



# Cross-cultural adaptation and psychometric properties of the Turkish version of the Manual Ability Measure-36 (MAM-36) in people with multiple sclerosis

Ozge Ertekin<sup>1</sup> · Turhan Kahraman<sup>2</sup> · Mona Aras<sup>3</sup> · Cavid Baba<sup>4</sup> · Serkan Ozakbas<sup>5</sup>

Received: 14 April 2020 / Accepted: 20 November 2020  
© Fondazione Società Italiana di Neurologia 2020

## Abstract

**Objective** The Manual Ability Measure-36 (MAM-36) has been used to assess subjective upper limb function in people with several neurological and non-neurological diseases. Besides, the MAM-36 is one of the most commonly used patient-reported outcome measures (PROMs) in people with multiple sclerosis (pwMS). The aim was to translate and conduct cross-cultural adaptation of the MAM-36 into Turkish and investigate its psychometric properties in pwMS.

**Methods** The MAM-36 was translated and culturally adapted into Turkish. Two hundred pwMS were recruited for the psychometric study. Hand skills, handgrip strength, upper limb spasticity, disability level, and quality of life were evaluated by the validated performance-based tests and questionnaires including the Arm Function in Multiple Sclerosis Questionnaire (AMSQ) which is a validated MS-specific PROM to assess upper limb function.

**Results** MAM-36 was significantly correlated with the performance-based tests and questionnaires, EDSS, age, and disease duration ( $p < 0.05$ ). MAM-36 and AMSQ were strongly correlated ( $r_s = -0.90, p < 0.01$ ). PwMS with spasticity had significantly lower MAM-36 scores compared to those without spasticity ( $p < 0.01$ ). Internal consistency (Cronbach's alpha = 0.97) and test-retest reliability (ICC = 0.97) was high.

**Conclusion** The Turkish version of MAM-36 has been found as a valid and reliable method for measuring upper limb function in pwMS.

**Keywords** Multiple sclerosis · MAM-36 · Upper limb function · AMSQ · Turkish

## Introduction

Multiple sclerosis (MS) is a chronic disease having highly variable and often unpredictable clinical presentations ranging from mild, infrequent relapses causing mild functional

impairments to rapidly accumulating severe disability, including loss of independent walking or severe cognitive impairment [1]. Walking impairment is one of the most visible and important symptoms among people with MS and may be present even in the early stages of the disease [2]. The Expanded Disability Status Scale (EDSS) is the most widely accepted clinical disability scale used for many years in MS, and it is mainly based on the maximum walking distance and does not assess upper limb function [3, 4]. Due to the importance of walking impairment in MS, the upper limb dysfunction has been under-recognized for many years. However, there is accumulating evidence that upper limb dysfunction is quite common symptom in MS and affects the activities of daily living and health-related quality of life adversely, even in the early stages of the disease [5–9].

Increasing awareness in the upper limb dysfunction in MS has led to design upper limb assessment methods. The Multiple Sclerosis Functional Composite (MSFC) was developed to overcome the shortcomings of the EDSS, which does

✉ Ozge Ertekin  
ozge.ertekin@deu.edu.tr

<sup>1</sup> School of Physical Therapy and Rehabilitation, Dokuz Eylül University, Izmir, Turkey

<sup>2</sup> Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Izmir Katip Celebi University, Izmir, Turkey

<sup>3</sup> Graduate School of Health Sciences, Dokuz Eylül University, Izmir, Turkey

<sup>4</sup> Multiple Sclerosis Research Association, Izmir, Turkey

<sup>5</sup> Department of Neurology, Faculty of Medicine, Dokuz Eylül University, Izmir, Turkey

not assess upper limb and cognitive functions [10]. The MSFC includes assessments related to walking, cognition, and upper limb function. In the MSFC, the upper limb function is assessed using the Nine-Hole Peg Test (9HPT), which assesses manual dexterity. After the introduction of the MSFC, the 9HPT has been the most commonly used and recommended as a gold standard outcome measure to assess upper limb dysfunction in clinical practice and trials in MS [9, 11]. However, the 9HPT only assesses fine manual dexterity and cannot assess other important upper limb functions in everyday life, such as manipulation of larger objects, proximal upper limb movements, or complex coordinated bimanual tasks [9, 11]. In addition, the 9HPT is a capacity measure and cannot assess performance. To gain a broader perspective about the upper limb dysfunction in activity level, both capacity and performance should be assessed.

In the last years, the development and validation of a patient-reported outcome measures (PROM) became mandatory to assess the upper limb function performance in research and clinical practice settings in people with MS [12]. The Disability of Arm, Shoulder and Hand (DASH), the Manual Ability Measure-36 (MAM-36), and ABILHAND questionnaires are the most used PROMs to assess upper limb dysfunction in MS [9, 11, 13]. The MAM-36 stands out among the other PROMs with its good psychometric properties in MS [9, 11, 13]. The MAM-36 is not a disease-specific PROM. Therefore, it has been used in people with different diseases including Charcot-Marie-Tooth [14], rheumatoid arthritis [15], orthopedic disease [16, 17], acquired brain injuries [16], spinal cord injuries [16], and multiple sclerosis [16, 18, 19]. In 2015, a new disease-specific PROM named “Arm function in Multiple Sclerosis Questionnaire (AMSQ)” to assess upper limb function in people with MS was introduced [20]. The AMSQ has shown good psychometric properties and stated to be used in the MS field [21–24]. Although using an MS-specific PROM seems appealing, it limits comparison with historical data in MS and other pathologies [25]. Therefore, it is still important to validate the MAM-36 into different languages [19]. The aim of this study was to translate and culturally adapt the MAM-36 into Turkish and investigate its psychometric properties in people with MS.

## Methods

### Ethical consideration

The Noninvasive Research Ethics Board of Dokuz Eylül University approved the study protocol with the date of 22.5.2019 and approval number of 2019/13-13, which was administered to the provisions of the Declaration of Helsinki

(as revised in Brazil 2013). Each participant signed an informed consent before participating to the study.

