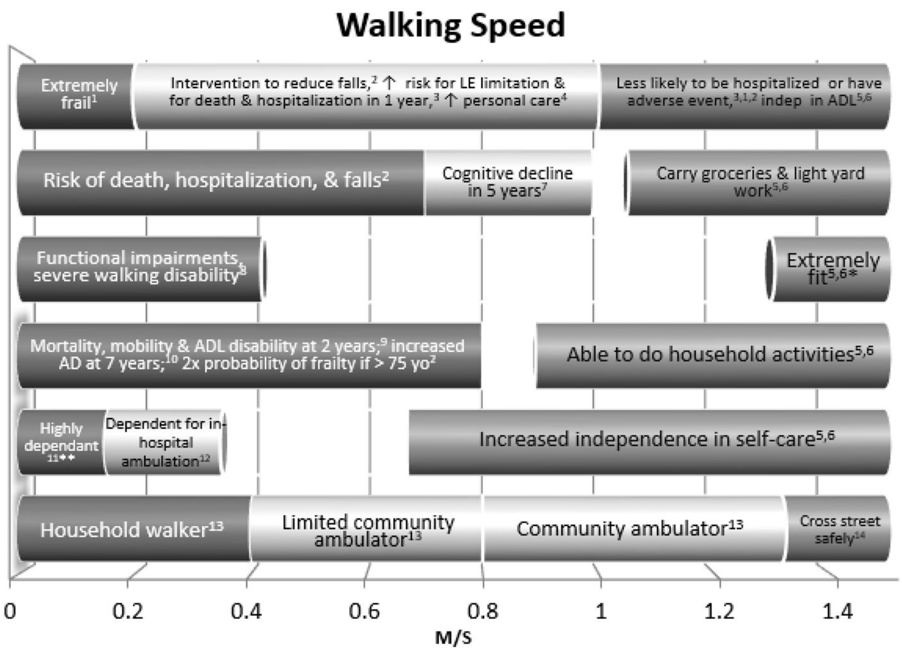

Figure 1.

Depiction of walking speeds and the associated outcomes. m/s, meters per second; ↑, increased; LE, lower extremity; indep, independent; ADL, activities of daily living; AD, Alzheimer's disease; 2x, two times; yo, years old; d/c, discharge

* Able to climb several flights of stairs

**More likely to require long term hospital care than d/c home or nursing home 1. (Studenski et al., 2003), 2. (Montero-Odasso et al., 2005), 3. (Cesari et al., 2005), 4. (Shimada et al., 2013), 5. (Ainsworth et al., 2011), 6. (Studenski, 2009), 7. (Inzitari et al., 2007), 8. (Atkinson et al., 2005), 9. (Ostir, Kuo, Berges, Markides, & Ottenbacher, 2007), 10. (Abellan van Kan et al., 2012), 11. (Friedman, Richmond, & Baskett, 1988), 12. (Graham, Fisher, Berges, Kuo, & Ostir, 2010), 13. (Perry, Garrett, Gronley, & Mulroy, 1995), 14. (Salbach et al., 2013)

Clinical Pearls

- Administer tests with a timed central straight path 5 to 10 meters in length.
- Stopwatch and premeasured length of rope provide a portable option.
- Include an acceleration phase.
    - Self-selected tests: ~2.5m
    - Maximal tests: 3 to 3.25m
- Include "real-life" example or demonstration to instructions for maximal tests.
- Maintain consistency at all subsequent testing sessions.

Figure 2.
Recommendations for assessment of walking speed

Table 1

Studies Included in Figure 1

	Population(s)	Design	Sample Size	Age, years (mean ± SD)	WS, m/s†
Studenski et al., 2003	Community-dwelling older adults (age >65 years)	Prospective (1 year)	n = 487	74.1 ± 5.7	0.88 ± 0.22
Montero-Odasso et al., 2005	Community-dwelling older adults (age >75 years)	Prospective (2 years)	n = 102	79.6 ± 4	0.27 – 1.33 (range)
Cesari et al., 2005	Community-dwelling older adults (age 70 – 79 years)	Prospective (4.9±0.9 years)	n = 3,047	74.2 ± 2.9	1.17 ± 0.24
Shimada et al., 2013	Older adults (age >65 years)	Cross-sectional	n = 10,351	78.8 ± 8	Personal care: 0.7 ± 0.3 No personal care: 1.2 ± 0.2
Inzitari et al., 2007	Community-dwelling older adults (age 70 – 79 years)	Prospective (5 years)	n = 2,276	73.5 ± 2.8	Quartiles*: <1.05, 1.06–1.19, 1.20–1.34, ≥1.35
Atkinson et al., 2005	Older women with moderate to severe disability	Prospective (3 years)	n = 558	78.0 ± 8.1	No decline: 0.83±0.25 Physical decline: 0.68±0.25 Cognitive decline: 0.75±0.16 Combined decline: 0.62±0.15
Ostir et al., 2007	Mexican-American older adults (age >65 years)	Prospective (7 years)	n = 1,630	72.0 ± 6.1	5 categories based on 8′ walk time*: unable, ≥9.0, 6.0–8.9, 4.0–5.9, ≤3.9 sec
Abellan van Kan et al., 2012	Older women (age >75 years)	Prospective (7 years)	n = 647	NR for group(s)	Dementia free: 0.9±0.2 Dementia: 0.8±0.2
Friedman et al., 1988	Patients in geriatric rehabilitation ward	Prospective (length of stay)	n = 125	Home alone: 74.0±8.5 Home-carer: 76.3±7.8 Rest-home: 83.7±8.5 Hospital: 80.5±7.6	Home alone: 0.55±0.28 Home-carer: 0.43±0.23 Rest-home: 0.34±0.19 Hospital: 0.19±0.18
Graham et al., 2010	Acute care older adults (age >65 years)	Cross-sectional	n = 174	75.27 ± 6.91	0.43 ± 0.23
Perry et al., 1995	Individuals >3 months post-stroke	Cross-sectional	n = 147	55.5 ± 12.2	Functional walking categories: Physiological 0.1±0.05, Limited Household 0.23±0.17, Unlimited Household 0.27±0.12, Most-limited Community 0.40±0.18, Least-limited Community 0.58±0.18, Community 0.80±0.18

