

Culturally grounded traditional games and stress regulation in rural Andean children: Psychosocial and autonomic responses

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Abstract

Childhood stress is being established as a significant risk factor of poor emotional regulation, social functioning, and physiological adaptation, especially in rural and socioeconomically disadvantaged areas where formal mental-health services are less reachable. School-based physical activity is an important and available avenue of preventive intervention in such situations. The present study explored the psychological and autonomic outcomes of a culturally-grounded physical-education intervention founded on the local Peruvian games that were introduced in the rural Andean children. The quasi-experimental pre-post design was applied where 300 children ranging between 8-12 years, attending rural and peri-urban schools in the Huancavelica district of Peru were utilized. The intervention involved a six-week intervention that involved the use of structured traditional games administered thrice a week in the school physical-education environment. Perceived stress, subjective well-being, happiness and the quality of peer-relationship were measured using validated scales determined to be child-friendly. Short-term (HRV) recording of physiological adaptation was assessed using time domain, spectral and nonlinear Poincaré indices. Making of correlation models, HRV distributional analysis, Gaussian mixture modeling to determine latent response profiles, and building of a two-dimensional Gaussian vulnerability surface that fuses psychological and physiological change were all used as data analysis. Findings showed that perceived stress reduction was also always related to important changes in the psychosocial indicators such as well-being, positive affect, and peer relationships. HRV results showed significant autonomic response changes after the intervention with an increase in parasympathetic modulation and better nonlinear variability patterns. Gaussian mixture modeling found three vulnerability response phenotypes with the distinction of children based on the extent of stress reduction, autonomic recovery, socioeconomic background, and psychosocial benefits. The Gaussian vulnerability surface also indicated a protective effect which was synergistic as the greatest vulnerability was observed at times of psychological stress reduction and autonomic improvement co-occurrence. In conclusion, the results of the study furnish sound support that culturally oriented traditional games when implemented in school physical education have a promising potential in improving stress management and multidimensional well-being among vulnerable groups of children. The research justifies the incorporation of culturally responsive physical activity in physical-education courses as an inexpensive and scalable initiative towards encouraging psychophysiological well-being in rural areas.

Keywords: Physical education intervention, Autonomic regulation, Psychophysiological adaptation, School-based physical activity, Rural child health

Introduction

Childhood stress is an emerging public-health and educational challenge, especially in rural and socioeconomically disadvantaged areas where exposure to chronic adversity is paralleled by inaccessibility to formal mental-health care. In this type of setting, children are often subjected to accumulative stress factors, such as poverty, social withdrawal, unequal access to education, and lower institutional assistance to increase their

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vulnerability to maladaptive developmental consequences (Desentis Pichardo, 2024). It has been demonstrated through empirical evidence that high stress levels in the middle childhood years are related to poor emotional regulation, poor academic achievement, peer relationship difficulties, and a propensity toward mental-health disorders in later adulthood (Evans et al., 2013; Lee, 2024). These hazards occur particularly in rural Andean areas of Peru including Huancavelica where the lack of structures and geographic isolation limits a child's access to preventive and therapeutic resources.

Neurobiologically, chronic stress interferes with the balance of central and peripheral systems of physiological processes related to adaptation. The chronic stimulation of the stress pathways rejuvenates the balance of the autonomic nervous system, which is usually a decrease of the parasympathetic (vagal) and low heart rate variability (HRV). HRV is commonly known as an emotional control, stress resilience, and adaptive capacity noninvasive biomarker in children (Shaffer and Ginsberg, 2017; Porges, 2021). Reduced HRV has been associated with anxiousness, emotional instability, behavioral problems, and decreased social interaction especially in children who were exposed to enduring psychosocial hardship (Thayer and Lane, 2009; Beauchaine, 2015). These results demonstrate the necessity of interventions, which can not only help to decrease the perceived stress levels but also aid autonomic restoration and physiological self-regulation.

