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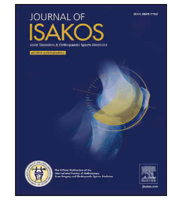

Original Research

Thai version of the Marx Activity Rating Scale: Cross-cultural adaptation and validation in patients with anterior cruciate ligament injury☆

Pakorn Chawanpaiboon, MD [a,b], Kongpob Reosanguanwong, MD [c], Wacharapol Tepa, MSc [a], Suchitphon Chanchoo, MSc [a], Pisit Lertwanich, MD [a,*]

[a] Division of Sports Medicine, Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand
[b] Golden Jubilee Medical Center, Faculty of Medicine Siriraj Hospital, Mahidol University, Nakhon Pathom, Thailand
[c] Division of Sports Medicine, Department of Orthopaedic Surgery, Faculty of Medicine, Naresuan University, Phitsanulok, Thailand

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ABSTRACT

Introduction/objectives: The Marx Activity Rating Scale (MARS) is a validated patient-reported outcome measure quantifying high-demand knee activity frequency in anterior cruciate ligament (ACL)–injured populations. The instrument consists of 4 domains: running, cutting, decelerating, and pivoting. This prospective validation study aimed to translate and cross-culturally adapt the MARS into Thai and evaluate its psychometric properties among ACL-injured patients.

Methods: Cross-cultural adaptation followed Beaton's established guidelines, including translation, synthesis, backward translation, expert committee review, and pretesting. Validation of the Thai version of the MARS used dual recall timeframes: MARS with a 1-year recall period ($MARS_{yr}$) and MARS with a 1-month recall period ($MARS_{mo}$). A total of 110 ACL-injured patients, aged 18–50 years with pre-injury Tegner Activity Scale (TAS) scores ≥4, completed questionnaires at the baseline and 2-week follow-up. Psychometric evaluation encompassed construct validity, internal consistency, test-retest reliability, measurement error, and floor/ceiling effects.

Results: Cross-cultural adaptation of the Thai version of the MARS was successfully completed. Construct validity of the instrument was demonstrated by correlations between the MARS and the TAS with corresponding time-frames (Spearman's correlation coefficient of 0.51–0.61). Internal consistency was excellent with Cronbach's α coefficients of 0.87 ($MARS_{yr}$) and 0.93 ($MARS_{mo}$). Test-retest reliability showed excellent intraclass correlation coefficients of 0.93 ($MARS_{yr}$) and 0.94 ($MARS_{mo}$). Notable floor effects (33.6% for $MARS_{mo}$) and ceiling effects (26.4% for $MARS_{yr}$) were observed.

Conclusion: The MARS was successfully cross-culturally adapted into the Thai version. It exhibits acceptable psychometric properties for quantifying physical activity in ACL-injured populations. Floor/ceiling effects necessitate complementary outcome measures for comprehensive functional assessment.

Level of evidence: II.

Abbreviations: ACL, Anterior cruciate ligament; CI, Confidence interval; EQ-5D-5L, European Quality of Life 5-Dimension 5-Level; GRoC, Global rating of change; ICC, Intraclass correlation coefficient; IKDC-SKF, International Knee Documentation Committee Subjective Knee Form; IQR, Interquartile range; KOOS, Knee Injury and Osteoarthritis Outcome Score; MARS, Marx Activity Rating Scale; $MARS_{mo}$, Marx Activity Rating Scale with a 1-month recall period; $MARS_{yr}$, Marx Activity Rating Scale with a 1-year recall period; MIC, Minimal important change; PROM, Patient-reported outcome measure; r_s, Spearman's correlation coefficient; SD, Standard deviation; SDC, Smallest detectable change; SDC_{grp}, Smallest detectable change at the group level; SDC_{ind}, Smallest detectable change at the individual level; SEM, Standard error of measurement; TAS, Tegner Activity Scale; TAS_{mo}, Tegner Activity Scale with a 1-month recall period; TAS_{yr}, Tegner Activity Scale with a 1-year recall period.

☆ **Primary institution where the study was performed:** Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkok Noi, Bangkok 10700, Thailand.

* Corresponding author. Division of Sports Medicine, Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkok Noi, Bangkok 10700, Thailand. Tel.: +66 2 419 7958; fax: +66 2 419 7967.

E-mail address: pisit.ler@mahidol.ac.th (P. Lertwanich).

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What are the new findings?

