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Systematic review of timed stair tests

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Abstract—Functional testing is particularly useful in the clinic and for making research translatable; however, finding measures relevant across ages and different conditions can be difficult. A systematic review was conducted to investigate timed stair tests as an objective measure of functional abilities and musculoskeletal integrity. Data were analyzed for their ability to differentiate between controls and patient groups and between different patient groups. Literature was reviewed using the Medline, CINAHL, and PubMed databases until February 2012. Data were grouped according to methodology, ages, and medical conditions. Time per step was calculated to allow comparison between studies. Eighty-eight studies were included in this review. Methodologies varied considerably with stair ascent, stair descent, or a combination of the two being used across a wide range of ages and medical conditions. Times increased with age for ascent, descent, and combined and for a variety of medical problems. Timed stair tests appear to be sensitive to medical conditions but further data are required to obtain normative values for this test. We suggest that timed stair tests should follow a more standardized methodology using a combination of ascent and descent and asking participants to complete the stairs as quickly and safely as possible.

Key words: age groups, functional measure, lower limb, musculoskeletal abnormalities, normative values, reference values, speed, stair navigation, task performance, time.

INTRODUCTION

Stair negotiation is a commonly performed activity in daily life and useful as a functional measure in a variety of populations [1–5]. However, many current functional assessment scales often neglect stair negotiation completely [6] and the time to complete stairs has largely been neglected as an objective outcome measure. Stair performance has been recognized as important in the Hospital for Special Surgery Score, whereby the ability to perform stair ascent and descent is heavily weighted [7], and the need for more challenging tests other than level walking has been recognized [8], particularly for more able populations.

Biomechanics research in the past has predominantly concentrated on level walking, because this is the gold standard of function and outcome for clinical populations. However, the literature examining stair ascent and descent has made significant gains in the understanding of the kinematics and kinetics of these tasks. Stairs require greater range of motion from the joints of the lower limb and greater muscle strength [9–10], with the demands on the joints and muscles differing between stair ascent and descent [11–12]. Stairs are a more advanced activity of daily living (ADL) and thereby may demonstrate functional difficulties more readily than walking tests.

Stair ascent stresses the cardiorespiratory system to a greater extent than level walking, increasing heart rate and respiratory measures [13]. Stairs therefore also have the benefit of being able to measure multiple systems and highlight the limiting factor(s) between the musculoskeletal,

Abbreviations: ADL = activity of daily living, SD = standard deviation.

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neurological, and cardiorespiratory systems. This makes one test even more valuable for assessing elderly or frail populations who may have multiple limitations. Information comparing stairs to other commonly used measures [14–15] demonstrates the reliability of measures associated with stairs [15] and their usefulness as an assessment tool directly related to function.

In clinical practice, stairs are increasingly being used as both an assessment tool and as part of exercise programs. Stairs make an excellent functional assessment measure because they are relevant to people's ADLs and have been related to independence and community participation [16–18]. Stairs often arise in measures of functional outcome postsurgery, and a greater understanding of the causes of performance difficulties with stairs can only assist in developing more specific and functional rehabilitation programs.

Of further benefit is the fact that stairs are readily available, convenient, and cheap to use. This article aims to summarize the literature related to timed stair tests. We aimed to determine whether stairs would be able to differentiate between participant groups by age or impairment and whether there were sufficient normative data for comparison as has been done for the timed up-and-go test [19].

METHODS

Search Strategy

Relevant articles were identified by searching the PubMed, CINAHL and Medline databases until February 2012. Searches were based on finding the words "stair" and "time" within 10 words of each other, with some other references found by hand searching. Only English references were included for this article.

Eligibility Criteria

The abstracts of all studies identified by the search strategy were screened by two of the three authors and a consensus was reached. The following criteria were used: (1) in English, (2) had human participants, (3) included data (not a review or protocol), and (4) included a timed measure of stair ascent and/or descent. Later, an additional criterion was added to improve the consistency of the methodology of the studies [20], in that the participants must have been instructed to perform the test as quickly and safely as possible. This command was felt to give a more consistent performance than allowing participants to use a self-selected pace.

Data Extraction and Analysis

Data were extracted by two of the three authors for all studies. Extraction included the size and type of participant population and treatment received, if a clinical trial. The methodology used was recorded, including the number of stairs used; whether studies assessed ascent, descent, or both; and the manner in which the stairs were performed (e.g., as quickly as possible, at a safe or comfortable pace, with or without use of handrails). The times obtained for all stair tests (mean ± standard deviation [SD]) were extracted. All stair times were divided by the number of stairs to generate a mean time in seconds per step. Studies reporting ascent and descent separately were not compared with those that examined the combination of stair ascent and descent. In prospective studies only baseline measures were directly compared.

RESULTS

PubMed, Medline, CINAHL and some reference-list searching generated 650 references after removing duplicates. A further 98 papers were excluded because they were not in English or did not study adult humans (**Figure**).

