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Cross-cultural adaptation, validity, and reliability of the Turkish version of the Athlete Disability Index

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Cross-cultural adaptation, validity, and reliability of the Turkish version of the Athlete Disability Index

Abstract

Background The Athlete Disability Index (ADI) is a self-administered scale developed specifically for athletes to assess functional disability due to low back pain. This study aimed to translate and adapt the ADI into Turkish, examine its validity and reliability, and to evaluate its clinical applicability in athletes with non-specific low back pain (NSLBP).

Methods A total of 130 athletes aged 18-35 years with NSLBP were recruited. Criterion validity was examined by correlating ADI-Tr scores with the Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), and Roland-Morris Disability Questionnaire (RMDQ). Floor and ceiling effects were evaluated. Test-retest reliability was assessed using the intraclass correlation coefficient (ICC), internal consistency using Cronbach's alpha, and measurement error using the standard error of measurement (SEM) and minimal detectable change (MDC_{95}). Structural validity was evaluated using exploratory (EFA) and confirmatory factor analyses (CFA).

Results No floor or ceiling effect (0% for both) was observed. The ADI-Tr demonstrated excellent reliability (ICC=0.98) and moderate to strong internal consistency (Cronbach's α=0.887) and significant correlations with established measures, such as the ODI (r=0.646), and RMDQ (r=0.615). The ADI-Tr demonstrated high measurement precision (SEM=2.20; MDC_{95}=6.10). EFA and CFA supported a unidimensional structure of the ADI-Tr. These results indicate that the ADI-Tr is a reliable instrument for evaluating functional disability due to NSLBP in Turkish-speaking athletes.

Conclusions This study demonstrated that the ADI-Tr is a culturally adapted, valid, and reliable with excellent test-retest reliability and high internal consistency for assessing functional limitations due to non-specific low back pain in athletes. It can be effectively used in both clinical practice and research settings.

Trial registration NCT06700707 (Registration Date: 20 November 2024)

Keywords Athletes, Disability, Low back pain, Reliability, Validity

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Background

Non-specific low back pain (NSLBP) is a common musculoskeletal problem worldwide, reducing quality of life and creating significant economic burdens at both individual and societal levels [1,2]. This condition affects not only the general sedentary population but also physically active individuals. A 2020 meta-analysis reported a 12-month prevalence of low back pain (LBP) among athletes of 51% [3]. Another meta-analysis conducted in adolescent athletes reported a prevalence rate of 42%, identifying high training volume, lower extremity pain, high body mass index, and female sex as significant risk factors [4].

While physical activity is known to play an important role in the prevention and treatment of LBP, intense physical activity may, in some cases, increase the risk of developing back pain [5]. Factors such as the frequency, duration, and intensity of training and competition in athletes, as well as the type of sport and level of competition, can increase the load on the musculoskeletal system and create stress on the low back region [5,6]. Even when the impact on activities of daily living is minimal, LBP can negatively affect the continuity of training and athletic performance [7]. Therefore, measurement tools that accurately assess functional limitations specific to athletes are needed.

The most commonly used scales for assessing LBP include the Oswestry Disability Index (ODI), the Roland-Morris Disability Questionnaire (RMDQ), and the Quebec Back Pain Disability Scale (QBPDS) [8-11]. However, although these scales are appropriate for the general population, they may be inadequate in reflecting sport- and training-specific functional limitations in athletes. The Micheli Functional Scale is one of the few instruments developed to assess low back pain in athletes; however, it was designed exclusively for adolescent and young athletic populations, lacks a Turkish adaptation, and has a relatively limited evaluative scope [12].

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The Athlete Disability Index (ADI) is a self-administered, athlete-specific instrument developed to assess functional disability associated with LBP in adult athletes aged 18 years and older [13]. It has demonstrated significant correlations with the ODI and the RMDQ, supporting its validity in evaluating functional impairment in athletic populations [8]. In addition, a prior cross-cultural adaptation of the ADI into Italian and French have been conducted, and the both studies demonstrated a valid and reliable instrument for assessing disability levels in athletes with LBP [14,15]. Despite its clinical relevance, a psychometrically validated Turkish version of the ADI is currently lacking, representing a notable limitation for clinicians and researchers working in athlete health in Türkiye. Given its broader applicability across diverse athletic age groups and its comprehensive assessment framework, adapting the ADI into Turkish is essential for effective use in both clinical practice and research.

The aim of this study was to translate and adapt the ADI into Turkish, evaluate its validity and reliability, and assess its clinical applicability in athletes with NSLBP. This study aims to contribute to the literature by providing a valid and reliable tool for assessing disability due to NSLBP in athletes in Türkiye.