- The Marx Activity Rating Scale (MARS) was successfully cross-culturally adapted into the Thai version following Beaton's established guidelines.
- The Thai version of the MARS demonstrates acceptable psychometric properties with dual-timeframe utility, enabling longitudinal and cross-sectional activity assessment in anterior cruciate ligament–injured populations.
- Substantial floor/ceiling effects mandate multi-instrument assessment batteries for comprehensive patient evaluation and outcome tracking.

INTRODUCTION

Anterior cruciate ligament (ACL) injury is a common knee injury in physically active individuals. This injury considerably impacts patients' quality of life and often necessitates prolonged rehabilitation or surgical intervention. Physical activity level assessment in ACL-injured patients provides crucial information throughout the care continuum [1]. Clinicians use pre-injury activity levels to determine functional demands and establish patient-specific recovery goals. For researchers, the activity level represents essential demographic data when comparing intervention efficacy across groups. Post-injury or post-surgical activity assessment facilitates objective treatment monitoring. It also serves as a meaningful outcome measure of functional recovery and return-to-sport readiness.

The Tegner Activity Scale (TAS) and Marx Activity Rating Scale (MARS) are widely recommended patient-reported outcome measures (PROMs) for assessing physical activity in knee disorders [1,2]. The TAS measures activity based on sport types and competition levels [3]. The MARS evaluates frequency of 4 knee-stressing functional activities: running, cutting, decelerating, and pivoting [4]. The MARS is easy to understand and can be completed in 1 min. Additionally, it is not limited to particular types of sports, providing good generalizability across different athletic activities. Initially developed for collecting patient demographic data [4], the MARS later became an outcome measure for knee disorders including ACL injury [2,5,6]. Its application has expanded to other lower extremity procedures. These include hip arthroscopy [7] and proximal hamstring tendon repair [8].

The original English version of the MARS demonstrated good validity and reliability [2,4]. Translations exist in Persian [9], Swedish [10], and Romanian [11]. However, no Thai version exists. This study aimed to translate and cross-culturally adapt the MARS into the Thai version and evaluate its psychometric properties. We hypothesized that the Thai version of the MARS would demonstrate good validity and reliability in ACL-injured patients.

METHODS

Study design and setting

This prospective study was conducted at Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. The MARS underwent translation and cross-cultural adaptation from English into Thai. Measurement properties of the translated version were evaluated in patients with ACL injury from July 2023 to September 2024. The Siriraj Institutional Review Board approved the study protocol (reference: 310/2023). All participants provided written informed consent before enrollment.

Translation and cross-cultural adaptation

After obtaining developer permission, the MARS was translated following established cross-cultural adaptation guidelines [12], which consist of five stages: translation, synthesis, back translation, expert committee review, and pretesting. The original English version of the MARS was independently translated into Thai by two translators: an orthopedic surgeon who was familiar with the instrument concepts and a naive professional translator with no medical background. The two translators and another orthopedic surgeon reviewed both forward translations and identified discrepancies item by item. These discrepancies were resolved through consensus discussion to synthesize a preliminary version. Two independent translators with no clinical background then performed backward translation of the preliminary version into English while remaining blinded to the original questionnaire. All translations were reviewed by a multidisciplinary committee that included all translators, another orthopedic surgeon, and clinical research staff. Minor discrepancies were resolved by consensus, creating a pre-final version. Pretesting was conducted in 30 ACL-injured patients to assess comprehensibility. Participants completed the questionnaire and were interviewed to explore what they thought was meant by each item and their chosen responses. Any difficulties or confusion with specific terms or phrases were documented. The pre-final version would be adopted as the final Thai version of the MARS if no modifications were required.

Validation process

The measurement properties of the Thai version of the MARS were evaluated in patients aged 18 to 50 years with ACL injury and pre-injury TAS scores of 4 or higher. All participants were recruited from the Siriraj Sports Medicine Clinic. Exclusion criteria included inflammatory arthritis, multi-ligamentous knee injury, previous knee surgery, and history of lower extremity fracture or dislocation. Patients with inadequate Thai-language proficiency or medical conditions impairing questionnaire comprehension were also excluded.

Patients completed 2 questionnaire sets with a 2-week interval between assessments. All questionnaires were Thai versions administered in the paper format. At the baseline, all participants received the first set comprising the MARS, TAS [13], International Knee Documentation Committee Subjective Knee Form (IKDC-SKF) [14], Knee Injury and Osteoarthritis Outcome Score (KOOS) [15], and European Quality of Life 5-Dimension 5-Level (EQ-5D-5L) [16].

