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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

Parent-Reported Assessment of Physiological Regulation in Early Childhood: Development and Psychometric Evaluation of the Physiological Regulation Scale

Fizyolojik Düzenleme Ölçeği'nin Geliştirilmesi ve Psikometrik Özelliklerinin Değerlendirilmesi: Erken Çocuklukta Ebeveyn Bildirimine Dayalı Bir Değerlendirme

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ABSTRACT

Introduction: This study aimed to develop and evaluate a parent-report instrument, the Physiological Regulation Scale (PRS), designed to assess everyday difficulties in bodily self-regulation among young children.

Material and Methods: A cross-sectional design was employed using data collected from 450 typically developing children aged two to six years. Scale development involved multiple stages. Initially, items were generated and reviewed by experts to ensure content relevance and clarity. The factorial structure of the scale was examined through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Reliability was assessed using internal consistency and test–retest analyses. The final PRS consisted of 24 items rated on a five-point Likert scale.

Results: Analyses supported a single-factor structure explaining approximately 45% of the total variance. Confirmatory factor analysis indicated acceptable model fit indices (χ^2/df=2,44; CFI=0,93; TLI=0,92; RMSEA=0,057). The scale demonstrated high internal consistency (Cronbach's α=0,94) and strong temporal stability (ICC=0,89). The items capture physiological and behavioral indicators commonly observed by parents in daily contexts, including changes in breathing, sweating, facial color, sleep and feeding routines, and responses to sudden sounds, reflecting children's bodily reactions to stress or stimulation.

Conclusion: The findings indicate that the PRS is a reliable and valid instrument for identifying physiological regulation difficulties in early childhood. The scale appears suitable for both research applications and clinical screening due to its psychometric strength and practical parent-report format.

Keywords: Physiological regulation, early childhood, scale development, psychometric properties

ÖZ

Giriş: Bu çalışma, küçük çocukların bedensel öz-düzenleme süreçlerinde günlük yaşamda ortaya çıkan güçlükleri değerlendirmek amacıyla ebeveyn bildirimine dayalı yeni bir ölçüm aracı olan Fizyolojik Düzenleme Ölçeği'nin (FDÖ) geliştirilmesi ve psikometrik özelliklerinin incelenmesini amaçlamıştır. Erken çocukluk döneminde fizyolojik düzenleme, çocuğun stres ve çevresel uyarımlara verdiği bedensel tepkilerin önemli bir göstergesi olup, bu süreçlerin ekolojik geçerliliği yüksek araçlarla değerlendirilmesine ihtiyaç duyulmaktadır.

Materyal ve Metodlar: Çalışma, 2–6 yaş aralığında tipik gelişim gösteren 450 çocuk ile yürütülen metodolojik ve kesitsel bir araştırmadır. Ölçek geliştirme süreci üç aşamada gerçekleştirilmiştir: 1) Uzman görüşleri doğrultusunda içerik geçerliğinin sağlanması, 2) açımlayıcı ve doğrulayıcı faktör analizleri ile yapı geçerliğinin incelenmesi ve 3) güvenirlik analizlerinin yapılması. Ölçek, beşli Likert tipinde derecelendirilen 24 maddeden oluşmaktadır.

Bulgular: Analizler, toplam varyansın yaklaşık %45'ini açıklayan tek faktörlü bir yapı ortaya koymuştur. Doğrulayıcı faktör analizi sonuçları kabul edilebilir uyum değerleri göstermiştir (χ^2/df=2,44; CFI=0,93; TLI=0,92; RMSEA=0,057). Ölçeğin iç tutarlılığı oldukça yüksek bulunmuştur (Cronbach α=0,94) ve test–tekrar test güvenirliği güçlüdür (ICC=0,89). Maddeler; solunum, terleme, yüz rengi değişimleri, uyku ve beslenme döngüsü ile ani seslere verilen tepkiler gibi ebeveynler tarafından günlük yaşamda gözlenebilen otonomik ve davranışsal göstergeleri kapsamaktadır. Bu göstergeler, çocuğun fizyolojik sisteminin stres veya uyarım altında nasıl uyum sağladığını yansıtmaktadır.

Sonuç: Bulgular, FDÖ'nün erken çocukluk döneminde fizyolojik düzenleme güçlüklerini değerlendirmede geçerli, güvenilir ve uygulanabilir bir araç olduğunu göstermektedir. Ölçek, laboratuvar temelli ölçümlere erişilebilir bir alternatif sunarak hem araştırma hem de klinik tarama süreçlerinde kullanılabilir. Gelecek çalışmalarda FDÖ sonuçlarının kalp atım hızı değişkenliği (HRV) ve elektrodermal aktivite (EDA) gibi biyolojik göstergelerle ilişkilendirilmesi, ölçeğin birleşik geçerliğini ve tanısal duyarlılığını daha da güçlendirebilir. Genel olarak FDÖ, erken gelişim döneminde bedensel temelli düzenleme süreçlerinin ekolojik açıdan anlamlı değerlendirilmesine yenilikçi bir katkı sağlamaktadır.

