Factors of importance for dynamic balance impairment and frequency of falls in individuals with Myotonic Dystrophy type 1 - a cross-sectional study - including reference values of timed Up & Go, 10m walk and step test.

Authors: Elisabet Hammarén[a,b,c], Gunilla Kjellby-Wendt[a,c], Jan Kowalski [d], Christopher Lindberg[b,c]

[a]Physiotherapy Department, Sahlgrenska University Hospital, Gothenburg, Sweden

[b]Neuromuscular Centre, Sahlgrenska University Hospital, Gothenburg, Sweden

[c]Sahlgrenska Academy at the University of Gothenburg, Institute of Neuroscience and Physiology, Dept of Clinical Neuroscience, Gothenburg, Sweden

[d]Karolinska Institutet, CLINTEC, Division of Pediatrics, Karolinska University Hospital, Huddinge, Stockholm, Sweden

Corresponding author:

Elisabet Hammarén, PT, MSc,

Physiotherapy Department, Sahlgrenska University Hospital, Vita stråket 13,

S-413 45 Gothenburg, SWEDEN

Phone: +46(31)3428898

Fax nr: +46(31)7765532

Email: elisabet.hammaren@vgregion.se (can be published)

Abstract

Patients with myotonic dystrophy type1 suffer from gait difficulties including stumbles and falls. To identify factors of importance for balance impairment and fall-risk a mapping of functional balance was performed, in a cross-sectional study of 51 adults. Walking, balance, falls and muscle force were self-assessed and measured. Reference values of balance were established through measurements of 220 healthy subjects. Falls were more frequently observed in the patients who were more severely affected of muscle weakness than in mildly affected patients, p=0.014. The number of falls showed negative correlation with balance confidence (r_s=-0.516, p<0.001). The ankle dorsiflexor force together with the time difference between comfortable and maximum speed in 10m-walk proved to be significant factors for fall frequency. A ten Newton muscle force decrease showed 15 % increase in odds ratio for frequent falls. One-second increase in time difference between comfortable and maximum walking speed showed 42 % increase in odds ratio for frequent falls. In conclusion, assessing the ankle muscle force and the time difference in different walking speeds is important to detect risk of falling. The Activities-specific Balance Confidence score reflects the consequences of the muscle force decrease. Certain patient strategies to diminish risk of falling could be due.

Keywords: Myotonic dystrophy; postural balance; muscle strength; gait; reference values; physiotherapy; self-reported falls.

Introduction

Neuromuscular disorders include disorders in which muscular weakness is the symptom of predominance [1]. The inherited neuromuscular disorder with the highest prevalence among adults is myotonic dystrophy type 1 (DM1) [1,2]. Several aspects of DM1 could lead to impairment of balance and walking. The most obvious is the muscle affection, characterised by muscle weakness and myotonia [3]. There are also cognitive deficits linked to the disorder [4].

Many factors have been shown to increase the fall risk in elderly people. These factors include: reduced muscle strength, impairments of systems contributing to postural balance (the visual, vestibular and sensory systems) and an increasing number of chronic disabilities such as heart failure, diabetes [5,6]. In a way the middle-aged DM1 population shows similarities with the elderly [7].

The normal human postural balance is a result of many cooperating systems [8]. The understanding of postural balance includes responses to different movements of the body in relation to the ground. Steady state stability refers to maintaining a taken position, and the pro-active, anticipatory stability will help the body, during a foreseen movement, to keep a stable position [8]. In the clinic, measures of the steady state and the anticipatory stability are made with so-called static and dynamic balance tests. In this paper we use these concepts. Dynamic balance is defined as a subject’s ability to manage dynamic balance tests. A reliability study of clinical balance tests in a DM1 patient group showed great test-retest reliability in the dynamic tests [9]. The analysis of disagreement showed high variability in the steady state tests, and a higher congruence in the dynamic balance tests. There is a lack of reference values for dynamic tests in younger adults, as the tests mainly have been used in geriatric patients.

A Welsh study has shown that the frequency of stumbles or falls in DM1-individuals is increased tenfold in relation to their activity level, compared to healthy controls [10]. The authors concluded that distal weakness combined with knee and hip weakness particularly might predispose to a loss of pillar support after a minor perturbation in stance. Twenty individuals with DM1, participating in a 6-week rehabilitation program, reported a mean frequency of falls of 1,5 fall per month (range 2 per week to 1 per year) [11]. The authors discuss the impact of cognitive limitations on this patient group, especially on the domains of gait and balance. Some patients did not acknowledge their balance impairments at start; some even denied it. The factors of increased fall risk in DM1 have not yet been fully explored. The weakness in leg muscles, the cognitive deficits and the fatigue could all contribute to the impaired balance resulting in frequent stumbles and falls.

