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Review

Expected values for steps/day in special populations

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ABSTRACT

Objective. To assemble expected values for free-living steps/day in special populations living with chronic illnesses and disabilities.

Method. Studies identified since 2000 were categorized into similar illnesses and disabilities, capturing the original reference, sample descriptions, descriptions of instruments used (i.e., pedometers, piezoelectric pedometers, accelerometers), number of days worn, and mean and standard deviation of steps/day.

Results. Sixty unique studies represented: 1) heart and vascular diseases, 2) chronic obstructive lung disease, 3) diabetes and dialysis, 4) breast cancer, 5) neuromuscular diseases, 6) arthritis, joint replacement, and fibromyalgia, 7) disability (including mental retardation/intellectual difficulties), and 8) other special populations. A median steps/day was calculated for each category. Waist-mounted and ankle-mounted instruments were considered separately due to fundamental differences in assessment properties. For waist-mounted instruments, the lowest median values for steps/day are found in disabled older adults (1214 steps/day) followed by people living with COPD (2237 steps/day). The highest values were seen in individuals with Type 1 diabetes (8008 steps/day), mental retardation/intellectual disability (7787 steps/day), and HIV (7545 steps/day).

Conclusion. This review will be useful to researchers/practitioners who work with individuals living with chronic illness and disability and require such information for surveillance, screening, intervention, and program evaluation purposes.

Contents

Introduction

The benefits of a physical active lifestyle are relevant to special populations living with chronic illness and disability, however, we know little about the actual physical activity patterns of such special populations (Tudor-Locke and Myers, 2001a). Accurate quantification of physical activity behaviors using feasible and appropriate

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assessment tools is essential to epidemiologists, physiologists, and behavioral scientists, as well as clinicians charged with the treatment of chronic illness and disability.

Objective monitoring of physical activity, using body worn accelerometers and pedometers, has advanced greatly in recent years. Accelerometers contain a piezoelectric element and typically provide time-stamped estimates of activity volume (i.e., total counts or steps taken) or activity rates (counts/min). Although accelerometers are without reproach in terms of the study of physical activity intensity in relation to health outcomes, pedometers are generally considered more practical for individual and population level applications, largely due to instrument cost and feasibility of data collection and management. Pedometers are typically based on a horizontal spring-suspended lever arm and on-instrument digital data presentation; their output correlates highly (median $r = 0.86$) with that of different accelerometers (Tudor-Locke et al., 2002b). Although they are not designed to directly detect physical activity intensity, they do provide a simple and affordable means of tracking daily physical activity volume (especially walking) expressed as a summary output of steps/day. An indicator of volume is likely sufficient when studying sedentary populations, who by definition, do not engage in high levels of physical activity (Tudor-Locke and Myers, 2001b).

Piezoelectric pedometers are a recent addition to the options for objective monitoring. Their measurement system is based on a basic accelerometer-type mechanism sensitive to detecting steps taken. They typically also provide on-instrument digital data and have been classified as pedometers since outputs include only steps and variables derived from steps. Most objective monitoring instruments are worn at the waist with few notable exceptions, for example, the ankle-mounted StepWatch Activity Monitor (SAM, originally developed by the Prosthetic Research Study, Seattle, WA and now distributed through CYMA Corporation, Mountlake Terrace, WA). The SAM is worn on one leg and detects a "stride," or "gait cycle," although this output has also been presented as steps/day. However, in order to generate a steps/day output comparable to waist-mounted instruments, it should be doubled.

Expected values are normative or benchmark values that convey estimates of central tendency and variability and are derived from a review of published literature (Myers, 1999). They are necessary to facilitate research and program planning and aid in comparisons and interpretation of similar data (for example in surveillance efforts, and especially identifying and studying "unusual" samples). When we first compiled expected values of habitual pedometer-determined physical activity in free-living samples (Tudor-Locke and Myers, 2001a), we located 12 studies that together represented heart and vascular diseases, chronic obstructive pulmonary disease, diabetes, joint replacement, and disabilities including blindness, physical handicaps, and mental retardation. From that review we concluded that adults living with chronic illnesses and disabilities accumulate 3500–5500 steps/day. In comparison, we found that relatively healthy adults (aged ≈20–50 years) took 7000–13,000 steps/day. The purpose of this review is to update expected values for steps/day pertinent to free-living special populations.

Methods

A literature search (current and verified as of January 05, 2009) began with a keyword (pedometer, "step counter," "step activity monitor" or "accelerometer" AND "steps/day") search of Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), SportDiscus, and PsychInfo. A publication date limit was set from 2000, coinciding with the acceptance of the original review (Tudor-Locke and Myers, 2001a). As unique studies were identified and assembled, and to the extent that it was possible, categories were assembled to generally depict similar illnesses and disability. Tables were generated capturing the original reference, sample descriptions (including sex, age descriptors as available, and verbatim descriptions of illness or disability), verbatim descriptions of objective monitoring instrument brands used, monitoring frame (i.e., number of days worn), and exact mean (or median) and standard deviation (or standard error) of steps/day (studies reporting distance traveled or other non-step outputs were not included). Inconsistencies in presentation across table columns reflect underlying inconsistencies in reporting across studies. Since the SAM 1) is uniquely an ankle-mounted accelerometer that, 2) is known to be more sensitive to low velocity stepping than waist-mounted pedometers (Karabulut et al., 2005; Silva et al., 2002; Silva et al., 2005), 3) is more likely to detect "fidgeting" activities (Karabulut et al., 2005), and 4) detects steps taken on only one leg differentiating itself from waist-mounted instruments that are sensitive to accelerations at both hips, we doubled originally reported data (after verifying that the original study did not do this) to make it more comparable to the traditional assessment of steps/day, and assembled relevant studies separately within each table.