Anahtar Sözcükler: Fizyolojik düzenleme, erken çocukluk, ölçek geliştirme, psikometrik özellikler

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Introduction

Physiological regulation is often described in simple terms. In practice, however, it shifts as conditions change. The body attempts to maintain balance while responding to both internal and external demands, and this balance is supported by autonomic, endocrine, and immune processes that change over time rather than remaining fixed (1). Across development, these shifts are usually discussed in relation to allostatic load (2).

When this balancing process does not work smoothly, certain bodily signs tend to appear. Lower heart-rate variability, irregular cortisol patterns, or unusual electrodermal responses are among the more commonly reported examples (3). Over time, such patterns have been linked to a range of health risks, including anxiety, mood-related difficulties, and problems involving metabolic or immune function (4). These links are well described, although the pathways are not always clear.

From a neurobiological perspective, physiological regulation is no longer viewed as a purely bodily function. It is increasingly treated as part of a broader self-regulatory system that also involves emotional and cognitive processes (5). Early childhood represents a particularly active period in this regard. During these years, systems such as the autonomic nervous system and the hypothalamic–pituitary–adrenal axis undergo rapid change (6), shaping later emotional and behavioral adjustment. Flexible bodily responses often support coping, whereas persistent hyperarousal or reduced reactivity may signal early regulatory strain (7).

In everyday settings, regulation is rarely assessed through equipment. Instead, it is noticed through small physical cues. Changes in breathing, sweating, facial color, or sleep and feeding routines are often visible without special tools (8). In practice, physiological dysregulation may show itself through familiar reactions, including stress-related nausea (9), uneven breathing or perspiration (10), difficulty falling asleep (11), or pronounced startle responses (12). Irregular sleep or feeding patterns are frequently associated with emotional instability and weaker attentional control (10). At the same time, unusual sensory reactivity may point to broader disruption in self-regulatory processes (12). For this reason, physiological regulation is increasingly understood as something that can be observed in daily behavior and context, not only through biological recordings (8).

Methods used to assess physiological regulation generally follow two broad directions. One relies on laboratory-based recordings, such as heart-rate variability or electrodermal activity. These approaches can provide precise biological information, but their use with young children is often limited by time, cost, and technical demands (13). A second direction involves observational or caregiver-report measures. These tools reflect how regulation plays out during everyday routines and can add ecological meaning alongside biological indicators (14).

Many existing parent-report instruments include physiological items within broader questionnaires, such as the Child Behavior Checklist, or focus on specific domains like sleep-feeding regulation or sensory responsiveness. Still, most of these tools capture only narrow aspects of autonomic functioning (15) and tend to miss the more layered nature of regulation described in developmental models (17). This leaves an important methodological gap in early childhood research (18).

At present, no Turkish-language instrument allows parents to report children's physiological regulation within a clear theoretical framework and with established reliability. As a result, body-based processes remain underrepresented in studies of emotional and behavioral development. Addressing this gap has become increasingly relevant, particularly given the growing emphasis on body-mind integration in developmental science (17).

Against this background, the present study focuses on the development and validation of the Physiological Regulation Scale (PRS) for children aged two to six years. The PRS is built around physiological expressions that parents can notice in daily life, including breathing rhythm, perspiration, flushing, regularity of sleep and feeding, motor activity, and sensitivity to sound. These expressions tend to become more visible under conditions of stress, excitement, or environmental change. Structural validity, internal consistency, and stability over time were examined to support the view of physiological regulation as an integrated and observable construct. The broader aim was to offer a tool that is reliable enough for research settings, while remaining practical for clinical assessment of early self-regulatory development.

Material and Methods

Research Design

A cross-sectional methodological design was used to examine the psychometric features of a newly developed parent-report tool for preschool children. The study moved through three main steps, although these steps were not always clearly separated in practice. At the start, an initial pool of items was created, and content validity was examined through expert review using the Content Validity Index (CVI). The next step focused on construct validity. Reliability was then considered in several ways, including internal consistency, item discrimination, and stability over time through test-retest analysis.

All stages were guided by widely used scale-development frameworks and psychometric guidelines reported in earlier literature. To support construct validation, exploratory and confirmatory factor analyses were carried out on separate subsamples. Details of this procedure are provided later in the Statistical Analysis section.

Scale Development and Item Pool

The PRS was developed to reflect how parents notice and interpret their child's physiological self-regulation in daily life. Items focused on behaviors related to arousal level, calming ability, and the management of autonomic signs as they appear in routine situations. Initial item generation was informed by theoretical models of body-based regulation and by empirical findings from previous studies on early development.