In this study, two recall periods were applied to the Thai version of the MARS for evaluating high-demand knee activity frequency. The 1-year timeframe (Marx Activity Rating Scale with a 1-year recall period [$MARS_{yr}$]) corresponds to the original English version of the MARS. The shortened 1-month timeframe (Marx Activity Rating Scale with a 1-month recall period [$MARS_{mo}$]) was previously implemented in Swedish MARS validation [10]. At both assessment time points (baseline and 2-week follow-up), participants completed both $MARS_{yr}$ and $MARS_{mo}$ to evaluate the psychometric properties of each recall period.

For test-retest reliability assessment, patients received a second questionnaire set containing the Thai version of the MARS and the global rating of change (GRoC) scale. Patients were instructed to complete questionnaires after 2 weeks and return them via provided stamped pre-addressed envelopes.

Questionnaires

The MARS is an activity-related instrument comprising 4 items: running, cutting, decelerating, and pivoting [4]. These items assess activity frequency based on the patient's healthiest and most active state. Each activity challenges knee function in patients with knee disorders. Items use a 5-point ordinal scale from 0 (less than once per month) to 4 (4 or more times per week). Total scores range from 0 to 16, with higher scores indicating higher activity levels. Completion requires approximately 1 min [4].

The TAS is a 1-item instrument assessing physical activity related to work and sports. Scores range from 0 to 10, with higher scores representing higher activity levels [3,13]. In this study, the Thai version was administered with 2 recall periods. These evaluated the highest activity level during the previous year (Tegner Activity Scale with a 1-year recall period [TAS_{yr}]) and previous month (Tegner Activity Scale with a 1-month recall period [TAS_{mo}]).

The IKDC-SKF is a knee-specific PROM that evaluates patients' symptoms, function, and sport activities. This instrument yields scores from 0 to 100. Higher scores indicate better function and fewer symptoms [14,17].

The KOOS contains 42 items across 5 subscales: pain, other symptoms, function in activities of daily living, function in sports and recreation, and knee-related quality of life. Each subscale scores from 0 (most severe symptoms) to 100 (no symptoms) [15,18].

The EQ-5D-5L is a general health-related questionnaire with 5 items. Raw responses were converted to utility scores using the Thai EQ-5D-5L value set [16]. Utility scores range from 0 to 1, with higher scores indicating better health-related quality of life [16,19].

The GRoC scale anchors assessment of physical activity changes since baseline. This study used a 7-point scale from −3 (greatly reduced) through 0 (no change) to +3 (greatly increased) [20]. This instrument was used to identify patients with a stable clinical condition (GRoC scores of −1, 0, or +1) for the test-retest reliability analysis to minimize the confounding effects of clinical change.

Statistical analysis

Demographic data were summarized using descriptive statistics. The Kolmogorov-Smirnov test and visual histogram inspection assessed normality. For normally distributed variables, data are presented as means and standard deviations (SDs); for non-normally distributed variables, data are presented as medians with interquartile ranges (IQRs). Categorical variables appear as frequencies and percentages. Statistical analyses were conducted using PASW Statistics version 18.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at *P* values of 0.05 or less. Bland-Altman plots for agreement analysis were generated using MedCalc Statistical Software version 20.023 (MedCalc Software Ltd., Ostend, Belgium).

Sample size calculations were performed for three primary analyses. For construct validity assessment, an estimated correlation of 0.75, a desired confidence interval (CI) width of 0.2, a type I error rate of 5%, and a type II error rate of 20% required a minimum of 100 participants. For internal consistency evaluation, an estimated Cronbach's α of 0.7, a CI width of 0.2, and a type I error rate of 5%, and the 4-item scale required a minimum of 96 participants. For test-retest reliability, a minimum of 75 participants were required based on a planning intraclass correlation coefficient (ICC) of 0.75 and CI width of 0.2. Therefore, 110 participants were recruited to satisfy all requirements with allowance for potential dropouts.

Validity

Construct validity was evaluated by analyzing correlations between both Thai MARS timeframe versions ($MARS_{yr}$ and $MARS_{mo}$) and established measures. These included Thai versions of the TAS, IKDC-SKF, KOOS, and EQ-5D-5L. Using Spearman's correlation coefficient (r_s), correlation strength was categorized as small ($0.10 \leq r_s < 0.30$), moderate ($0.30 \leq r_s < 0.50$), or large ($r_s \geq 0.50$) [21].

Reliability

MARS reliability was comprehensively evaluated across 3 domains: internal consistency, test-retest reliability, and measurement error.