### Translation and cross-cultural adaptation

Translation and cross-cultural adaptation process was conducted according to the published guidelines [26]. The permission for the Turkish validation study of MAM-36 was obtained by Dr. Christine C. Chen, who was the developer of MAM-36 [18].

Two bilingual translators whose mother tongue is Turkish translated the English version of MAM-36 into Turkish. The expert committee, including two physiotherapists, one neurologist, and one psychologist, produced a draft Turkish version by consensus, discussing the disagreements between the two versions. Then, two native English translators who can also speak Turkish translated this draft Turkish version into English. The expert committee consolidated all the versions of the MAM-36 and developed the pre-final Turkish version. This pre-final version was administered to 22 people with MS, and they read the questions and verbally evaluated the comprehensibility of each item. After this stage, the final version (see supplemental file) was ready to investigate its psychometric properties.

### Participants

People with MS were recruited from the Multiple Sclerosis Outpatient Clinic of Department of Neurology, Dokuz Eylül University Hospital, Izmir, Turkey. The inclusion criteria were a definite diagnosis of MS [27], writing and reading ability in Turkish, aged older than 18 years, and relapse-free period for at least 1 month. Exclusion criteria were other chronic neurological or orthopedic disease, pregnancy, and physician-confirmed relapse during the test-retest period.

Two to 20 participants per item are generally recommended for a validation study [28, 29]. A priori sample size was determined as 180; 5 participants for each 36 items. Since above the 200 participants are typically suggested for conducting factor analyses [30], we recruited 200 participants for the psychometric evaluation phase of the study.

The MAM-36 was re-administrated in 31 patients after 4 weeks to assess the test-retest reliability. The clinical stability of these patients in the meantime was assessed using the Global Perceived Effect scale which asked, “How would you rate your hand/arm functioning, compared to four weeks ago?”. Response options were the following: (1) much better, (2) somewhat better, (3) about the same, (4) somewhat worse, and (5) much worse. Patients who reported 2, 3, and 4 on the Global Perceived Effect Scale were regarded as stable patients.

## Study outcome measures

The demographic and clinical data were collected. The neurological examinations of all patients and calculations of EDSS scores were conducted by the same certified neurologist. The EDSS score is based on the patient's neurological examination and ambulatory status, and higher scores indicate higher disability [3, 4]. Then, the following study outcome measures were conducted in a random order to prevent a possible order effect.

As a PROM of neurological disability, the PDDS was used. The PDDS asks the patients to select one of 9 items that best describes the current walking ability status [31]. The Turkish version of PDDS presented high validity and test-retest reliability in people with MS [32].

The upper limb function assessments included the 9HPT, coin rotation test (CRT), handgrip strength, Modified Ashworth Scale (MAS), MAM-36, and AMSQ. The 9HPT and CRT are valid and reliable capacity measures to assess manual dexterity in people with MS [10, 33]. Scores of the 9HPT and CRT were presented in seconds. Higher times indicate lower manual dexterity in both tests. For the assessment of body functions, handgrip strength and upper limb spasticity was measured. Handgrip strength was measured using a hydraulic hand dynamometer (JAMAR®, Performance Health Holdings, Inc., USA). The American Society of Hand Therapists' standardized arm position for handgrip strength testing was utilized, three trials were performed, and the average of these trials was reported in kilogram [34]. Higher scores indicate higher handgrip strength. Spasticity of the elbow flexor muscles was assessed using the MAS [35]. Patients with the MAS score  $\geq 1$  were considered as having spasticity.

The MAM-36 and AMSQ were used as PROMs of upper limb function. The MAM-36 includes 36 items that ask perceived ease or difficulty in performing common tasks using the hands without the use of adaptive equipment. In the MAM-36, of which hand is used is not regarded. Items are rated on a 4-point Likert-type scale from 0 (almost never performed) to 4 (easy). Scores on the 36 items were summed to create a raw total score, and then the raw scores were converted to transformed manual ability measures which range from 0 to 100 [16]. Higher MAM-36 scores indicate higher upper limb function. The AMSQ was a disease-specific PROM to measure upper limb function in MS. The AMSQ consists of 31 items, which are all graded on a 6-point Likert-type scale from 1 (not at all) to 6 (no longer able to). The items include questions asking the patient to what extent MS has limited the patient performing specific activities of daily living during the last 2 weeks. The sum score of AMSQ ranges from 31 to 186, where higher scores indicate lower upper limb function [20].

The health-related quality of life was assessed using the Multiple Sclerosis International Quality of Life

Questionnaire (MusiQoL), which is a disease-specific PROM and was developed for many languages including Turkish [36]. The MusiQoL has 31 items related with 9 domains of health-related quality of life, including activities of daily living, psychological well-being, symptoms, relationships with friends, relationships with family, relationship with the healthcare system, sentimental and sexual life, coping, and rejection [36]. Higher scores indicate a better level of health-related quality of life.

## Statistical analysis

The patients' demographic characteristics and assessment results were described using descriptive statistics. The Cronbach's alpha coefficients were calculated to assess the internal consistency. The Cronbach's alpha coefficients were interpreted as excellent,  $> 0.80$ ; adequate,  $0.70$ – $0.79$ ; and inadequate,  $< 0.70$  [37]. The intraclass correlation coefficient (ICC) values with 95% confidence intervals (95% CI) were calculated to assess test-retest reliability. The ICC values were reported as very low  $\leq 0.25$ , low  $= 0.26$ – $0.49$ , moderate  $= 0.50$ – $0.69$ , high  $= 0.70$ – $0.89$ , and very high  $\geq 0.90$  [38].

Test-retest reliability was assessed by calculating the ICC values with 95% confidence interval (CI) for individual items and total scores. Absolute agreement was calculated, and the ICC values for the single measures were reported for individual items. The ICC value for the average measures was reported for the total score of MAM-36.