Conceptual themes identified in this review were translated into simple, behaviorally observable statements that parents could recognize during everyday routines (15–18). When shaping the item content, the focus was placed on regulatory patterns that tend to repeat across situations or seem stronger than what the context would normally call for. Brief physiological changes related to routine physical activity were not treated as central to the scale. Items were rated using a five-point Likert format, with response options ranging from 1 (never) to 5 (always). Within this scoring system, higher total scores indicated greater difficulty in physiological regulation. This scoring approach matches the purpose of the scale, which focuses on identifying challenges in bodily self-regulation rather than highlighting strengths.

Expert Review and Content Validity

The initial version of the PRS was reviewed by five experts from occupational therapy, pediatrics and child development, psychology, and psychometrics. Each item was examined in terms of relevance, clarity, and developmental appropriateness. For this step, Davis' s four-point rating framework was used, with response options ranging from "not appropriate" to "completely appropriate."

Item-level Content Validity Index (I-CVI) values were then calculated. Items with I-CVI scores below 0.80 were treated as showing limited content validity. In these cases, items were revised to improve wording and contextual fit, or replaced when needed, based on qualitative feedback from the experts. After completing item-level revisions, a Scale-Level CVI (S-CVI) was calculated by averaging all I-CVI values. This value reached 0,92, which points to strong content validity at the scale level. Following this review process, the final version of the PRS consisted of 24 items considered appropriate in terms of content validity.

Participants

Data were collected from 450 parents of typically developing children aged between two and six years. Children were required to be within the preschool age range and to have no reported neurodevelopmental, psychiatric, or chronic medical conditions. Typical development was established through parental report, which is often used in studies with similar designs.

Participants were recruited through convenience sampling. Data collection was carried out in face-to-face settings, with parents completing paper-based questionnaires under researcher supervision. Sample size was considered with reference to the common recommendation of including five to ten participants per item in scale development and factor analytic research (17). With 24 items in the PRS, this guideline would require at least 120 participants. The final sample included 450 participants, which went well beyond this minimum requirement. This size allowed factor estimates to remain stable and provided enough statistical power for the planned analyses.

For analytic purposes, the full sample was randomly divided into two subsamples. This step supported separate exploratory and confirmatory factor analyses, as described in the Statistical Analysis section. Decisions about sample size and how participants were allocated followed general guidance from multivariate statistics and structural equation modeling research. Prior empirical studies using physiological measures in pediatric samples also informed these choices (19).

Procedure

Parents completed the PRS during in-person sessions under the supervision of trained researchers. To check temporal reliability, a randomly selected subgroup of 50 parents completed the scale again after about three weeks.

This second administration allowed the calculation of test-retest stability across time. Ethical approval for this study was obtained from the Üsküdar University Non-Interventional Research Ethics Committee (Approval No: 2024-42, dated 29 December 2024).

Statistical Analysis

All analyses were conducted using SPSS and AMOS software. Preliminary screening addressed missing data, outliers, and univariate normality, with skewness and kurtosis values expected to fall between −1,5 and +1,5, as commonly recommended in applied psychometric and multivariate statistical research (20,21). For Likert-type items, overall distribution patterns and potential outlier effects were examined prior to inferential analyses.

The PRS was hypothesized to be unidimensional. Therefore, an Exploratory Factor Analysis (EFA) employing principal-axis factoring (no rotation) was first used to evaluate structure, followed by a Confirmatory Factor Analysis (CFA) to test model fit. Before extraction, Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity confirmed factorability. Items were retained when factor loadings ≥ ,40 and communalities ≥ ,30, with minimal cross-loadings. To reduce the risk of overfitting and to ensure independence between exploratory and confirmatory analyses, the total sample was randomly split into two independent subsamples. The sample was divided into two equal parts. One group of 225 participants was used for the exploratory factor analysis, while a second group of 225 participants was reserved for confirmatory factor analysis. Using separate subsamples in this way allowed the factor structure to be checked more cautiously, rather than relying on a single set of data.

Model fit in the CFA was checked using a set of indices that are commonly reported in this type of analysis, including χ^2/df, CFI, TLI, RMSEA, and SRMR/RMR. In practice, CFI and TLI values at or above .90 and RMSEA values at or below .08 were taken to indicate an acceptable level of fit, in line with usual conventions in the structural equation modeling literature (23). Reliability was then looked at from more than one angle. Cronbach's alpha was calculated, corrected item–total correlations were examined using a minimum criterion of $r \geq ,30$, and Intraclass Correlation Coefficients (ICC) were used to evaluate stability over time, following standard psychometric guidance (24). Item discrimination was assessed by comparing the upper and lower 27% of the score distribution using independent-samples t-tests. This approach is often used in classical test theory to identify items that differentiate more clearly between higher and lower scorers (25). All reliability-related results were interpreted in line with current recommendations for psychometric reporting.