Methods

Study Design and Participants

This study is a cross-cultural adaptation and psychometric evaluation of the ADI, involving its translation from the original language into Turkish, cultural adaptation, and the assessment of its validity and reliability in athletes with LBP. The research was conducted between February and June 2025 at Istanbul Medipol University and Medipol Koşuyolu Hospital.

The diagnostic criteria for NSLBP in this study were defined in accordance with international clinical guidelines, including the NICE guideline NG59, the WHO guideline for chronic primary LBP, and the IASP Classification of Chronic Pain [1,16,17]. All participants were screened to exclude red-flag conditions such as infection, fracture, malignancy, and significant neurological deficits. A total of 130 athletes aged 18-35 years from sports clubs and university sports teams with NSLBP persisting for more than six weeks were recruited from sports clubs and university sports teams. Inclusion criteria were as follows: (1) fluency in spoken and written Turkish, (2) engagement in ≥6 hours of training per week, and (3) pain aggravated by changes in posture, movement, or physical activity. Athletes were excluded if they had a recent musculoskeletal injury; spinal pathologies

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such as malignancy, inflammatory spondyloarthropathy, cauda equina syndrome, or progressive neurological deficits; a history of recent lumbar surgery, corticosteroid use; abnormal bowel or bladder function; or pregnancy. Written informed consent was obtained from all athletes and the study was conducted with ethical approval from the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee. The study has been registered at ClinicalTrials.gov (NCT06700707). All procedures were conducted in accordance with the ethical standards of the responsible committee on human experimentation and with the Declaration of Helsinki.

Translation and Cross-Cultural Adaptation

Permission for the cultural adaptation, validity, and reliability assessment of the ADI was obtained from the original developers of the questionnaire. The five-step translation and cross-cultural adaptation model proposed by Beaton et al. was applied [18]. Figure 1 illustrates the flowchart of the translation and adaptation processes of the ADI.

(1) **Initial Translation:** The original ADI was translated into Turkish by two bilingual translators whose native language is Turkish and who are fluent in English. One translator was familiar with health and disability terminology, while the other had no medical background, in order to capture both medical and everyday cultural nuances. This step resulted in two initial Turkish versions (V1 and V2).

(2) **Synthesis of Translations:** The two translated versions were compared to identify discrepancies and ambiguous terms. These issues were discussed by the translators, and a third independent reviewer synthesized V1 and V2 to produce a preliminary Turkish version of the scale.

(3) **Back-Translation:** The preliminary Turkish version was back-translated into English by two independent linguists who were blinded to the original version and unfamiliar with the concepts of the scale. Both were proficient in English and Turkish.

(4) **Expert Committee Review:** The expert panel, consisting of two physiotherapists specialized in musculoskeletal rehabilitation (with 9 and 18 years of clinical and academic experience) and one sports medicine physician carefully reviewed the translated version of the Turkish version of the ADI. The panel compared the back-translated version with the original English scale to identify potential discrepancies, semantic

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inconsistencies, and culturally inappropriate expressions. All identified issues were discussed until a consensus was reached. In addition, feedback was obtained from the original developer of the ADI scale to ensure conceptual and semantic equivalence. Based on the expert and author feedback, minor modifications were made to better reflect Turkish language clarity and cultural context. These refinements ensured both linguistic fidelity and cultural relevance of the final ADI-Tr version.

(5) **Pilot Testing:** The pre-final version was administered to 20 athletes with NSLBP who met the study's inclusion criteria. Athletes were asked to evaluate the clarity, readability, and cultural relevance of each item and to provide feedback. Items that were not understood by at least 20% of participants were revised by the expert committee, resulting in the finalized Turkish version of the ADI (ADI-Tr).