Ultimately, we assembled expected values for steps/day pertinent to free-living special populations, specifically: 1) heart and vascular diseases, 2) chronic obstructive lung disease, 3) diabetes and dialysis, 4) breast cancer, 5) neuromuscular diseases, 6) arthritis, joint replacement, and fibromyalgia, and 7) disability (including mental retardation/intellectual difficulties), and 8) other special populations. Wherever possible, an overall median steps/day was calculated for each category (and by each instrument type, i.e., waist-mounted and ankle-mounted) considering at least two assembled samples (even if those samples were reported within the same study) of similar special populations originally reporting mean values. If only a single sample was identified then it necessarily stood alone as an indicator of expected values for steps/day. No attempt was made to weight any of the values since few variables were sufficiently detailed and/or consistently reported across all studies and it was decided that any attempt to weight the data would imply a precision of the estimate that we do not believe is appropriate or valid at this time.

Heart and vascular diseases (Table 1)

Ten studies reporting expected values for habitual steps/day using waist-mounted instruments were identified representing populations described as living with chronic heart failure (Houghton et al., 2002), coronary artery disease (VanWormer et al., 2004), myocardial infarction/cardiac rehabilitation (Ayabe et al., 2008; Izawa et al., 2004; Savage and Ades, 2008), peripheral arterial disease (Crowther et al., 2007) and/or intermittent claudication (Nasr et al., 2002), hypertension (Hyman et al., 2007; Iwane et al., 2000), and post-stroke (Katoh et al., 2002). Two studies (Crowther et al., 2007; Houghton et al., 2002) reported mean steps/week and it was necessary to divide the output by 7 in order to derive mean steps/day for comparison purposes. It is important to note that two of the studies (Ayabe et al., 2008; Savage and Ades, 2008) captured steps/day in patients actively engaged in a cardiac rehabilitation program and another reported steps/day in patients who continued to exercise post cardiac rehabilitation (Izawa et al., 2004). The overall median value for habitual steps/day using waist-mounted instruments was 4684 steps/day (Table 1).

Four studies were identified that used the ankle-mounted SAM. Two focused on intermittent claudication (Gardner et al., 2007; Gardner et al., 2008) and two on post-stroke chronic hemiparesis (Bowden et al., 2008; Resnick et al., 2008). We calculated a median value of 6515 for habitual steps/day using ankle-mounted instruments specifically for individuals living with intermittent claudication and 4695 steps/day for post-stroke chronic hemiparesis.

Chronic obstructive lung disease (COPD; Table 2)

Only two studies (de Blok et al., 2006; McGlone et al., 2006) were identified reporting expected values for habitual steps/day using waist-mounted instruments in COPD samples. Only one (de Blok et al., 2006) of these studies reported mean steps/day in at least two samples (the other (McGlone et al., 2006) reported median values). Therefore the computed median expected value for this category was 2237 steps/day. No studies of COPD samples were identified using ankle-mounted instruments (Table 2).

Diabetes and dialysis (Table 3)

Seven unique studies using waist-mounted instruments were identified focused on Type 2 diabetic populations (Araiza et al., 2006; Bjorgaas et al., 2005; Matsushita et al., 2005; Richardson et al., 2007; Strycker et al., 2007; Tudor-Locke, 2001; Tudor-Locke et al., 2002a), and another study captured both Type 1 and Type 2 diabetes (Smaldone et al., 2006). We also included a single study of a dialysis population (Zamojska et al., 2006) in this category, since diabetes is a leading cause of dialysis. The calculated mean expected value for studies of Type 2 diabetes using waist-mounted instruments was 6342 steps/day (Table 3).

Three studies (Kanade et al., 2006; Lemaster et al., 2008; Smith et al., 2004) were identified using ankle-mounted instruments (specifically the SAM accelerometer). Type of diabetes was not identified in any of these studies, however, based only on reported age we assumed they focused on Type 2 diabetes. One study reported data weighted by number of days provided by participants (Lemaster et al., 2008). The median value for steps/day obtained from this ankle-mounted instrument was 7407 steps/day.

Breast cancer (Table 4)

Five studies of habitual steps/day using waist-mounted instruments in breast cancer survivors were identified (Irwin et al., 2008; Matthews et al., 2007; Rogers et al., 2005; Vallance et al., 2007; Wilson et al., 2005). The study that used a waist-mounted accelerometer (Matthews et al., 2007) reported steps/day values after censoring those values coinciding with accelerometer activity counts below 260 counts/min. A third study focused on breast cancer patients undergoing treatment (Rogers et al., 2005). The median expected value for breast cancer survivors was 7409 steps/day. No studies were identified using ankle-mounted instruments (Table 4).