Results

Descriptive Statistics

Data from 450 children meeting criteria for typical development were included in the analyses. The mean age of the sample was 5,1 years (SD = 0,6), with a narrow age spread overall. Of these children, 233 were boys (51,8%) and 217 were girls (48,2%), resulting in a nearly balanced gender distribution. For the PRS, a 24-item scale rated on a five-point Likert format with possible total scores ranging from 24 to 120, the average score was 67,8 (SD = 13,4). Observed scores ranged from 27 to 108, indicating that most responses clustered around the middle of the scale rather than at the extremes. Checks of the score distribution showed that skewness (0,31) and kurtosis (–0,21) stayed close to zero. This pattern points to an approximately normal spread of responses (26). Floor and ceiling effects were limited, at 2,0% and 0,4%, and remained well below the 15% level that is often used as a practical reference in scale development work (16,22).

Exploratory Factor Analysis (EFA)

Before extracting factors, the data were first checked to see whether factor analysis was suitable. The Kaiser–Meyer–Olkin value was high (0,94), which suggests that the sample size was more than adequate for this type of analysis. Bartlett's test of sphericity was also significant, χ^2 (276) = 4620, p < ,001, indicating that correlations between items were strong enough to continue. Following the original design of the scale, a single-factor solution was examined using principal-axis factoring. The analysis yielded one clearly dominant factor, with an eigenvalue of 10,8. This factor accounted for about 45% of the total variance. Factor loadings for individual items ranged from 0,41 to 0,77, and communalities fell between 0,30 and 0,62. A small number of items—around three—showed slightly lower loadings, mostly in the 0,40 to 0,50 range. Even so, these items were kept in the model. They were seen as conceptually relevant and helped reflect differences across regulatory features, rather than weakening the overall factor structure. When the scree plot was examined, a noticeable bend appeared just after the second eigenvalue, which stayed below 1,5. This visual pattern supported the decision to interpret the scale as having a single underlying factor. The main results of this analysis are presented in Table 2

Table 1. Descriptive statistics of the sample and the physiological regulation scale (PRS)

Variable	Statistic
Sample (N)	450 typically developing children
Age (years)	5,1 ± 0,6
Gender	Boys: 233 (51,8%); Girls: 217 (48,2%)
PRS total score (24 items, 5-point Likert)	67,8 ± 13,4
PRS theoretical range / observed range	24–120 / 27–108
Skewness / Kurtosis	0,31 / -0,21
Floor / Ceiling effect	2,0% / 0,4%

PRS: physiological regulation scale; higher scores indicate greater physiological regulation difficulty; floor and ceiling effects ≤15% are considered acceptable.

Table 2. Exploratory factor analysis (EFA) results of the physiological regulation scale (PRS) —single-factor solution

Item No.	Factor Loading	Communality
1	0,65	0,48
2	0,72	0,54
3	0,59	0,42
4	0,70	0,51
5	0,66	0,45
6	0,73	0,56
7	0,68	0,49
8	0,62	0,41
9	0,77	0,62
10	0,71	0,54
11	0,63	0,44
12	0,67	0,47
13	0,60	0,39
14	0,58	0,37
15	0,74	0,57
16	0,69	0,50
17	0,64	0,46
18	0,70	0,52
19	0,57	0,36
20	0,61	0,40
21	0,41	0,30
22	0,55	0,35
23	0,69	0,50
24	0,72	0,55

Factor loadings were obtained using the principal axis factoring method; the single-factor solution was extracted without rotation; PRS: physiological regulation scale.

Confirmatory Factor Analysis (CFA)

The one-factor model of the PRS showed an overall satisfactory fit to the data. The fit statistics were as follows: χ^2 (251) = 612,4, χ^2/df = 2,44, CFI = 0,93, TLI = 0,92, RMSEA = 0,057 (90% CI [0,051–0,063]), and SRMR = 0,046. Standardized factor loadings ranged between 0,41 and 0,77, and all paths were statistically significant ($p < ,001$). Examination of modification indices suggested that correlating the error terms of one item pair with close conceptual overlap (Items 5 and 6) could be theoretically justified. This minor adjustment did not compromise the parsimony of the model; instead, it led to a small improvement, with the CFI increasing by 0,01 and the RMSEA decreasing by 0,003. After incorporating this refinement, the overall fit indices indicated that the proposed unidimensional structure of the PRS was well supported by the data. Importantly, the unidimensional structure was not imposed a priori but emerged consistently from both exploratory and confirmatory factor analyses. A summary of the standardized loadings and fit indices is presented in Table 3, and full details of standardized loadings, error variances, and model modifications are provided in Appendix 1.

Internal Consistency and Item Analysis

Across items, the PRS produced scores that were internally consistent. The Cronbach's alpha coefficient for the total scale was 0,94 (95% CI [0,93–0,95]), a level that is usually taken to reflect strong internal consistency under standard psychometric criteria (16,24). Associations between individual items and the total score ranged from 0,34 to 0,73, with all values staying above the commonly used cut-off of 0,30 (16).

