Invariance Testing of the Disablement in the Physically Active Scale Short Form-10

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Introduction: Psychometrically sound instruments are needed to accurately track treatment effectiveness and assess quality of patient care. The Disablement in Physically Active Scale Short Form-10 (DPAS-10) was developed as a more parsimonious version of the DPA Scale to assess disablement in the physically active. Psychometric assessment of the DPAS-10 has not been completed; specifically, scale properties must be assessed in a sample of individuals who only respond to the 10-item scale at multiple time points.

Objectives: To assess the psychometric properties of the DPAS-10 using confirmatory factor analysis (CFA) and invariance procedures across multiple time points.

Methods: Confirmatory factor analyses and longitudinal invariance tests were conducted.

Results: The DPAS-10 met contemporary fit index recommendations and demonstrated longitudinal invariance; however, localized fit issues suggest further modification is needed.

Conclusion: Adoption of the DPAS-10 into widespread clinical practice and research is not recommended until further psychometric testing and scale modification is performed.

Key Words: disablement, confirmatory factor analysis, longitudinal invariance

Word Count: 150
Introduction

The Disablement in Physically Active Scale (DPAS) is a patient reported outcome (PRO) measure used to assess and track patient perceptions of the injury process utilizing the disablement framework. Although a number of scales have been created to assess disablement, the 16-item DPA Scale is unique because it was developed specifically for physically active individuals who suffered a musculoskeletal injury. Clinicians who work in physically active populations may find this instrument particularly valuable because other instruments do not adequately assess the disablement constructs in physically active populations. However, researchers have since identified concerns with the psychometric properties of the DPA Scale.

The model fit concerns led to scale modifications which produced a shortened version of the scale: The Disablement in the Physically Active Short Form-10 (DPAS-10). The DPAS-10 utilizes 10 of the original items and is a more parsimonious version of the 16-item DPA Scale. The DPAS-10 closely resembles the DPA Scale structure with a second order disablement construct, DIS, that includes first-order factors impairment, IMP, and functional limitations, FL; the disablement construct, DIS, covaries with a first-order quality of life construct, QOL. Initial findings indicated the DPAS-10 addressed some of the model misspecification and multicollinearity concerns found in the original 16-item DPA Scale, while also resulting in improved model fit, reduced response burden, and increased administration efficiency. The potential multicollinearity among the constructs, however, was not fully resolved with the DPAS-10 despite the positive initial psychometric findings. Additionally, the sample used to develop the DPAS-10 included only individuals who had responded to all 16-items of the original DPA Scale. Thus, the 6-items removed from the scale may have influenced participant responses on the remaining 10-items.
Further analysis is needed to address remaining concerns with the psychometric properties of the scale. Therefore, the primary purpose of this study was to evaluate the psychometric properties of the DPAS-10, using a sample of individuals who only respond to the 10-items contained in the short form. Additionally, because the DPAS-10 would be used as a measure to track and evaluate patients, it is important to ensure the underlying constructs can be adequately measured and compared across repeated measures (i.e., if the instrument is invariant across time, clinicians are able to interpret score changes across treatment sessions). Therefore, the secondary purpose of this study was to assess invariance (i.e., equal factor variances, equal factor covariance, and equal means) of the DPAS-10 across repeated measures.

**Methods**

**Participants**

This study was approved by the Institutional Review Board. Participants provided informed consent prior to survey completion. Physically active individuals were included in the study, while those with chronic pain were excluded (Table 1). Participants were recruited from twenty-two athletic training clinics and two outpatient rehabilitation clinics across the United States.

**Instrumentation**

Participants completed paper versions of the DPAS-10 and a demographic information questionnaire. The DPAS-10 was completed at three different visits; time of completion was dependent on injury type (Table 1) and based on the methods used to create the DPA Scale. Participants who were healthy, as well as those who had suffered an acute or subacute injury, completed the DPAS-10 at the initial visit (time point 1), 3-5 days post-initial visit (time point 2), and 6-10 days post initial visit (time point 3). Participants who suffered from a persistent injury
completed the DPAS-10 at the initial visit (time point 1), 7-10 days post-initial visit (time point 2), and 3 weeks post-initial visit or at their discharge visit if it occurred prior to this time period (time point 3).

The de-identified participant demographic information collected included injury category, patient athletic status, age, sex, sport, general injury location, specific injury location, and type of injury. The collected DPAS-10 data and demographic information were inputted into Qualtrics (Qualtrics, LLC, Provo, UT) by the collecting athletic trainer.