Fourteen pre-defined hypotheses were constructed to evaluate the construct validity, including concurrent, discriminant, and known groups. For testing the concurrent validity, the following hypotheses were constructed:

1. A high correlation was expected between the MAM-36 and AMSQ because they measure the same construct;
2. A moderate correlation was expected between the MAM-36 and 9HPT because the MAM-36 is a performance test that measures a broad range of activities, whereas the 9HPT is a capacity test that measures dexterity;
3. A higher correlation between the MAM-36 and 9HPT-dominant was expected as compared with the correlation between the MAM-36 and 9HPT-nondominant, because the dominant hand is more important for arm functions;
4. A moderate correlation was expected between the MAM-36 and CRT, because the MAM-36 is a performance test measures that broad range of activities, whereas the CRT is a capacity test that measures dexterity;
5. A higher correlation between the MAM-36 and CRT-dominant was expected as compared with the correlation between the MAM-36 and CRT-nondominant because the dominant hand is more important for arm functions;

6. A low correlation was expected between the MAM-36 and handgrip strength because the MAM-36 does not specifically measure hand strength;
7. A higher correlation between the MAM-36 and dominant handgrip strength was expected as compared with the correlation between the MAM-36 and the dominant handgrip strength because the dominant hand is more important for arm functions;
8. A moderate correlation was expected between the MAM-36 and EDSS because the EDSS is mostly based on ambulatory function;
9. A moderate correlation was expected between the MAM-36 and PDDS because the PDDS is mostly based on ambulatory function;
10. A high correlation was expected between the MAM-36 and activities of daily living subdomain of the MusiQoL because arm function is important for activities of daily living;
11. A higher correlation between the MAM-36 and activities of daily living subdomain of the MusiQoL was expected as compared with the correlations between the MAM-36 and other subdomains of MusiQoL because arm function is more important for activities of daily living compared to other subdomains;
12. A moderate correlation was expected between the MAM-36 and age because arm function decreases with aging.

For assessing discriminant validity, a low correlation was expected between the MAM-36 and BMI, because BMI has no direct influence of arm function. For testing known-groups validity, the relationship between MAM-36 and MAS was examined. As spasticity can cause activity limitations due to upper limb impairments, it was expected that the scores of the MAM-36 in the patients with spasticity ( $MAS \geq 1$ ) would be significantly lower as compared with those without spasticity ( $MAS = 0$ ). In addition, an exploratory principal component analysis, using baseline data to determine the underlying factorial structure of the MAM-36, was used to verify unidimensionality as defined in the original validation study [16].

The Spearman rho rank-order correlation coefficients were calculated and interpreted as low correlation  $< 0.30$ , moderate correlation  $0.30\text{--}0.59$ , and high correlation  $\geq 0.60$ . Mann-Whitney  $U$  test was used to compare the patients with and without spasticity. Statistical significance was set at  $p < 0.05$ . Data were analyzed using the IBM® SPSS® (Version 25.0. Armonk, NY: IBM Corp.).

## Results

Some changes were made during the adaptation process. In the original version, there are brackets beside the items, and

patients asked to write the descriptor numbers (from 0 to 4). We changed this format as descriptor numbers were written upside, and the patients were asked to make a tick to the corresponding box (see supplementary information). We think that this method is a much easier and more conventional way. Item 11 is as “Wring a towel” in the original version [18]. Since “wring a cleaning cloth” is more common than “wring a towel,” therefore, this item was changed as “wring a towel/cleaning cloth”. Item 29 is as “count money (bills and coins)”. This item was changed as “count/handle bills and coins”. Item 30 is as “take things out of a wallet (bills, papers, credit cards)” in the original version [18]. This item was changed as “take things such as bills, papers (driver’s license, identity card), credit cards out of a wallet” since the term of “papers” is quite uncommon. All these examples/changes are recommended by the Rehabilitation in Multiple Sclerosis (RIMS) (available at <https://www.eurims.org/E-education/manual-ability-measurement.html>). After the pilot study on 22 people with MS, some minor changes (changing the place of words in the introduction section) were made to make the readability much easier.

The mean age was 38.8 (10.8) years, and 69.5% of the participants were female. Most of the participants had a relapsing-remitting MS (87.5%). Twenty-four participants (12.0%) had upper limb spasticity. Table 1 presents the demographic and clinical characteristics of the participants.

The Turkish version of MAM-36 showed an excellent internal consistency (Cronbach’s  $\alpha = 0.97$ ). The corrected item-total correlations ranged from 0.40 to 0.87 (Table 2). The test-retest reliability was very high as the ICC was 0.97 (95% CI = 0.94–0.99). The ICC values for individual items ranged from 0.38 to 1.0 (Table 2).

The exploratory factor analysis revealed one component explaining 53% of the variance for the Turkish version of the MAM-36. The Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy (0.93) and Bartlett’s Test of Sphericity ( $p < 0.001$ ) results showed that the respondent data for factor analysis was suitable. The individual factor loadings ranged from 0.45 to 0.88 (Table 2).

To test construct validity, most of the predetermined hypotheses were confirmed (11/14). For concurrent validity, a low correlation was expected between the MAM-36 and handgrip strength; however, the correlations were moderate ( $r_s = 0.30\text{--}0.59$ ,  $p < 0.05$ ). Besides, a moderate correlation was expected between the MAM-36 and EDSS and PDDS; however, the correlations were high ( $r_s \geq 0.60$ ,  $p < 0.05$ ). When assessing the discriminant validity, a low correlation was expected between the MAM-36 and BMI, and it was confirmed ( $r_s = -0.05$ ,  $p = 0.464$ ). For assessing the known-groups validity, it was expected that the scores of the MAM-36 in the patients with spasticity ( $MAS \geq 1$ ) will be significantly lower as compared