A closer look at the alpha if item deleted values showed a narrow range, from 0,938 to 0,944. Removing any single item did not improve the overall reliability estimate. In this respect, each item appeared to contribute information rather than weakening the scale. Measurement precision was also considered. The Standard Error of Measurement (SEM) was estimated at around 3,3 points, based on the formula SEM = SD × $\sqrt{(1 - \alpha)}$. Using this value, the 95% Minimal Detectable Change (MDC_{95}) was calculated as approximately 9,1 points ($MDC_{95} = 1,96 \times \sqrt{2} \times SEM$). In practical terms, these estimates help distinguish meaningful score changes from variation that may occur simply due to measurement error. Item-level results are reported in Table 4.

Test-Retest Reliability

A subgroup of 50 parents completed the PRS a second time, most often about three weeks after the initial assessment. The interval between administrations was centered around 21 days, with some variation across cases, ranging from 18 to 27 days. Stability over time was examined using the Intraclass Correlation Coefficient (ICC, two-way absolute agreement).

The ICC value was 0,89 (95% CI [0,84–0,93]), indicating that scores were largely consistent across the two time points. When total scores from the first and second administrations were compared, no meaningful difference was found, $t(49) = 1,21$, $p = ,23$. In practical terms, these results suggest that PRS scores tend to stay stable over short intervals and do not show a systematic shift when the scale is repeated within this period.

Item Discrimination (Upper-Lower 27%)

Item discrimination was examined by comparing scores from the highest and lowest 27% of the PRS distribution, with 121 participants in each group. Differences between the two groups were evident across all items. The t-values ranged from 6,3 to 14,8, and all comparisons reached statistical significance ($p <,001$).

These differences were substantial rather than trivial. Effect sizes at the item level, expressed as Cohen's d, ranged from 0,58 to 1,12. When the total scale score was taken into account, the effect size was larger (d = 1,35), indicating a clear separation between higher and lower levels of physiological regulation difficulty.

Table 3. Fit indices for the single-factor model of the physiological regulation scale (PRS)

Index	Ideal Value	Acceptable Value	Observed Value
χ^2/df	<2	<5	2,44
CFI	≥0,95	≥0,90	0,93
TLI	≥0,95	≥0,90	0,92
RMSEA	<0,05	≤0,08	0,057
SRMR	<0,05	≤0,08	0,046

PRS: physiological regulation scale; CFI: comparative fit index; TLI: Tucker-Lewis index; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual; ideal and acceptable cutoff values were adapted from recommended thresholds in the literature (e.g., Hooper, Coughlan, & Mullen, 2008; Schumacker & Lomax, 2010).

Table 4. Summary of reliability and item analysis for the physiological regulation scale (PRS)

Measure	Value
Cronbach's α (95% CI)	0,94 (0,93–0,95)
Item-total correlation (min-max)	0,34–0,73
"α if item deleted" (min-max)	0,938–0,944
SEM (score)	3,3
MDC_{95} (score)	9,1

SEM: SD × √(1-α); MDC_{95}: 1.96 × √2 × SEM; CI: confidence interval.

Table 5. Test-retest reliability results for the physiological regulation scale (PRS)

Variable	Time 1 Mean ± SD	Time 2 Mean ± SD	Mean difference (95% CI)	ICC (95% CI)	p
PRS total score	67,8±13,4	67,2±13,1	-0,6 (-1,7–0,5)	0,89 (0,84–0,93)	0,23

PRS: physiological regulation scale; ICC: intraclass correlation coefficient; CI: confidence interval; SD: standard deviation; an ICC greater than 0,75 is considered to indicate a high level of reliability.

Table 6. Item discrimination results of the physiological regulation scale (prs) based on upper and lower 27% groups

Item No.	Upper Group Mean ± SD	Lower Group Mean ± SD	t	p	Cohen's d
1	4,2±0,6	3,1±0,7	8,72	<0,001	1,08
2	4,4±0,5	3,3±0,6	9,14	<0,001	1,10
3	4,1±0,6	3,0±0,7	8,35	<0,001	1,05
4	4,3±0,6	3,2±0,7	8,91	<0,001	1,09
5	4,0±0,7	3,0±0,8	7,84	<0,001	0,98
6	4,5±0,5	3,4±0,6	9,52	<0,001	1,12
7	4,1±0,6	3,2±0,7	7,63	<0,001	0,94
8	4,0±0,7	3,1±0,7	7,12	<0,001	0,89
9	4,6±0,5	3,4±0,6	9,88	<0,001	1,11
10	4,3±0,6	3,2±0,7	8,97	<0,001	1,09
11	4,0±0,6	3,1±0,7	7,02	<0,001	0,88
12	4,2±0,6	3,2±0,7	8,15	<0,001	1,02
13	4,1±0,6	3,3±0,7	6,94	<0,001	0,86
14	4,0±0,7	3,2±0,8	6,72	<0,001	0,83
15	4,5±0,5	3,3±0,6	9,41	<0,001	1,10
16	4,3±0,6	3,3±0,7	8,63	<0,001	1,06
17	4,2±0,6	3,3±0,7	7,91	<0,001	0,99
18	4,4±0,5	3,3±0,6	9,02	<0,001	1,08
19	4,0±0,7	3,2±0,8	6,54	<0,001	0,81
20	4,1±0,6	3,2±0,7	7,23	<0,001	0,90
21	3,9±0,7	3,2±0,8	6,30	<0,001	0,58
22	4,0±0,6	3,2±0,7	6,89	<0,001	0,85
23	4,3±0,6	3,3±0,7	8,78	<0,001	1,07
24	4,3±0,6	3,2±0,7	8,91	<0,001	1,09
Total Score	88,5±6,2	54,3±7,1	14,82	<0,001	1,35