**Data Analysis**

**Data cleaning.** Data was downloaded from Qualtrics (Provo, UT) for analyses using Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) Version 25.0 and Analysis of Moment Structure (AMOS, SPSS, Inc.) Version 25.0. Individuals who did not respond to DPAS-10 items at all three time points were removed from the data set, as were those who did not respond to at least 90% (i.e., 9 of the 10) of the DPAS-10 items. Normality was assessed using histograms, skewness and kurtosis values, and assessment of multivariate outliers were assessed using Mahalanobis distance at a p < .01.³

**Scale Structure.** The full sample was used to conduct a confirmatory factor analysis (CFA) in AMOS software on the DPAS-10 by time point to assess scale structure and verify the underlying constructs of DIS and QOL. A hierarchical confirmatory factor analysis was performed, grouping the disablement variables IMP and FL together to create a second-order variable, DIS, that would then covary with the first-order variable, QOL. To assess correlations between the three latent variables (i.e., IMP, FL, QOL), an additional first-order CFA was conducted. Model fit indices were evaluated based on a priori values; the Comparative Fit Index (CFI; ≥ .95), Tucker-Lewis Index (TLI; ≥ .95), Root Mean Square Error of Approximation
(RMSEA ≤ .06), and Bollen's Incremental Fit Index (IFI; ≥ .95) were computed to assess overall goodness-of-fit.\(^3\,5\,6\) Although not used as a primary assessment of model fit, the likelihood ratio statistic (Chi square) was also assessed.

**Longitudinal invariance testing.** To ensure that individuals were interpreting the items and meanings of the items similarly across time (i.e., across time 1, 2, and 3), invariance testing was conducted to assess measurement and structural invariance of the DPAS-10 across three time points. Longitudinal testing involved assessment of measurement parameters (i.e., equal form, loadings, and intercepts) and if the model passed invariant criteria, substantive parameters were also assessed (i.e., variances, covariances, means). The same criteria utilized for the CFAs were used to assess model fit.\(^3\,7\) Invariance was evaluated based on a CFI difference (CFI\(_{\text{DIFF}}\)) of less than .01, and the chi-square difference test ($\chi^2_{\text{DIFF}}$), with a $p$-value cut-off of 0.01.\(^3\,7\) Given the sensitivity of the $\chi^2_{\text{DIFF}}$ test to sample size, the CFI\(_{\text{DIFF}}\) test held greater weight in decisions regarding invariance testing model fit.\(^7\)

**Results**

A total of 315 individuals participated in the study; 13 participants did not complete the DPAS-10 items from all three time points and were removed from the data set. A total of 23 participants were identified as univariate and multivariate outliers and were removed from the analysis. When examining distributional properties (i.e., skewness and kurtosis values) of the sample, only 1 item had non-normal distribution (i.e., kurtosis ≥ 3.4 but ≤ 4.00). Transformation of the data was considered; however, data transformation was not completed because it was unlikely to lead substantial differences in results or interpretations.\(^8\) The sample comprised of 279 individuals with an age range from 18-78 years (mean age = 23.6 ± 8.9 years; median age = 21.0 years), with females accounting for 53% ($n = 149$) of the sample (Table 2). In the sample,
57 (20.4%) individuals were healthy and 222 were injured; injuries were classified as persistent (n = 95; 34.17%), acute (n = 66; 23.7%), or subacute (n = 61; 21.9%). Most individuals were competitive athletes (n = 169; 61.0%) and had a high level of activity (n = 157; 56.3%).

**Scale Structure**

**Time point one.** The CFA of the DPAS-10, time 1 model, indicated acceptable fit to the sample data (Figure 1). All factor loadings were significant (p ≤ .001) and goodness-of-fit indices met recommended values for CFI (.978), TLI (.969), and IFI (.978) however, slightly exceeded the RMSEA (.073) cutoff. Five path coefficients exceeded .90. Inspection of the first-order model indicated moderate to high correlations between first-order latent variables: IMP and FL (r = .82), IMP and QOL (r = .46), FL and QOL (r = .38). Modification indices demonstrated meaningful cross-loadings.

**Time point two.** The CFA of the DPAS-10, time 2 model, indicated acceptable fit to the sample data. All factor loadings were significant (p ≤ .001) and goodness-of-fit indices met recommended values for CFI (.970), TLI (.958), and IFI (.971), but exceeded the recommended RMSEA value (.082). Five path coefficients exceeded .90. Inspection of the first-order model revealed moderate to high correlations between first-order latent variables: IMP and FL (r = .89), IMP and QOL (r = .48), FL and QOL (r = .44). Modification indices demonstrated meaningful cross-loadings as well as specification between a number of error term covariances.