Neuromuscular diseases (Table 5)

Two original articles were identified reporting steps/day determined by waist-mounted instruments (Gosney et al., 2007; Motl et al., 2006). A third one presented steps/day data only in a figure (Kilmer et al., 2005). We successfully contacted the first author directly to obtain the exact mean and SD for steps/day. Therefore, the median expected value for this category was 5887 steps/day (Table 5).

Two studies were identified that used the ankle-mounted instrument to detect steps/day in individuals living with neuromuscular

Table 1
Expected values for habitual steps/day in free-living individuals living with heart and vascular diseases.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Iwane et al. (2000)	17 hypertensive males	48.7 ± 1.9	Pedometer: Hello Walk, Tanita, Tokyo, Japan	Not reported	5790	SE 458
Houghton et al. (2002)	31 males, 5 females with stable mild-moderate chronic heart failure	Mean 69 Range 48–80	Pedometer: Digiwalkers, Steiner, Brentford, UK	14 days	4342.4[a]	SE 734.1[a]
Katoh et al. (2002)	16 male and 4 female community-dwelling post-stroke patients	64 ± 9 years old	Accelerometers: Kenz Life Corder, Suzuken, Co., Nagoya, Japan	12 ± 4 days	4346	2933
Nasr et al. (2002)	39 males, 11 females with intermittent claudication	Median 67 Range 62–73	Pedometer: Sportline 345, Sportline, Campbell, CA, USA	7 days	Median 5728	Not reported
Izawa et al. (2004)	90 acute myocardial infarction patients who continued to exercise post cardiac rehabilitation, 19 who quit	63.5 ± 10.1	Accelerometer: Kenz Lifecorder, Suzuken, Nagoya, Japan	7 days	Continued exercisers: 9252.5 Quitters: 4246.2	3046.6 2024.9
VanWormer et al. (2004)	14 males, 8 females with coronary artery disease	29.42 ± 7.18	Pedometer: Brand not reported	Not reported	6152.1	2927.0
Crowther et al. (2007)	28 patients with peripheral arterial disease presenting with intermittent claudication	69.9 ± 1.5	Pedometer: Yamax Digi-Walker SW-700, Yamax Corp, Tokyo, Japan	7 days	4156.1[a]	572.6[a]
Hyman et al. (2007)	92 AA males and 189 AA females, current smokers with hypertension	Range 45–65	Pedometer: Brand not reported	1 week	3624.4[b] 3306.0[b] 3933.0[b]	2917.5[b] 2785.3[b] 3363.6[b]
Ayabe et al. (2008)	53 males, 24 females, cardiac rehabilitation program participants	68.1 ± 9.2	Accelerometer: Lifecorder, Suzuken Co., Tokyo Japan	7 days	6752	2659
Savage and Ades (2008)	79 males, 28 females at entry to cardiac rehabilitation	63 ± 10	Pedometer: Walk4Life, Inc, Plainfield, Illinois	7 days	Males non-rehab day 5515 Males rehab day 7580 Females non-rehab day 4684 Females rehab day 6755	4684 3409 2863 3330
Ankle-mounted instruments						
Gardner et al. (2008)	54 males, 44 females with intermittent claudication	Range 50–90	Accelerometer: Step Watch 3, Cyma Inc, Mountlake Terrace, WA	7 days	6298	3114
Gardner et al. (2007)	133 patients with intermittent claudication	67 ± 10 Range 50–90	Accelerometer: Step Watch 3, Cyma Inc, Mountlake Terrace, WA	7 days	6732	3388
Bowden et al. (2008)	48 males, 11 females with chronic hemiparesis (>6 months post-stroke)	61.9 ± 10.8	Accelerometer: StepWatch Activity Monitor, OrthoCare Innovations, Washington, DC	5 days	Household ambulators (walking speed <0.4 m/s) 2822 Limited community ambulators (walking speed 0.4–0.8 m/s) 5336 Community ambulators (walking speed >0.8 m/s) 7318	1606 2386.6 2894.8
Resnick et al. (2008)	51 males, 36 females with chronic hemiparetic stroke (>6 months post-stroke)	63.7 ± 12.3	Accelerometer: Step Watch Activity Monitor (SAM)	2 days	4055.17	2401.2

AA = African American.
[a] Reported as steps/week in paper, steps/day imputed by dividing by 7.
[b] Values for otherwise equivalent groups at baseline.

Table 2
Expected values for habitual steps/day in free-living individuals living with chronic obstructive lung disease (COPD).