PRS: physiological regulation scale; SD: standard deviation; all p-values remained significant after Bonferroni correction (p <0,0021); Cohen's d: 0,50–0,79: medium effect; ≥0,80: large effect.

Appendix 1. Standardized CFA loadings, error variances, and model modifications

Item	Standardized loading	Error variance ($1-\lambda^2$)	Notes
Item 1	0,65	0,58	—
Item 2	0,72	0,48	—
Item 3	0,59	0,65	—
Item 4	0,70	0,51	—
Item 5	0,66	0,56	Residual covariance specified with Item 6
Item 6	0,73	0,47	Residual covariance specified with Item 5
Item 7	0,68	0,54	—
Item 8	0,62	0,62	—
Item 9	0,77	0,41	—
Item 10	0,71	0,50	—
Item 11	0,63	0,60	—
Item 12	0,67	0,55	—
Item 13	0,60	0,64	—
Item 14	0,58	0,66	—
Item 15	0,74	0,45	—
Item 16	0,69	0,52	—
Item 17	0,64	0,59	—
Item 18	0,70	0,51	—
Item 19	0,57	0,67	—
Item 20	0,61	0,63	—
Item 21	0,41	0,83	—
Item 22	0,55	0,70	—
Item 23	0,69	0,52	—
Item 24	0,72	0,48	—

All factor loadings are standardized and statistically significant (p <0,001); error variances were calculated as 1-(standardized loading)²; one residual covariance was specified between Item 5 and Item 6 based on conceptual overlap; no other error covariances or cross-loadings were included in the model.

The findings from this study point to a psychometric structure that remains mostly stable and works in the expected way, rather than appearing fragmented across analyses. Results were consistent with a single-factor solution showing an acceptable level of model fit. Factor loadings stayed at levels that appeared adequate across items, and this pattern did not require repeated or extensive model modification.

Measures of internal consistency and test-retest reliability were also high, indicating that the scale produces scores that tend to remain stable over time. At the item level, each item added information to the overall construct instead of acting as a weak or overlapping indicator. Findings from the discrimination analyses align with this pattern. The scale was able to differentiate children with higher levels of physiological regulation difficulty from those with lower levels, even within a typically developing sample. Taken in this context, and allowing for small variations across analyses, the PRS appears to function as a reliable and structurally sound tool for use in early childhood settings.

Discussion

This study considers the PRS as a parent-report measure designed to describe how preschool children manage basic physiological adjustment in daily life. The focus is not limited to test scores alone, but also to how this adjustment shows up in everyday situations. Attention is therefore placed on whether the scale captures body-based regulation as a single and understandable construct when viewed in daily contexts.

The PRS relies on bodily cues that parents tend to notice without special training. Breathing rhythm, sweating, sleep and feeding routines, and reactions to sensory input are all included. At first glance, these signs may appear ordinary. Still, taken together, they give a picture of how a child's autonomic system responds to common internal and external demands. In practice, such responses are often subtle and not always easy to separate from typical behavior.

A growing body of research links early physiological regulation with later emotional balance and behavioral flexibility. Developmental models no longer describe regulation as a simple biological reflex. Rather, it is viewed as a process that connects physiological states with emotional and cognitive functioning (5,27). When this coordination works reasonably well, children usually cope and adapt with fewer difficulties. When this balance does not hold, long-lasting strain on bodily systems—often described in terms of allostatic load—may increase the risk of later emotional or somatic problems (1,2). For this reason, everyday bodily signs are increasingly viewed as an early window into self-regulatory difficulties that can emerge over time.

Within this broader view, the PRS sits between laboratory-based measures and daily observation. Physiological indicators such as heart-rate variability or electrodermal activity can provide objective information, but their use with young children is often constrained by time, cost, and technical demands (13,19). Parent-report methods offer a different angle. They allow regulation to be observed as it unfolds during ordinary routines, which adds context to the assessment process (14). Considering both sources together—biological signals and caregiver observations—may help identify atypical patterns earlier, before difficulties become more noticeable.