Of the remaining 551 references, 38 were not published research papers, 90 did not include a physical stair test, 196 did not include data on the times achieved, and 134 did not ask the participants to complete the stairs as fast or as quickly as possible. On examination of the data from the full text, a further 5 studies were excluded because the baseline data were duplicate data from other papers.

The 88 studies included used a variety of methodology. Ascent, descent, or a combination of both directions of the stairs including the turnaround time were considered. Interestingly, no studies looked at a combined ascent/descent time for the younger population or the medical groups. This variability in methodology has hampered the ability to compare groups, and there are insufficient data for some comparisons as well as groups that do not fit the expected trends.

A wide range of populations were covered in the studies, from the healthy young to the healthy elderly to those with mobility limitations and patient populations. Patient populations included those with musculoskeletal problems (arthritis, joint replacement, or fractures of the lower

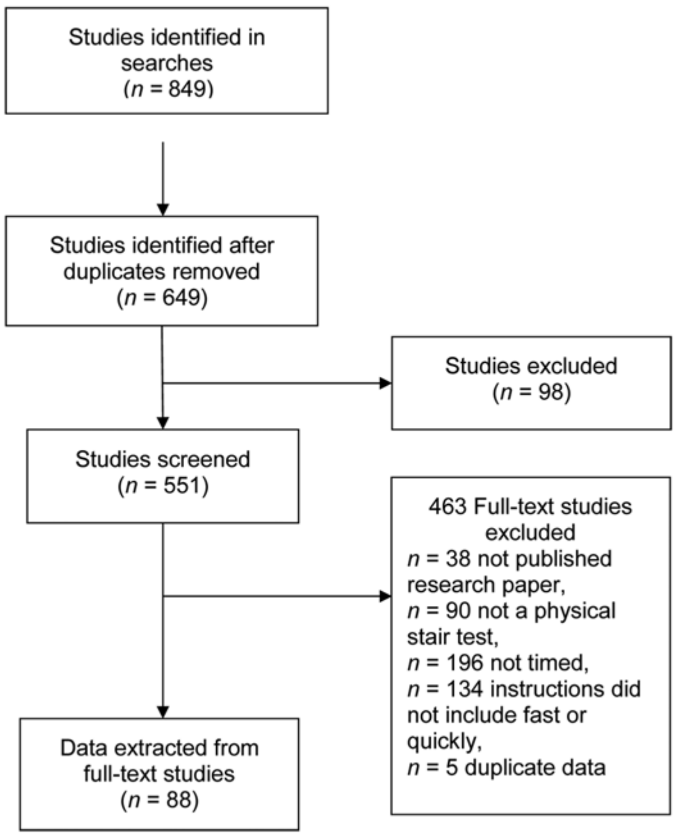

Figure.
Flowchart of search.

limb), medical conditions (cardiac arrhythmias, respiratory conditions, chronic obstructive pulmonary disease, cancer, or long-standing kidney disease), and neurological conditions (stroke, Parkinson disease, multiple sclerosis, Charot-Marie-Tooth, Down syndrome, or cerebral palsy). To examine the quantity of data, the healthy or control group data were separated by age groups (**Table 1**), because many feel that the ability to use stairs deteriorates with age [21]. The patient data were also grouped by neurological (**Table 2**), medical (**Table 3**), and musculoskeletal conditions (**Table 4**) to see whether different types of limitations would affect the data.

Due to the large number of studies, a summary of the number of studies in an area, number of participants, and time per stair is provided in **Table 5**. This gives an indication of how thoroughly a group has been investigated and the robustness of the associated data. A good example is comparison of the data for subjects older than 65 with and without mobility restrictions: those with mobility restrictions appear to descend stairs faster, which does not fit the expected trend. This may well have occurred because of the small number of studies using this methodology and relatively small participant numbers in the groups.

Overall within the healthy population, the expected trends are seen. It takes longer to ascend than descend stairs. The length of time to ascend or descend stairs, or a combination of both, increases with age. Comparing ascent and descent when measured singly to a combined stair ascent and descent time, only the neurological group took longer with a combined ascent and descent methodology than when the ascent and descent time were added together.

Finally, of the 88 studies considered, 54 were treatment or longitudinal studies, using stairs as an outcome measure to evaluate the effect of treatment or changes over time. Forty-eight (89%) of these studies found a change in the ability to negotiate stairs, with the effects varying between the time and treatment domains depending on the study, suggesting that stairs may be a sensitive measure of functional performance. However, because of the wide variety of treatments and participant groups considered, no further analysis of this has been attempted in this review.

DISCUSSION

As expected and predicted by the literature, measures of timed stair tests increase with increasing age and demonstrate differences between groups based on impairment. However, due to insufficient data and inconsistencies in methodology, normative values are insufficient for any group, except possibly the over 65 age group.

Timed stair tests are increasingly used in a range of research and clinical situations as an easy-to-administer, objective test of functional ability. However, the lack of normative data hampers the ability to use these data except to measure change over time [22]. Studies are continuing to examine data to differentiate between healthy and injured young people because commonly used objective measures, mainly based around level walking, are not sufficiently challenging for these groups [23]. Objective functional measures also continue to be more discerning than patient self-reports of function [24].