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
de Blok et al. (2006)	16 patients with COPD (sex breakdown not reported for this subsample who wore pedometers)	Range 40–85	Pedometer: Yamax Digi-Walker, SW-200 Tokyo, Japan	7 days	Experimental group: 2140[a] Control group: 2334[a]	Not reported
McGlone et al. (2006)	74 males, 50 females with COPD	70 ± 8 Range 50–89	Pedometer: HJ 003 Omron Healthcare, Singapore	7 days	Median 3716	Not reported

[a] Values for otherwise equivalent groups at baseline.

diseases (Busse et al., 2004; Xanthopoulos et al., 2008). The median value for this category was 6006 steps/day.

Arthritis, joint arthroplasty and fibromyalgia (Table 6)

Eight unique studies were identified that presented habitual steps/day using waist-mounted instruments in individuals with arthritis (Talbot et al., 2003), joint (hip or knee) arthroplasty (Bennett et al., 2008; Goldsmith et al., 2001; Schmalzried et al., 2000; Silva et al., 2002; Silva et al., 2005), a combination of arthritis and arthroplasty (Ono et al., 2007), or fibromyalgia (Fontaine and Haaz, 2007). The median expected value for individuals with arthritis was 4086 steps/day and for those with joint arthroplasty it was 4892 steps/day. The single study that included a combination of arthritis and arthroplasty (Ono et al., 2007) (without distinctly presenting the data as such) was not considered in the calculation for either the arthritis or the arthroplasty expected values (Table 6).

Three studies were identified that used the ankle-mounted SAM accelerometer. Two focused on individuals with hip arthroplasties (Schmalzried et al., 2000; Silva et al., 2002) and the third assessed individuals living with hip or knee osteoarthritis (Brandes et al., 2008). The median value for hip replacement was 10,494 steps/day.

Disability (Table 7)

We located five unique studies of disabled individuals reporting steps/day using waist-mounted instruments (Mitsui et al., 2003; Mitsui et al., 2006; Peterson et al., 2008; Stanish and Draheim, 2005; Temple, 2007). Two studies (Mitsui et al., 2003; Mitsui et al., 2006) examined older (i.e., over 70 years) disabled individuals and three

Table 3
Expected values for habitual steps/day in free-living individuals living with diabetes) or dialysis.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Tudor-Locke (2001)	3 males, 6 females with Type 2 diabetes	53 ± 6	Pedometer: Yamax Digi-Walker SW-200	3 days	6342	2244
Tudor-Locke et al. (2002)	98 males, 62 females with Type 2 diabetes	52.4 ± 5.3	Pedometer: Yamax Digi-Walker SW-200, Accusplit, CA	3 days	6662	3077
Matsushita et al. (2005)	46 males, 16 females with Type 2 diabetes	58.1 ± 9.5 Range 33–77	Accelerometer: Suzuken, Lifecorder	1 week	9030[a] 9049[a] 8809[a]	SE 686[a] SE 652[a] SE 665[a]
Bjorgaas et al. (2005)	29 males with Type 2 diabetes	57.4 ± 7.8	Pedometer: Yamax Digi-Walker ML AW-320, Yamax, Tokyo, Japan	3 days	4194	Not reported
Araiza et al. (2006)	30 patients with Type 2 diabetes mellitus (sex not reported)	Range 33–69	Pedometer: Yamax Digi-Walker SW-701, New Lifestyles, Kansas City, MI	10 days	6239[b] 7220[b]	2985[b] 2792[b]
Smaldone et al. (2006)	38 males, 63 females with Type 1 diabetes	44 ± 12.4	Pedometer: Brand not reported	3 days	Type 1 diabetes 8008	3781
	60 males, 47 females with Type 2 diabetes	57 ± 9.2			Type 2 diabetes 5491	3828
Zamojska et al. (2006)	33 male, 27 female chronic haemodialysis patients	60 ± 13	Pedometer: Oregon Scientific PE316CA, Portland, OR	2 days	3448[c]	1178.5[c]
Strycker et al. (2007)	270 postmenopausal females with type 2 diabetes	40–70+	Pedometer: Yamax Model SW-701	7 days	4352	2981
Richardson et al. (2007)	10 males, 20 females with type 2 diabetes	Mean 52.5	Accelerometer: Omron HJ-720IT	7 days	4596	1794
Ankle-mounted instruments						
Smith et al. (2004)	57 males with diabetes	Mean 68 Range 41–85	Accelerometer: Step Activity Monitor (SAM)	14 days	6585.6	4073.2
Kanade et al. (2006)	19 males, 2 females with diabetic neuropathy without plantar ulceration	62.9 ± 6.2	Accelerometer: StepWatch Activity Monitors (SAM; Prosthetics Research Study, Seattle, WA)	7 days	8228	3864
Lemaster et al. (2008)	40 males, 39 females with diabetic peripheral neuropathy	≥50	Accelerometer: StepWatch, OrthoCare Innovations, Washington, DC	14 days	Control group baseline 6700[d] Intervention group baseline 6670[d]	SE 494[d] SE 492[d]

[a] Values reported by HbA1c tertiles.
[b] Values for otherwise equivalent groups at baseline.
[c] Mean and SD divided by 2 since data was originally reported per 48 h.
[d] Data weighted by days worn.