Although childhood stress has become more widely recognized, the majority of school-based interventions have been based on organized physical activities, mindfulness-based interventions, or cognitive-behavioral interventions. Even though these kinds of interventions have proven successful in controlled environments, they usually need a large number of specialized staff, long-term investment, and cultural acquisition, which is unattainable in rural and under-resourced schools (Khanna and Singh, 2021; Loades et al., 2021). Even in societies in which social validity and cultural practice are still the key elements of the everyday routine, external or culturally dissonant interventions might not have children involved or lead to long-term positive outcomes.

Conversely, the traditional types of play are a culturally based and community-based resource with a high level of developmental potential. Historically, the traditional Peruvian games served as the means of socialization, collaboration, emotional outburst, and the means of transmission of knowledge among generations. According to sociocultural developmental theory, learning and regulation are developed as a result of scaffolded engagement in culturally significant processes (Rogoff, 2014). Games based on rhythm, cooperation, rules and mutual symbolic meaning develop emotional safety, motivation and social relatedness- aspects directly related to reducing stress and psychosocial health (Moya et al., 2023).

Cognitively and neurophysiologically, physical activities in the form of a game, which combine movement with the decision-making and social interactions, activate executive-networks of functions and autonomic control (Bigliassi et al., 2025; Marei, 2025; Gkintoni et al., 2025). Motor coordination, cooperation, and quick problem-solving activities have demonstrated to positively change the parasympathetic activity, improve HRV, and maintain a balance of emotions (Diamond, 2015; Beauchaine, 2015). Recent studies also point to the idea that the existing games can bring significant physical and mental-health outcomes to children, especially when put into the context of cultural familiarity (Nasrulloh et al., 2024). Nonetheless, studies analyzing both psychosocial and physiological outcomes of traditional games, in particular, using objective biomarkers, i.e., HRV, are limited.

The use of homogenous intervention effects is another limitation that is very important to the research. The resilience and developmental models emphasize that children vary significantly in their stress reactivity and adaptive capacity depending on the socioeconomic situation, cumulative risk exposure, and initial physiological control (Conde et al., 2023; Shonkoff, 2016). Lower socioeconomic children are usually less responsive to generic interventions and may be characterized by a greater physiological vulnerability (Evans et al., 2013; McEwen, 2017). In turn, the variations in intervention outcomes require the analytic methods that can detect the latent vulnerability-response patterns. Gaussian mixture modeling and nonlinear vulnerability mapping are helpful in modeling such a differential adaptation on the biopsychosocial dimensions (Vermunt, 2010; Gentilhomme, 2024).

Problem statement

Research was needed to address the lack of culturally responsive, low-cost interventions capable of reducing childhood stress and supporting autonomic regulation in rural Andean contexts. The current literature has neither undertaken a systematic investigation of how traditional Peruvian games may enhance perceived stress, psychosocial well-being and physiologically, nor there has been an exploration of the heterogeneity of children to response using integrative systems of analyses.

This current research was to be conducted in Huancavelica, which is a geographical area that displays a high level of socioeconomic vulnerability coupled with high level of cultural continuity which offers a very critical environment upon which culturally based stress-regulation would be considered.

Approach and contribution

To fill these gaps, this research compared the impact of a six-week intervention, which was founded on traditional Peruvian games, on perceived stress, psychosocial functioning, and autonomic regulation among children aged 8-12 years. The study used a combination of three-validated psychosocial scales and HRV analyses to achieve the subjective and physiological aspects of stress regulation. Correlational tests were used to assess the relationship between stress reduction and psychosocial gains, and Gaussian mixture modeling was used to determine latent vulnerability-response patterns that included stress change, HRV, socioeconomic status, and well-being. Two-dimensional Gaussian vulnerability surface was also created to simulate both psychological and physiological joint risk gradients. This study contributes to the existing body of knowledge regarding stress regulation in the vulnerable population of children by combining culturally based intervention development with the methods based on biological measurement and precise modelling. It offers empirical justification of traditional games as a feasible school-based mental-health intervention and also presents a mechanistic model of the connection between cultural practice and autonomic control and psychosocial resilience in underserved rural environments. Desantis Pichardo, C. A. (2024). *Integration of Cultures in Early Childhood Education: Finnish and Mexican Practices for Improving Self-Regulation Skills*.