The data obtained in this review do suggest that there are measurable differences between groups and that the method of testing may influence the size of the differences found. However, there are still gaps in the data,

Table 1.
Stair times (in seconds) for healthy participants grouped by age (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)	Ascent/Descent (s)
18–49 yr					
Butler et al. (2009) [14]	50 young men (age 28.4 ± 4.7)	Ascent & descent 8 steps; median time	0.40	0.34	—
Haus et al. (2007) [36]	20 young persons (age 25 ± 1)	Ascent 10 steps	0.26	—	—
LeBrasseur et al. (2008) [37]	30 young men (age 38.7 ± 1.4)	Ascent 12 steps	0.29	—	—
Lindeman et al. (1998) [27]	20 Con (age 35 ± 11)	Ascent & descent of 10 steps; median time	0.59	0.58	—
Sartorio et al. (2003) [38]	200 obese subjects in 3wk body mass reduction program (age 49.7 ± [standard error] 1.0)	Ascent 13 steps	0.36	—	—
Sartorio et al. (2004) [39]	1273 obese subjects in body mass reduction program (age 45.3 ± 15.4)	Ascent 13 steps	0.38	—	—
Sartorio et al. (2001) [40]	230 obese subjects in body mass reduction program (age 49.9 ± [standard error] 0.9)	Ascent 13 steps	0.55	—	—
Sartorio et al. (2001) [41]	60 obese subjects in body mass reduction program (age 39.6 ± 14.6)	Ascent 13 steps	0.34	—	—
Teh & Aziz (2000) [25]	103 healthy Con (age 44.8 ± 13.9): *n* = 18 Val	Ascent 180 steps	♂ 0.62, ♀ 0.67, Val ♂ 0.53, ♀ 0.56	—	—
Teh & Aziz (2002) [26]	103 healthy Con (age 44.1 ± 13.4)	Ascent & descent 180 steps	0.63	0.57	—
50–65 yr					
Eyigor et al. (2008) [42]	33 Con (age 60.27 ± 10.70)	Ascent/descent 10 steps	—	—	0.94
Grant et al. (2004) [43]	26 overweight participants (age 63 ± 4): 13 exercisers, 13 Con	Ascent/descent 12 steps	Rx 0.58, Con 0.68	Rx 0.75, Con 0.91	Rx 1.35, Con 1.58,
Parisi et al. (2006) [44]	28 Con (age 58.4 ± 12.4)	Ascent & descent 10 steps	0.336	0.338	—
Petterson et al. (2007) [45]	44 Con (age 61.3 ± 7.7)	Ascent/descent 12 steps	—	—	♂ 0.68, ♀ 0.83
Yoshida et al. (2008) [46]	12 Con matched for age (61.6 ± 6.2) & body mass	Ascent/descent 12 steps	—	—	0.72
Over 65 yr					
Butler et al. (2009) [14]	684 community-dwelling elderly (age 80.1 ± 4.4)	Ascent & descent 8 steps; median time	0.63	0.63	—
Capodaglio et al. (2007) [47]	38 healthy elderly (age 77.0 ± 3.5)	Ascent/descent 2 flights of 12 steps	—	—	♀ Rx 1.51, Con 1.62, ♂ Rx 1.43, Con 1.36
Christiansen & Stevens-Lapsley (2010) [48]	17 Con (age 66.8 ± 6.5)	Ascent/descent 12 steps	—	—	0.74
Eyigor et al. (2007) [49]	33 healthy adults (age 70.3 ± 6.5)	Ascent/descent 10 steps	—	—	1.10
Eyigor et al. (2009) [50]	37 healthy adult volunteers (age 72.0 ± 6.5)	Ascent/descent 10 steps	—	—	Gp1 1.00, Gp2 1.10
Farquhar & Snyder-Mackler (2010) [51]	50 Con (age 66.4 ± 8.5)	Ascent/descent 12 steps	—	—	0.81
Galvao & Taaffe (2005) [52]	28 community-dwelling men and women (age 69 ± 4.6)	Ascent 11 steps	Rx1 0.48, Rx2 0.41	—	—
Haus et al. (2007) [36]	22 older persons (age 78 ± 1)	Ascent 10 steps	0.46	—	—
Henwood & Taaffe (2006) [53]	67 independent-living older adults (age 70.0 ± 4.5)	Ascent 11 steps	Rx1 0.44, Rx2 0.44, Con 0.45	—	—
Hirota et al. (2010) [54]	493 active elderly (age 73.5)	Ascent/descent 4 steps	—	—	♂ 1.32, ♀ 1.47
LeBrasseur et al. (2008) [37]	31 older men (age 68.4 ± 1.4)	Ascent 12 steps	0.42	—	—