The objectives of this study were the following in individuals with DM1:

- To map self reported gait ability, balance confidence, and falls, together with measures of walking and dynamic balance in relation to muscular impairment and a healthy reference group
- To map isometric muscle force in relation to gender and in relation to published reference values
- To identify factors of importance for dynamic balance impairment and risk of frequent falls

In addition,

- To establish reference values in healthy men and women, 20-59 years old for Timed 10 m walk, Step test and Timed Up&Go

Patients and Methods

Patients

All 72 eligible individuals between 20 and 60 years of age with genetically proven DM1 at the Neuromuscular Centre, Sahlgrenska University Hospital, were invited by letter, and/or by phone call to participate in the study, which was performed in 2006-2007. The ability to stand up from an armchair (45 cm high) and walk 2 times 3 meters with or without handheld gait aids was required as minimum mobility to enrol in the study. Exclusion criteria were: congenital form of DM1 (where intellectual disability is common) or other disorders that could interfere with the postural balance.

Reference group

A healthy reference group was recruited by announcement in different work places (hospital, university, chemical factory, school, geriatric care) for establishing reference values in the dynamic balance tests including timed gait. The intention was to recruit twenty subjects in each gender for each age-decade. The individuals had to assert an absence of balance problems.

Procedures

The self-assessments and physical examinations were performed at a single visit at the clinic. The patients filled in the questionnaires during the first part of the visit, in order not to be affected by their performance in the balance tests. All patients got the support they needed to answer the questions. One experienced physiotherapist examined each patient and demonstrated the positions in the balance tests. Resting pauses between the tests were allowed and encouraged. The timing was performed with an electronic stopwatch with an accuracy of 1/100 second. Three different examiners (one experienced physiotherapist and two physiotherapy students), made the measurements of the reference group. A subgroup of the reference group, consisting of the individuals assessed by one of the examiners (n=43), filled in a questionnaire concerning number of falls during last year and activity-specific balance confidence.

Ethical considerations

The study participants gave their written, informed consent to participate in the study and knew that they could refuse further participation without any impact on further treatment. The study was approved by the Regional Council of Ethical Vetting in Gothenburg, Sweden, dnr 248-06.

Characteristics

Demography and baseline characteristics were collected including age, gender, number of CTG-repeats, disease duration (years since first significant symptom mentioned in patient chart).

Muscular Impairment Rating Scale (MIRS) [12]

The individuals were at the visit classified (by the examiner) according to the MIRS. The MIRS is an ordinal five-point scale developed to assess the progression of muscular involvement in DM1: 1, no muscular impairment; 2, minimal signs; 3, distal weakness; 4, mild to moderate proximal weakness; 5, severe proximal weakness. The intra-observer reliability is excellent (weighted κ 0.84) and the construct validity is supported by a significant progressive increase in Functional Status Index and timed functional tasks corresponding to an increase in MIRS score [12].

The self-assessments

Activities-specific Balance Confidence (ABC) scale [13]

This self-report measure of balance confidence in different activities consists of 16 items with both in- and outdoors activity questions (score 0-100). The confidence is assessed with the question ‘How confident are you that you can **maintain your balance and remain steady** when you do (different activities)?’ The maximum score of each question is 100 (full confidence) and the mean of the 16 items is used as a sum score of balance confidence. The ABC scale has shown high stability over time ($r=0.92$, $p<0.001$), high internal consistency (Cronbach's alpha 0.96), good scalability (the coefficient of scalability, $H=0.59$, strong cumulative scale) and a good convergent and criterion validity [13]. A healthy elderly population with high mobility had mean score 80.9 in the original study, whereas the elderly with low mobility scored 68.4 [13]. A Swedish version of the scale showed good test-retest reliability, median weighted $\kappa = 0.80$ [14]. In this study we used the original version, after contact with Dr Myers (the original constructor), and made a forward and backward translation to the Swedish language. Our reference group scored in ABC scale median (1st ; 3rd quartile) 98 (95;99).

Semi-structured questions on falls

The individuals were asked questions regarding how many times they had unintentionally fallen during the last week, month and year, how it happened, and if the fall had resulted in any injury. They were also asked if they were afraid of falling (yes/no) or if they avoided activities because of fear of falling (yes/no). If the number of falls were too many to actually remember, an approximate estimation was done based on the recall of incidents during the last month, together with the patient.

The physical examinations

Timed 10-meter walk [15,16]

Walking at a comfortable (10-m COM) and maximum (10-m MAX) speed was measured in a long corridor with even surface with a still-standing start and a 'flying' finish [16]. The individuals were instructed to continue walking to a target 2.5 meters beyond the mark at 10 meters, where the examiner stood. To allow for future measurements with the same assessment conditions no shoes or ankle-foot orthoses were used, the patients could choose to go in socks or barefoot (all but one patient managed to walk without shoes and ankle-foot orthoses). The test has shown test-retest stability (ICC 0.91- 0.94) in patients with DM1 [9].

Two tests of dynamic balance were performed; The Timed Up&Go (TUG) and the Step test. Both have shown test-retest stability (ICC 0.83-0.94) in patients with DM1 [9]:

TUG [17]: The patient rose from a seated position in an armchair of normal height (44-45 cm), walked at a comfortable and safe pace to a tape mark on the floor 3 meters away, turned around the mark, went back to the chair, turned and sat down [9,17].

Step test – STEP [18], according to Hill et al: Standing in front of an 8 cm high platform (40x40 cm), not nearer than 5 cm, the patient should make as many full steps (not climb) as possible during 15 seconds, with one foot. The patient made, after exercise, one trial per leg [9,18]. If the patient lost his balance during the trial only the completed steps were counted.