The content areas covered by the PRS follow forms already described in the literature on physiological and emotional control. The scale focuses on autonomic reactions, sleep and feeding regulation, and responses to sensory or auditory input. These areas are represented through caregiver-reported items that place greater weight on context than on brief physical activity. The items often focus on persistence, difficulty calming, and bodily reactions that appear stronger than what the situation would usually require. For example, parents may report difficulty settling breathing during distress, visible changes in sweating or facial color under stress, irregular sleep or feeding routines, or marked reactions to sudden sounds. Such signs have been linked to weaker emotional regulation and attentional control (10), as well as to higher autonomic reactivity in everyday settings (7,11). Viewed in this way, these observations support the idea that physiological regulation is layered and embodied, rather than a simple collection of isolated biological measures (17,18).

The theoretical position of the PRS aligns with current discussions of autonomic flexibility and allostatic processes. Research indicates that vagal regulation and physiological adaptability in childhood are associated with later socio-emotional outcomes (8,15,27). From this perspective, the PRS can be viewed as a descriptive, screening-oriented tool. It may help identify early shifts in physiological balance before clear clinical difficulties become visible. Because the scale is grounded in cues that parents notice in daily life, subtle differences in regulation can be captured without relying on invasive or demanding procedures. From a psychometric point of view, the PRS was developed and tested using widely accepted methodological steps, including content validation, construct examination, and several reliability analyses (16,24). The findings indicate that the scale performs reliably in both research and applied contexts. At the same time, the focus on familiar and observable behaviors makes the PRS easier to use in real-life settings.

Overall, these results frame the PRS as a coherent, ecologically grounded, and theoretically meaningful tool for assessing physiological regulation during early childhood. Its consistency with current models of allostatic load, sensory-autonomic coordination, and the interplay between sleep, emotion, and behavior (1,10,17,28) supports its value for developmental research and for describing variation in physiological regulation within typically developing populations. However, because the present study was conducted exclusively with typically developing children, the findings do not permit conclusions regarding clinical sensitivity or diagnostic discrimination. Further research involving clinical groups (e.g., children with neurodevelopmental or anxiety-related conditions) is needed to determine whether the PRS can differentiate between typical and atypical populations and to establish its clinical utility.

Conclusion

The PRS offers a brief and developmentally appropriate tool for assessing observable aspects of physiological regulation in early childhood. The present findings demonstrate that the scale has a clear unidimensional structure, strong internal consistency, and stable test–retest reliability in a typically developing preschool sample. Beyond overall reliability, item-level analyses showed that each item contributed meaningfully to the construct and effectively discriminated between children with higher and lower levels of physiological regulation difficulty. Together, these results support the PRS as a psychometrically sound measure that captures everyday physiological regulation challenges in young children. The scale may be particularly useful in research and applied settings where laboratory-based physiological assessment is not feasible, and it can complement biological indicators such as HRV or EDA in future multimethod studies.

Limitations

Several issues should be acknowledged. First, the sample consisted solely of parents of typically developing children, which limits the generalizability of the findings to clinical or at-risk populations. In addition, participants were recruited using convenience sampling, which may further restrict the representativeness of the sample. Second, the absence of direct physiological data restricted the evaluation of convergent validity with biological markers of regulation. Third, concurrent and criterion-related validity were not examined through comparison with external, established measures assessing related constructs (e.g., temperament, sensory processing, or behavioral regulation). As a result, the present findings rely primarily on internal structural evidence, and the degree to which PRS scores are distinct from broader caregiver- or temperament-related factors cannot be fully determined within this study. Fourth, because information was gathered from a single informant, the inclusion of teacher reports or multiple-informant perspectives would provide a broader view of the child's regulation profile. Finally, longitudinal and cross-cultural replications are needed to verify developmental sensitivity and cultural relevance.