Table 1. (cont)
Stair times (in seconds) for healthy participants grouped by age (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)	Ascent/Descent (s)
Miller et al. (2003) [55]	316 overweight adults (age 68.6)	Ascent/descent 5 steps	—	—	BMI Gp 1–4 2.18, 1.84, 2.06, 2.40
Morie et al. (2010) [56]	62 community-dwelling older men (age 74.1 ± 5.3) divided into high and low activity Gp	Ascent 12 steps	Low 0.61, High 0.44	—	—
Rees et al. (2007) [57]	43 older adults (age 73.0 ± 4.6)	Ascent/descent 5 steps twice	—	—	Rx1 0.81, Rx2 0.84, Con 0.82
Sayers et al. (2003) [58]	25 older women (age 72.6 ± 1.2)	Ascent 8 steps	Rx1 0.71, Rx2 0.78	—	—
Hiroyuki et al. (2003) [59]	34 older persons (age 80.9 ± 6.4)	Ascent/descent 5 steps	Con 1.52, Rx1 1.50, Rx2 1.66	Con 1.66, Rx1 1.42, Rx2 1.88	—
Sun et al. (2010) [60]	571 older persons (age 73.0 ± 5.4)	Ascent/descent 4 steps	—	—	♂ 1.27, ♀ 1.44
Suzuki et al. (2001) [61]	34 older persons (age 75.4 ± 5.1)	Ascent 8 steps	0.625	—	—
Vincent et al. (2002) [62]	62 older persons (age 69.0 ± 5.5)	Ascent 23 steps	Con 0.40, Rx1 0.41, Rx2 0.36	—	—
Over 65 & Frail					
Bean et al. (2002) [63]	45 community-dwelling mobility-limited people (age 72.7 ± 4.6)	Ascent 10 steps	—	—	0.63
Fahlman et al. (2007) [64]	109 community-dwelling elderly (age 75.6 ± 1.1) with some functional limitations	Ascent & descent 27 steps	Rx1 0.69, Rx2 0.69, Con 0.68	Rx1 0.68, Rx2 0.74, Con 0.73	—
Fahlman et al. (2007) [65]	74 older adults (age 75.6 ± 1.2) who reported & exhibited limited functional ability	Ascent & descent 21 steps	Rx 0.90, Con 0.85	Rx 0.85, Con 0.93	—
Herman et al. (2005) [66]	37 community-dwelling, older persons (age 75.6 ± 6.6) with chronic medical conditions	Ascent 10 steps	0.40	—	—
Hiroyuki et al. (2003) [59]	34 frail elderly subjects (age 81.0 ± 6.2)	Ascent/descent 5 steps	Con 1.52, Rx1 1.50, Rx2 1.66	Con 1.66, Rx1 1.42, Rx2 1.88	—
LeBrasseur et al. (2008) [37]	39 older men with mobility limitations (age 73.3 ± 0.8)	Ascent 12 steps	0.61	—	—

♂ = males, ♀ = females, BMI = body mass index, Con = control(s), Gp = group(s), Rx = treatment, Val = validity.

making normative data at present insufficient. Highlighting the insufficiencies is a recently published study by Wilkin et al. [22], which investigated stair ascent in young military personnel. The values are very quick (mean 2.82 ± 0.37 s for 12 stairs or 0.23 s/step) in comparison with the results of this review (0.49 s/step) and may reflect the young, active participant group. The data obtained in this review for the young group (18–49 yr), although appearing sufficient to possibly be close to a normative value, were influenced by four of the nine studies being from studies examining participants who were healthy but obese and a further two of the studies [25–26] using a stairway of 180 stairs. Hypotheses would be that the data from this review would be slower than expected for a young healthy population. However, further data collection in homogenous participant groups and with consistent methodology should produce data with smaller SDs to demonstrate more clearly the differences between groups and data for normative values.

In the studies considered, the length of the stairs used varied and appeared to be predominantly influenced by availability. The influence of stair length can be primarily seen in the 18–49 age group (**Table 1**), where the Teh and Aziz studies have used a significantly longer stairway (180 vs 13 steps) [25–26], with the result being an increase in the time per step for those studies. As well as influencing

Table 2.
Stair times (in seconds) for neurological conditions (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)	Ascent/Descent (s)
Alzahrani et al. (2009) [16]	42 participants poststroke (age 70 ± 10)	Ascent/descent 11 steps	—	—	1.23
Erel et al. (2011) [67]	28 hemiparetic patients (age 46.5 ± 12.0) 14 dynamic AFO, 14 Con	Ascent & descent 10 steps	AFO 1.36, Con 1.89	AFO 1.53, Con 1.80	—
Flansbjer et al. (2006) [68]	50 patients 6–46 mo poststroke (age 58.0 ± 6.4)	Ascent & descent 12 steps	0.86	0.91	—
Ouellette et al. (2004) [4]	42 patients poststroke (age 65.9 ± 2.3) 20 in resistance training, 21 Con	Ascent 10 steps	Rx 1.62, Con 1.93	—	—
Parisi et al. (2006) [44]	16 patients with ET including head, 14 with ET no head involvement (age 58.4 ± 12.4)	Ascent/descent 10 steps	Head 0.43, ET 0.39	Head 0.42, ET 0.36	—
Dibble et al. (2006) [69]	19 individuals with idiopathic Parkinson Disease; RCT of eccentric training (*n* = 10, age 64.0 ± 9.6), Con (*n* = 9, age 67.0 ± 10.2)	Ascent & descent 10 steps	0.51	0.51	—
Hayes et al. (2011) [70]	19 participants with multiple sclerosis (age 49 ± 11) 10 standard exercise or 9 negative eccentric program for 12/52	Ascent & descent 10 steps	Rx 0.92, Con 1.59	Rx 1.02, Con 1.32	—
Lindeman et al. (1998) [27]	33 patients with Dys (age 39 ± 10), 29 with CMT (age 37 ± 11)	Ascent/descent 10 steps; median time	Dys 1.29, CMT 1.1	Dys 1.23, CMT 1.09	—
Lindeman et al. (2009) [71]	12 adults with cerebral palsy: 6 in 8 wk resistance training program (median age 36), 6 Con (median age 43)	Ascent/descent 9 steps	—	—	Rx 3.22, Con 2.78
Cowley et al. (2010) [3]	35 individuals (age 27.1 ± 7.5) with Down syndrome	Ascent & descent 10 steps	0.44	0.53	—
Cowley et al. (2011) [35]	30 participants with Down syndrome (age 28 ± 8): 19 resistance training, 11 Con	Ascent & descent 10 steps	Rx 0.41, Con 0.45	Rx 0.49, Con 0.52	—