**Table 1** Demographic and clinical characteristics of the participants ( $n = 200$ )

Age (years)	38.8 (10.8)
Gender (female), $n$ (%)	139 (69.5)
BMI, $\text{kg/m}^2$	24.6 (4.4)
Level of education, $n$ (%)	
Primary school	34 (17)
Secondary school	28 (14)
High school	50 (25)
University	88 (44)
Hand dominance (right), $n$ (%)	188 (94)
EDSS	2.4 (2.1)
PDSS	1.9 (1.8)
Subtype of MS, $n$ (%)	
Relapsing-remitting MS	175 (87.5)
Secondary progressive MS	22 (11)
Primary progressive MS	3 (1.5)
Presence of upper limb spasticity ( $\text{MAS} \geq 1$ ), $n$ (%)	24 (12.0)
9HPT-dominant (s)	22.4 (7.5)
9HPT-nondominant (s)	24.3 (9.0)
CRT-dominant (s)	19.8 (7.8)
CRT-nondominant (s)	21.5 (9.7)
Grip strength-dominant (kg)	24.5 (10.1)
Grip strength-nondominant (kg)	23.2 (9.4)
MAM-36	80.6 (17.8)
AMSQ	49.3 (23.6)
MusiQoL	
Total score	67.6 (15.11)
Activities of daily living	62.3 (28.5)
Psychological well-being	62.3 (25.1)
Symptoms	76.0 (20.3)
Relationships with friends	60.2 (28.6)
Relationships with family	72.2 (28.4)
Relationship with the healthcare system	87.8 (20.0)
Sentimental and sexual life	45.3 (33.6)
Coping	71.9 (25.3)
Rejection	71.8 (26.0)

BMI, body mass index; EDSS, Expanded Disability Status Scale; PDSS, Patient Determined Disease Steps; MS, multiple sclerosis; MAS, Modified Ashworth Scale; 9HPT, Nine-Hole Peg Test; CRT, Coin Rotation Test; MAM-36, Manual Ability Measure-36; AMSQ, Arm Function in Multiple Sclerosis Questionnaire; MusiQoL, Multiple Sclerosis International Quality of Life

with the patients without spasticity ( $\text{MAS} = 0$ ), and it was confirmed (MAM-36 score = 66.7 ( $\text{SD} = 18.2$ ) in the patients with spasticity vs. 82.4 ( $\text{SD} = 17.0$ ) in those without spasticity ( $p < 0.001$ )). Table 3 presents the predetermined hypotheses, correlation coefficients of the MAM-36 with other measurements, and comparison statistics for assessing construct validity.

## Discussion

In this study, the MAM-36 was successfully translated and culturally adapted into Turkish. The Turkish version of MAM-36 showed good psychometric properties, including excellent internal consistency, very high test-retest reliability, good concurrent, discriminant, and known-groups validity. In addition, it was found as having a unidimensional structure as the original version. For the first time, our study showed the MAM-36 has very high test-retest reliability in people with MS.

Our results indicated that the Turkish version of MAM-36 had excellent internal consistency, as reported by the previous studies conducted in individuals with neurological and neurologi- cal diseases. These studies showed that the MAM-36 or MAM-16 had good internal consistency in mix populations having different hand impairments, including musculoskeletal and neurological diseases including MS [16, 39, 40]. Some studies conducted only in people with MS also presented similar internal consistency results [18, 19]. Although the previ- ous studies used a Rasch method to assess internal consis- tency, we used a traditional method. Despite the different statis- tical methods, populations, and items, it seems that MAM is an internally consistent measure.

Comparing the high number of studies investigated the internal consistency of the MAM, only one study investigated the test-retest reliability. In that study, the MAM-36 was ad- ministered at two points 1 week apart in 14 people with Charcot-Marie-Tooth disease [14], and it was found that the MAM-36 had very high test-retest reliability ( $\text{ICC} = 0.96$ ). Although we used different time points (4 weeks), we also found a similar result ( $\text{ICC} = 0.97$ ). Since the MAM-36 is widely used in the MS field [9, 11, 13], our study further supports its use by showing another valuable psychometric property.

The validity of the MAM-36 has been widely investi- gated in individuals with different diseases, including MS, and these studies reported that the MAM-36 had excellent and/or adequate concurrent and discriminant validity [14–19, 39–41]. To assess concurrent and discriminant va- lidity of the MAM-36, we constructed several predetermined hypotheses and most of them have been confirmed. Indeed, due to the results of previous studies and thinking about the underlying construct of the MAM- 36, a low correlation was expected between the MAM-36 and handgrip strength, and a moderate correlation was ex- pected between the MAM-36 and EDSS and PDSS. However, we found a greater magnitude of correlations than our expectations. These observed high correlations support the validity of MAM-36; yet, since we did not find our expected results, we accepted them as non-confirmed hypotheses. Specifically, the high correlation between the MAM-36 and EDSS is an important finding of our study

**Table 2** Inter-item reliability, test-retest reliability, and factor loadings for the items of the Turkish version of the MAM-36