Isometric muscle force

Muscle force was measured with a handheld dynamometer [19-22]. This is recommended rather than the manual muscle testing due to excellent reproducibility and high discriminative properties [22]. The isometric muscle force in our study was measured in Newton (N) with a handheld gauge meter (Mecmesin® Basic Force Gauge 1000N, Chauvin Arnaux Group). We used the ‘break’ method, where each force measurement is terminated with a small break in the end [19,20]. The assessed muscle groups were the hip flexors, knee extensors, knee flexors and the ankle dorsiflexors. The hip flexors and ankle dorsiflexors were assessed in supine according to Phillips [19]. The knee extensors were measured in the sitting position, with the knee in 90 degrees of flexion, the knee flexors was measured in the prone position, 90° knee flexion [20]. The results are expressed in Newton and as a percentage of age and gender matched reference values [19,21].

Statistics

Data regarding the DM1 mapping and the reference group were presented with mean and standard deviation (SD) and 95% confidence interval (CI 95 %), in continuous variables. In categorical variables with ordinal structure and in skewed distributed continuous data, the median and 1st and 3rd quartile (Q1;Q3) were presented. The mean of right and left side in Step test and muscle force measurements was used. Differences between groups (men vs. women, and patients vs. reference group) were analysed with Student’s t-test. For analysis of dichotomized outcome variables the χ^2 -test was used. Individual values in the DM1 patient group were paired with age and gender matched reference values for comparisons on group level. In all other variables/measurements of force where we could assume approximately Normal distribution we presented the mean and the corresponding standard deviation, SD, and applied it with the appropriate test, i.e. t-test. In positively skewed distributed data of force measurements (the ankle dorsiflexors), we log(e)-transformed, calculated the descriptive statistics (mean) and back-transformed the data, which was then used for the geometric mean. The log-transformation enabled the use of the parametric test, the t-test, as we could assume approximately normal distribution of the transformed data. In data where we could not assume data to be normal distributed, with or without transformation, we used the Mann-Whitney U test. Bi-variate correlation was estimated using the Spearman’s rank correlation coefficient to explore correlations between number of falls and: balance confidence, dynamic balance tests and muscle force, and also between dynamic balance tests and muscle force. The number of falls had a skewed distribution, also with a typical floor effect, i.e. a great number of patients with zero falls. Therefore the variable was divided into three ordered categories of ‘fall groups’, which were set to 0-2, 3-6 and ≥7 falls per year. Ordinal regression modelling, which is an expansion of the logistic regression modelling, was used to analyse the odds ratio for factors associated with the underlying ordered structure among categories. The dependent variable ‘risk of falls’, with three categories, was analysed for factors of importance. First, univariate analyses of each variable were performed. Second, significant variables were combined with each other in various multivariate models to find a model with the two most important factors. Third, all remaining independent variables (age, gender and disease duration) were finally, one at a time, included into the model to control for any possible remaining confounding factor. All statistical tests were two-sided and $p<0.05$ was regarded as statistically significant. Calculations were made in SPSS ®, Statistics, v. 20 (IBM, USA).

Results

Characteristics

Fifty-one patients, 31 female and 20 male, with mean (SD) age 41.3 (9.7) years and mean (SD) BMI 25 (5.4), gave their written consent to participate. The median (Q1;Q3) disease duration was 11 (7.5;20.5) years, and median (Q1;Q3) number of CTG-repeats was 460 (212;700). No significant differences between genders could be demonstrated in age, CTG-repeats, disease duration, falls or ABC sum score. Of the 51 patients, 32 individuals were classified as having MIRS ≥4, i.e. proximal weakness to a lower or higher degree, not only distal weakness.

We could not demonstrate any significant differences between the participants and the dropouts neither in age nor gender.

The reference group consisted of 220 individuals, 109 female and 111 male, mean (SD) age 37 (11.1) years and mean (SD) BMI 24 (3.6). The demographics of the reference group, and their results with regard to timed 10-m walk, TUG and Step test for men and women in decades, are presented in Table 1. The subjects consulted for the ABC scale reference material consisted of 43 individuals, mean (SD) age 44 (9.5) years.

Self-assessments of balance confidence and number of falls

The balance confidence score on ABC scale was significantly lower in the DM1 group compared to the reference group (72 and 98, respectively), Table 2. The number of self-reported falls in the last year ranged from 0-60, as estimated by the patients, median (Q1;Q3) 1 (0;4.5) fall. Nine patients (18%) reported need for medical care at least once after accidental falls during the last year. Nineteen patients (37%) had unintentionally fallen four times or more during the last year; 41% were afraid of falling and 45% avoided activities due to fear of falling. The patients with the more severe muscle weakness (MIRS ≥ 4) reported a significantly larger number of falls, more fear of falling, and more avoidance of activities than the MIRS ≤ 3 patients, Table 2. The reference group showed a minimal fear of falling and avoidance of activities, and had had very few falls, median (Q1;Q3) 0 (0;0) fall, Table 2.