AFO = ankle foot orthosis, CMT = Charcot-Marie-Tooth, Con = control(s), Dys = myotonic dystrophy, ET = essential tremor, RCT = randomized controlled trial, Rx = treatment.

performance times, increased stair length can also influence the limiting factor of performance to the cardiovascular system over musculoskeletal limitations such as muscle strength and joint range.

Another methodological consideration that was taken note of in the first round of data extraction, and that could be important to performance times, was the use of handrails or assistive devices. However, by limiting study inclusion to those asking participants to do the stairs as quickly or fast as possible, the use of handrails became less variable, with all articles instructing participants not to use the handrails or to use them for balance only.

This review suggests that stair ascent time increases with age, with stair descent time increasing to a greater extent. However, analysis is incomplete because of the lack of data in the young healthy group for combined ascent and descent. Considering the three studies that looked at both stair ascent and descent individually in the 18–49 age group [14,26–27], stair descent in these studies was faster than ascent. Given the small number of studies, one could hypothesize that further data collection would confirm this trend and that stair descent would be faster than ascent in 18–49 yr olds. Stair descent may deteriorate to a greater extent with aging, possibly making this a more sensitive measure than stair ascent. Alternatively,

Table 3.
Stair times (in seconds) for medical conditions (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)
Gammage et al. (1991) [72]	12 patients with symptomatic heart block & atrial fibrillation (age 75.1 ± 6.2)	Ascent 52 steps	Gp1 0.58, Gp2 0.51	—
Cataneo et al. (2010) [73]	51 hospital patients referred for spirometry, (age 52 ± 16)	Ascent 6 flights of 12 steps	0.57	—
Pancieri et al. (2010) [74]	40 patients in pulmonary resection (age 48 ± 16)	Ascent 6 flights of 12 stairs	0.46	—
Kongsgaard et al. (2004) [75]	13 people with COPD: 6 in 12 wk resistance program (age 71.0 ± 1.3), 7 Con (age 73 ± 1.8)	Ascent 13 steps	Rx 0.36, Con 0.67	—
Rejeski et al. (2000) [76]	209 adults with COPD (age 67.2)	Ascent 21 steps	0.59	—
Galvao et al. (2006) [77]	10 men (age 70.3 ± 8.3) with prostate cancer in progressive resistance training for 20 wk	Ascent 13 steps	0.54	—
LaStayo et al. (2011) [78]	40 cancer survivors (age 74 ± 6) 20 eccentric program, 20 standard care for 12 wk	Descent 10 stairs	—	Rx 0.68, Con 0.58
Mercer et al. (2002) [79]	16 dialysis patients: 7 12 wk exercise program (age 63.0 ± 14.5), 9 Con (age 59.0 ± 12.3)	Ascent & descent 22 steps	Rx 0.85, Con 0.80	Rx 0.99, Con 0.90
Mercer et al. (1998) [80]	25 dialysis patients: 14 validation study, 18 reliability (age 60.3 ± 12.0)	Ascent & descent 22 steps	Val 0.80, Rel 0.72	Val 0.89, Rel 0.80
Storer et al. (2005) [5]	12 adults in maintenance hemodialysis & exercise training (age 44 ± 9)	Ascent 4 steps	0.56	—
Herman et al. (2005) [66]	37 older persons (age 75.6 ± 6.6) with chronic medical conditions	Ascent 10 steps	0.40	—

Con = control(s), COPD = chronic obstructive pulmonary disease, Gp = group, Rel = reliability, Rx = treatment, Val = validity.

combining stair ascent and descent in the methodology may be sufficient to provide a sensitive measure to differentiate between age groups and patient groups, with the present available data suggesting differences between patient groups and matched controls, e.g., those with neurological and musculoskeletal problems and healthy groups of a similar age.