Items	Corrected item-total correlation	Cronbach's alpha if item deleted	ICC (95% CI)	Factor loadings
Item 1	0.46	0.97	0.48 (0.17–0.71)	0.49
Item 2	0.65	0.97	0.38 (0.05–0.64)	0.68
Item 3	0.76	0.97	0.48 (0.15–0.71)	0.75
Item 4	0.70	0.97	0.64 (0.37–0.81)	0.73
Item 5	0.61	0.97	0.44 (0.11–0.69)	0.66
Item 6	0.83	0.97	0.79 (0.62–0.89)	0.84
Item 7	0.66	0.97	0.92 (0.84–0.96)	0.70
Item 8	0.63	0.97	0.78 (0.59–0.89)	0.68
Item 9	0.60	0.97	0.70 (0.47–0.84)	0.62
Item 10	0.40	0.97	0.66 (0.41–0.82)	0.45
Item 11	0.78	0.97	0.72 (0.49–0.85)	0.79
Item 12	0.77	0.97	0.58 (0.29–0.77)	0.79
Item 13	0.78	0.97	0.81 (0.65–0.91)	0.80
Item 14	0.83	0.97	0.86 (0.74–0.93)	0.84
Item 15	0.81	0.97	0.92 (0.85–0.96)	0.81
Item 16	0.84	0.97	0.78 (0.59–0.89)	0.85
Item 17	0.70	0.97	0.82 (0.65–0.91)	0.70
Item 18	0.47	0.97	1.00	0.51
Item 19	0.54	0.97	1.00	0.58
Item 20	0.61	0.97	0.80 (0.63–0.90)	0.64
Item 21	0.75	0.97	0.88 (0.76–0.94)	0.76
Item 22	0.66	0.97	0.60 (0.33–0.79)	0.66
Item 23	0.76	0.97	0.70 (0.47–0.84)	0.77
Item 24	0.79	0.97	0.69 (0.44–0.84)	0.80
Item 25	0.81	0.97	0.60 (0.32–0.79)	0.82
Item 26	0.79	0.97	0.72 (0.50–0.86)	0.80
Item 27	0.74	0.97	0.72 (0.49–0.86)	0.76
Item 28	0.87	0.97	0.74 (0.52–0.86)	0.88
Item 29	0.76	0.97	0.75 (0.55–0.87)	0.78
Item 30	0.70	0.97	0.60 (0.32–0.79)	0.71
Item 31	0.68	0.97	0.86 (0.72–0.93)	0.69
Item 32	0.65	0.97	0.67 (0.42–0.83)	0.68
Item 33	0.82	0.97	0.63 (0.36–0.81)	0.83
Item 34	0.77	0.97	0.75 (0.54–0.87)	0.77
Item 35	0.59	0.97	0.92 (0.84–0.96)	0.62
Item 36	0.68	0.97	0.43 (0.10–0.68)	0.70
Total	Cronbach's alpha = 0.97		0.97 (0.94–0.99)	53%

MAM-36, Manual Ability Measure-36; ICC, intraclass correlation coefficient; CI, confidence interval

since the EDSS is commonly criticized for its lack of assessment of upper limb function [10]. However, our results revealed that the Turkish version of MAM-36 could better reflect the neurological disability assessed by both clinician-rated and self-reported measures, which are mainly based on walking impairment. In addition to the concurrent and discriminant validity, we also showed that the MAM-36 has good know-group validity. As expected,

the scores of the MAM-36 in the patients with spasticity was found to be significantly lower as compared with the patients without spasticity. Since spasticity is a causative for activity limitations due to impairments of the arm and hand, the MAM-36 can assess this impairment related to spasticity. A factorial analysis was conducted to further assess the construct validity, and it showed that the MAM-36 had a unidimensional structure as reported by

**Table 3** Predetermined hypotheses, correlation coefficients of the MAM-36 with other measurements, and comparison statistics for assessing construct validity

Hypothesis	Result	Confirmed
1. A high correlation was expected between the MAM-36 and AMSQ, because they measure the same construct.	$r_s = -0.90$ ( $p < 0.001^*$ )	Yes
2. A moderate correlation was expected between the MAM-36 and 9HPT, because the MAM-36 is a performance test that measures broad range of activities, whereas the 9HPT is a capacity test that measures dexterity.	Dominant: $r_s = -0.58$ ( $p < 0.001^*$ ) Nondominant: $r_s = -0.51$ ( $p < 0.001^*$ )	Yes
3. A higher correlation between the MAM-36 and 9HPT-dominant was expected as compared with the correlation between the MAM-36 and 9HPT-nondominant, because the dominant hand is more important for arm functions.	$r_s = -0.58$ vs. $r_s = -0.51$	Yes
4. A moderate correlation was expected between the MAM-36 and CRT, because the MAM-36 is a performance test that measures that broad range of activities, whereas the CRT is a capacity test that measures dexterity.	Dominant: $r_s = -0.48$ ( $p < 0.001^*$ ) Nondominant: $r_s = -0.38$ ( $p < 0.001^*$ )	Yes
5. A higher correlation between the MAM-36 and CRT-dominant was expected as compared with the correlation between the MAM-36 and CRT-nondominant, because dominant hand is more important for arm functions.	$r_s = -0.48$ vs. $r_s = -0.38$	Yes
6. A low correlation was expected between the MAM-36 and handgrip strength, because the MAM-36 does not specifically measure hand strength.	Dominant: $r_s = 0.38$ ( $p < 0.001^*$ ) Nondominant: $r_s = 0.30$ ( $p < 0.001^*$ )	No
7. A higher correlation between the MAM-36 and dominant handgrip strength was expected as compared with the correlation between the MAM-36 and dominant handgrip strength, because dominant hand is more important for arm functions.	$r_s = 0.38$ vs. $r_s = 0.30$	Yes
8. A moderate correlation was expected between the MAM-36 and EDSS, because the EDSS is mostly based on ambulatory function.	$r_s = -0.62$ ( $p < 0.001^*$ )	No
9. A moderate correlation was expected between the MAM-36 and PDDS, because the PDDS is mostly based on ambulatory function.	$r_s = -0.68$ ( $p < 0.001^*$ )	No
10. A high correlation was expected between the MAM-36 and activities of daily living subdomain of the MusiQoL, because arm function is important for activities of daily living.	$r_s = 0.67$ ( $p < 0.001^*$ )	Yes
11. A higher correlation between the MAM-36 and activities of daily living subdomain of the MusiQoL was expected as compared with the correlations between the MAM-36 and other subdomains of MusiQoL, because arm function is more important for activities of daily living compared to other subdomains.	Activities of daily living: $r_s = 0.67$ ( $p < 0.001^*$ ) Psychological well-being: $r_s = 0.37$ ( $p < 0.001^*$ ) Symptoms: $r_s = 0.46$ ( $p < 0.001^*$ ) Relationships with friends: $r_s = 0.04$ ( $p = 0.625$ ) Relationships with family: $r_s = 0.02$ ( $p = 0.791$ ) Relationship with the healthcare system: $r_s = 0.13$ ( $p = 0.073$ ) Sentimental and sexual life: $r_s = 0.29$ ( $p < 0.001^*$ ) Coping: $r_s = 0.17$ ( $p = 0.016^*$ ) Rejection: $r_s = 0.32$ ( $p < 0.001^*$ ) Total: $r_s = 0.47$ ( $p < 0.001^*$ )	Yes
12. A moderate correlation was expected between the MAM-36 and age, because arm function decreases with aging.	$r_s = -0.39$ ( $p < 0.001^*$ )	Yes
13. A low correlation was expected between the MAM-36 and BMI, because BMI has no direct influence of arm function.	$r_s = -0.05$ ( $p = 0.464$ )	Yes
14. It was expected that the scores of MAM-36 in the patients with spasticity ( $MAS \geq 1$ ) would be significantly lower as compared with those without spasticity ( $MAS = 0$ ), because spasticity can cause activity limitations due to upper limb impairments.	Mean = 66.7 (SD = 18.2) in the patients with spasticity vs. mean = 82.4 (SD = 17.0) in the patients without spasticity ( $p < 0.001^*$ )	Yes