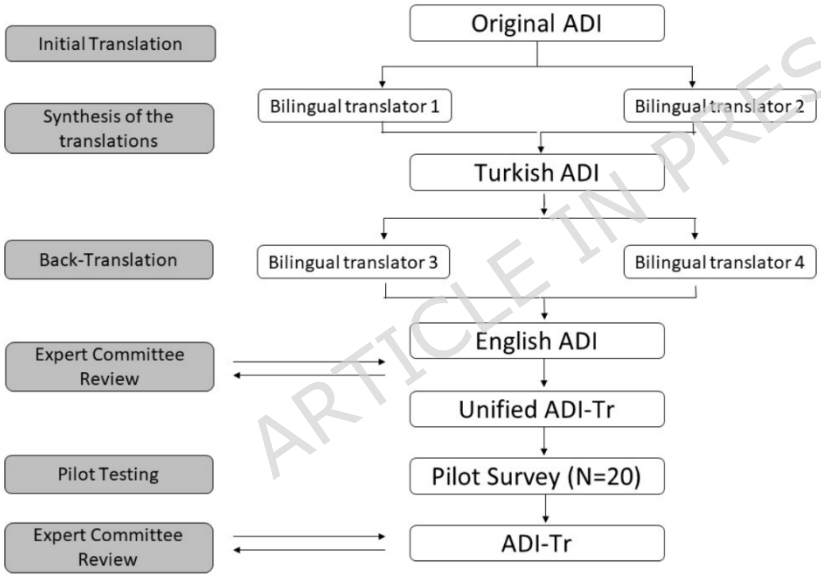

Fig. 1 Flowchart of the translation and adaptation procedures for the ADI

Measurement instruments

Athletes' age, gender, sport, duration of participation in this sport, and the duration of NSLBP were recorded using a demographic information form. Athletes were asked to complete the ADI-Tr, the Visual Analogue Scale (VAS), the ODI, and the RMDQ. To assess test-retest reliability, the same athletes were asked to complete the ADI-Tr again 7 days later [19]. All questionnaires were completed face to face by the participants.

The ADI-Tr is a self-administered, athlete-specific scale consisting of 12 items

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that assess pain and functional limitations related to stretching, strength, technical skills, rotational movements, fear of re-injury, sitting, walking, sleep, and personal care. Each item is scored on a 4-point Likert scale reflecting the severity of pain and functional limitation, with response options as follows: 0=“no pain or restrictions,” 1=“no restrictions but some pain,” 2=“some restrictions to limit pain,” and 3=“restricted due to pain.” The total score is calculated by summing the scores of all 12 items, yielding a minimum score of 0 and a maximum score of 36. The total score is then divided by 36 and multiplied by 100, with higher scores indicating greater pain-related functional limitation [13].

The VAS is a self-report measure consisting of a horizontal or vertical line, usually 10 cm in length, with the endpoints representing “no pain” and “worst imaginable pain.” Participants are asked to mark the point on the line that best represents their perceived pain intensity [20].

The ODI is a 10-item Likert-type questionnaire assessing pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. Each item is scored from 0 to 5 (0=no difficulty, 5=maximum difficulty), and the total score is 50. The following formula is used to calculate the score: Final score=[total score]/[(number of marked questions)x5]x100. Higher percentages indicate greater perceived disability. The validity and reliability of the Turkish version of the ODI have been previously established [21].

The RMDQ was developed by selecting 24 of the 136 items from the Illness Impact Profile. The scale assesses activity level, activities of daily living, eating, and sleep. A "Yes" response to each item is calculated as 1 point, and a "No" response is calculated as 0 points. The total score ranges from 0 to 24; higher scores indicate worse functional status. The validity and reliability study of the Turkish version was conducted by Kücükdeveci et al [22].

Statistical analysis

All analyses were performed using Statistical Product and Service Solutions (SPSS) software, version 27.0 (SPSS INC, Armonk, New York). Descriptive statistics were utilized to summarize participant demographics, pain duration, and pain intensity. Normality of the continuous variables including age, training duration, pain duration, and scores on the VAS, ODI, RMDQ, and ADI-Tr, was assessed using the Kolmogorov-Smirnov test. The results indicated that none of the continuous variables were normally distributed ($p<0.05$). A two-tailed significance level of $p<0.05$ was adopted for all statistical analyses.

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Sample Size Calculation. The minimum sample size required to evaluate the test-retest reliability of the ADI-Tr was calculated using the method suggested by Bonett [23]. Within the scope of the analysis, the target reliability coefficient (Intraclass Correlation Coefficient, ICC) was set at 0.80 and the width of the confidence interval was limited to ±0.10 (total width:0.20). According to the calculation made based on the 95% confidence level ($Z_{1-\alpha/2}$=1.96) and two repeated measurements (k=2), at least 100 participants are required to evaluate the test-retest reliability at the desired level and precision. Assuming a potential dropout rate of 20%, the minimum required sample size was increased to 125 participants.

Floor or Ceiling Effects. The presence of potential floor and ceiling effects on the ADI-Tr was evaluated. A floor effect occurs when a significant portion of participants achieve the lowest possible score, while a ceiling effect occurs when a significant portion of participants receive the highest possible score. This reduces the scale's ability to discriminate between individuals at extreme values, leading to decreased measurement sensitivity and potential bias. To assess floor and ceiling effects, frequency and percentage distributions of participants who received the minimum (0) and maximum (3) scores for each item were calculated. A similar analysis was also performed on the total ADI score. According to a widely accepted criterion in the literature, if the lowest or highest score for an item or total score is received by more than 15% of participants, this indicates the presence of a floor or ceiling effect [24,25]. In this context, floor and ceiling effects analyses were conducted for all items and the total score for the ADI-Tr scale, and the evaluation was based on a 15% threshold.