This review has determined gaps but demonstrates trends similar to those reported by Bohannon [19] in the timed up-and-go test of increasing times with age but overlapping values between age bands. Bohannon used smaller age bands, because of the participant age range being smaller than this study; however, their conclusions were very similar, with a call for a more consistent methodology being required. The overlapping values between the age bands also meant that reference values for below-average performance were only determined as those times above the upper limit of the confidence band, possibly due to a lack of homogeneity in the groups; however, the bigger age ranges used in this study also demonstrated overlapping values between age bands.

Timed stair tests appear to have moderate validity as a functional measure, with correlations being present to other functional measures (e.g., timed up-and-go test [15,23], walking speed [14,28–29], sit to stand [14,30], alternate step [14]). Functional tests (e.g., timed up-and-go and sit to stand) all appear to be composite measures of strength and balance [31–33], and stair tests are no different, correlating to balance tests (functional reach test [15,23], timed one-legged stance [15], coordinated stability [14], near tandem balance [14]), and strength [9,28,34–35]. However, these correlations have been investigated most in participant groups, including the elderly and those with disabilities. These correlations need to be considered over the wider population because young and healthy participant data are more likely to be influenced by ceiling effects, which are commonly found in other functional measures. Correlations to both strength and balance and the differences between stair ascent and descent with aging also generate questions about the mechanism of the changes seen with age. Is eccentric strength altered detrimentally first over concentric strength? Or is it the combined challenge of the increased balance requirements with stair descent that slows the completion times?

For stairs to become a comparable measure between sites and projects, the manner in which the test is administered needs to be standardized. We found that testing just ascent or descent or combined ascent/descent did lead to differing results. One would expect those with greater balance issues, such as the elderly and patients with neurological problems, to be particularly slower if a combined ascent/ descent was used, which the data support for the neurological group. However, unequal group sizes in the

Table 4.
Stair times (in seconds) for musculoskeletal conditions (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)	Ascent/Descent (s)
Galea et al. (2008) [81]	23 patients (age 67.6 ± 8.8) with unilateral THR: 11 center-based, 12 home-based exercise program	Ascent 4 steps	Center 1.05, Home 0.93	—	—
Pua et al. (2010) [82]	67 adults with hip OA: 27 ♂, 40 ♀ (age 61 ± 10)	Ascent/ descent 6 steps	—	—	♂ 1.03, ♀ 1.2
Pua et al. (2009) [83]	100 adults with hip OA (age 62 ± 10)	Ascent/ descent 6 steps	—	—	1.15
Lin et al. (2001) [30]	106 subjects with knee or hip OA (age 69.4 ± 5.9)	Ascent/ descent 4 steps	1.04	1.02	—
Marsh et al. (2003) [84]	313 people with knee pain & difficulties in ADLs (age 71.8 ± 5)	Ascent/ descent 5 steps	—	—	1.80
Miller et al. (2006) [85]	87 obese adults with knee pain (age 69.5 ± 0.9): 31 weight loss program, 36 Con for 6 mo	Ascent/ descent 5 steps	—	—	Rx 1.84, Con 2.14
Miller et al. (2008) [86]	67 obese adults with knee pain (age 69.7 ± 1.0): 31 weight loss program, 36 Con for 6 mo	Ascent/ descent 5 steps	—	—	1.90
Christiansen & Stevens-Lapsley (2010) [48]	50 participants with knee OA (age 64.1 ± 8.4)	Ascent/ descent 12 steps	—	—	1.54
Durmus et al. (2007) [87]	50 women with knee OA (age 54.7 ± 2.0): 25 electrical stimulation & 25 biofeedback	Ascent/ descent 10 steps	—	—	Rx1 2.36, Rx2 2.37
Mizner et al. (2005) [88]	40 TKR patients (age 64 ± 9): presurgery, 1, 2, 3, & 6 mo postsurgery	Ascent/ descent 12 steps	—	—	1.67
Mizner et al. (2005) [89]	40 TKR patients (age 63 ± 8) pre- & 1 yr postsurgery	Ascent/ descent 12 steps	—	—	1.63
Ni et al. (2010) [90]	35 older Chinese women (age 63.2 ± 2.8) with knee OA; RCT with tai chi (18 Rx, 17 Con)	Ascent/ descent 5 steps	—	—	Rx 1.83, Con 1.87
Petterson et al. (2007) [45]	44 patients with knee OA (age 62.3 ± 6.8)	Ascent/ descent 12 steps	—	—	♂ 1.12, ♀ 1.78
Rejeski et al. (1995) [91]	440 adults with knee OA (age 68.8 ± 5.6): aerobic, strength, or education program	Ascent/ descent 5 or 9 steps	—	—	5 steps 2.04, 9 steps 1.95
Swank et al. (2011) [92]	71 participants scheduled for TKR (age 62.9 ± 7.5): 35 usual care, 36 usual care + exercise for 4–8 wk	Ascent & descent 11 steps	Rx1 1.07, Rx2 1.0, Con1 0.94, Con2 0.98	Rx1 1.18, Rx2 1.04, Con1 0.98, Con2 1.10	—
Talbot et al. (2003) [93]	34 older persons with knee OA (age 70.2 ± 5.7): 17 pedometer Gp, 17 education	Ascent/ descent 4 steps	—	—	Rx1 2.54, Con 1.80
Talbot et al. (2003) [94]	30 older persons with knee OA (age 70.5 ± 5.3): 18 electrical stimulation 12 wk program, 16 Con	Ascent/ descent 4 steps	—	—	Rx 2.04, Con 1.79
Topp et al. (2002) [95]	102 knee OA adults (age 63.3): 35 Con, 35 dynamic, 32 isometric exercise	Ascent & descent 23 steps	Con 0.82, Rx1 0.82, Rx2 0.78	Con 0.78, Rx 0.84, Rx2 0.73	—
Farquhar & Snyder-Mackler (2010) [51]	Post-TKA (age 66.4 ± 8.5): 183 at 1 yr, 124 at 2 yr, 52 at 3 yr	Ascent/ descent 12 steps	—	—	1 yr 1.04, 2 yr 1.05, 3 yr 1.05
Gur & Cakin (2003) [96]	18 women with bilateral knee OA (age 56+10 yr)	Ascent/ descent 12 steps	0.59	0.62	—
Jan et al. (2008) [97]	43 subjects with knee OA (age 63.3 ± 8.1): 20 exercise, 23 Con	Ascent/ descent 13 steps	—	—	Rx 2.63, Con 2.48
Kraemer et al. (2004) [98]	40 people with knee OA (age 63.7 ± 11.1): 20 topical CFA cream, 20 placebo	Ascent/ descent 11 steps	—	—	Rx 1.25, Con 1.15
Maly et al. (2005) [99]	54 patients with medial compartment OA (age 68.3 ± 8.7)	Ascent/ descent 5 steps	—	—	1.80