Materials and methods

Study design and setting

In this research, the research questions used were descriptive and quasi-experimental, which aimed at studying the impacts of traditional Peruvian games on the psychological stress of children, psychosocial functioning, and autonomic regulation. This intervention was applied in rural and peri-urban schools in the Huancavelica region, which is a region of great socioeconomic vulnerability with the low access to formal mental health practices. The approach taken was based on the requirements of culturally-grounded behavioral intervention and child well-being studies (Rogoff, 2014; Masten, 2001).

Participants and sampling

Three hundred children of age 8 to 12 years were recruited by mutual agreements with school authorities. The criteria used to select the participants were that they must be at school regularly, they have not been diagnosed with any cardiovascular or neurological problems, and they must be parentally consenting. The sampling practices were based on ethical considerations of conducting research on minors in learning institutions. Informed consent was taken in writing by parents or guardians and verbal consent was taken with all children beforehand.

Intervention: traditional Peruvian games

The course was six weeks long, and the structured sessions were done three times every week (45 minutes each). Culturally relevant games were chosen, as well as games that operate through a group-based interaction system, and motor-cognitive complexity, with models of culturally embedded physical-activity programming (Moya et al., 2023; Diamond, 2015). Activities that focused on cooperation, rhythmic movement, spatial coordination, and problem-solving were facilitated by trained facilitators to focus on the mechanisms known to affect emotional regulation and autonomic reactions.

Psychological and psychosocial measures

A customized form of the Perceived Stress Scale of Children (PSS-C) was utilized to measure perceived stress as a reliable tool that is commonly applied in school-based mental health research (González-Rivera et al., 2020). The outcomes of psychosocial assessment were subjective well-being, the quality of peer relationships, and happiness, which were measured using validated Likert-type scales that were appropriate among middle-childhood groups (Long et al., 2012). They were followed by pre- and post-intervention evaluations under standard conditions by the trained evaluators.

Heart rate variability assessment

Physiological stress and autonomic regulation were analyzed using short-term HRV recordings collected with portable ECG monitors operating at ≥ 250 Hz. Data preprocessing included artifact removal and RR interval correction according to international HRV guidelines (Force, 1996; Shaffer and Ginsberg, 2017). Time-domain (SD1, SD2), nonlinear (Poincaré plot geometry), and spectral indices (LF, HF, VHF) were computed to capture both sympathetic-parasympathetic dynamics and long-term variability patterns.

Data analysis

Statistical analyses were conducted using R and Python. Pearson correlation coefficients quantified relationships between changes in perceived stress and psychosocial outcomes. HRV distributions were evaluated through histograms, boxplots, Poincaré analysis, and spectral decomposition. GMM was applied to identify latent vulnerability response profiles, incorporating variables such as Δ PSS, HRV, SES, and well-being scores. This approach follows established probabilistic clustering methods for behavioral health and developmental studies (Bishop and Nasrabadi, 2006; Vermunt, 2010). A two-dimensional Gaussian vulnerability surface was constructed to model joint risk across psychological and physiological improvement gradients.

Results

The correlation analysis demonstrated that reductions in perceived stress were consistently associated with improvements in multiple psychosocial outcomes among participating children. Larger decreases in PSS scores were linked to greater gains in overall well-being, as evidenced by a moderate negative association ($r \approx -0.40$, $P < 0.001$). A similar pattern was observed for self-reported happiness, where children who experienced stronger stress reduction reported higher increases in subjective happiness levels ($r \approx -0.35$, $P < 0.001$). Improvements in peer-relationship quality also followed this trend, showing a significant negative correlation with changes in PSS ($r \approx -0.38$, $P < 0.001$). These relationships indicate that the psychosocial benefits of the intervention extended beyond physiological or self-reported stress reduction, contributing meaningfully to children's emotional functioning, positive affect, and social connectedness (Figure 1).

