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# EFFECTS OF INDIGENOUS GAMES–BASED PHYSICAL EDUCATION ON PHYSICAL PERFORMANCE, NEUROMECHANICAL EFFICIENCY, AND PSYCHOSOCIAL OUTCOMES IN TRIBAL SCHOOL CHILDREN: A RANDOMIZED CONTROLLED TRIAL

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## ABSTRACT

Indigenous games represent culturally embedded physical activities with potential benefits for holistic development; however, experimental evidence in school-based settings remains limited. This randomized controlled trial examined the effects of an eight-week indigenous games-based physical education programme on physical performance, neuromechanical efficiency, and psychosocial outcomes in tribal school children. The participants (11-15 years old) were randomly divided into 48 experimental (indigenous games) and control (conventional physical education) groups. The intervention was conducted three times per week for eight weeks. Pre- and post-intervention measures of physical performance (30 m sprint, agility, standing broad jump, and estimated VO2 max), neuromechanical variables (reactive strength index, ground contact time, and change-of-direction deficit), and psychosocial outcome (social cohesion, motivation, and enjoyment) were measured. The covariance analysis indicated that there were significant group x time group effects in favour of the experimental group in all the variables ($p < 0.001$), and the effect sizes (n2p) are very large (0.27-0.35). The experimental group showed significant changes in sprint performance (−7.0%), agility (−8.1%), lower-limb power (+11.3%), and aerobic capacity (+14.1%). Neuromechanical changes involved a more reactive strength index and less ground contact time, which showed more efficiency in the stretch-shortening cycle. Psychosocial measures demonstrated significant improvements in social cohesion and intrinsic motivation. These results indicate that indigenous games offer a culturally pertinent and scientifically sound strategy of enhancing multidimensional developmental outcomes of tribal youth in school-based physical education.

**Keywords:** Physical Education and Training, Motor Skills, Physical Fitness, Biomechanical Phenomena, Social Behavior, Adolescent

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## 1. INTRODUCTION

Physical education (PE) is widely recognized as a fundamental component of holistic child development, contributing to physical fitness, motor competence, and psychosocial well-being. Within the field of sports science, there has been increasing emphasis on identifying pedagogical approaches that not only enhance physiological performance but also promote engagement, inclusivity, and cultural relevance (Chu et al., 2018). Despite these developments, conventional PE programmes in many school settings continue to rely on standardized, technique-based activities that may not adequately reflect the sociocultural context of learners, particularly among indigenous and tribal populations (Eather et al., 2023).

Tribal children represent a distinct population characterized by unique cultural practices, lifestyles, and movement traditions. However, research examining their physical development within formal educational systems remains limited (Malina et al., 2018). Existing studies have primarily focused on nutritional status, general health indicators, or basic fitness profiling, often overlooking the role of culturally embedded physical activities. Furthermore, conventional PE programmes may not align with the lived experiences of tribal children, potentially reducing participation, motivation, and long-term engagement in physical activity (Fleischhacker et al., 2016; Thompson et al., 2001). This gap highlights the need for context-specific, culturally responsive interventions that bridge traditional practices with modern educational frameworks (Pate et al., 2022).

Indigenous games are an integral part of tribal culture and have traditionally served as a means of physical conditioning, social interaction, and skill development. These activities are typically characterized by multidirectional movement patterns, intermittent high-intensity efforts, and dynamic decision-making demands (Amlor, 2016). From a scientific perspective, these characteristics align with the principles of motor learning, which emphasize variability, adaptability, and the interaction between the individual, task, and environment. In contrast to repetitive drill-based training, indigenous games provide enriched movement environments that support the development of both fundamental motor skills and advanced neuromuscular adaptations (Newell & Rovegno, 2021).

Recent theoretical advancements, particularly within the framework of ecological dynamics, further support the integration of game-based approaches in physical education. This perspective posits that movement behavior emerges from continuous interaction between the individual and environmental constraints, suggesting that learning is optimized in environments that encourage exploration and problem-solving (Moy et al., 2019; Roberts et al., 2018). Indigenous games inherently embody these principles, requiring participants to adapt to unpredictable situations, respond to opponents' actions, and coordinate movements in real time. Consequently, such activities may enhance not only physical performance but also movement efficiency and perceptual–cognitive abilities (Otero et al., 2018).

From a physiological perspective, the intermittent and high-intensity nature of indigenous games has the potential to induce significant adaptations in both aerobic and anaerobic systems. Repeated bouts of sprinting, jumping, and directional changes can improve cardiovascular endurance, muscular strength, and power (Drachuk et al., 2018). Additionally, these activities may positively influence neuromechanical properties, particularly the efficiency of the stretch–shortening cycle, which is essential for dynamic movements. However, empirical evidence examining these mechanisms within indigenous games-based interventions remains limited, especially in school-aged tribal populations (Lyoka, 2011).

In addition to physical and neuromechanical benefits, the psychosocial dimension of physical education is increasingly recognized as a critical factor influencing student engagement and overall development (Kiran & Knights, 2010; Louth & Jamieson-Proctor, 2018). Constructs such as motivation, enjoyment, and social cohesion are essential for fostering lifelong participation in physical activity. Indigenous games, due to their cooperative and culturally meaningful nature, may provide an effective context for enhancing these outcomes. Participation in community-based activities can strengthen social connectedness, reinforce cultural identity, and promote inclusive engagement, particularly among children who may feel marginalized within conventional educational settings (Sulaiman, 2015).