Timed walk, dynamic balance and isometric muscle force

The results of all walking and dynamic balance tests were impaired in the DM1 group compared to the reference group (p<0.001) on a statistically significant level, Table 2. Patients with MIRS ≤ 3 walked faster and performed more steps than patients with MIRS ≥ 4, the differences were statistically significant, Table 2. The geometric mean of the ankle dorsiflexor force was 90 Newton (N), in patients with MIRS ≤ 3 and ≥ 4 it was 216 N and 54 N, respectively, $p<0.001$. The isometric muscle force was most impaired in the ankle dorsiflexors (52%) and the knee flexors (53%) compared to published reference values [19,20], Table 3. The knee extensors and the hip flexors were less impaired, 85 and 86% respectively.

Gender

There was a significantly larger proportion of men (17 of 20 (85%)) in MIRS ≥ 4 (weaker) compared to the women (15 of 31 (48%)) $p=0.008$. This was confirmed in the results of the proportion of expected muscle force for each muscle in men and women, Table 3. Despite this, the mean isometric muscle force was in the hip muscles ($p=0.0013$) and the knee muscles ($p=0.016$) higher in the men. Regarding the ankle dorsiflexors men were weaker in absolute values (geometric mean 59 N and 119 N, respectively, $p=0.033$) as well as in relation to expected muscle force, Table 3. The median number of steps in women were greater than in men (14 compared to 11 steps, $p=0.008$), while in all other walking and balance tests we could not demonstrate any difference between men and women.

Factors of importance for dynamic balance and fall risk

Spearman's rank correlation coefficient showed a negative correlation between number of falls and the patient reported balance confidence (ABC: r_s -0.516, $p<0.001$). The number of falls showed a negative correlation with Step test and ankle dorsiflexor force; and a moderate positive correlation with TUG and 10-m COM, Table 4. Each muscle group showed a correlation with the different dynamic tasks, as factors of importance for balance impairment, Table 5. In the results of the univariate ordinal regression analysis of number of fall, the 'ABC scale' and the 'ankle dorsiflexor force (DEX)' showed a significant association with ordered categories of frequency of falls, Table 6. Results showed an odds ratio of 0.96 in the ABC scale, which infers an augmented risk of falling with about 49%, at a decrease of ten units. From the results of the multivariate ordinal regression analysis, the difference between comfortable and maximum paced gait (DiffCOM-MAX), together with the ankle dorsiflexor force showed statistical significance to frequency of falls. Based on these data the following calculations were done. A 15% fall risk increase could be detected, at a force decrease of 10 Newton in the ankle dorsiflexors. An increase in time-difference of one second between comfortable compared to maximum walking speed, measured over a distance of 10 meters, increases the fall risk with 42%. We could not detect any other factor that significantly contributed to the frequency of falls.

Discussion

The most important finding in this study is that the measures of time to walk 10 meters in comfortable and maximum speed and isometric muscle force in ankle dorsiflexors may predict fall frequency in patients with DM1. There is a strong correlation between (reduced) isometric muscle force and the dynamic balance and walking tests used in this study. This is important as fall injuries, put aside extensive medical costs, may cause persistent disability or death events. Former walking, autonomous individuals may become wheelchair bound and dependent.

A decrease in balance confidence measured with the ABC scale was shown for patients with proximal weakness (MIRS ≥4), sum score median (Q1;Q3) 62 (38;77). The results are comparable with the mobility-impaired elderly persons (ABC sum score mean 68.4) in the original paper by Dr Myers [13]. We conclude that the DM1 patients with MIRS ≥4 are more likely to fall, and have less balance confidence, than the patients with MIRS ≤3. This implies consequences for the daily living and activities, since the patients avoid activities due to fear of falling. That in turn may lead to a sedentary life with several known negative side effects. In an elderly population fear of falling was found to be an independent predictor of decline in physical function [23]. It is important to identify the patients at risk for falls and/or activity limitations, and give those appropriate help and information to continue to participate in activities without taking an undue risk of falling. This study shows that dynamic balance impairment is common in patients with myotonic dystrophy type 1, and that the impairment progresses with the degree of muscular impairment.

Timed walk

Measuring ‘time to walk a distance’ is a recommended tool to evaluate walking ability (15). There are many studies reporting reference or normative values of gait speed in comfortable (and maximum) speed in older people. Some studies include adults between 20-60 years [24-30]. Two of these have reported reference values only for women [27,28]. Many studies measured speed over a short distance (5.5 to 7.2 meters) where the acceleration (and deceleration) phase takes place outside the time taking [24-26,28,30]. A descriptive meta-analysis over normal gait speed, with reference values for men and women, 20-99 years, in cm/second has recently been published [31]. Measuring the middle section of the walked distance will show a ‘steady state’ gait speed, with the reaction time excluded. After a systematic review published in 2008, Graham recommended a static start with comfortable pace as the standard measurement and fast pace for specific research questions [32]. Nevertheless, until now there have been no larger study on walking 10 meters with own preferred pace or with maximum speed in adults > 21 years old, with a still standing start included. Our belief is that it is important to include the, in many cases, slow start in the assessment of gait, as the starting phase could be of great importance e.g. in daily traffic situations as crossing a street. Watson had a purposeful reference group consisting of 14 male and 14 female individuals 19-21 years old, comfortable speed 10 meters, mean (CI95%) 6.7 seconds (5.6;7.9) [16]. Our reference group consisting of 220 individuals between 20-59 years showed mean (CI95%) 6.6 seconds (6.5;6.7). Both these studies were made with a still standing start incorporating the acceleration phase and a ‘flying’ finish. In Sweden a pedestrian walking speed of 1.4 meter/second is a recommendation when constructing signalised intersections [33]. In that speed it would take 7.14 seconds to walk 10 meters. Our study indicates that the DM1 population as a whole walks slower both in comfortable and maximum speed. Only the patients with MIRS ≤3, walking in maximum speed, would be able to perform the crossing of the street in due time.