Table 4. (cont)
Stair times (in seconds) for musculoskeletal conditions (mean per step of baseline values for each group).

Publication	No. of Participants & Description	Method	Ascent (s)	Descent (s)	Ascent/Descent (s)
Maly et al. (2006) [100]	54 patients with medial compartment OA (age 68.3 ± 8.7)	Ascent/descent 5 steps	—	—	1.80
Almeida et al. (2010) [101]	43 participants 2–6 mo post unilateral TKR (age 67.7 ± 8.1)	Ascent/descent 11 steps & Ascent 11 steps	0.73	—	1.65
Mizner & Snyder-Mackler (2005) [102]	14 TKR patients (62 ± 7)	Ascent/descent 12 steps	—	—	0.95
Nyland et al. (2007) [103]	31 patients post-TKR (age 63.0 ± 6.4): graded (1, 2, or 3) by ability to rise from chair	Ascent & descent 10 steps	Gp1 1.96, Gp2 1.13, Gp3 0.83	Gp1 2.17, Gp2 1.24, Gp3 0.72	—
Petterson et al. (2009) [104]	200 adults post-TKR (age 65.3 ± 8.4): 100 exercise, 100 electrical stimulation + exercise 6 wk program	Ascent/descent 12 steps	—	—	Con 2.14, Rx 2.29
Valtonen et al. (2009) [105]	48 TKR patients (age 66.5 ± 5.9) 4–18 mo postsurgery: 19 ♂, 29 ♀	Ascent & descent time 10 steps	♂ 0.39, ♀ 0.59	♂ 0.41, ♀ 0.67	—
Valtonen et al. (2010) [106]	50 TKR patients (age 66.9 ± 6.1): 21 Con, 25 aquatic program	Ascent 10 steps	Con 0.47, Rx 0.50	—	—
Valtonen et al. (2011) [107]	37 participants post-TKR (age 66 ± 6), 21 in 12 wk aquatic program, 16 Con	Ascent 10 steps	Rx 0.50,| Con 0.49	—	—
Yoshida et al. (2008) [46]	12 adults post unilateral TKR (age 61.3 ± 6.9) 3 & 12 mo postsurgery	Ascent/descent 12 steps	—	—	3 mo 0.95, 2 mo 0.84
Zeni et al. (2010) [108]	80 knee arthritis sufferers (age 63.3 ± 8.3), 40 post-TKR (age 57.6 ± 9.8)	Ascent/descent time 12 steps	—	—	Arthritis 1.2, TKA 1.62
Zeni & Snyder-Mackler (2010) [109]	155 unilateral TKR patients (age 64.7 ± 8.7)	Ascent/descent time 12 steps	—	—	2.17
Eyigor et al. (2008) [42]	33 patients with chronic RA (age 55.79 ± 12.40)	Ascent/descent 10 steps	—	—	1.41
Mengshoel et al. (2004) [110]	31 rheumatoid & 26 AS patients (age RA 45 ± 7, AS 42 ± 9)	Time to ascend/descend 11 steps	—	—	RA 1.82, AS 1.45
Moseley et al. (2005) [111]	120 ankle fracture patients (age 46 ± 15): 4 wk stretching program Con, short duration & long duration stretching	Ascent/descent 4 steps 3 times	—	—	Con 3.28, Rx1 2.65, Rx2 3.39

♂ = males, ♀ = females, ADL = activities of daily living, AS = ankylosing spondylitis, Con = control(s), Gp = group, OA = 0steoarthritis, RA = rheumatoid arthritis, Rx = treatment, TKR = total knee replacement, THR = total hip replacement.