**Time point three.** The CFA of the DPAS-10, time 3 model, indicated acceptable fit to the sample data. All factor loadings were significant (p ≤ .001) and goodness-of-fit indices met recommended values for CFI (.973), TLI (.962), and IFI (.973), but exceeded the recommended RMSEA value (.078). Four path coefficients were ≥ .90, with one exceeding 1.0. Inspection of the first-order model demonstrated moderate to high correlations between first-order latent
variables: IMP and FL ($r = .94$), IMP and QOL ($r = .44$), FL and QOL ($r = .36$). Similar to Time 1 and Time 2, modification indices demonstrated meaningful cross-loads, as well as specification between error term covariances.

**Longitudinal Invariance Testing**

The full sample ($n = 279$) was used to perform longitudinal invariance testing. The initial model (configural) demonstrated acceptable model fit ($CFI = .970$; $\chi^2 [339] = 585.637$; RMSEA = .051; Table 3), indicating equal form across repeated measures. The metric model (i.e., equal loadings) passed both the $CFI_{DIFF}$ test and the $\chi^2_{DIFF}$ test. Because the model satisfied invariance criteria, an equal latent variance model was conducted. Both $CFI_{DIFF}$ and $\chi^2_{DIFF}$ non-invariant criteria were exceeded, indicating variances were not equal across repeated measures. For first-order latent variable IMP, variance ranged from .63 to 1.04, for FL variance ranged from .54 to .95, and for QOL variance ranged from .15 to .66. At each time point, variance for all latent variables significantly decreased, indicating that the DPAS appears to capture less variability across the sample with repeated administrations.

The scalar model (i.e., equal loadings and intercepts) passed both the $CFI_{DIFF}$ test and the $\chi^2_{DIFF}$ tests. The invariant scalar model results allowed comparison of reported levels of the latent variables across repeated measures. All means for first-order latent variables IMP, FL, and QOL were significantly different across repeated measures. The means of the latent variables significantly decreased, indicating that across repeated measures, participants reported less impairment and functional limitations and better quality of life.

**Commentary**

The psychometric properties of the DPAS-10 were assessed at three time points. Overall, the DPAS-10 met many model fit recommendations, which indicates it may be a suitable tool to
measure patient disablement. Although overall goodness of fit (i.e., model fit indices) was met, there were a number of localized areas of strain in the solution that indicate potential ill-fit. ¹ For example, one local area of concern involved the high (≥0.99) path coefficient from DIS to IMP found in all repeated measures. Standardized path loadings of this magnitude typically indicate the presence of multicollinearity in the data and model misspecification. ⁷ Additionally, the high correlations (≥.82) between IMP and FL suggest multicollinearity was present, and that IMP and FL are either not measuring unique constructs or the items are being interpreted similarly by respondents. Lastly, model misspecification may be evidenced by the large modification indices; the indices revealed meaningful cross-loadings and suggested specification between error term covariances. ⁷ The presence of multicollinearity within factors, as well as the potential model misspecification, was also noted in previous research. ³ Our findings, when combined with the previous research, support the need to further remove items or reduce factors to produce a parsimonious and psychometrically sound scale. ³,⁷

Longitudinal invariance was conducted to determine measurement and structural invariance of the DPAS-10 across multiple measures. An invariant solution implies participants, across repeated measures, interpret the questions and underlying latent factors (IMP, FL, QOL) in the same way. ³,⁷ Thus, when a model is invariant, comparisons between repeated measures, levels, and groups of individuals is possible. Clinically, clinicians would be able to assess change over repeated measures and conclude measured change was a true change in the patient’s perceived disablement instead of measurement error. Our invariant solution allowed us to compare sample variances and means for IMP, FL, and QOL across repeated measures. Overall, variance in scores significantly decreased and participants reported improved scores for IMP, FL,
and QOL, implying that treatment improved an individual’s overall disablement and QOL across repeated measures.