Internal consistency was quantified with Cronbach's α, where values between 0.70 and 0.95 denote good reliability for PROMs [22].

Test-retest reliability was examined among participants who reported stable conditions at the second assessment (GRoC: −1 to +1) using the ICC. Values ≥0.70 with ≥50 participants indicate high test-retest reliability [22].

Measurement error was explored via the standard error of measurement (SEM) and smallest detectable change (SDC) [22,23]. The SEM was computed from baseline SD using the following formula: $SEM = SD \times \sqrt{(1 - ICC)}$. The smallest detectable change at the individual level ($SDC_{ind} = SEM \times 1.96 \times \sqrt{2}$) represents the minimal meaningful change exceeding measurement error [24]. The smallest detectable change at the group level (SDC_{grp}) was obtained by dividing SDC_{ind} by $\sqrt{n}$. Agreement between first and second MARS administrations was assessed using Bland-Altman analysis.

Interpretability

MARS interpretability was assessed by examining floor and ceiling effects and the minimal important change (MIC). Floor and ceiling effects were considered present if more than 15% of patients achieved the lowest or highest possible scores, respectively [22]. The MIC represents the smallest within-person change that patients recognize as meaningful improvement. A distribution-based method was used to determine the MIC using the following formula: $MIC = 0.5 \times SD$ [25].

RESULTS

Translation and cross-cultural adaptation

The original English version of the MARS was successfully translated into Thai following established guidelines. During cross-cultural adaptation, the word "skiing" was removed from the "pivoting" item to reflect local context, as skiing is not a relevant activity in Thailand. Pretesting of the pre-final questionnaire showed excellent comprehensibility among all 30 ACL-injured patients. Participants could clearly explain their understanding of questionnaire items and chosen responses. No difficulties with specific terms or phrases were identified. Consequently, the pre-final version was adopted as the final Thai version of the MARS without modifications.

Patient characteristics

A total of 120 patients were initially eligible for the study. After excluding 4 patients with multi-ligamentous knee injury and 6 patients with previous knee surgery, 110 patients with ACL injury participated in this study. Participants had a median age of 29 years, 84.5% were male, and median time since injury was 4 months (Table 1).

All participants completed both assessments. All of them reported stable conditions (GRoC scores: −1 to +1) at the second evaluation. Furthermore, MARS scores remained stable over the 2-week period. The $MARS_{yr}$ showed median scores of 12 (IQR: 8-16) and the $MARS_{mo}$ showed median scores of 3 (IQR: 0-9) at both time points. The distribution of baseline MARS scores is shown with histograms (Fig. 1).

Validity

Construct validity analysis demonstrated convergent validity for both MARS versions when correlated with corresponding TAS timeframes. The $MARS_{yr}$ showed large correlation with the TAS_{yr} ($r_s = 0.51$, $P < 0.001$). The $MARS_{mo}$ also demonstrated large correlation with the TAS_{mo} ($r_s = 0.61$, $P < 0.001$). Cross-timeframe correlations between the

Table 1
Participant demographic and clinical characteristics ($N = 110$).

Characteristics	Values
Male, *n* (%)	93 (84.5)
Age (years), median (IQR)	29 (22-38)
BMI (kg/m^2), mean ± SD	24.9 ± 4.1
Left knee, *n* (%)	59 (53.6)
Occupation, *n* (%)	
Officer	42 (38.2)
Student	30 (27.3)
Laborer	12 (10.9)
Police/Military	11 (10.0)
Professional athlete	3 (2.7)
Other	12 (10.9)
Sport type, *n* (%)	
Football	72 (65.5)
Basketball	12 (10.9)
Badminton	7 (6.4)
Running	5 (4.5)
Other	14 (12.7)
Time since injury (months), median (IQR)	4 (2–10)
Less than 1 month, *n* (%)	8 (7.3)
One month to 1 year, *n* (%)	83 (75.4)
More than 1 year, *n* (%)	19 (17.3)
Mechanism of injury, *n* (%)	
Sport injury	90 (81.8)
Falling	16 (14.6)
Traffic accident	4 (3.6)

Abbreviations: BMI = body mass index; IQR = interquartile range; SD = standard variation.
Data are reported as *n* (%) unless otherwise indicated. Medians have been shown with IQR; means have been shown with SD.