Criterion Validity. Criterion validity was evaluated by examining the relationship between ADI-Tr and the VAS, ODI and the RMDQ, using Spearman’s rho (r_s) [26,27]. Convergent validity was assessed through correlations of the ADI-Tr with age, VAS, ODI, and RMDQ. Divergent validity was examined using sport career, weekly training time, and pain duration. The strength of the correlations was interpreted based on the criteria proposed by Portney and Watkins [28]: values above 0.75 indicated a strong to excellent correlation; values between 0.50 and 0.75 indicated a moderate to strong correlation; values between 0.25 and 0.50 reflected a fair correlation; and values below 0.25

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suggested little or no correlation.

Structural Validity. To examine the factor structure of the ADI-Tr, a two-step approach was employed. First, exploratory factor analysis (EFA) was conducted to examine the underlying factor structure of the scale. Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity [29]. EFA was performed using principal axis factoring, which is recommended for identifying latent constructs when data may deviate from multivariate normality. The number of factors was determined based on eigenvalues greater than 1 and visual inspection of the scree plot [30].

Second, confirmatory factor analysis (CFA) was conducted to test the factor structure identified by the EFA and to evaluate model fit. Model fit was assessed using the chi-square to degrees of freedom ratio (χ^2/df), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA) [31]. Conventional criteria were applied to determine acceptable and excellent model fit. This two-step approach allowed for a comprehensive evaluation of the structural validity of the ADI-Tr and ensured that the observed factor structure was both data-driven and theoretically supported.

Test-Retest Reliability. To assess the test–retest reliability, the ADI-Tr was administered twice with a 7-day interval. In accordance with established psychometric guidelines, a 7-day interval was selected, as it is sufficiently long to minimize recall bias while remaining short enough to reduce the likelihood of true clinical or functional change in individuals with stable musculoskeletal conditions [ref]. To support the assumption of participant stability, all athletes were instructed to maintain their usual training routines, avoid initiating new treatment or rehabilitation programs, and refrain from increasing training intensity during the interval. Participants reporting any changes were excluded from the analysis. Test–retest reliability of the ADI-Tr was assessed using the Intraclass Correlation Coefficient (ICC), calculated via a two-way random-effects model for absolute agreement, single measures, following the Shrout and Fleiss notation as ICC(2,1). ICC values above 0.75 were interpreted as excellent reliability, between 0.60–0.74 as good, between 0.40–0.59 as fair, and below 0.40 as poor reliability [32].

Internal consistency was assessed using Cronbach's alpha coefficient. In addition, item-total correlations were calculated by correlating each item with

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the total score, excluding that item from the total. To control for potential inflation of Type I error due to multiple item-total correlation analyses, p values were adjusted using the Benjamini-Hochberg false discovery rate (FDR) procedure (q=0.05). Cronbach's alpha values ranging between 0.70 and 0.90 were considered to indicate high internal consistency [28]. The standard error of measurement (SEM) and, minimal detectable change (MDC_{95}) were calculated using the standard formulas ($SEM=SD\sqrt{(1–ICC)}$; $MDC_{95}=SEM\times1.96\times\sqrt{2}$) on the 0–100 scale [33]. Responsiveness and anchor-based minimal clinically important difference (MCID) were not evaluated due to the cross-sectional design of the study and the absence of an external criterion of change. Instead, measurement error was quantified using the SEM and the minimal detectable change at the 95% confidence level (MDC_{95}), in accordance with psychometric recommendations for reliability studies. Distribution-based MCID estimates were interpreted as preliminary indicators of meaningful change rather than definitive clinical thresholds.

Results

A pilot test was conducted with a sample of 20 athletes to evaluate the preliminary ADI-Tr. Based on feedback from expert reviewers and findings from the pilot testing, the final version of the ADI-Tr was established for psychometric evaluation. This final version was subsequently administered to 130 athletes in the main study to assess its validity and reliability. Of the 130 participants, 122 completed the second administration and were included in the test–retest reliability analysis. Eight participants declined to participate in the retest and were therefore excluded from this analysis. Consequently, test–retest reliability was evaluated using data from 122 athletes. The flowchart illustrating the validity and reliability process is presented in Figure 2.