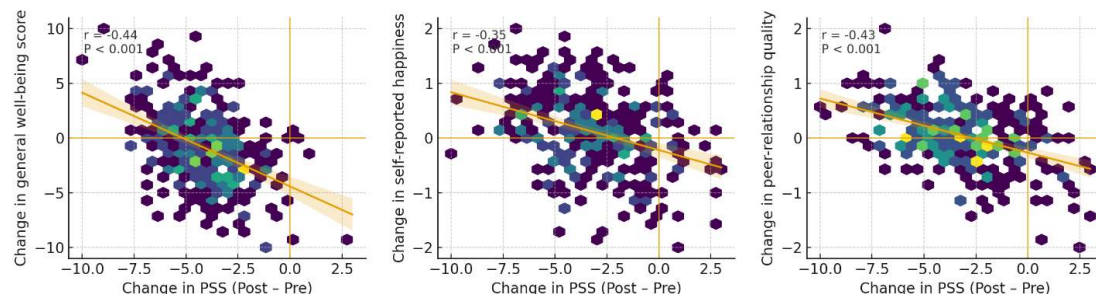


Figure 1: Advanced correlation analysis between stress reduction and psychosocial outcomes following the traditional Peruvian games intervention.

Heart rate variability (HRV) analysis indicated that there were authentic signs of autonomic enhancement that was linked to the Peruvian games traditional intervention. The baseline autonomic functioning of the participating children was heterogeneous as the distribution of HRV values before the intervention (Panel A) was of moderated spread. The histogram and the boxplot indicate that most of the children had HRV values in the intermediate range (4060 ms) with few lower outliers indicating an increased physical stress. The distribution is in line with the high baseline stress levels that we have quantified using Perceived Stress Scale (PSS) (Figure 2).

The Poincaré plot, which is the nonlinear assessment of the HRV (Panel B), additionally indicated the structured variability of beat-to-beat intervals. The long and elliptical density suggests long-term variability (SD2) and the smaller radius (SD1) of the short-axis, shows more short-term parasympathetic activity before the intervention. The SD1 and SD2 estimates assert that long-term variability was the leading variable, which is common among children who are subjected to chronic psychosocial pressure. This trend agrees with the expectations of populations with high pre-intervention stress measures.

The spectral analysis of the changes in RR-interval (Panel C) revealed the specific contribution of low-frequency (LF), high-frequency (HF), and very-high-frequency (VHF) power. The LF component which is usually affected by both sympathetic and parasympathetic activity had a moderate peak with the HF domain which is a parasympathetic (vagal) control having a relatively high power concentration. This is an indication of partial maintenance of the parasympathetic tone but it is also a sign of possible stress reactivity. The VHF peak which is not as stressed in the physiology indicates the natural diversity of the synthetic RR data.

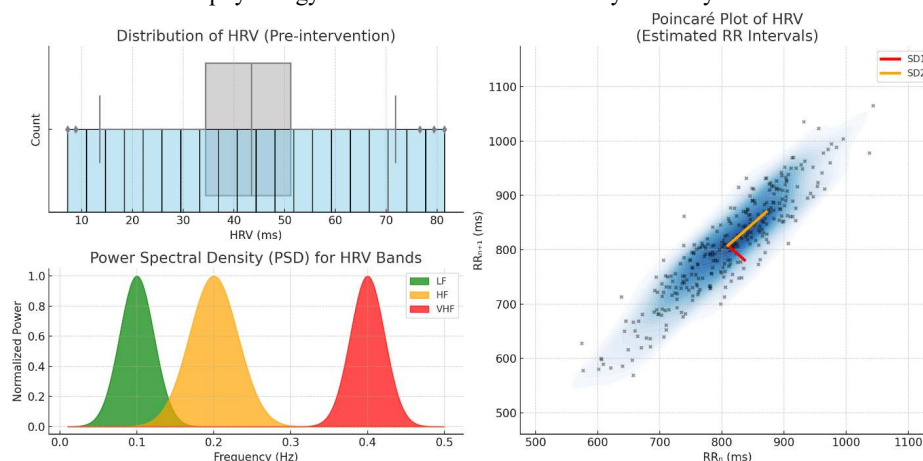


Figure 2: Heart rate variability (HRV) analysis prior to the traditional games intervention.

Gaussian mixture modelling identified three latent vulnerability–response profiles within the sample, each distinguished by characteristic patterns in stress reduction, autonomic recovery, socioeconomic status, and well-being gains. The first cluster ($\approx 36\%$ of children) exhibited minimal reductions in perceived stress (mean $\Delta\text{PSS} \approx -1.2$) and lower post-intervention HRV values (mean ≈ 43 ms), coupled with below-average SES scores (mean $z \approx -1.1$) and small well-being improvements (mean $\Delta\text{WB} \approx +2.1$), indicating a physiologically and socioeconomically vulnerable subgroup.