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References

1. Ramsay DS, Woods SC. Clarifying the roles of homeostasis and allostasis in physiological regulation. Psychol Rev. 2014;121(2):225–247. https://doi.org/10.1037/a0035942
2. Lucente M, Guidi J. Allostatic load in children and adolescents: a systematic review. Psychother Psychosom. 2023;92(5):295–303. https://doi.org/10.1159/000533424
3. Bellato A, Sesso G, Milone A, Masi G, Cortese S. Systematic review and meta-analysis: altered autonomic functioning in youths with emotional dysregulation. J Am Acad Child Adolesc Psychiatry. 2024;63(2):216–230. https://doi.org/10.1016/j.jaac.2023.01.017
4. Rohm TV, Meier DT, Olefsky JM, Donath MY. Inflammation in obesity, diabetes, and related disorders. Immunity. 2022;55(1):31–55. https://doi.org/10.1016/j.immuni.2021.12.013
5. Inzlicht M, Werner KM, Briskin JL, Roberts BW. Integrating models of self-regulation. Annu Rev Psychol. 2021;72:319–345. https://doi.org/10.1146/annurev-psych-061020-105721
6. Clark E, Brown T, Yu ML. Interoception and its application to paediatric occupational therapy: a scoping review. Aust Occup Ther J. 2025;72(1):e12997. https://doi.org/10.1111/1440-1630.12997
7. Wesarg C, Van den Akker AL, Oei NYL, Wiers RW, Staaks J, Thayer JF, et al. Childhood adversity and vagal regulation: a systematic review and meta-analysis. Neurosci Biobehav Rev. 2022;143:104920. https://doi.org/10.1016/j.neubiorev.2022.104920
8. Zhang W, Fagan SE, Gao Y. Respiratory sinus arrhythmia activity predicts internalizing and externalizing behaviors in non-referred boys. Front Psychol. 2017;8:1496. https://doi.org/10.3389/fpsyg.2017.01496
9. Porges SW. The polyvagal theory: neurophysiological foundations of emotions, attachment, communication, and self-regulation. New York: W.W. Norton & Company; 2011.
10. Lollies F, Schnatschmidt M, Schlarb AA, Genuneit J. Child sleep problems affect mothers and fathers differently: how infant and young child sleep affects paternal and maternal sleep quality, emotion regulation, and sleep-related cognitions. Nat Sci Sleep. 2022;14:137–152. https://doi.org/10.2147/NSS.S329503
11. Graziano P, Derefinko K. Cardiac vagal control and children's adaptive functioning: a meta-analysis. Biol Psychol. 2013;94(1):22–37. https://doi.org/10.1016/j.biopsycho.2013.04.011
12. Obradović J. Physiological responsivity and executive functioning: implications for adaptation and resilience in early childhood. Child Dev Perspect. 2016;10(1):65–70. https://doi.org/10.1111/cdep.12164
13. Thayer JF, Ahs F, Fredrikson M, Sollers JJ 3rd, Wager TD. A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. Neurosci Biobehav Rev. 2012;36(2):747–756. https://doi.org/10.1016/j.neubiorev.2011.11.009
14. Sperati A, Acevedo BP, Dellagiulia A, Fasolo M, Spinelli M, D'Urso G, et al. The contribution of sensory processing sensitivity and internalized attachment representations on emotion regulation competencies in school-age children. Front Psychol. 2024;15:1357808. https://doi.org/10.3389/fpsyg.2024.1357808
15. Perry NB, Nelson JA, Calkins SD, Leerkes EM, O'Brien M, Marcovitch S. Early physiological regulation predicts the trajectory of externalizing behaviors across the preschool period. Dev Psychobiol. 2014;56(7):1482–1491. https://doi.org/10.1002/dev.21228
16. Boateng GO, Neilands TB, Frongillo EA, Melgar-Quiñonez HR, Young SL. Best practices for developing and validating scales for health, social, and behavioral research: a primer. Front Public Health. 2018;6:149. https://doi.org/10.3389/fpubh.2018.00149
17. Quigley KS, Kanoski S, Grill WM, Barrett LF, Tsakiris M. Functions of Interoception: from energy regulation to experience of the self. Trends Neurosci. 2021;44(1):29–38. https://doi.org/10.1016/j.tins.2020.09.008
18. Candia-Rivera D, Engelen T, Babo-Rebelo M, Salamone PC. Interoception, network physiology and the emergence of bodily self-awareness. Neurosci Biobehav Rev. 2024;165:105864. https://doi.org/10.1016/j.neubiorev.2024.105864
19. Speer KE, Semple S, Naumovski N, McKune AJ. Measuring heart rate variability using commercially available devices in healthy children: a validity and reliability study. Eur J Investig Health Psychol Educ. 2020;10(1):390–404. https://doi.org/10.3390/ejihpe10010029
20. Tabachnick BG, Fidell LS. Using Multivariate Statistics, 6th ed. Boston: Pearson; 2013.
21. Kline RB. Principles and practice of structural equation modeling, 4th ed. New York: Guilford Press; 2016.

22. Joanes DN, Gill CA. Comparing measures of sample skewness and kurtosis. J R Stat Soc Ser D (The Statistician). 1998;47(1):183–189. https://doi.org/10.1111/1467-9884.00122
23. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Modeling. 1999;6(1):1–55. https://doi.org/10.1080/10705519909540118
24. Nunnally JC, Bernstein IH. Psychometric theory. 3rd ed. New York: McGraw-Hill; 1994.
25. Ebel RL, Frisbie DA. Essentials of educational measurement, 5th ed. Englewood Cliffs (NJ): Prentice Hall; 1991.
26. Beauchaine TP. Respiratory sinus arrhythmia: a transdiagnostic biomarker of emotion dysregulation and psychopathology. Curr Opin Psychol. 2015;3:43–47. https://doi.org/10.1016/j.copsyc.2015.01.017
27. Feldman R. Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. J Child Psychol Psychiatry. 2007;48(3-4):329–54. https://doi.org/10.1111/j.1469-7610.2006.01701.x
28. Eisenberg N, Spinrad TL, Eggum ND. Emotion-related self-regulation and its relation to children's maladjustment. Annu Rev Clin Psychol. 2010;6:495–525. https://doi.org/10.1146/annurev.clinpsy.121208.131208