Abbreviations: SD, standard deviation; WS, walking speed; NR, not reported

†Information is presented for WS data from the listed articles. When available WS (mean±SD) provided for sample as whole or groups within sample.

*Indicates information on how authors used WS to dichotomize sample for study; means not provided in article.

Table 2

Minimal Detectable Change Values and Testing Protocols by Diagnosis and Setting

DIAGNOSIS	Sample Characteristics†	MDC$_{95}$ SS WS	MDC$_{95}$ Max WS	Timed*	Acceleration*
Community-dwelling older adults[1]	n = 30				
All participants	Age 60+ y	0.14	n/a	4	2
SS WS 0.6–1.0 m/s	33.3% AD use	0.11		4	2
SS WS >1.0 m/s	13.3% AD use	0.14		4	2
Chronic stroke[2]**	n = 61				
All participants	Age 63.5±10.0 y	0.18	0.13	10	2
MAS=0	25% AD use	0.2	0.13	10	2
MAS 1-1+	69% AD use	0.18	0.15	10	2
MAS ≥2	59% AD use	0.09	0.07	10	2
Incomplete spinal cord injury[3]	n = 16 3–88 mo post-injury 75% AD use	0.17	n/a	3.84	0.6 – 0.9
Following hip fracture[4]	n = 16 Age 77.9±9.0 y s/p 4.7±2.0 d	0.08	n/a	10	1
Multiple Sclerosis[5]	n = 120 MAS LE 1.6±2.9 6MWT 484.1±181.2m	0.26	0.26	10	NR
Parkinson's Disease[6]	n = 88 47% H&Y Stage 1 25% H&Y Stage 2 28% H&Y Stage 3/4	0.09	0.13	10	2
Huntington's Disease[7]	n = 81				

DIAGNOSIS	Sample Characteristics[†]	MDC_{95} SS WS	MDC_{95} Max WS	Timed[*]	Acceleration[*]
Pre-manifest	UHDRS TMS 2±2	0.23	n/a	10	2
Manifest	UHDRS TMS 39±18	0.34		10	2
Early-Stage	UHDRS TMS 28±18	0.20		10	2
Middle-Stage	UHDRS TMS 40±15	0.46		10	2
Late-Stage	UHDRS TMS 48±17	0.29		10	2
Alzheimer's Disease[8]	n = 51 Age 80.71±8.77 y 76.5% living at home <50% AD use	0.16	n/a	4.57	NR
Dementia[9]	n = 58 Age 82.47±5.31 y 34% Nursing Home 44.8% AD use	0.27	n/a	6	NR
SETTING					
Short term rehabilitation[10]	n = 136 TKA (36) Infection (13) THA (10) Fracture (10) Stroke (7) Cardiopulmonary (22) Other (38)	0.13	n/a	5.2	1
Acute care[11]	n = 46 Orthopedic (18) Cardiopulmonary (13) GI/Genitourinary (6) CNS (3)	0.18	n/a	3	1.5

DIAGNOSIS	Sample Characteristics[†]	MDC_{95} SS WS	MDC_{95} Max WS	Timed[*]	Acceleration[*]
	Other (6)				
Cardiac rehabilitation[12]	n = 49 PCI (19) CABG (16) MI (7) Other (7)	0.16	n/a	4	1
Residential Care Unit[13]	n = 31 Age 74–100 y 77% AD use	n/a	0.31	10	2

MDC_{95}, minimal detectable change at 95% confidence level; SS, self-selected; Max, Maximal; WS, walking speed; AD, assistive device; y, years; d, days; mo, months; m, meters; MAS, Modified Ashworth Scale; NR, not reported; 6MWT, 6 Minute Walk Test; H&Y Hoehn & Yahr scale; UHDRS TMS, Unified Huntington's Disease Rating Scale total motor score (range 0–124, lower score better); MMSE Mini-Mental State Examination; TKA, total knee arthroplasty; THA, total hip arthroplasty; GI, gastrointestinal; CNS, central nervous system; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graph; MI, myocardial infarction

[†]Selected sample characteristics are provided to assist with determining applicability of MDC to patient/participant of interest

[*]Values presented in "Timed" and "Acceleration" columns are distances in meters of timed and acceleration phases of walking speed test administered in referenced study

[**]MAS scores for plantarflexor muscle group

n/a indicates not assessed in referenced study

[1]Goldberg & Schepens, 2011,

[2]Hiengkaew, et al., 2012,

[3]Nair, et al., 2012,

[4]Hollman et al., 2008,

[5]Paltamaa, et al., 2008,

[6]Combs, et al., 2014,

[7]Quinn et al., 2013,

[8]Ries, et al., 2009,

[9] Blankevoort, et al., 2013,

[10] Barthuly, et al., 2012,

[11] Braden, et al., 2012,

[12] Puthoff & Saskowski 2013,

[13] Adell, et al., 2013