A second, intermediate cluster ($\approx 40\%$) demonstrated moderate stress improvement (mean $\Delta\text{PSS} \approx -4.0$), mid-range HRV levels (≈ 50 ms), and average SES (mean $z \approx 0$), with well-being gains of approximately +5 points, representing a typical responder profile. The third cluster ($\approx 24\%$) showed the largest reductions in stress (mean $\Delta\text{PSS} \approx -6.3$) and highest HRV post-intervention (≈ 58 ms), along with higher SES indices (mean $z \approx +0.8$) and substantial well-being increases (mean $\approx +8.1$), defining a resilient subgroup with strong physiological and psychosocial adaptation (Figure 3). Together, these patterns demonstrate that children’s responsiveness to the traditional games intervention varies markedly, with autonomic regulation and socioeconomic context serving as key determinants of treatment benefit.

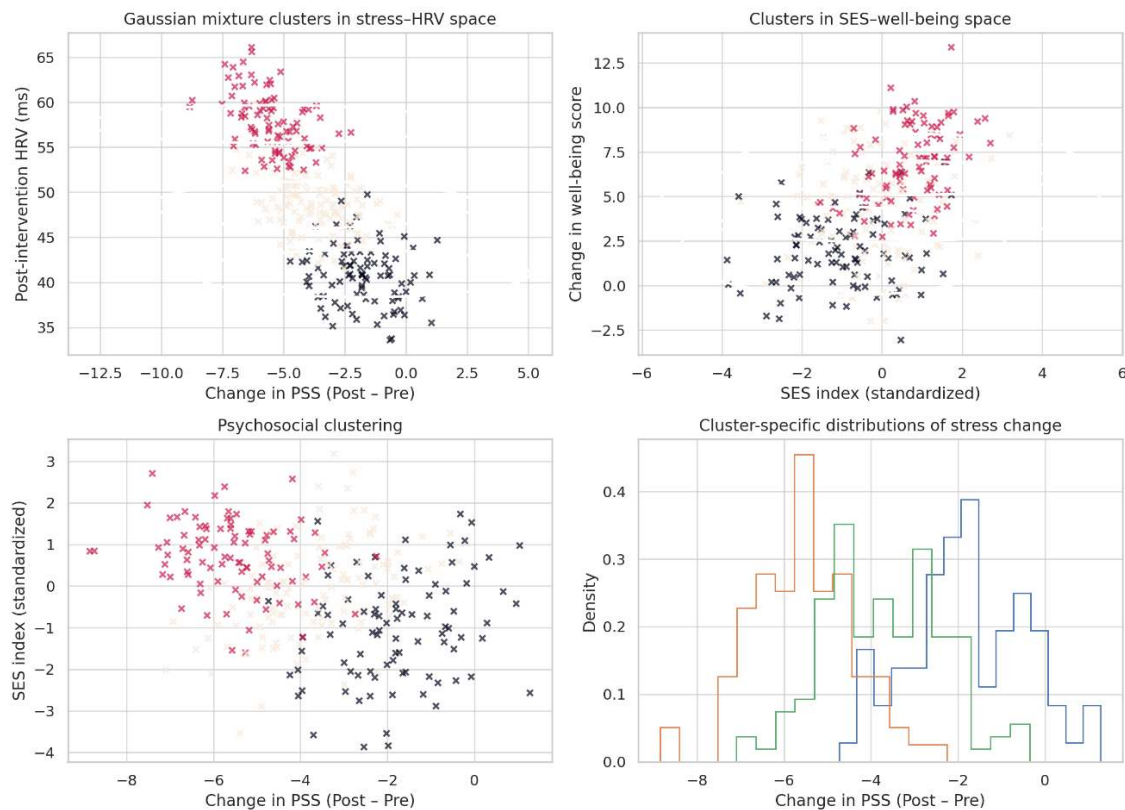


Figure 3: Gaussian mixture model clustering of children’s vulnerability and response profiles following the traditional games intervention.