Table 4
Expected values for habitual pedometer-determined physical activity in free-living breast cancer survivors or breast cancer patients undergoing treatment.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Wilson et al. (2005)	24 AA breast cancer survivors	Mean 55	Pedometer: Brand not reported	Not reported	4791	Not reported
Rogers et al. (2005)	15 breast cancer patients undergoing treatment	75%≥50 years	Pedometer: Yamax SW-701 Digi-Walker, Yamax, Tokyo, Japan	7 days	5525	2906
Vallance et al. (2007)	337 breast cancer survivors	Mean 58 Range 30–90	Pedometer: Digi-Walker SW 200 (New Lifestyles Inc, Lee's Summit, MO)	7 days	7938[a] 8306[a] 8476[a] 7993[a]	3906[a] 3831[a] 3248[a] 3559[a]
Irwin et al. (2008)	75 postmenopausal breast cancer survivors	40–75	Pedometer: Brand not reported	7 days	Exercisers 5145[a] Usual care 5342[a]	2312[a] 2744[a]
Matthews et al. (2007)	23 breast cancer survivors	≥45 years	Accelerometer: Manufacturing Technology (MTI, Fort Walton Beach, FL) Actigraph	7 days	Usual care 5939[a,b] Intervention 7409.4[a,b]	2203.5[a,b] 2791.1[a,b]

AA = African American.
[a] Values for intervention groups otherwise equivalent at baseline.
[b] Steps/day values after censoring those values coinciding with accelerometer activity counts below 260 counts/min.

studies examined younger (i.e., between 30 and 40 years) individuals with mental retardation/intellectual disability (Peterson et al., 2008; Stanish and Draheim, 2005; Temple, 2007). The median expected value for older individuals with disability was 1214 steps/day and 7787 steps/day for younger individuals with mental retardation/intellectual disability (Table 7).

Six studies using the ankle-mounted SAM accelerometer were identified. Three reported steps/day values for individuals living with prostheses (Kanade et al., 2006; Rosenbaum et al., 2008; Stepien et al., 2007), one reported values for individuals who had suffered an incomplete spinal cord injury (Bowden and Behrman, 2007), one focused on females post-hip fracture (Resnick et al., 2007), and another focused on older adults reporting functional limitations (Cavanaugh et al., 2007). The median value for individuals living with prostheses was 6126 steps/day. No other median values were computed.

Other special populations (Table 8)

HIV infection is a chronic disease and we identified a single study that used both waist-mounted pedometers (DigiWalker Model 200) and accelerometers (ActiGraph Model GT7164) (Ramirez-Marrero et al., 2008). The computed median expected value for waist-mounted instruments combined from these four samples within the same study is 7545 steps/day (Table 8).

Another study was identified that focused on older community-dwelling individuals living with multiple chronic illnesses (Ashe et al., 2007). The most frequently reported illnesses/disabilities were high blood pressure (58%), cataracts (55%), and osteoarthritis (50%). Pedometer-determined physical activity was not presented by illness. However, steps/day for the total sample averaged 6078 ± 4031.

Discussion

An amalgamation of expected values of steps/day focused on special populations, specifically those defined by chronic illness or disability, was missing from the scientific literature. We ultimately located 60 unique studies of free-living special populations published since 2000 that provided descriptive data necessary to address this gap. Forty-three studies used waist-mounted instruments, specifically, waist-mounted pedometers ($n=31$), accelerometers ($n=9$), both pedometers and accelerometers ($n=2$) or piezoelectric pedometers ($n=1$). Another 16 studies used the ankle-mounted SAM accelerometer and a single study used both waist- and ankle-mounted instruments (Silva et al., 2002). At least 19 (33%) studies clearly identified using a Yamax pedometer model (i.e., Yamasa, Yamax, Digi-Walker), followed by Sportline (3 studies or 5%). There were seven studies that did not report a pedometer brand. The Lifecorder was the most frequently used accelerometer (7 studies or 12%) followed by the ActiGraph (3 studies or 5%). Monitoring frames (where reported) ranged from 2 days to 2 weeks; the modal length of time was 7 days (29 studies, or 50%).

Fig. 1 is a visual presentation of expected values for waist-mounted instruments for each of the categories identified. Despite the fact that the assembled values reflect a fragmented and at times sparse

Table 5
Expected values for habitual steps/day in free-living individuals living with progressive neuromuscular diseases.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Kilmer et al. (2005)	12 males, 18 females with slowly progressive neuromuscular diseases	49.9 ± 13.2	Pedometer: Yamax Digi-Walker, Yamax Corp, Tokyo, Japan	3 days	4323.8[a]	2216.9[a]
Motl et al. (2006)	2 males, 28 females with multiple sclerosis	42.3 ± 9.5	Pedometer: Yamax SW-200, Yamax Corporation, Tokyo, Japan	7 days	7097	3931
Gosney et al. (2007)	23 males, 173 females with multiple sclerosis	46.1 ± 9.8	Pedometer: Yamax SW-200, Yamax Corporation, Tokyo, Japan	7 days	5887	3218
Ankle-mounted instruments						
Busse et al. (2004)	5 males, 6 females mixed neurology patients 10 females with muscular sclerosis 7 males, 3 females with Parkinson's disease 6 males, 4 females with muscular dystrophy	59.4 ± 13.4 37.9 ± 10.1 67.1 ± 8.2 52.1 ± 12.5	Accelerometer: Step Watch, Cymatech, Seattle, WA	7 days	5922 5970 7636 6006	Not reported
Xanthopoulos et al. (2008)	10 males, 6 females with idiopathic Parkinson's disease	71 ± 11	Accelerometer: CYMA step activity monitor (SAM)	2 days	8756	4114

[a] Exact values obtained from first author of original publication.