MARS and TAS were not statistically significant, confirming divergent validity. The $MARS_{mo}$ showed small to moderate correlations with the IKDC-SKF ($r_s = 0.29$, $P = 0.002$) and 4 of 5 KOOS subscales, including sport/recreation ($r_s = 0.38$, $P < 0.001$), pain ($r_s = 0.26$, $P = 0.006$), activities of daily living ($r_s = 0.24$, $P = 0.012$), and quality of life ($r_s = 0.25$, $P = 0.008$) (Table 2). In contrast, the $MARS_{yr}$ demonstrated no statistically significant correlations with these measures ($r_s = -0.01$ to 0.18, all $P > 0.05$).

Reliability

Cronbach's α values were 0.87 (95% CI: 0.83-0.91) for the $MARS_{yr}$ and 0.93 (95 % CI: 0.91-0.95) for the $MARS_{mo}$. These values indicate excellent internal consistency. The Thai version of the MARS demonstrated excellent test-retest reliability. ICC values were 0.93 (95% CI: 0.89-0.95) for the $MARS_{yr}$ and 0.94 (95% CI: 0.92-0.96) for the $MARS_{mo}$ (Table 3). Individual-level SDC values were 3.3 points for the $MARS_{yr}$ and 3.5 points for the $MARS_{mo}$. Group-level SDC values were substantially lower at 0.3 points for both recall timeframes. The Bland-Altman analysis demonstrated good agreement between repeated measurements for both versions (Fig. 2). The $MARS_{yr}$ showed a mean difference of 0.2 with 95% limits of agreement of −3.3 to 3.6. The $MARS_{mo}$ showed a mean difference of 0.2 with 95% limits of agreement of −3.2 to 3.7.

Interpretability

Floor and ceiling effects varied substantially between the 2 MARS recall periods (Table 4). The $MARS_{yr}$ exhibited notable ceiling effects, with 26.4% of patients achieving maximum scores. This effect was particularly prominent in patients with acute injuries less than 1 month (37.5%). The $MARS_{mo}$ demonstrated substantial floor effects, with 33.6% achieving minimum scores. This effect was most prominent in patients with recent injuries (50.0%). The MIC calculated using a distribution-based approach was 2.3 points for the $MARS_{yr}$ and 2.6 points for the $MARS_{mo}$ (Table 3).

DISCUSSION

The MARS is a recommended PROM for assessing physical activity in patients with knee disorders, especially ACL injury. In this study, the MARS was successfully translated and cross-culturally adapted into Thai following international guidelines. Using two recall periods, the Thai version of the MARS demonstrated acceptable construct validity based on large correlations between the MARS and the TAS with corresponding timeframes. Both the $MARS_{yr}$ and $MARS_{mo}$ showed good test-retest reliability. However, interpretability was limited by substantial ceiling effects (26.4%) in the $MARS_{yr}$ and floor effects (33.6%) in the $MARS_{mo}$.

Cross-cultural adaptation approaches varied across MARS language versions despite following similar guidelines [12]. These variations reflected linguistic and cultural differences. The Thai version of the MARS required minimal changes, removing only “skiing” from the “pivoting” item due to cultural irrelevance. The Swedish version underwent more comprehensive modifications. These included substituting “fast change of direction” for “cutting” due to lack of equivalent terminology and replacing sample sports of the last item with activities commonly associated with knee injuries in Sweden [10].

Two recall timeframes were adopted for the Thai version of the MARS to comprehensively assess patient activity levels. The original version of the MARS uses a 1-year timeframe to capture patients' peak activity levels [4]. This aligns with the instrument's primary purpose of assessing pre-injury activity status and study population demographics.