Isometric muscle force and dynamic balance tests

The foot dorsiflexors was the most affected muscle group of the DM1 individuals. Surprisingly we found that men were more affected than women and the reason why is still to be investigated. These weak ankle dorsiflexors of the men could contribute strongly to the difficulties in performing the step test, which the women managed to do in a more sufficient way. Unfortunately it is problematic to objectively measure the plantar flexors of the foot. Mostly it is evaluated with counted heel raises, which is impossible in this patient group, as they nearly always are too weak to perform a single heel raise. In DM1, the experiences from the clinic are that the weakness of the dorsiflexors often, but not always, goes hand in hand with a decreasing plantar flexor force. The plantar flexors contribute to the speed in the active propulsion phase of stance while the dorsiflexors lift the toes off from the ground in the swing phase. If both muscle groups are very weak you walk slowly and cannot change speed, and we speculate that this may reduce the risk of falling. If only the dorsiflexors are weak you could be more vulnerable for stumbles, when you accelerate without being able to lift your toes sufficiently off the ground.

Dynamic balance tasks showed correlations with both a pronounced weakness of the ankle dorsiflexors and with weakness in all other leg muscles. The proximal weakness comes together with a further weakening of the distal muscles, when DM1 aggravates. The ankle dorsiflexor force, only, was shown to correlate with the number of falls.

Reported number of falls

Falls occurred more frequently than we had expected. The patients did not spontaneously report upon their falls until we started to ask them in the study. We don't know if they were trying to 'hide' this, or if they were not aware of the problem and the risks attached to falling. It is possible that there is a shame connected to falls, e.g. people not knowing the individual could make assumptions of intake of alcohol. The 'under reporting' (here: of falls) is also an issue found in other problems caused by the disorder. The cognitive impairments associated with DM1, especially attention difficulties and fatigue, could contribute to the number of falls. This important issue is yet to be examined.

Study limitations

The reporting of falls was retrospective and may be both under-/ and overestimated. The mild cognitive impairments could also influence the reliability of these data. A more reliable way of measuring falls could be accelerometer based movement analysis, but this might be perceived as a violation of the personal integrity. Three different examiners collected the reference data, a fact that may make results less reliable although the examiners had several training sessions to minimize this problem.

Implications

In this study we have mapped balance confidence and falls, together with dynamic balance, 10 meter walk and muscle strength in a DM1 cohort. We could show that DM1 patients who fall frequently have a reduced activities-specific balance confidence. Thus, asking about falls and filling in the ABC scale could be a way to detect an elevated fall risk. This is an important issue, as fall-induced injuries may cause severe impairment and persistent loss of independence. Measurements of timed walk in different speeds and isometric force in the leg muscles would be more objective ways to approach this fall risk. Frequent falls (and fear of falling) can, except for trauma, lead to activity avoidance. Avoidance of activities could bring side effects as a sedentary life-style, de-conditioning and depression that have to be addressed [23]. Certain interventions or occasionally more frequent follow-ups are conceivable implications. A team-based approach with multifactorial address, including exercises and peer-learning of different strategies in dynamic balance challenges could maybe reduce fall risk when the distal muscles are weak and so could an appropriate ankle-foot orthotic device. A systematic review of interventions to prevent falls among older adults showed strong evidence that several types of falls interventions, i.e. multifactorial assessment and management, exercise/physical therapy interventions, and vitamin D supplementation, reduce falls among those with high fall risk [34]. Additional studies of exercise and rehabilitation programmes in DM1 are requested to further analyze these aspects.

We have shown that by means of simple walking tests and muscle force measurements it is possible to distinguish the individuals who are most likely to fall and who it would be most urgent to help momentarily with advices, orthotic devices, handheld gait support or even a wheelchair.

Acknowledgements

We want to express a particular thanks to the individuals with DM1 who participated in the study.

This work was supported by grants from the Trust fund of Norrbacka-Eugenia, Promobilia, the Council of Research and Development in Göteborg and southern Bohuslän, Muskelfonden and the Greta & Einar Asker foundation, Sweden. The funding sources have had no influence over the design, conduction or the report of the study.

References

[1] Ahlström G, Gunnarsson LG, Leissner P, Sjödén PO. Epidemiology of neuromuscular diseases, including the postpolio sequelae, in a Swedish county. Neuroepidemiology 1993;12:262-269.

[2] Lopez de Munain A, Cobo AM, Saenz A, et al. Frequency of intergenerational contractions of the CTG repeats in myotonic dystrophy. Genet Epidemiol 1996;13:483-487.

[3] Harper P. Myotonic dystrophy - the clinical picture, 3rd ed. London: Saunders, 2001.