Table 6
Expected values for habitual steps/day in free-living individuals living with arthritis, joint arthroplasty, or fibromyalgia.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Schmalzried et al. (2000)	14 males, 17 females with total hip replacements	Mean 72 Range, 46–85	Pedometer: Brand not reported	Not reported	6795	3762
Goldsmith et al. (2001)	29 males, 25 females THA out-patients	Mean 57.7 Range 17–73	Pedometer: Brand not reported	Not reported	7815	Not reported
Silva et al. (2002)	14 males, 19 females with well-functioning hip arthroplasties	71.5 ± 9.7	Pedometer: Sportline, Campbell, CA	4 days	6878[a]	3736[a]
Talbot et al. (2003)	4 males, 13 females with OA in one or both knees assigned to a pedometer group	69.5 ± 6.74	Pedometer: New Lifestyles Digi-Walker SW-200, Yamax, Tokyo, Japan	72 h	3519	2603
	4 males, 13 females with OA in one or both knees assigned to education group	70.76 ± 4.71			4652	2622
Silva et al. (2005)	131 patients with either THA or TKA	57.6 ± 12.8 Range 23–82	Pedometer: Sportline, Campbell, CA	7 days	5737	1650
Ono et al. (2007)	61 patients with OA in one or more hips 54% with THA	53.3 ± 11.3	Accelerometer: Lifecorder, Suzuken Co., Nagoya, Japan	At least 5 days	6309	2392
Fontaine and Haaz (2007)	22 participants with fibromyalgia assigned to a lifestyle intervention	48 ± 10	Pedometer: Accusplit Eagle Activity Pedometer, San Jose, California	Not reported	2337	427
Bennett et al. (2008)	100 patients 10 years post-hip replacement	70.3 ± 6.9	Pedometer: FitPro Yamax, Japan	14 days	55–64 years 4873 65–69 years 4892 70–74 years 3440 75–79 years 3428 >80 years 2213	2810 3037 2023 1604 777
Ankle-mounted instruments						
Schmalzried et al. (2000)	14 males, 17 females with total hip replacements	Mean 72 Range, 46–85	Accelerometer: Step Activity Monitor (SAM), Prosthetic Research Study, Seattle, WA	Not reported	10550	4416
Silva et al. (2002)	14 males, 19 females with well-functioning hip arthroplasties	71.5 ± 9.7	Accelerometer: Step Activity Monitor (SAM), Prosthetic Research Study, Seattle, WA	4 days	10438	4388
Brandes et al. (2008)	9 males, 17 females with hip or knee osteoarthritis	58.6 ± 13.4	Accelerometer: Step Activity Monitor 3.0 (SAM) Cyma Corp., WA	7 days	9564	4232

OA = osteoarthritis, THA = total hip arthroplasty, TKA = total knee arthroplasty.
[a] Reported pedometer data as "cycles/day" therefore multiplied by 2 to convert back to steps/day.

Table 7
Expected values for steps/day in free-living individuals living with disability or mental retardation/intellectual disability.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instrument — older						
Mitsui et al. (2003)	8 male, 7 female, disabled attending a day-care center	76.2 ± 2.2	Accelerometer: Lifecorder, Suzuken, Nagoya, Japan	7 days	1056	SE 243
Mitsui et al. (2006)	19 male, 23 female, "variously disabled"	78.8 ± 1.1	Accelerometer: Lifecorder, Suzuken, Nagoya, Japan	7 days	1371	SE 235
Waist-mounted instruments — younger						
Stanish and Draheim (2005)	65 males, 38 females with mental retardation	Males 35.9 ± 11.2 Females 39.7 ± 9.5	Pedometer: Yamax Digi-Walkers SW-500 and SW-700	7 days	Males 7958 Females 7616	3888 3804
Temple (2007)	18 males, 19 females with intellectual disability	Males 32.6 ± 9.4 Females 34.1 ± 7.1	Pedometer: Yamax Digi-Walker SW-700, New Lifestyles, Inc., Lee's Summit, Missouri, USA	7 days	8100.5	3735.4
Peterson et al. (2008)	63 males and 68 females with mild to moderate intellectual disability	37.2 ± 11.6	Piezoelectric pedometer: Omron Model HJ700IT, Omron Healthcare, Kyoto, Japan	7 days	6621	3366
Ankle-mounted instruments						
Kanade et al. (2006)	18 males, 3 females with diabetic neuropathy and trans-tibial amputation, prosthetic	63.8 ± 5.7	Accelerometer: StepWatch 3 Activity Monitor	7 days	3882	2168
Bowden and Behrman (2007)	9 males, 2 females with incomplete spinal cord injury	Range 21–63	Accelerometer: Step Activity Monitor (SAM), Cyma Corporation, Seattle, WA	4 days	3280.4	867.4
Cavanaugh et al. (2007)	5 males, 7 females reporting functional limitations	79.3 ± 4.5	Accelerometer: StepWatch 3 Activity Monitor (SAM; Cyma Corporation, Mountlake Terrace, WA)	6 days	7681.5	SE 844.4
Resnick et al. (2007)	51 females post-hip fracture	79.7 ± 6.7	Accelerometer: Step Activity Monitor (SAM)	2 days	8120	SE 1246
Stepien et al. (2007)	60 males, 17 females unilateral lower limb amputees following prosthetic rehabilitation	60 ± 15	Accelerometer: StepWatch Activity Monitor (SAM), Prosthetics Research Study, Seattle, WA	6 days	6126	3786
Rosenbaum et al. (2008)	14 male, 8 female with modular prostheses following malignant bone tumor treatment	34.5 ± 18.4	Accelerometer: SAM Step Activity Monitor, Cyma, Inc., Seattle, OR	7 days	9572	3540