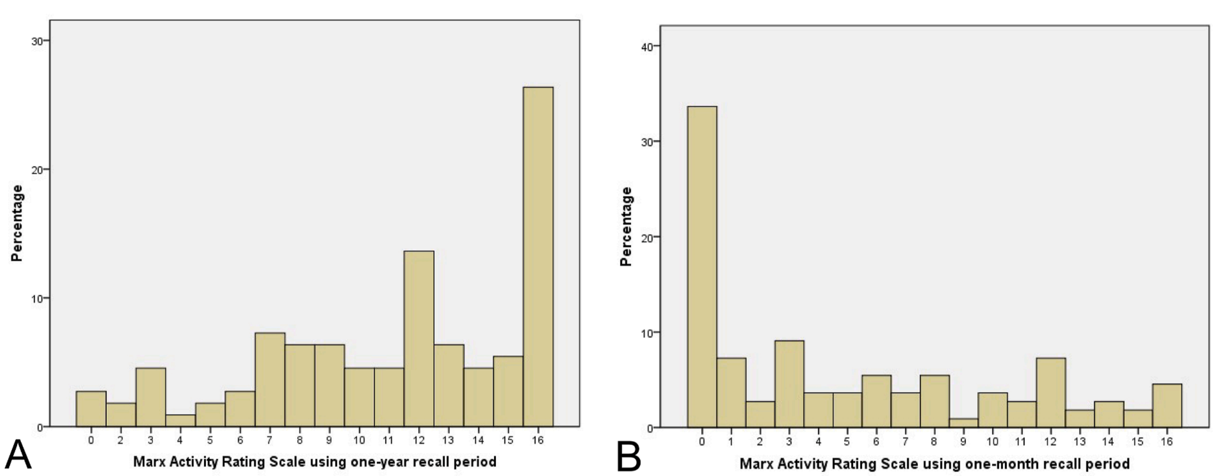

Fig. 1. Baseline Thai Marx Activity Rating Scale (MARS) score distribution by recall period. (A) One-year recall ($MARS_{yr}$) and (B) 1-month recall ($MARS_{mo}$).

Table 2
Construct validity of the Thai Marx Activity Rating Scale (MARS): Spearman's correlations with comparator patient-reported outcome measures.

	$MARS_{yr}$			$MARS_{mo}$		
	r_s	95% CI	*P* value	r_s	95% CI	*P* value
TAS_{yr}	0.51[a]	0.38 to 0.64	<0.001	−0.01	−0.18 to 0.16	0.929
TAS_{mo}	0.02	−0.15 to 0.19	0.817	0.61[a]	0.49 to 0.72	<0.001
IKDC-SKF	0.07	−0.10 to 0.23	0.503	0.29[a]	0.13 to 0.44	0.002
KOOS						
Pain	0.07	−0.11 to 0.23	0.499	0.26[a]	0.10 to 0.41	0.006
Symptoms	0.07	−0.11 to 0.23	0.502	0.17	0.01 to 0.33	0.075
ADL	0.15	−0.02 to 0.31	0.121	0.24[a]	0.08 to 0.40	0.012
Sport/Rec	0.11	−0.06 to 0.28	0.239	0.38[a]	0.23 to 0.52	<0.001
QoL	−0.01	−0.18 to 0.16	0.949	0.25[a]	0.09 to 0.41	0.008
EQ-5D-5L	0.18	0.02 to 0.34	0.058	0.13	−0.04 to 0.29	0.181

Abbreviations: ADL = activities of daily living; CI = confidence interval; EQ-5D-5L = European Quality of Life 5-Dimension 5-Level; IKDC-SKF = International Knee Documentation Committee Subjective Knee Form; KOOS = Knee Injury and Osteoarthritis Outcome Score; $MARS_{mo}$ = Marx Activity Rating Scale with a 1-month recall period; $MARS_{yr}$ = Marx Activity Rating Scale with a 1-year recall period; QoL = quality of life; r_s = Spearman's correlation coefficient; Sport/Rec = sports and recreation; TAS_{mo} = Tegner Activity Scale with a 1-month recall period; TAS_{yr} = Tegner Activity Scale with a 1-year recall period.
[a] P value < 0.05.

Table 3
Test-retest reliability for the Thai Marx Activity Rating Scale (MARS; $N = 110$).

	Mean difference[a] (95% CI)	ICC (95% CI)	SEM	SDC_{ind}	SDC_{grp}	MIC
$MARS_{yr}$	0.2 (−0.2 to 0.5)	0.93 (0.89–0.95)	1.2	3.3	0.3	2.3
$MARS_{mo}$	0.2 (−0.1 to 0.6)	0.94 (0.92–0.96)	1.3	3.5	0.3	2.6

Abbreviations: CI = confidence interval; ICC = intraclass correlation coefficient; $MARS_{mo}$ = Marx Activity Rating Scale with a 1-month recall period; $MARS_{yr}$ = Marx Activity Rating Scale with a 1-year recall period; MIC = minimal important change; SDC_{grp} = smallest detectable change at the group level; SDC_{ind} = smallest detectable change at the individual level; SEM = standard error of measurement.
[a] Mean difference between baseline and 2-week follow-up.