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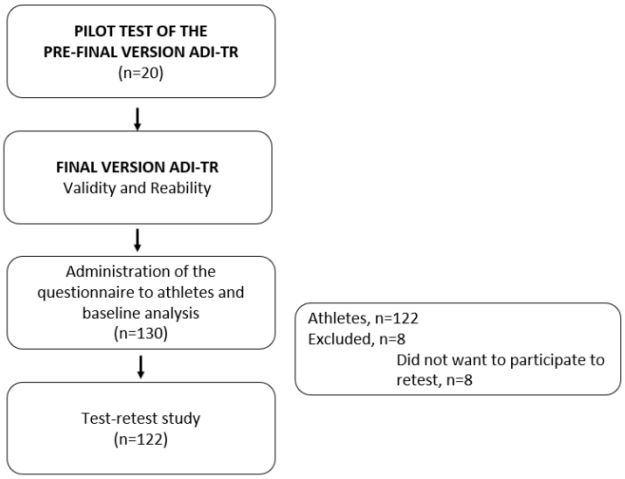

Fig. 2 A Flowchart for the validity and reliability process

The demographic characteristics of the participants and the scores of patient-reported outcome measures are presented in Table 1. Pain duration exhibited a highly skewed distribution and was therefore reported using the median and interquartile range (IQR). The median pain duration was 4 months (IQR = 8).

Table 1 Participants' characteristics (n=130)

Demographics	Mean±SD (Min-max)	N (Percentage)
Age (years)	23.93±4.43 (18-35)	
Sport career (years)	9.17±4.6 (1-25)	
Training time (hour/weeks)	9.72±3.76 (6-22)	
VAS (0-10)	4.42±1.74 (1-8)	
RMDQ	7.5±4.41 (0-21)	
ODI	26.43±16.5 (2-74)	
ADI-Tr	30.24±15.61 (2.78-94.44)	
Sex (male/female)		90/40 (69% / 31%)
Types of sports		
Football		42 (32.3%)
Combat sports		27 (20.8%)
Body building		19 (14.6%)
Volleyball		14 (10.8%)
Basketball		10 (7.7%)
Swimming		5 (3.8%)
Cycling		5 (3.8%)
Track and field		5 (3.8%)
Racket sports		3 (2.3%)

SD: Standard deviation, LBP:Low back pain, VAS: Visual analog scale, RMDQ:Roland-Morris Disability Questionnaire, ODI: Oswestry Low Back Pain Disability Index, ADI-Tr:Turkish Version of Athlete Disability Index

Content validity

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Based on recommendations from the expert panel and feedback from the original authors, minor linguistic and cultural modifications were made to items 5, 10, and 11 of the ADI-Tr during the pilot testing phase to enhance clarity and comprehensibility for the target population. The translations were reviewed and refined while preserving conceptual equivalence. Following expert consensus and evaluation of the pilot test results, the finalized items were determined to more clearly and accurately reflect the intended constructs.

Floor or ceiling effects

No floor or ceiling effects were observed in the current study. Among the total sample (n=130), the ADI-Tr scores ranged from 2.78 to 94.44 (M=30.24, SD=15.61), with no participants scoring the minimum (0) or maximum (36) possible points on the scale. According to the commonly accepted criterion, a floor or ceiling effect is considered present if more than 15% of the participants achieve the lowest or highest possible score. In this study, both the floor and ceiling effect rates were 0%, well below the 15% threshold.

Criterion validity

The ADI-Tr demonstrated a statistically significant fair positive association with age (rs=0.266, p=0.002) and pain intensity measured by the VAS (r_s=0.448, p<0.001) and moderate to strong positive association with the ODI (r_s=0.646, p<0.001), as well as the RMDQ (r_s=0.615, p<0.001), supporting convergent validity. No significant associations were observed between the ADI-Tr and sport career, training time and duration of the pain (p>0.05), providing evidence for divergent validity (Table 2).

Table 2 Criterion validity of ADI-Tr (indicated by Spearman's rho)

Measure	Spearman's rho (r_s)	p value
Age (years)	0.266**	0.002
Sport career (years)	0.005	0.954
Training time (hour/weeks)	0.076	0.387
Duration of LBP (months)	-0.048	0.590
VAS (0-10)	0.448**	<0.001
RMDQ	0.615**	<0.001
ODI	0.646**	<0.001

**. Correlation is significant at the 0.01 level (2-tailed), ADI-Tr: Turkish Version of Athlete Disability Index,
LBP:Low Back Pain, VAS: Visual Analog Scale, RMDQ:Roland-Morris Disability Questionnaire, ODI: Oswestry Low Back Pain Disability Index

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Structural Validity

Exploratory factor analysis demonstrated that the data were suitable for factor analysis (KMO=0.92; Bartlett's test χ^2=533.08, p<0.001). EFA revealed a clear one-factor structure with an eigenvalue of 5.45, explaining approximately 45% of the total variance. All items loaded strongly on the single factor, all above 0.40, with factor loadings ranging from 0.48 to 0.76 (Table 3).