Table 8
Expected values for steps/day in free-living individuals living with other disease or disabilities.

Study	Sample	Age (years)	Instrument	Monitoring frame	Mean steps/day	SD (unless indicated as SE)
Waist-mounted instruments						
Ramirez-Marrero et al. (2008)	35 Hispanic males and 23 Hispanic females	46.5 ± 8.8	Pedometer: DigiWalker Model 200	7 days	Males 7594	2817
					Females 7495	2540
			Accelerometer: ActiGraph Model GT7164		Males 7151	2589
					Females 7886	2662
Ashe et al. (2007)	70 males, 130 females living with multiple chronic illnesses	74 ± 5.7	Pedometer: New Lifestyles DigiWalker SW-200, Lee's Summit, MO	3 days	6078	4031

literature representing differing measurement protocols (including brands of pedometers used and monitoring frames), obvious patterns of habitual pedometer-determined physical activity emerged. The lowest median values for pedometer-determined steps/day are found in disabled older adults (1214 steps/day) followed by people living with COPD (2237 steps/day) and fibromyalgia (2337 steps/day). These very low values are not surprising since these are the very individuals we can expect to be limited in habitual physical activity by the nature of their illness/disability. The highest values were seen in individuals with Type 1 diabetes (8008 steps/day), mental retardation/intellectual disability (7787 steps/day), HIV (7545 steps/day), and breast cancer survivors (7409 steps/day). These populations are relatively younger and otherwise healthy and less restricted in their daily physical activity. Scrutinizing the breast cancer category alone reveals that only one study examined patients undergoing treatment. The remaining four studies were conducted with survivors of breast cancer, who we can assume are living their lives without the same physical limitations associated with other chronic diseases. Despite these relatively higher values for steps/day within populations living with chronic diseases or disabilities, as stated earlier, we can expect otherwise healthy adults to take between 7000–13,000 steps/day (Tudor-Locke and Myers, 2001a), so that most of the values presented herein appear relatively lower in comparison. In agreement with these general findings, self-report data also suggest that individuals with Type 2 diabetes do not engage in regular physical activity (Morrato et al., 2007), and cancer survivors are more likely to be physically inactive than those who have never had cancer (Coups and Ostroff, 2005). Other patterns were also evident: physical activity differs by type of diabetes (Type 1 at 8008 steps/day vs. Type 2 at 6291 steps/day) and those who are most ill (i.e., receiving dialysis) are the least active (3448 steps/day).

In 2004, Tudor-Locke and Bassett, Jr. established preliminary pedometer-determined physical activity cut points for healthy adults: 1) <5000 steps/day (sedentary); 2) 5000–7499 steps/day (low active); 3) 7500–9999 (somewhat active); 4) 10,000–12,499 (active); and 5) ≥12,500 steps/day (highly active). These categories were reinforced in 2008 (Tudor-Locke et al., 2008). Since these cut points were established with the measurement parameters of research quality waist-mounted instruments in mind, we only use these to interpret the similarly reported data herein. According to these cut points, individuals living with heart and vascular diseases, COPD, arthritis, and fibromyalgia, and those undergoing dialysis or who are disabled older adults, are considered sedentary. Individuals living with Type 2 diabetes, neuromuscular diseases, and multiple chronic illnesses (otherwise unspecified) are considered low active. And individuals living with Type 1 diabetes, HIV, breast cancer, and mental retardation/intellectual disabilities are considered somewhat active. Since the lowest echelon labeled sedentary is actually quite broad (it covers 5000 steps whereas all other categories span only 2500 steps, with the exception of the highest echelon), and since it is apparent that there are individuals who take considerably few steps/day than the simple 5000 steps/day cut point, we propose that the previously established sedentary category be cut into <2500 steps day (indicative of basal physical activity) and 2500 to <5000 steps/day (indicative of limited physical activity) (Tudor-Locke et al., in press). Using these adaptations, disabled older adults and individuals living with COPD or fibromyalgia exhibit basal physical activity and those living with heart and vascular disease or arthritis, or undergoing dialysis, display limited physical activity.