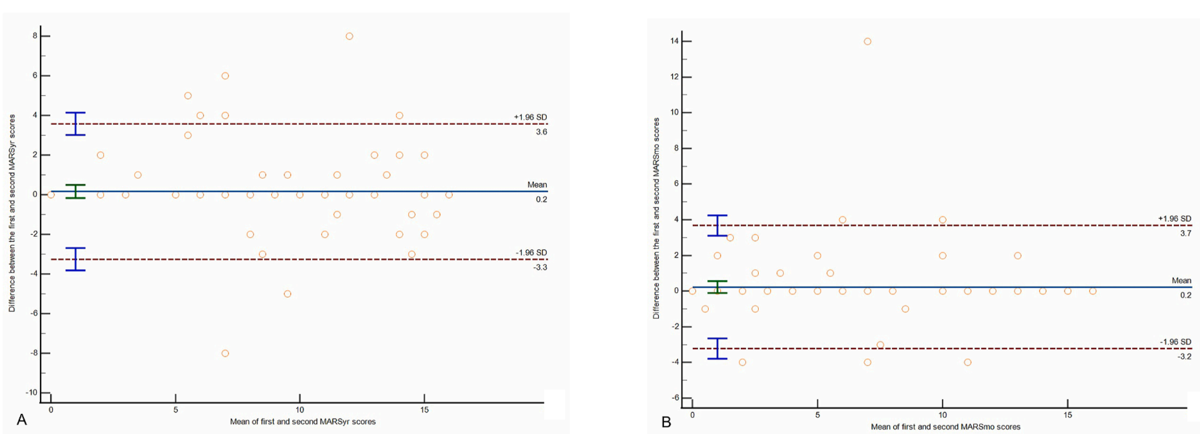

Fig. 2. Test-retest agreement of the Thai Marx Activity Rating Scale (MARS) depicted in Bland-Altman plots. (A) One-year recall ($MARS_{yr}$) and (B) 1-month recall ($MARS_{mo}$).

The 1-month timeframe is utilized to evaluate patient progression. The Swedish MARS validation study previously introduced this timeframe [10]. It corresponds to the instrument's lowest score option of "less than 1 time in a month." This distinction proved particularly relevant since most participants sustained injuries within the past year. The $MARS_{yr}$ indicated pre-injury status, while the $MARS_{mo}$ reflected current capabilities. The same dual timeframes were applied to the TAS to evaluate construct validity. Unlike the MARS, the original TAS does not specify a particular recall period [3,13].

Construct validity analysis confirmed the expected pattern. The strongest correlations occurred between the MARS and TAS with corresponding timeframes. This reflected their conceptual similarity in assessing physical activity levels, unlike other instruments that focus on symptoms and quality of life. The $MARS_{yr}$ demonstrated large correlation with the TAS_{yr} with $r_s = 0.51$. This value was lower than that of the original English version of the MARS ($r_s = 0.66$) but higher than that of the Swedish version ($r_s = 0.45$) [4,10]. The reported correlation between the $MARS_{mo}$ and TAS_{mo} in this study ($r_s = 0.61$) was also higher than in the Swedish version ($r_s = 0.50$), which also validated the $MARS_{mo}$ [10].

In this study, the $MARS_{mo}$ showed stronger correlations with IKDC-SKF and KOOS subscales than the $MARS_{yr}$, suggesting greater association with current functional status. The closer temporal alignment of the $MARS_{mo}$ with these instruments' recall periods may explain this pattern. The IKDC-SKF uses 4 weeks, KOOS uses 1 week, and $MARS_{mo}$ uses 1 month. Among knee-specific instruments, the $MARS_{mo}$ showed the strongest correlation with the KOOS sport/recreation subscale ($r_s = 0.38$), reflecting their shared focus on knee-demanding activities. However, these instruments differ in assessment approach. The MARS evaluates activity frequency while the KOOS sport/recreation subscale assesses perceived difficulty in performing activities. Validation studies across populations demonstrate different correlation patterns. In the Persian MARS validation study, the KOOS pain subscale had the highest

Table 4
Floor and ceiling effects of the Thai Marx Activity Rating Scale (MARS) stratified by time since injury.

	Time since injury			Total
	Less than 1 month	1 month to 1 year	More than 1 year	
$MARS_{yr}$				
Floor effect, *n* (%)	0 (0)	3 (3.6)	0 (0)	3 (2.7)
Ceiling effect, *n* (%)	3 (37.5)	24 (28.9)	2 (10.5)	29 (26.4)
$MARS_{mo}$				
Floor effect, *n* (%)	4 (50.0)	32 (38.6)	1 (5.3)	37 (33.6)
Ceiling effect, *n* (%)	0 (0)	5 (6.0)	0 (0)	5 (4.5)

Abbreviations: $MARS_{mo}$ = Marx Activity Rating Scale with a 1-month recall period; $MARS_{yr}$ = Marx Activity Rating Scale with a 1-year recall period.
Floor/ceiling effects defined as ≥15% of respondents attaining the minimum or maximum possible score.

correlation with MARS (r_s = 0.42), while the KOOS sport/recreation subscale had a small correlation (r_s = 0.12) [9].