Low correlation  $< 0.30$ ; moderate correlation  $0.30$ – $0.59$ ; high correlation  $\geq 0.60$

MAM-36, Manual Ability Measure-36; AMSQ, Arm Function in Multiple Sclerosis Questionnaire; 9HPT, Nine-Hole Peg Test; CRT, Coin Rotation Test; BMI, body mass index; EDSS, Expanded Disability Status Scale; PDDS, Patient Determined Disease Steps; MusiQoL, Multiple Sclerosis International Quality of Life; BMI, body mass index; MAS, Modified Ashworth Scale

\*Statistically significant

the original [16] and other validation studies [18, 19, 39, 40].

There are some limitations to this study. The major limitation of this study that most of our participants had a relapsing-

remitting subtype of MS, lower levels of neurological disability, and younger ages. Therefore, most of our participants did not have substantial upper extremity dysfunction and spasticity. Second, we recruited the participants from only one MS center. However, since this center is very extensive and has lots of patient visits from the whole of Turkey, we believe that our sample is relatively representative of Turkish MS population. Nevertheless, these two limitations decrease the generalizability of the results. Third, we did not investigate the responsiveness of the MAM-36, which is an essential psychometric property. However, Chen et al. showed that the MAM-36 was responsive to changes in hand function in patients receiving occupational therapy services [41]. Nevertheless, further studies should investigate the responsiveness of the MAM-36 in people with MS. Lastly, we investigated the correlation between the MAM-36 and AMSQ as a scale measuring the same construct. We chose to use the AMSQ since it is a MS-specific measure. Although the authors of this study also conducted the Turkish validation study of the AMSQ which also showed good psychometric properties, the results have not been published yet. Using another upper extremity function assessment scale validated in Turkish would be better. However, during the planning of this study, only the DASH and Motor Activity Log were officially validated in Turkish [42, 43]. Since these PROMs did not show adequate psychometric properties in people with MS [9, 11, 13], we decided not to use them in our study.

Apart from the limitations noted above, our study has several strengths. Our sample size was relatively large compared to most of the other studies. We investigated other important psychometric properties, including test-retest reliability and know-group validity of the MAM-36 which have not been widely investigated in the previous studies. In addition, for the first time, we demonstrated a very high correlation between the MAM-36 and AMSQ, which has been recently introduced with good psychometric properties that were specifically developed to measure upper limb dysfunction for people with MS [20]. Although the AMSQ is a promising PROM, due to the extensive use of the MAM-36 in the MS field, it limits comparison with historical data in MS and other pathologies [25]. Our results support that the MAM-36 as a generic PROM is highly associated with a disease-specific PROM in people with MS.

## Conclusions

The MAM-36 has been adapted and validated in Turkish and found as a valid and reliable method for measuring upper limb function in people MS. The results of this study extend the evidence on the psychometric properties of MAM-36 in people with MS and support its usability in the daily practice and

international studies. The Turkish version of the MAM-36 is available in the supplementary information.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s10072-020-04927-z>.

**Acknowledgments** The authors would like to thank Dr. Christine C. Chen for giving permission of this validation study; Asiye Tuba Ozdogar, Ozge Sagici, and Dr. Buse Ozcan Kahraman for their help during the translation and adaptation process; the Multiple Sclerosis Research Association for helping patient recruitment, and all the participants.

**Data availability** Data available on request from the authors.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethics approval** The Noninvasive Research Ethics Board of Dokuz Eylul University approved the study protocol with the date of May 22, 2019 and approval number of 2019/13-13, which was administered to the provisions of the Declaration of Helsinki (as revised in Brazil 2013).

**Consent to participate** Each participant signed an informed consent before participating to the study.

## References

1. Vukusic S, Confavreux C (2007) Natural history of multiple sclerosis: risk factors and prognostic indicators. *Curr Opin Neurol* 20(3):269–274. <https://doi.org/10.1097/WCO.0b013e32812583ad>
2. Smrtka J, Brown T, Bjorklund G (2016) Loss of mobility and the patient burden of multiple sclerosis: expert opinion on relevance to daily clinical practice. *Postgrad Med* 128(1):145–151. <https://doi.org/10.1080/00325481.2016.1120162>
3. Kahraman T, Savci S, Coskuner Poyraz E, Ozakbas S, Idiman E (2016) Utilization of the Expanded Disability Status Scale as a distinctive instrument for walking impairment in persons with multiple sclerosis with mild disability. *NeuroRehabilitation* 38(1):7–14. <https://doi.org/10.3233/nre-151290>
4. Kurtzke JF (1983) Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). *Neurology* 33(11):1444–1452. <https://doi.org/10.1212/wnl.33.11.1444>
5. Holper L, Coenen M, Weise A, Stucki G, Cieza A, Kesselring J (2009) Characterization of functioning in multiple sclerosis using the ICF. *J Neurol* 257(1):103–113. <https://doi.org/10.1007/s00415-009-5282-4>
6. Johansson S, Ytterberg C, Claesson IM, Lindberg J, Hillert J, Andersson M, Widén Holmqvist L, von Koch L (2007) High concurrent presence of disability in multiple sclerosis. *J Neurol* 254(6):767–773. <https://doi.org/10.1007/s00415-006-0431-5>
7. Cattaneo D, Lamers I, Bertoni R, Feys P, Jonsdottir J (2017) Participation restriction in people with multiple sclerosis: prevalence and correlations with cognitive, walking, balance, and upper limb impairments. *Arch Phys Med Rehabil* 98(7):1308–1315. <https://doi.org/10.1016/j.apmr.2017.02.015>
8. Yozbatiran N, Baskurt F, Baskurt Z, Ozakbas S, Idiman E (2006) Motor assessment of upper extremity function and its relation with fatigue, cognitive function and quality of life in multiple sclerosis