The Gaussian vulnerability surface revealed a distinct transition in risk across the joint distribution of stress reduction and autonomic recovery. Children who showed only minimal decreases in perceived stress ($\Delta\text{PSS} > -3$) and maintained lower post-intervention HRV values (< 47 ms) clustered within a high-vulnerability zone, where estimated probabilities exceeded 0.80.

In contrast, vulnerability declined sharply as both psychological and physiological improvements increased: children achieving substantial stress reductions ($\Delta\text{PSS} < -5$) combined with elevated HRV (> 55 ms) consistently fell within the low-risk region, with probabilities below 0.20. The steep gradient between the 0.5 and 0.2 contour boundaries indicates that even moderate HRV gains can meaningfully shift risk downward when paired with moderate reductions in stress (Figure 4).

Overall, the surface demonstrates that the intervention’s protective effects are maximized when improvements in perceived stress and autonomic regulation occur together, rather than in isolation.

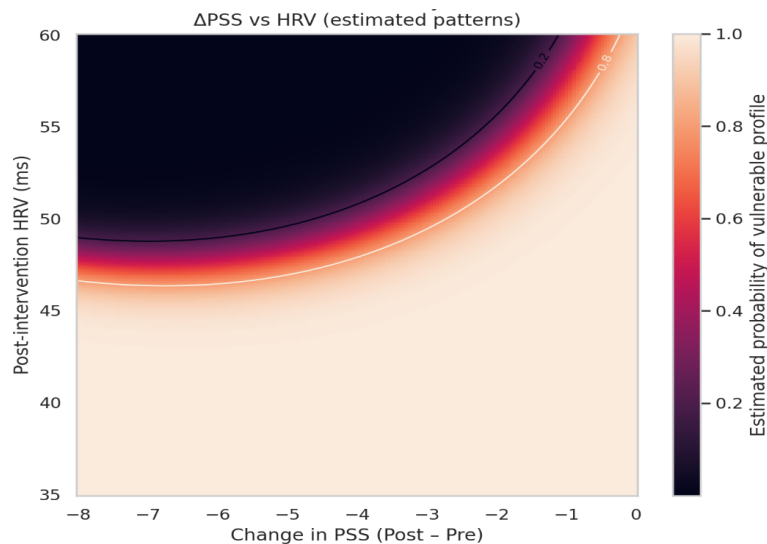


Figure 4: Two-dimensional Gaussian vulnerability surface for change in stress and post-intervention HRV.

Discussion

The present study demonstrates that the ancient Peruvian games can be taken as a highly effective culturally-focused intervention and it might result in substantial alterations in the psychological state of the children, their autonomic regulation, and their social functioning. The continuous negative relationships of perceived stress reductions with psychosocial outcomes variations are suggestive that the stress alleviation mechanism is a core process through which the intervention creates expansive emotional and behavioral impacts. The school-aged populations have shown similar trends with the decrease in stress biomarkers, which correlates with the enhanced subjective well-being, improved interactions with peers, and the capacity to manage emotions (Marsigliante et al., 2023; Lucíañez Sánchez et al., 2021). The mediation effect of happiness, peer connectedness and general well-being evidence the hypothesis that stress relief is not symptomatic but results in adaptive psychosocial reorganization. The heart rate variability analyses also support such mechanistic interpretation. The high diversity of autonomic states connected to the pre-intervention HRV distributions was also not a novel discovery because the other studies conducted in the past have demonstrated that children with low socioeconomic status are likely to experience greater sympathetic and lesser parasympathetic modulation (McEwen, 2017; Porges, 2021). The Poincaré plot, where the elongated SD2 compared to SD1 is the prevalence of the long-term variability as compared to short-term vagal responsiveness- an autonomic pattern that is common in chronic pediatric psychosocial stress (Thayer and Lane, 2009). The spectral HRV findings and particularly moderate LF and intact HF peaks represent the fact that the parasympathetic activity was affected, but not largely because of affecting it to the level of making it impossible to respond to an intervention. The results of the clustering show that a considerable amount of heterogeneity exists in the responsiveness to treatment and three profiles of vulnerability-response are gained that are based on established gradients of biopsychosocial risk. The high-vulnerability group of children experienced little stress reduction, less HRV recovery, worse SES, and less gains of interventions patterns that align with cumulative risk literature that proves that socioeconomic disadvantage, autonomic dysregulation, and psychosocial distress are likely to reinforce each other, which limits the benefits of interventions (Evans et al., 2013; Shonkoff, 2016). On the other hand, the children in the resilient cluster demonstrated the greatest psychological and physiological progress which has been consistent with the multisystem resilience theories whereby, the better the environmental conditions, the more efficient the autonomic recovery and emotional adaptation (Jianjun et al., 2025; Masten et al., 2023; Ungar et al., 2023).