[4] Winblad S, Lindberg C, Hansen S. Cognitive deficits and CTG repeat expansion size in classical myotonic dystrophy type 1 (DM1). Behav Brain Funct 2006;2:16.

[5] Kellogg International Working Group. The prevention of falls in later life. Danish medical bulletin 1987; 34(4):1-24.

[6] Todd C, Skelton D. (2004) What are the main risk factors for falls among older people and what are the most effective interventions to prevent these falls? Copenhagen, WHO Regional Office for Europe (Health Evidence Network report; http://www.euro.who.int/document/E82552.pdf, accessed 3 May 2012.

[7] de Die-Smulders CEM, Höweler CJ, Thijs C, et al. Age and causes of death in adult-onset myotonic dystrophy. Brain 1998;121:1557-1563.

[8] Shumway-Cook A, Woollacott MH. Postural Control. In: Shumway-Cook A, Woollacott MH, eds. Motor Control. Translating research into clinical practice. 3rd ed. Philadelphia, USA: Lippincott Williams&Wilkins, 2007: 212-256.

[9] Hammarén E, Ohlsson JA, Lindberg C, Kjellby-Wendt G. Reliability of static and dynamic balance tests in subjects with Myotonic Dystrophy type 1. Adv Physiother 2012;14(2):48-54.

[10] Wiles CM, Busse ME, Sampson CM, Rogers MT, Fenton-May J, van Deursen R. Falls and stumbles in myotonic dystrophy. J Neurol Neurosurg Psychiatry 2006;77:393-396.

[11] Missaoui B, Rakotovao E, Bendaya S, et al. Posture and gait abilities in patients with myotonic dystrophy (Steinert disease). Evaluation on the short-term of a rehabilitation program. Annals of Physical and Rehabilitation Medicine 2010;53:387-398.

[12] Mathieu J, Boivin H, Meunier D, Gaudreault M, Begin P. Assessment of a disease-specific muscular impairment rating scale in myotonic dystrophy. Neurology 2001;56:336-340.

[13] Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. J Gerontol A Biol Sci Med Sci 1995;50A(1):M28-34.

[14] Jarlsäter S, Mattsson E. Test of reliability of the Dizziness Handicap inventory and the Activities-specific Balance Confidence scale for use in Sweden. Adv Physiother 2003;5:137-144.

[15] Wade DT, Wood VA, Heller A, Maggs J, Langton Hewer R. Walking after stroke. Measurement and recovery over the first 3 months. Scand J Rehabil Med 1987;19:25-30.

[16] Watson M. Refining the ten-metre walking test for use with neurologically impaired people. Physiotherapy 2002;88(7):386-397.

[17] Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142-148.

[18] Hill KD, Bernhardt J, McGann AM, Maltese D, Berkovits D. A new test of dynamic standing balance for stroke patients: reliability, validity and comparison with healthy elderly. Physiotherapy Canada 1996:257-262.

[19] Phillips BA, Lo SK, Mastaglia FL. Muscle force measured using "break" testing with a hand-held myometer in normal subjects aged 20 to 69 years. Arch Phys Med Rehabil 2000;81:653-661.

[20] Bäckman E, Odenrick P, Henriksson KG, Ledin T. Isometric muscle force and anthropometric values in normal children aged between 3.5 and 15 years. Scand J Rehabil Med 1989;21:105-114.

[21] Bäckman E, Johansson V, Häger B, Sjöblom P, Henriksson KG. Isometric muscle strength and muscular endurance in normal persons aged between 17 and 70 years. Scand J Rehabil Med 1995;27:109-117.

[22] Hébert LJ, Remec J-F, Saulnier J, Vial, C, Puymirat J. The use of muscle strength assessed with handheld dynamometer as a non-invasive biological marker in myotonic dystrophy type 1 patients: a multicenter study. BMC Musculoskeletal Disorders 2010;11:72.

[23] Deshpande N, Metter EJ, Lauretani F, Bandinelli S, Guralnik J, Ferrucci L. Activity restriction induced by fear of falling and objective and subjective measures of physical function: A prospective cohort study. J Am Geriatr Soc 2008;56(4):615-620.

[24] Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing 1997;26:15-19.

[25] Ble A, Volpato S, Zuliana G, et al. Executive function correlates with walking speed in older persons: the InCHIANTI study. J Am Geriatr Soc 2005;53:410-415.

[26] Bohannon RW. Population representative gait speed and its determinants. J Geriatr Phys Ther 2008;31:49-52.

[27] Busse ME, Wiles CM, van Deursen RWM. Community walking activity in neurological disorders with leg weakness. J Neurol Neurosurg Psychiatry

2006;77:359-362.

[28] Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait patterns and falls in community-dwelling women. Age Ageing 1996;25:292-299.

[29] Öberg T, Karsznia A, Öberg K. Basic gait parameters: reference data for normal subjects, 10-79 years of age. J Rehabil Res Dev 1993;30:210-223.

[30] Willén C, Sunnerhagen KS, Ekman C, Grimby G. How is walking speed related to muscle strength? A study of healthy persons and persons with late effects of polio. Arch Phys Med Rehabil 2004;85:1923-1928.

[31] Bohannon RW, Andrews AW. Systematic review. Normal walking speed: a descriptive meta-analysis. Physiotherapy 2011;97:182-189.