Confirmatory factor analysis was conducted to test the one-factor model identified by EFA. The model demonstrated excellent fit to the data (χ^2/df=1.04, p=0.40; CFI=0.996; TLI=0.995; RMSEA=0.017). All items loaded significantly on the latent factor, confirming the unidimensional structure of the ADI-Tr.

Test-retest reliability

The test–retest reliability of the ADI-Tr was found to be excellent, as indicated by a very high intraclass correlation coefficient (ICC(2,1)=0.98, 95%CI: 0.96–0.98, F(121,121)=78.73, p<0.001), demonstrating that the instrument yields highly stable and reproducible scores over repeated administrations.

Item-Total Correlations and Internal Consistency

The corrected item–total correlation coefficients for the ADI-Tr items ranged from 0.451 to 0.715, indicating acceptable to strong correlations between individual items and the total scale score (Table 3). The lowest item-total correlation was observed for item 12 (r_s=0.451; sexual activity), while the highest was found in item 9 (r_s=0.715; personal care).

The internal consistency of the ADI-Tr was assessed using Cronbach's alpha, which was calculated as 0.887 (95%CI:0.805–0.921), reflecting a high level of internal reliability. This value exceeds the commonly accepted threshold of 0.70 for adequate internal consistency [28], suggesting that the scale items consistently measure the same underlying construct functional disability in athletes with low back pain.

The standard error of measurement (SEM=2.20) and the minimal detectable change at the 95% confidence level (MDC_{95}=6.10) suggest that the ADI-Tr demonstrates excellent measurement precision. A distribution-based estimate of minimal clinically important difference (MCID) was calculated to provide an initial benchmark for clinically meaningful change. Using the 0.5 SD approach, the estimated MCID was 7.81 points on the 0–100 ADI-Tr scale.

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Table 3 Structural validity and item-total correlation of the ADI-Tr

No	Test item	Factor Loadings	Corrected item-total correlation	p*
1	Low Back Pain	0.65	0.610	<0.001
2	Stretching exercises	0.63	0.592	<0.001
3	Strengthening /weight training exercises	0.52	0.482	<0.001
4	Your sport-specific moves or skills	0.69	0.640	<0.001
5	Movement involving back rotations or change of direction	0.64	0.598	<0.001
6	Sitting	0.60	0.565	<0.001
7	Walking	0.70	0.667	<0.001
8	Sleep	0.63	0.594	<0.001
9	Personal care (putting on socks and shoes, going to the bathroom)	0.76	0.715	<0.001
10	Fear of causing pain or damaging the back	0.62	0.577	<0.001
11	Leisure activities	0.67	0.631	<0.001
12	Sexual Activity	0.48	0.451	<0.001

ADI-Tr: Turkish version of athlete disability index, *All items–total correlation p values remained statistically significant after Benjamini–Hochberg FDR correction (q=0.05).

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Discussion

The aim of this study was to validate the Turkish version of the ADI-Tr and to examine its psychometric properties in athletes with NSLBP. The findings demonstrated that the ADI-Tr possesses adequate psychometric properties comparable to those reported for the original Persian version of the scale [34]. Overall, the results indicate that the ADI-Tr is a culturally adapted, valid, and reliable instrument for assessing functional limitations associated with NSLBP in athletic populations. In addition, the ADI-Tr showed statistically significant correlations with other validated measures, including the ODI and the RMDQ, supporting its concurrent validity. Furthermore, both exploratory and confirmatory factor analyses confirmed a clear unidimensional structure of the ADI-Tr, consistent with the original version of the scale. This supports the interpretation of the ADI-Tr using a single total score and strengthens its practicality and holistic usefulness in clinical settings. Collectively, these findings provide strong evidence for the structural validity of the Turkish adaptation.

Azevedo et al. (2023) identified the ADI as one of the three most valid and reliable questionnaires for assessing disability in athletes, highlighting its sport-

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specific focus [8]. Unlike widely used instruments such as the ODI and RMDQ, which were developed for the general population, the ADI uniquely incorporates both daily activity–based and performance- and sport-specific domains. In the present study, the cultural adaptation process conducted according to the methodology proposed by Beaton et al. ensured that the ADI-Tr accurately reflected the experiences of Turkish-speaking athletes with NSLBP. The significant correlations with established disability measures and the high internal consistency observed in this study further support the validity and reliability of the ADI-Tr in this population.

Analysis of floor and ceiling effects revealed that no participants achieved either the minimum (0) or maximum (36) total ADI-Tr score, indicating that the scale has sufficient discriminatory capacity across the full range of disability severity. According to the widely accepted 15% threshold criterion [35], no floor or ceiling effects were present for the total score of the ADI-Tr. This finding suggests that the scale is capable of capturing both mild and more severe functional limitations, supporting its sensitivity to change. Consequently, the ADI-Tr appears suitable for monitoring rehabilitation progress and evaluating treatment effectiveness over time in both clinical and research settings.