Although the invariant model offers a promising tool for tracking a patient’s disablement, the issues in overall model fit and potential multicollinearity are cause for concern. While it can be argued that scales assessing disablement should be multidimensional, scale sub-dimensions must uniquely contribute without substantial overlap to provide a psychometrical sound and precise measure. While the DPAS-10 meets many fit requirements and offers reduced response burden compared to the original DPA Scale, our data suggests the multicollinearity and model mis-specification issues found in previous research are still present in a sample who only responded to the 10 included items. Further, our results confirm previous findings that demonstrate the QOL and DIS latent variables are unique constructs. The uniqueness of these constructs suggests the same phenomenon is not being measured, and that these responses should not be summed together as a score of DIS if one construct that is different than QOL is already labeled disablement. Our findings support previous findings suggesting clinicians should score and assess the individual construct scores to evaluate patient health status across physical (i.e., DIS) and mental (i.e., QOL) health constructs. Our overall findings, when considered in the context of previous findings, suggest further alteration of the DPAS-10 is necessary prior to use in clinical practice and research.

Limitations and Future Research

A diverse population was recruited from sites across the United States; however, participants were primarily from a small group of clinics and consisted of younger individuals. Thus, future research should include psychometric assessment of the scale in samples that include active pediatric, older adult, and geriatric individuals to ensure psychometrics of the
scale. Further, we did not establish the responsiveness of the DPAS-10; future research should include this step if the scale is to be used to assess clinical practice effectiveness. Previous researchers have also indicated the model fit issues in the DPAS-10 may be adequately addressed with an 8-item scale solution (i.e., DPAS-8) that removes items 4 (i.e., Stability) and 6 (i.e., Skill Performance) from the DPAS-10. The DPAS-8 solution fully addressed the multicollinearity issues present in both the DPA Scale and the DPAS-10; thus the DPAS-8 may be an appropriate instrument to use if its psychometric properties can be validated in a new sample of participants who only respond to the 8 items included in the DPAS-8. Thus, future research should be conducted using similar methods to our study to confirm the psychometric properties of the DPAS-8, while also conducting invariance testing to ensure the scale can be used to assess change with repeated measures or differences across groups, in a sample who only answers those 8 items.

Conclusion

Psychometric properties of the DPAS-10 were assessed at and across repeated measures. The CFA procedures indicated the DPAS-10 met some goodness-of-fit indices and invariant criteria; however, a number of localized issues previously identified for the scale were confirmed in a sample who only answered the items included in the DPAS-10. While the DPAS-10 has improved the measurement properties and reduced response burden compared to the original DPA Scale, adoption into clinical practice is not recommended until further psychometric testing and model alteration confirms the most psychometrically sound instrument.
References

1. Vela LI, Denegar CR. The Disablement in the Physically Active Scale, part II: The psychometric properties of an outcomes scale for musculoskeletal injuries. *J Athl Train*. 2010;45(6):630-641. doi:10.4085/1062-6050-45.6.630

2. Baker RT, Burton D, Pickering MA, Start A. Confirmatory factor analysis of the Disablement in the Physically Active Scale and preliminary testing of short-form versions: A calibration and validation study. *J Athl Train*. 2019;54(3):302-318. doi:10.4085/1062-6050-355-17

3. Kline RB. *Principles and Practice of Structural Equation Modeling*. Fourth ed. New York, NY: Guilford Publications; 2015.

4. U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans*. 2nd edition. Washington, DC, 2018.

5. Bryant FB, Yarnold PR. Principal-components analysis and exploratory and confirmatory factor analysis. In: *Reading and Understanding Multivariate Statistics*. Washington, DC: American Psychological Association; 1995:99-136.

6. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct Equ Model Multidiscip J*. 1999;6(1):1-55. doi:10.1080/10705519909540118

7. Brown TA. *Confirmatory Factor Analysis for Applied Research*. Second Ed. New York, NY: Guilford Publications; 2014.

8. Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2001). *Using multivariate statistics* (4th Edition). Needham Heights, MA: Allyn & Bacon.

9. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med*. 1994;38(1):1-14.
10. Jette AM. Outcomes research: shifting the dominant research paradigm in physical therapy.

*Phys Ther.* 1995;75(11):965–970.