Table 5.
Summary of group data: (number of studies and number of participants contributing to result in parentheses), mean time (in seconds) ± standard deviation to complete stair (ascent, descent, or ascent and descent together).

Group	Ascent	Descent	Ascent/Descent
18–49 yr	(10, 2,089) 0.48 ± 0.14	(3, 183) 0.50 ± 0.14	No data
50–65 yr	(2, 54) 0.46+ ± 0.17	(2, 54) 0.54 ± 0.29	(4, 115) 0.90 ± 0.27
>65 yr	(10, 1,049) 0.65 ± 0.41	(2, 718) 1.4 ± 0.55	(9, 1,598) 1.38 ± 0.48
>65 yr with Decreased Mobility	(5, 254) 0.95 ± 0.44	(3, 217) 1.11 ± 0.47	(1, 45) 0.63
Neurological	(9, 315) 1.01 ± 0.57	(8, 273) 0.9 ± 0.47	(2, 54) 2.41 ± 1.05
Medical	(10, 425) 0.6 ± 0.15	(3, 81) 0.81 ± 0.15	No data
Musculoskeletal	(11, 572) 0.82 ± 0.33	(6, 376) 0.96 ± 0.41	(28, 2,489) 1.77 ± 0.60

elderly and elderly with mobility limitations and a lack of data in the young healthy group make it difficult to elaborate further. Until further data are obtained for stair descent and combined ascent/descent, methodologies for stair testing should include both stair ascent and descent. This methodology of testing provides the most challenging aspect of timed stair tests to be included, whether strength, balance, or joint range of motion is the major limiting factor. As a functional test with ceiling effects likely to be present for young healthy participants, instructions should include to do the test as fast as possible without the use of the handrail or aids.

More controllable and possibly important is the length of the stairway used for testing. The majority of studies use a stairway of 10 to 12 stairs for testing, which is likely to be the average flight length available in buildings and therefore a practical length for testing. The exception to this are those studies looking at medical conditions involving the heart and lungs, where longer stairways are used to elicit a more cardiovascular response. Combined stair ascent/descent is not considered in these studies because this would slow the participants down, decreasing the cardiovascular response. However, the influence of asking participants to complete the stairs as fast as possible may elicit a cardiovascular limitation in some populations and requires at least some consideration, if not investigation. Given the data to date, the inclusion of both stair ascent and descent is warranted and would include the greatest number of possible limitations.

Finally, as far as setting standardized testing procedures, the stair height should be considered. Building codes in Australia have a set range of acceptance for the steepness of stair flights, giving an element of consistency to the stair dimensions. However, the relative stair height to the participant is not compensated for in this manner. If the timed stair test is being used as a purely functional measure, it may be sufficient for the range of normal values, hopefully obtained more accurately and consistently in the future, to compensate for this. However, if strength or joint range is of interest, times are not as relevant and measures will need to be normalized for participant height. Therefore, timed stairs fall into the category of a more advanced functional measure and differentiating test over a wider age range in contrast to other commonly used functional tests, such as the timed up-and-go [14] and the 6 min walk test.

The major limitation of this review was our ability to extract all articles that use timed stair tests. Our search strategy was kept simple to obtain as many relevant articles as possible; however, many studies do not list all test methods in the abstract because they may be included to satisfy secondary objectives. In saying this, we still found it necessary to limit the data extraction further by adding the requirement of the stair methodology being as fast or quick as possible to enable articles to be compared with one another. This further information is not easily obtained through a search strategy and therefore complicates this type of review where a testing method is trying to be evaluated.

CONCLUSIONS

The recommendation from this review is that normative values for stair ascent and descent would be a useful clinical tool. There are still groups that have insufficient data from which to draw definite conclusions; however, the data obtained suggests that stair times change with age and can be used to differentiate between patient groups. We would recommend that further data are required for descent in the over 65 yr olds and the young healthy, as well as combined ascent/descent in the young healthy, over 65 with mobility limitations, and neurological group because of low participant numbers and increasing SDs. Further information on the number of stairs to elicit a cardiovascular response would also be useful to see whether the command to complete the stairs as fast as possible may be sufficient to differentiate between people on a smaller flight of stairs.

Standardization of stair protocols for musculoskeletal and neurological problems would involve a flight of at least 10 stairs and would include both stair ascent and descent. Participants would be asked to complete the stairs as quickly as possible with the handrail only to be used for balance and no aids used.

Key Points

- Findings: The findings of this review are that a standardized methodology should be used for timed stair tests, with stair descent included either singularly or in combination with stair ascent.
- Implications: Presently there are not enough data for normative values across age ranges or patient groups; however, with a consistent methodology being used, there is evidence that this is an achievable goal with valuable information being available for both research and clinical purposes.

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