Previous research by Noormohammadpour et al. (2018) demonstrated that the original ADI exhibits high test–retest reliability (ICC=0.74-0.94) and strong internal consistency (Cronbach's α=0.91) in elite athletes with low back pain. That study also reported strong correlations with the ODI (r_s=0.918), moderate correlations with the RMDQ (r_s=0.669), and fair correlations with the VAS (r_s=0.448), supporting the instrument's reliability and validity [34]. Similar psychometric properties have been reported in subsequent French and Italian cross-cultural adaptation studies, both of which demonstrated good internal consistency, satisfactory construct validity, and meaningful associations with established disability and pain-related measures [14,15]. These findings collectively support the robustness of the ADI across different linguistic and cultural contexts.

Consistent with the existing literature, this study demonstrated that the ADI-Tr provides highly stable measurements over time in Turkish athletes, exhibiting excellent test–retest reliability (ICC=0.98) and high internal consistency (Cronbach's α=0.887). These findings suggest that the scale is a reliable instrument for use in clinically stable conditions [36]. Furthermore, the significant correlations observed between the ADI-Tr and the VAS (r_s=0.448),

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ODI (r_s=0.646), and RMDQ (r_s=0.615) support the construct validity of the scale in assessing disability related to LBP. The moderate correlation between the ADI-Tr and the VAS is consistent with previous evidence indicating that pain intensity and functional disability, although related, represent distinct constructs. This finding suggests that assessments focusing solely on pain intensity may underestimate functional limitations in athletic populations. While the VAS evaluates pain intensity as a unidimensional construct, the ADI-Tr captures the multidimensional impact of pain on sports performance, functional capacity, and activities of daily living. Consequently, changes in pain intensity may not directly correspond to changes in functional disability. Finally, the consistency of these findings with those reported in other language versions further strengthens the evidence supporting the validity of the ADI-Tr and underscores its potential utility in both clinical practice and research across diverse athletic populations.

The construct validity of the ADI-Tr, specifically its convergent validity, was supported by significant correlations with age, pain intensity, and established disability measures (ODI and RMDQ), consistent with previous validation study [34]. These findings, supporting significant correlations with age, are consistent with previous evidence showing that increasing age increases the functional impact and disability associated with low back pain, even in physically active populations [37]. Lack of significant correlations with sport career, training time, and pain duration provides evidence for divergent validity, demonstrating that the ADI-Tr specifically measures disability rather than unrelated factors. These findings support the scale's use for assessing functional limitations in athletes. In other words, an athlete's current level of disability is not solely determined by training history or chronic pain exposure. This observation suggests that the ADI-Tr reflects functional disability related to low back pain, which may vary across individuals and age groups. Consistent with previous literature, performance limitations appear to be more strongly associated with individual load tolerance and pain response [38].

The standard error of measurement (SEM=2.20) and the minimal detectable change at the 95% confidence level (MDC_{95}=6.10) demonstrate that the ADI-Tr provides high measurement precision with minimal random error. A change exceeding 6 points on the 0-100 scale can therefore be interpreted as a true change. Due to the cross-sectional design of the study and the absence of longitudinal intervention data and an external anchor reflecting true clinical change, anchor-based or distribution-based analyses of the MCID could not be

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performed. Accordingly, the reported MDC_{95} value reflects a threshold for change that exceeds measurement error rather than a clinically meaningful improvement or deterioration. Nevertheless, the SEM and MDC findings indicate that the ADI-Tr demonstrates high measurement stability and is capable of reliably detecting real changes in disability levels among athletes with LBP. The accuracy of this measurement is clinically significant, as it can influence training modifications, rehabilitation planning, and return-to-sport decisions for athletes with LBP. From a psychometric perspective, these results support the use of ADI-Tr as a suitable, stable, and reliable outcome measure for both individual follow-up and group-level comparisons in clinical and research settings.

All items of the ADI-Tr demonstrated acceptable items–total correlations. However, the “sexual activity” item (item 12) showed a relatively lower correlation (r=0.451) compared to other items. This finding does not indicate poor item reliability; rather, it likely reflects variability in response patterns related to factors such as age, marital status, athletes’ engagement in this activity, as well as personal values and sociocultural norms. Similar response patterns have been reported in the original validation of the ADI, where cultural sensitivity was noted to influence responses to this item, resulting in comparatively lower item–total correlations. In the present study, this relative inconsistency did not adversely affect the overall internal consistency or structural validity of the scale, as evidenced by the Cronbach’s alpha remaining high even when this item was included. Importantly, this observation underscores that certain items—particularly those addressing sensitive topics—may exhibit different psychometric behavior, a phenomenon commonly reported in disability questionnaires. Accordingly, the lower item–total correlation for the sexual activity item likely reflects socially influenced response variability or differential item functioning rather than a weakness in the overall reliability of the ADI-Tr [39].