Fig. 2 presents expected values for the ankle-mounted SAM across identified conditions. It is important to emphasize that these categories emerged from the studies identified for this instrument and therefore a lack of direct comparison between numbers and naming of the categories must be expected. The lowest values are for incomplete spinal cord injury (3280 steps/day) and post-stroke (4695 steps/day). The highest values are observed for arthritis (9564 steps/day) and joint replacement (10,438 steps/day). A direct comparison with waist-mounted instruments is not always possible since studies have independently pursued different samples. In the most comparable categories, waist-mounted vs. ankle-mounted expected values are: 6291 vs. 7407 steps/day for Type 2 diabetes, 5887 vs. 6006 for neuromuscular diseases, 4086 vs. 9564 for arthritis, and 4883 vs. 10,438 for joint replacement.

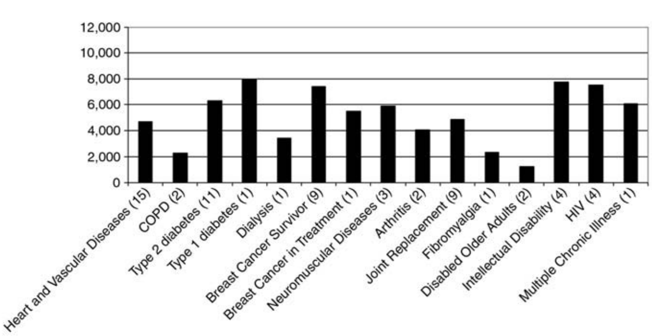

Fig. 1. Expected values for steps/day in special populations (living with chronic disease or disability) using waist-mounted instruments. Parentheses note number of samples expected value is based upon.

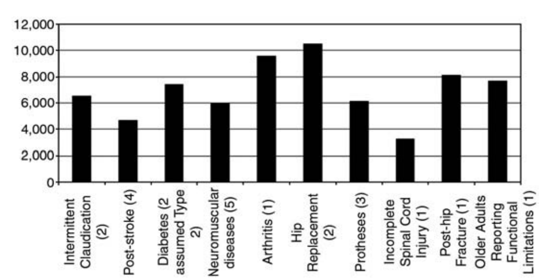

Fig. 2. Expected values for steps/day in special populations (living with chronic disease or disability) using an ankle-mounted instrument. Parentheses note number of samples expected value is based upon.

Although the studies assembled herein used a variety of objective monitors, the majority reported using instruments that have been previously validated. The Yamax pedometer is considered a criterion research quality pedometer (Schneider et al., 2004), the Lifecorder's validity is well documented (Crouter et al., 2003; Schneider et al., 2004), and the ActiGraph has been adopted by national surveillance strategies (Troiano et al., 2008) and is perhaps the most utilized accelerometer in research today. In addition the SAM is considered to be an important objective monitor specifically sensitive to low force threshold gaits associated with age and impairment (Karabulut et al., 2005; Silva et al., 2002; Silva et al., 2005). That being said, we firmly believe that it was prudent to present data from waist-mounted and ankle-mounted instruments separately as the absolute difference in detected steps was likely to impair direct comparisons. Although it is plausible that at least some disease/disability-related reduction in steps/day is complicated by slower gaits with advanced disability, the pattern displayed is congruent with what we know from other assessments of physical activity in these populations, including doubly labeled water (Kulstad and Schoeller, 2007). Ultimately, the choice of which instrument is best to capture the unique ambulatory activity patterns of a population is a function of the research question, participant burden, and resources available to the researcher or practitioner. By assembling expected data here representing a number of instruments, we hope to establish useful benchmarks and to facilitate comparisons between and across populations.

It is important to emphasize here that expected values convey estimates of central tendency and variability for habitual steps/day derived from a review of published literature. Their use does not imply any association with what people with such diseases or disabilities "should" be taking (i.e., an "indicator," "cut point," or "threshold" value). The end product of assembled expected values will be useful to researchers and practitioners who work with individuals living with chronic illness and disability. For example, a clinician who is familiar with such expected values can identify those individuals who are most likely to benefit from a physical activity intervention. Researchers can use the values to assist with study recruitment and screening procedures as well as calculate sample sizes and conduct power analyses for their studies. That being said, it is important to acknowledge that these estimates are largely based on small, non-representative samples thus limiting external validity. It is quite possible that the results represent individuals who are less severely affected by their condition and are more capable of consenting and adhering to wearing an objective monitor for several days. There is little evidence to draw firm conclusions about degrees of morbidity and steps/day. Although extremely useful, these expected values should be used with due caution. Full-scale surveillance research with nationally-representative samples is needed to obtain true estimates, however, the cost of such an endeavor is currently beyond reach for many of these special populations. Regardless, the expected values assembled herein offer an important resource that should be expanded and refined as future studies inevitably emerge.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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