11. Houston MN, Hoch JM, Van Lunen BL, Hoch MC. The development of summary components for the Disablement in the Physically Active Scale in collegiate athletes. *Qual Life Res.* 2015;24(11):2657–2662. doi:10.1007/s11136-015-1007-6.
Table 1. Inclusion and Exclusion Criteria for Participant Activity Level, Injury, and Pain

| Inclusion¹ | | | |
|---|---|---|---|
| Physically Active, and Healthy, or | “An individual who engages in athletic, recreational, or occupational activities that require physical skills and who uses strength, power, endurance, speed, flexibility, range of motion, or agility at least 3 days per week.” | |
| Acute Injury, or Sub-Acute Injury, or Persistent Injury | “A musculoskeletal injury that precludes full participation in sport or activity for at least 2 consecutive days (study participation occurred within 0-72 hours post-injury).” | “A musculoskeletal injury that precludes full participation in sport or activity for at least 2 consecutive days (study participation occurred within 3 days to 1-month post-injury).” | “A musculoskeletal injury that has been symptomatic for at least 1 month (study participation occurred at least 1-month post-injury).” |

| Exclusion¹ | | | |
|---|---|---|---|
| Chronic Pain | “Pain that consistently does not get any better with routine treatment or non-narcotic medication.” | |

| Participant Athlete Status Stratification² | | | |
|---|---|---|---|
| Competitive Athlete | “A participant who engages in a sport activity that requires at least 1 pre-participation examination, regular attendance at scheduled practices and/or conditioning sessions, and a coach who leads practices and/or competitions.” | |
| Recreational Athlete | “Participants who meet the criteria for physical activity and participate in sport, but do not meet the criteria for competitive status.” | |
| Occupational Athlete | “Participants who meet the criteria for physical activity for occupation or recreation, but do not meet the criteria for competitive or recreational athlete.” | |

¹ Inclusion and exclusion criteria were adapted from previous work and referenced in the study.² Participant athlete status stratification definitions were adapted from previous work and referenced in the study.
### Table 2. Demographic information

|                          | Full Sample (n = 279) |
|--------------------------|-----------------------|
| **Sex**                  |                       |
| Male                     | 129 (46.2)            |
| Female                   | 149 (53.4)            |
| Other                    | 1 (0.4)               |
| **Age (years)**          | 23.62 ± 8.9           |
| **Activity Level**       |                       |
| Low                      | 49 (17.6)             |
| Medium                   | 71 (25.4)             |
| High                     | 157 (56.3)            |
| Unknown                  | 2 (0.7)               |
| **Occupational**         |                       |
| Competitive Athlete      | 169 (60.6)            |
| Recreational Athlete     | 27 (9.7)              |
| Occupational Athlete     | 37 (13.3)             |
| Activities of Daily Living | 44 (15.8)         |
| Unknown                  | 2 (0.7)               |
| **Injury Category**      |                       |
| Persistent Injury        | 95 (34.1)             |
| Acute Injury             | 66 (23.7)             |
| Sub-Acute Injury         | 61 (21.9)             |
| Healthy                  | 57 (20.4)             |
| **Ethnicity**            |                       |
| Caucasian/White          | 201 (72.0)            |
| African American         | 42 (15.1)             |
| Hispanic                 | 23 (8.2)              |
| Asian/Pacific Islander   | 8 (2.9)               |
| Other                    | 5 (1.8)               |
| Measure 1 (n = 279) | $\chi^2$ | df | $\chi^2_{\text{diff}}$ (df_{diff}) | CFI | CFI_{diff} | TLI | RMSEA |
|-------------------|--------|----|----------------------------------|-----|----------|-----|-------|
| Measure 2 (n = 279) | 79.06  | 32 |        | 0.978 |        | 0.969 | 0.073 |
| Measure 3 (n = 279) | 92.17  | 32 |        | 0.970 |        | 0.958 | 0.082 |
| Model A (equal form) | 86.12  | 32 |        | 0.973 |        | 0.962 | 0.078 |
| Model B (equal loadings) | 585.637 | 339 |        | 0.970 |        | 0.970 | 0.051 |
| Model C (equal factor variances) | 597.347 | 352 | 11.71(13) | 0.970 | <.001 | 0.970 | 0.050 |
| Model D (equal indicator intercepts) | 766.771 | 358 | 181.13(19) | 0.950 | 0.020 | 0.950 | 0.064 |
| Model E (equal latent means) | 616.932 | 366 | 31.30(27) | 0.969 | 0.001 | 0.969 | 0.050 |
| Model E (equal latent means) | 828.263 | 372 | 242.63(33) | 0.944 | 0.026 | 0.934 | 0.066 |
Figure 1. Confirmatory Factor Analysis DPAS-10. ChiSq = Chi Square (χ²); df = degrees of freedom, p = alpha level; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; IFI = Bollen’s Incremental Fit Index; RMSEA = Root Mean Square Error of Approximation.

chiSq=79.060 DF=32 p=.000
CFI=.978 TLI=.969 IFI=.978
RMSEA=.073