The Thai version of the MARS demonstrated excellent internal consistency for both recall timeframes. Cronbach's α coefficients of 0.87 ($MARS_{yr}$) and 0.93 ($MARS_{mo}$) were acceptable and comparable to previous studies that reported values between 0.80 and 0.96 [9–11]. The excellent internal consistency indicates that all four MARS items consistently measure the same underlying construct of high-demand knee activity participation.

The Thai version of the MARS also demonstrated excellent test-retest reliability with ICC values of 0.93 to 0.94. Previous studies of other language versions reported a wide range of ICC values (0.78-0.97) [4,9–11], indicating consistently acceptable reliability across different populations. The excellent ICC values of the instrument indicate minimal measurement error and high stability over time, supporting its suitability for both research applications and clinical practice. The 2-week test-retest interval used in this study represents an optimal timeframe for reliability assessment, being long enough to minimize memory effects while short enough to expect stable clinical conditions [22]. In addition, the GRoC scale was administered alongside the Thai version of the MARS in the second assessment to verify the stable clinical condition of participants before including their data in the test-retest reliability analysis [24]. The consistent GRoC scores (range: −1 to +1) across all participants in this study supported the suitability of the chosen time interval.

For monitoring current activity progression, clinicians can use the $MARS_{mo}$ with a distribution-based MIC value of 2.6 points. This threshold is appropriate for group-level analyses, exceeding the corresponding SDC_{grp} value. For individual patient assessment, clinicians should use the higher SDC_{ind} value (3.5 points). This value ensures observed changes truly exceed measurement error. For instance, a 3.5-point increase in $MARS_{mo}$ score would indicate meaningful improvement in a patient's ability to participate in high-demand activities.

This study demonstrated substantial ceiling effects in the $MARS_{yr}$ and floor effects in the $MARS_{mo}$. This raises concerns about using the MARS as a standalone PROM. The instrument has limited ability to detect changes at the extreme ends of the scale. These limitations align with previous research. In the original MARS validation study, 17.5% of patients reported the lowest scores and 17.5% reported the highest scores [4]. Flosadottir et al. validated the Swedish MARS with 2 recall timeframes [10]. They demonstrated 56% floor effects in the $MARS_{mo}$. The $MARS_{yr}$ had 22% floor effects and 20% ceiling effects. Shirazi et al. found considerable ceiling effects (50.6%) when evaluating the MARS in patients younger than 18 years [26]. They attributed this to teenagers' diverse activity participation. This includes physical education classes, unorganized sports activities, and organized sports competitions. Cameron et al. evaluated 1169 cadets entering the US Military Academy [27]. Participants with knee injury history had higher median MARS scores than those without such history. Despite this difference, ceiling effects were present in both groups. This further demonstrates the instrument's limited discriminative ability at higher activity levels.

This study had some limitations. First, this study included predominantly male participants, which may affect the generalizability of results to female ACL-injured populations. Second, responsiveness analysis was not conducted for the Thai version of the MARS. The original English version of the MARS has not reported responsiveness data [2,4]. The Swedish MARS demonstrated responsiveness by confirming more than 75% of predefined hypotheses [10]. Third, MIC values were derived solely from a distribution-based approach. This may not reflect patients' perception of meaningful change. An anchor-based approach using patient-reported outcomes would provide more clinically relevant MIC estimates. Fourth, substantial floor and ceiling effects restrict the instrument's sensitivity to change. This particularly affects patients with very low current activity levels or a high pre-injury activity status. To overcome these limitations, clinicians should consider integrating the MARS with other knee-specific PROMs for comprehensive functional assessment.

CONCLUSION

The MARS was successfully cross-culturally adapted into the Thai version. It exhibits acceptable psychometric properties for quantifying physical activity in ACL-injured populations. Floor/ceiling effects necessitate complementary outcome measures for comprehensive functional assessment.

Informed consent

All enrolled patients provided written informed consent to participate in this study.

Ethics approval

The study protocol was approved by the Siriraj Institutional Review Board of the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (reference: 310/2023).

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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