- patients. *J Neurol Sci* 246(1):117–122. <https://doi.org/10.1016/j.jns.2006.02.018>
9. Kahraman T (2018) Performance measures for upper extremity functions in persons with multiple sclerosis. *Noro psikiyatri arsivi* 55 (Suppl 1):S41–s45. doi:<https://doi.org/10.29399/npa.23317>
  10. Cutter GR, Baier ML, Rudick RA, Cookfair DL, Fischer JS, Petkau J, Syndulko K, Weinshenker BG, Antel JP, Confavreux C, Ellison GW, Lublin F, Miller AE, Rao SM, Reingold S, Thompson A, Willoughby E (1999) Development of a multiple sclerosis functional composite as a clinical trial outcome measure. *Brain* 122(Pt 5): 871–882. <https://doi.org/10.1093/brain/122.5.871>
  11. Lamers I, Feys P (2014) Assessing upper limb function in multiple sclerosis. *Mult Scler J* 20(7):775–784. <https://doi.org/10.1177/1352458514525677>
  12. Tacchino A, Ponzio M, Pedullà L, Podda J, Bragadin MM, Pedrazzoli E, Konrad G, Battaglia MA, Mekkink L, Bricchetto G (2020) Italian validation of the Arm Function in Multiple Sclerosis Questionnaire (AMSQ). *Neurol Sci* 41(11):3273–3281. <https://doi.org/10.1007/s10072-020-04363-z>
  13. Lamers I, Kelchtermans S, Baert I, Feys P (2014) Upper limb assessment in multiple sclerosis: a systematic review of outcome measures and their psychometric properties. *Arch Phys Med Rehabil* 95(6):1184–1200. <https://doi.org/10.1016/j.apmr.2014.02.023>
  14. Poole JL, Huffman M, Hunter A, Mares C, Siegel P (2015) Reliability and validity of the Manual Ability Measure-36 in persons with Charcot-Marie-Tooth disease. *Journal of hand therapy : official journal of the American Society of Hand Therapists* 28(4): 364–367; quiz 368. <https://doi.org/10.1016/j.jht.2015.04.003>
  15. Tsai CL, Lin CF, Lin HT, Liu MF, Chiu HY, Hsu HY, Kuo LC (2017) How kinematic disturbance in the deformed rheumatoid thumb impacts on hand function: a biomechanical and functional perspective. *Disabil Rehabil* 39(4):338–345. <https://doi.org/10.3109/09638288.2016.1141244>
  16. Chen CC, Bode RK (2010) Psychometric validation of the Manual Ability Measure-36 (MAM-36) in patients with neurologic and musculoskeletal disorders. *Arch Phys Med Rehabil* 91(3):414–420. <https://doi.org/10.1016/j.apmr.2009.11.012>
  17. Rallon CR, Chen CC (2008) Relationship between performance-based and self-reported assessment of hand function. *Am J Occup Ther* 62(5):574–579. <https://doi.org/10.5014/ajot.62.5.574>
  18. Chen CC, Kasven N, Karpatkin HI, Sylvester A (2007) Hand strength and perceived manual ability among patients with multiple sclerosis. *Arch Phys Med Rehabil* 88(6):794–797. <https://doi.org/10.1016/j.apmr.2007.03.010>
  19. Solaro C, Di Giovanni R, Grange E, Bricchetto G, Mueller M, Tacchino A, Bertoni R, Patti F, Pappalardo A, Prosperini L, Castelli L, Rosato R, Cattaneo D, Marengo D (2020) Italian translation and psychometric validation of the Manual Ability Measure-36 (MAM-36) and its correlation with an objective measure of upper limb function in patients with multiple sclerosis. *Neurological sciences : official journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology*. doi:<https://doi.org/10.1007/s10072-020-04263-2>
  20. Mekkink LB, Knol DL, van der Linden FH, Sonder JM, D'hooghe M, Uitdehaag BMJ (2015) The Arm Function in Multiple Sclerosis Questionnaire (AMSQ): development and validation of a new tool using IRT methods. *Disabil Rehabil* 37(26):2445–2451. <https://doi.org/10.3109/09638288.2015.1027005>
  21. Kalkers NF, Galan I, Kerbrat A, Tacchino A, Kamm CP, O'Connell K, McGuigan C, Edan G, Montalban X, Uitdehaag BM, Mekkink LB (2019) Differential item functioning of the Arm function in Multiple Sclerosis Questionnaire (AMSQ) by language, a study in six countries. *Multiple sclerosis (Houndmills, Basingstoke, England)*:1352458519895450. doi:<https://doi.org/10.1177/1352458519895450>
  22. van Munster CE, Kaya L, Obura M, Kalkers NF, Uitdehaag BM (2019) Minimal clinically important difference of improvement on the arm function in multiple sclerosis questionnaire (AMSQ). *Multiple sclerosis (Houndmills, Basingstoke, England)*: 1352458518823489. <https://doi.org/10.1177/1352458518823489>
  23. van Leeuwen LM, Mekkink LB, Kamm CP, de Groot V, van den Berg P, Ostelo R, Uitdehaag BMJ (2017) Measurement properties of the Arm Function in Multiple Sclerosis Questionnaire (AMSQ): a study based on Classical Test Theory. *Disabil Rehabil* 39(20): 2097–2104. <https://doi.org/10.1080/09638288.2016.1213898>
  24. Steinheimer S, Wendel M, Vanbellingen T, Westers LT, Hodak J, Blatter V, Uitdehaag BMJ, Kamm CP (2018) The Arm Function in Multiple Sclerosis Questionnaire was successfully translated to German. *Journal of hand therapy : official journal of the American Society of Hand Therapists* 31 (1):137–140.e131. doi:<https://doi.org/10.1016/j.jht.2017.09.010>
  25. Lamers I, Feys P (2018) Patient reported outcome measures of upper limb function in multiple sclerosis: a critical overview. *Mult Scler J* 24(14):1792–1794. <https://doi.org/10.1177/1352458518809294>
  26. Beaton DE, Bombardier C, Guillemin F, Ferraz MB (2000) Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976)* 25(24):3186–3191
  27. Polman CH, Reingold SC, Banwell B, Clanet M, Cohen JA, Filippi M, Fujihara K, Havrdova E, Hutchinson M, Kappos L, Lublin FD, Montalban X, O'Connor P, Sandberg-Wollheim M, Thompson AJ, Waubant E, Weinshenker B, Wolinsky JS (2011) Diagnostic criteria for multiple sclerosis: 2010 revisions to the McDonald criteria. *Ann Neurol* 69(2):292–302. <https://doi.org/10.1002/ana.22366>
  28. Hair JF, Anderson RE, Tatham RL, Black WC (1995) *Multivariate data analyses with readings*, 4th edn. Pearson College Div, New Jersey, United States of America
  29. Kline P (1979) *Psychometrics and psychology*. Academic Press Inc, London, United Kingdom
  30. Bandalos DL (2014) Relative performance of categorical diagonally weighted least squares and robust maximum likelihood estimation. *Struct Equ Model Multidiscip J* 21(1):102–116. <https://doi.org/10.1080/10705511.2014.859510>
  31. Schwartz CE, Vollmer T, Lee H (1999) Reliability and validity of two self-report measures of impairment and disability for MS. *North American Research Consortium on Multiple Sclerosis Outcomes Study Group. Neurology* 52 (1):63–70. doi:<https://doi.org/10.1212/wnl.52.1.63>
  32. Kahraman T, Ozdogar AT, Ozakbas S (2019) Cross-cultural adaptation, validity and reliability of the Turkish version of the patient determined disease steps scale in persons with multiple sclerosis. *Physiotherapy theory and practice*:1–8. doi:<https://doi.org/10.1080/09593985.2019.1633715>
  33. Heldner MR, Vanbellingen T, Bohlhalter S, Mattle HP, Muri RM, Kamm CP (2014) Coin rotation task: a valid test for manual dexterity in multiple sclerosis. *Phys Ther* 94(11):1644–1651. <https://doi.org/10.2522/ptj.20130252>
  34. MacDermid J, Solomon G, Valdes K, American Society of Hand T (2015) *Clinical assessment recommendations*
  35. Ansari NN, Naghdi S, Arab TK, Jalaie S (2008) The interrater and intrarater reliability of the Modified Ashworth Scale in the assessment of muscle spasticity: limb and muscle group effect. *NeuroRehabilitation* 23(3):231–237
  36. Simeoni M, Auquier P, Fernandez O, Flachenecker P, Stecchi S, Constantinescu C, Idiman E, Boyko A, Beiske A, Vollmer T, Triantafyllou N, O'Connor P, Barak Y, Biermann L, Cristiano E, Atweh S, Patrick D, Robitail S, Ammouy N, Beresniak A, Pelletier J, MusiQol study g (2008) Validation of the Multiple Sclerosis International Quality of Life questionnaire. *Multiple sclerosis*