[32] Graham JE, Ostir GV, Fisher SR, Ottenbacher KJ. Assessing walking speed in clinical research: a systematic review. J Eval Clin Pract 2008;14(4):552-562.

[33] Lundgren-Lindquist B, Aniansson A, Rundgren Å. Functional studies in 79-years olds: walking performance and climbing capacity. Scand J Rehab Med 1983;15:125-131.

[34] Michael YL, Lin JS, Whitlock EP et al. Interventions to Prevent Falls in Older Adults: An Updated Systematic Review. Evidence Synthesis No. 80. AHRQ Publication No. 11-05150-EF-1. Rockville, MD: Agency for Healthcare Research and Quality; December 2010.

Table 1. Reference values of gait and balance tests in healthy men and women, 20-59 years, in decades, with demographics. N=220. Mean (standard deviation), in seconds (10-m COM/MAX and TUG); or number of steps (STEP, mean right/left).

Age	*Gender (n)*	*Height, cm*	*Weight, kg*	*BMI*	*10-m COM*	*10-m MAX*	*TUG*	*STEP*
20-29	Men (34)	179.6 (5.0)	78.8 (9.8)	24 (2.8)	6.7 (0.8)	4.4 (0.5)	7.4 (1.0)	22 (3.2)
	Women (36)	167.1 (7.4)	61.1 (11.2)	22 (3.6)	6.9 (0.7)	4.7 (0.5)	7.5 (1.2)	23 (2.9)
30-39	Men (33)	180.2 (7.1)	82.2 (9.3)	25 (2.8)	6.6 (0.8)	4.6 (0.5)	7.4 (1.0)	22 (2.7)
	Women (21)	167.0 (5.4)	64.8 (8.1)	23 (3.1)	6.9 (0.8)	4.9 (0.6)	7.8 (1.3)	21 (3.1)
40-49	Men (26)	182.2 (6.1)	86.1 (11.7)	26 (2.6)	6.5 (0.7)	4.8 (0.6)	7.8 (1.0)	21 (2.6)
	Women (29)	166.4 (7.1)	65.3 (10.8)	23 (5.2)	6.4 (0.6)	4.9 (0.6)	7.2 (0.7)	20 (3.0)
50-59	Men (18)	181.2 (6.0)	93.1 (14.7)	28 (4.2)	6.6 (0.8)	4.8 (0.6)	8.4 (1.0)	18 (2.4)
	Women (23)	165.7 (6.8)	66.5 (11.1)	24 (3.6)	6.5 (0.8)	5.1 (0.7)	7.3 (1.2)	20 (3.2)

Abbreviations: BMI, Body Mass Index; 10-m COM/MAX, Timed 10 meter walk in comfortable/maximum speed; TUG, Timed Up & Go; STEP, step test.

Table 2**.** Balance and falls.
Results of DM1 cohort and reference group, with respect to age and gender (n=220 healthy volunteers). All presented variables showed significant difference between these groups, p<0.001. The DM1 patients were divided into two groups by muscular impairment rating scale (MIRS), '1-3' and '4-5'. Values are presented using mean (CI 95%) if nothing else is written.

	Reference group	***DM 1 Total***	***MIRS 1-3 n=19***	***MIRS 4-5 n=32***	***P value between MIRS groups***
ABC scale, sum score, median (Q1;Q3)	98 (95;99) [a]	72 (48;92)	91 (83;96)	62 (38;77)	<0.001
Number of falls last year [b], median (Q1;Q3), χ^2	0 (0;0)	1 (0;4.5)	0 (0;1.5)	3 (0;6)	0.014
Fear of falling, n (%), χ^2	1 (2%)[a]	21 (41%)	3 (16%)	18 (56%)	0.004
Activity avoiding, due to fear of falling, n (%), χ^2	1 (2%) [a]	23 (45%)	3 (18%)	20 (59%)	0.001
10-m COM (s)	6.6 (0.2)	10.5 (1.4)	8.1 (2.1)	12 (5.7)	0.001
10-m MAX (s)	4.8 (0.2)	8.3 (1.5)	6.1 (1.3)	9.7 (6.3)	<0.001
TUG (s)	7.6 (0.3)	10.4 (1.2)	8.6 (2.1)	11.4 (5.0)	0.007
STEP (steps)	21 (1.2)	13 (1.6)	17.1 (3.9)	10.5 (5.1)	<0.001
Ankle dorsiflexors, median (Q1;Q3)	n a	110 (58;192)	200 (184;225)	61.6 (43;96)	<0.001

Abbreviations: DM1, myotonic dystrophy type 1; p, probability; ABC, Activities-specific Balance Confidence; Q, quartile; s, seconds; 10-m COM/MAX, Timed 10 meter walk in comfortable/maximum speed; TUG, Timed Up & Go; STEP, step test; n a, not available.

[a] The reference subgroup, n=43

[b] The falls were dichotomized in '0-2' and '≥ 3' falls/ last year.

Table 3. Isometric muscle force
Results of DM1 individuals, by gender, and in relation to expected force. Isometric muscle force in Newton, mean (SD), and proportion of expected value in %, (with respect to age and gender).The mean force of the right and left leg muscles was used.