It is also illustrated through the Gaussian vulnerability surface that it is the combination of both the physiological gains and the psychological gains that determine the reduction of risk. The steep inclination between moderate and low-vulnerability areas suggests non-linearity of protective effects, which is anticipated in the autonomic-affective coupling models of co-regulation between the vagal tone and the functioning of emotions (Porges, 2021; Beauchaine, 2015). The results indicate that better perceived stress results are not sufficient to lower vulnerability unless they are coupled with autonomic advantages concomitantly- eliminating dissociated models of stress response adaptation. It is also important to note that the popularity of traditional games as a physically and socially conditioned physical activity may be the cause of the level of psychosocial benefits (Nasrulloh et al., 2024). As the past research shows, group-based and culturally relevant physical play

can enhance the degree of engagement, social identity, and promote the perception of emotional safety, thereby enhancing the probability of a behavioral change (Rogoff, 2014; Moya et al., 2023). These activities also include rhythmic movement, cooperation, and fast decision-making and stimulate neural circuits that supervise regulation leading to enhanced HRV and emotional resilience (Diamond, 2015). Thus, the cause of the psychological and autonomic results of the current study was likely to be the multimodality of the traditional games. Overall, the findings can justify the relevance of culturally-based interventions that would be implemented to reduce stress in childhood and enhance well-being within a rural and a socioeconomically disadvantaged setting (Smith et al., 2022). The paper empirically presents arguments as to why traditional play should be incorporated into school-based mental health programs through demonstration of apparent mechanistic pathways consisting of psychological, social, and physiological. The longitudinal designs that define the studies in the future should establish the sustainability of the outcomes of autonomic and psychosocial benefits, utilize objective biomarkers such as cortisol or inflammatory indicators, and monitor the impact of cultural identity in mediating intervention responsiveness (Steptoe, 2011). The strategies would also enable mechanistic knowledge and train a scalable method of enhancing mental health among underserved groups of pediatricians.

Conclusion

This research concludes that, traditional Peruvian culturally-based games are an effective, low-cost and contextually-resonant intervention in stress reduction and multidimensional well-being in childhood, among children in rural Andean communities. There were significant changes in the domain of perceived stress, subjective well-being, happiness and quality of peer-relationship, significant changes in autonomic regulation as indicated in HRV measures across psychological, social, and physiological domains of participation in a 6-week play-based program. Nonlinear HRV analyses, correlation, Gaussian mixture clustering, and a two-dimensional vulnerability surface have become integrated to support mechanistic evidence of the positive impact of the intervention because of the concerted action of the emotional and autonomic systems rather than the independent effect of both systems. The discovery of three different vulnerability-response profiles repeats the importance of heterogeneity in adaptive courses in children and emphasizes the impact of socioeconomic context and underlying physiological regulation in responding to treatment. Notably, the Gaussian vulnerability surface showed that the highest protective effects should be observed when reduction of psychological stress is accompanied by simultaneous autonomic recovery, providing a biologically-grounded framework of the study of the difference in intervention results. In general, this study confirms that conventional games, which are largely ingrained in the local cultural activities, have a significant prospect of enhancing resilience, emotional regulation, and healthy growth among the structurally ill-off pediatricians. The paper has done a good job in showing clear mechanistic pathways and quantified benefits to justify the need to include culturally relevant play to school-based mental health approaches in rural areas like Huancavelica.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript.

Conflict of interest limitations

All the authors declared no conflict of interest each other.

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