Existing LBP assessment scales inadequately capture sport-specific demands such as exercise performance, technical skills, and rapid directional changes, and athletes may experience limitations during sports activities despite reporting no difficulties in daily living [7,40]. In this regard, the ADI differs from conventional LBP questionnaires by addressing both daily living and sport-specific functions and by offering a broader score distribution that allows more precise discrimination between individuals. Establishing the validity and reliability of the ADI for the Turkish population therefore represents an important contribution to

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the assessment of LBP in athletes. This need is further emphasized by the absence of a Turkish adaptation of the Micheli Functional Scale, which was limited to adolescent athletes [12]. Overall, the findings demonstrate that the ADI-Tr is a psychometrically robust instrument capable of identifying sport-related functional limitations that may be overlooked by general LBP measures, thereby supporting individualized rehabilitation planning and informed clinical decision-making. From a clinical perspective, the usability of ADI-Tr allows sports physicians and physiotherapists to measure the functional limitations associated with LBP in athletes using a tool specifically tailored to athletic activities. Traditional LBP scales may not record problems that only arise in high-performance situations. For example, an athlete might receive a score of zero on the ODI, indicating no disability if they can perform daily tasks, but receive a significant disability score on the ADI-Tr due to pain experienced during sprinting or weightlifting. Our findings demonstrate that ADI-Tr can capture these more subtle, sport-specific deficits, which have significant real-world implications: coaches and clinicians can identify issues that might be missed by general scales, leading to more targeted interventions.

This study has several limitations. First, the predominance of male athletes in the sample may limit the generalizability of the findings to female athletes. In addition, because the study included only individuals aged 18-35 years, the validity and reliability of the ADI-Tr cannot be inferred for younger or older athletic populations. The restriction of the age range to 18-35 years was intentionally adopted to minimize the potential confounding effects of age-related variability in musculoskeletal function and to ensure a more homogeneous athletic cohort; however, this methodological choice inherently limits generalizability. Although participants were recruited from various sports branches, sport-specific functional differences were not examined. Future research should therefore evaluate the psychometric properties of the ADI-Tr in larger and more representative samples with balanced sex distribution, broader age ranges, and different sport levels (e.g., amateur, professional, elite). Moreover, prospective studies incorporating pre- and post-treatment assessments are needed to determine the scale’s sensitivity and responsiveness to clinical change. Beyond these factors, psychological and sport-specific variables such as fear-avoidance beliefs, pain conceptualisation, pain catastrophizing, recovery–stress balance, and training load characteristics should also be explored, as they may influence perceived disability and enhance

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understanding of the ADI-Tr's applicability. Finally, conducting validation studies across diverse cultural and linguistic groups would further support the international utility of the scale.

Conclusion

This study demonstrated that the ADI-Tr can be successfully adapted culturally and is a valid and reliable assessment tool for athletes with NSLBP. Unlike scales designed for the general population, the ADI-Tr uniquely evaluates both activities of daily living and sport-specific functional skills, providing clinicians with a more comprehensive understanding of how pain affects athletic performance. The scale's excellent test–retest reliability, high internal consistency, significant correlations with established measures, and absence of floor and ceiling effects further confirm its psychometric robustness. By addressing athlete-specific domains not captured by generic instruments such as the ODI and RMDQ, the ADI-Tr offers added clinical value for individualized rehabilitation planning and return-to-sport decision-making. Moreover, as part of the internationally validated ADI framework, this Turkish adaptation facilitates cross-cultural comparisons and enables the inclusion of Turkish-speaking athletes in multinational research and meta-analyses on sports-related low back pain.

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Declarations

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication Not applicable.

Conflict of interest The authors have no competing interests to declare that are relevant to the contents of this article.

Ethical approval and consent to participate This study was approved by the Istanbul Medipol University Non-Interventional Clinical Studies Ethics Committee (E-10840098-202.3.02-7375; 04.12.2024). This study followed the ethical principles of the Helsinki Declaration for human research.

Authors' contributions

Conceptualization, G.A.B., G.E.S.; methodology, G.A.B., G.E.S., M.S, B.U., and R.K.; software, G.A.B., G.E.S.; validation, MS., G.E.S., and R.K.; formal analysis, G.A.B., and G.E.S.; data curation, G.E.S., and B.U.; writing-original draft

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preparation, G.A.B., G.E.S., M.S, B.U., and R.K.; writing-review and editing, G.A.B., G.E.S., and R.K. All authors have read and agreed to the published version of the manuscript.

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