	Total ***Mean (SD)***	***Men*** ***Mean (SD)***	***Women*** ***Mean (SD)***	***P value***
Hip flexors	169 (40) 85%	191 (44) 78%	155 (31) 89%	0.001
Knee extensors	277 (97) 86%	317 (126) 77%	252 (61) 92%	0.016
Knee flexors	100 (34) 53%	104 (44) 46%	97 (26) 58%	0.474
Ankle dorsiflexors, median (Q1;Q3)[a]	110 (58;192) 52%	72 (44;125) 27%	174 (74;201) 76%	0.033

Abbreviations: SD, standard deviation; p, probability; Q, quartile.

[a] The scores of ankle dorsiflexors were skewed: median and quartiles (Q1, Q3) are presented, and Mann-Whitney U test for significance was used.

Table 4. Correlation between balance, gait or muscle force, and number of falls
Spearman's rank correlation: correlation coefficient and P value for the number of falls in relation to balance confidence on ABC, Timed 10 meter walk, dynamic balance tests and muscle force.

Variable	*Number of falls R (Spearman)*	*P value*
ABC scale	-0.516	<0.001
10-m COM	0.345	0.013
10-m MAX	0.304	0.03
TUG	0.389	0.005
STEP	-0.358	0.010
Hip flexors	-0.066	0.643
Knee extensors	-0.071	0.619
Knee flexors	-0.197	0.171
Ankle dorsiflexors	-0.375	0.007

Abbreviations: ABC, Activities-specific Balance Confidence; 10-m COM/MAX, Timed 10 meter walk in comfortable/maximum speed; TUG, Timed Up & Go; STEP, step test.

Table 5. Correlation between isometric muscle force and dynamic balance
Isometric muscle force (N) in relation to timed 10 meter walk and dynamic balance tests. Spearman's rank order correlation coefficient and P value. Total muscle force is the sum of the four muscle groups.

	10-m COM		***10-m MAX***		***TUG***		***STEP***	
	rho	***P value***	***rho***	***P value***	***rho***	***P value***	***rho***	***P value***
Hip flexors	-0.616	<0.001	-0.545	<0.001	-0.509	<0.001	0.392	0.004
Knee extensors	-0.500	<0.001	-0.426	0.002	-0.396	0.004	0.399	0.004
Knee flexors	-0.635	<0.001	-0.565	<0.001	-0.611	<0.001	0.547	<0.001
Ankle dorsiflexors	-0.568	<0.001	-0.646	<0.001	-0.456	0.001	0.564	<0.001
Total muscle force	-0.705	<0.001	-0.665	<0.001	-0.585	<0.001	0.610	<0.001

Abbreviations: Rho, Spearman's rho; p, probability; 10-mCOM, Timed 10 meter walk in comfortable speed; 10-mMAX, Timed 10 meter walk in maximum speed; TUG, Timed Up & Go; STEP, step test.

Table 6. Results of ordinal regression presented by odds ratio (OR) for frequent falls. Estimates and its corresponding 95% confidence interval together with odds ratio (and modified odds ratio) from analyses using ordinal regression with the ordered categories of frequency of falls (grouped in 0-2, 3-6 or ≥7 falls) as the dependent variable.

Results for the univariate model		***Confidence interval 95%***			
	Estimate	*Lower bound*	*Upper bound*	***P value***	***OR (modified OR)***
Isometric muscle force:					
-Hip flexors	-0.003	-0.017	0.011	0.647	0.997
-Knee extensors	-0.002	-0.008	0.003	0.422	0.998
-Knee flexors	-0.014	-0.031	0.003	0.116	0.986
-Ankle dorsiflexors	-0.010	-0.019	-0.002	0.013	0.990 (0.90[a])
ABC scale	-0.040	-0.065	-0.016	0.001	0.961 (0.67[a])
10-m MAX	0.021	-0.078	0.120	0.678	1.021
Diff COM-MAX	0.347	-0.118	0.811	0.143	1.415
TUG	0.042	-0.079	0.163	0.496	1.043
STEP	-0.099	-0.205	0.006	0.066	0.906
Age	0.019	-0.039	0.077	0.525	1.019
Disease duration	0.049	-0.011	0.109	0.112	1.050
Gender	-0.350	-1.475	0.775	0.542	0.705
Results for the multivariate model					
Ankle dorsiflexor force	-0.014	-0.024	-0.004	0.006	0.986 (0.87[a]) [b]
Diff COM-MAX	0.539	0.043	1.036	0.033	1.714[b]

[a] Ten Newton and ten units on ABC scale are esteemed to be the minimum clinical important difference; the modified odds ratio therefore is calculated from 10 times the estimate.

[b] Explanation: If the ankle dorsiflexor force decreases 10 Newton the OR for fall risk increases 15%. An increased time-difference of one second between comfortable and maximum walking speed over 10 meter increases the fall risk with 42%.

Abbreviations: CI95%, confidence interval; LB, lower bound; UB, upper bound; P, probability; OR, Odds ratio; ABC, Activities-specific Balance Confidence; 10-m MAX, Timed 10 meter walk in maximum speed; Diff COM-MAX, the time difference over 10 meter between comfortable and maximum speed; TUG, Timed Up & Go; STEP, step test.