- (Houndmills, Basingstoke, England) 14(2):219–230. <https://doi.org/10.1177/1352458507080733>
37. Andresen EM (2000) Criteria for assessing the tools of disability outcomes research. *Arch Phys Med Rehabil* 81(12 Suppl 2):S15–S20. <https://doi.org/10.1053/apmr.2000.20619>
  38. Munro BH (2005) *Statistical methods for health care research*, vol 1. Lippincott Williams & Wilkins,
  39. Chen CC, Giustino J (2007) Grip strength, perceived ability, and health status in individuals with arthritis: an exploratory study. *Occupational therapy in health care* 21(4):1–18. [https://doi.org/10.1080/J003v21n04\\_01](https://doi.org/10.1080/J003v21n04_01)
  40. Chen CC, Granger CV, Peimer CA, Moy OJ, Wald S (2005) Manual Ability Measure (MAM-16): a preliminary report on a new patient-centred and task-oriented outcome measure of hand function. *Journal of hand surgery (Edinburgh, Scotland)* 30(2): 207–216. <https://doi.org/10.1016/j.jhsb.2004.12.005>
  41. Chen CC, Palmon O, Amini D (2014) Responsiveness of the Manual Ability Measure-36 (MAM-36): changes in hand function using self-reported and clinician-rated assessments. *Am J Occup Ther* 68(2):187–193. <https://doi.org/10.5014/ajot.2014.009258>
  42. Düger T, Yakut E, Öksüz Ç, Yörükan S, Bilgütay BS, Ayhan Ç, Leblebicioğlu G, Kayıhan H, Kırdı N, Yakut Y Reliability and validity of the Turkish version of the Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire. *Fizyoterapi Rehabilitasyon* 17 (3):99–107
  43. Ersöz Hüseyinsinoğlu B, Razak Özdoğan A, Erkan Oğul Ö, Krespi Y Reliability and validity of Turkish version of Motor Activity Log-28. *Turkish Journal of Neurology* 17 (2):83–89

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.