Despite their theoretical and practical potential, there is a lack of rigorous experimental studies evaluating the effectiveness of indigenous games using multidimensional outcome measures. Most existing research is descriptive and does not incorporate advanced performance indicators such as biomechanical efficiency or neuromuscular function (Fernández et al., 2021). Furthermore, few studies have employed controlled experimental designs capable of establishing causal relationships between interventions and outcomes. This limitation restricts the translation of traditional practices into evidence-based educational strategies. Guzmán (2026)

Therefore, the present study aimed to address these limitations by systematically investigating the effects of an indigenous games-based physical education programme on physical performance, neuromechanical efficiency, and psychosocial development in tribal school children. By integrating quantitative performance measures with psychosocial assessments, this study provides a comprehensive evaluation of culturally relevant physical activity interventions. It was hypothesized that participation in indigenous games would result in significant improvements across all measured domains compared with conventional physical education.

The intervention was designed within an ecological dynamic's framework; wherein indigenous games provide a variable and constraint-rich movement environment that facilitates perception–action coupling and adaptive motor responses. These task characteristics are expected to promote neuromuscular adaptations alongside improvements in physical and psychosocial outcomes. The conceptual relationships underpinning these mechanisms are illustrated in Figure 1.

The findings contribute to the existing literature that supports the use of culturally responsive pedagogy in physical education. Moreover, the research intends to offer empirical data to facilitate the need for inclusion of indigenous movement practices in school curricula, thus facilitating the development of science and cultural preservation.

**Figure 1**

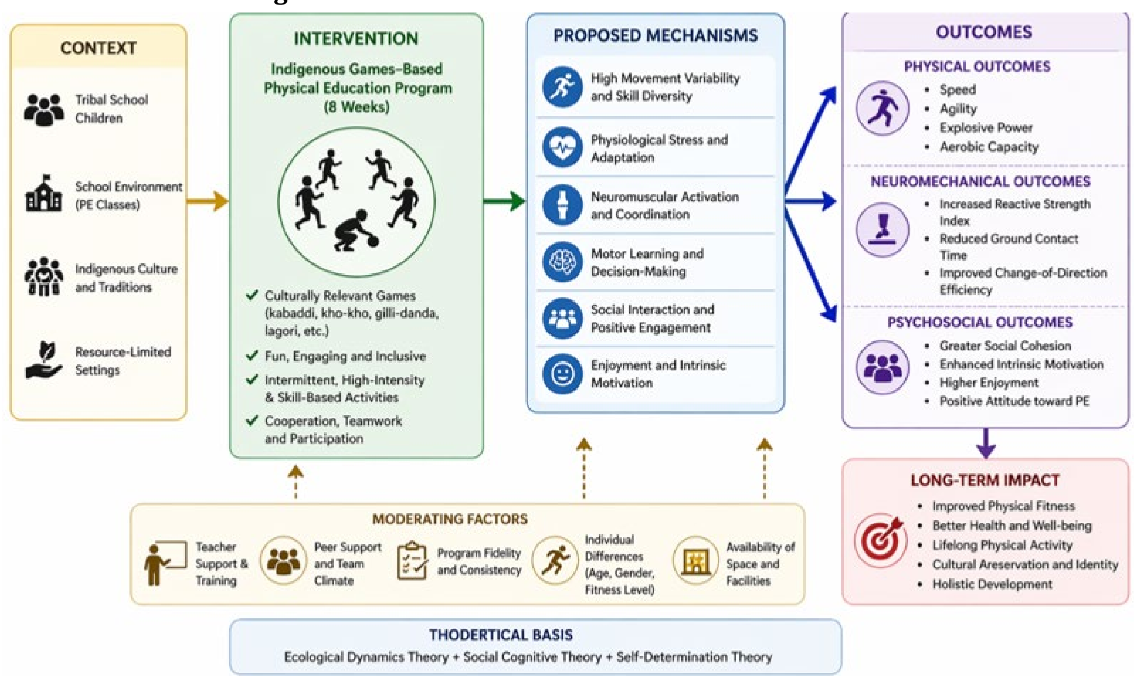


**Figure 1** Conceptual Framework of the Indigenous Games-Based Physical Education Intervention Showing Relationships Between Task Constraints, Neuromuscular Adaptations, and Multidimensional Outcomes.

## 2. MATERIALS AND METHODS

### 1) Study Design

The study utilized a randomized controlled pre-post experimental design to investigate the impact of an indigenous games-based physical education programme on physical, neuromechanical, and psychosocial outcomes. The experiment involved two parallel groups, an experimental group and a control group, in which the former engaged in the training of indigenous games and the latter engaged in traditional physical education. The design was based on the standard principles of reporting in randomized trials, which guaranteed methodological transparency and internal validity. The research was carried out and presented in line with the CONSORT 2010 guidelines.

### 2) Participants

Forty-eight tribal school children (both boys and girls) aged 11-15 years were selected in government schools in a rural tribal area, Kerala, India. Purposive sampling was employed to select the participants based on their availability and then randomized to two groups: experimental (n = 24) and control (n = 24).

### 3) Sample Size Determination

G*Power (version 3.1) was used to calculate the necessary sample size to achieve a statistical power of 0.80 and an alpha level of 0.05 in a repeated-measures study to detect a moderate effect (f = 0.25). The analysis showed that there was a minimum of 34 participants. In order to take into consideration, the possible attrition, 48 participants were recruited.

### 4) Randomization and Allocation

A randomization sequence generated by a computer was used to assign participants to either the experimental or control group. An independent researcher who was not a part of data collection or intervention delivery ensured allocation concealment. There were no people who dropped out of the study. Figure 2 shows the flow of the participants through the study.

**Figure 2**

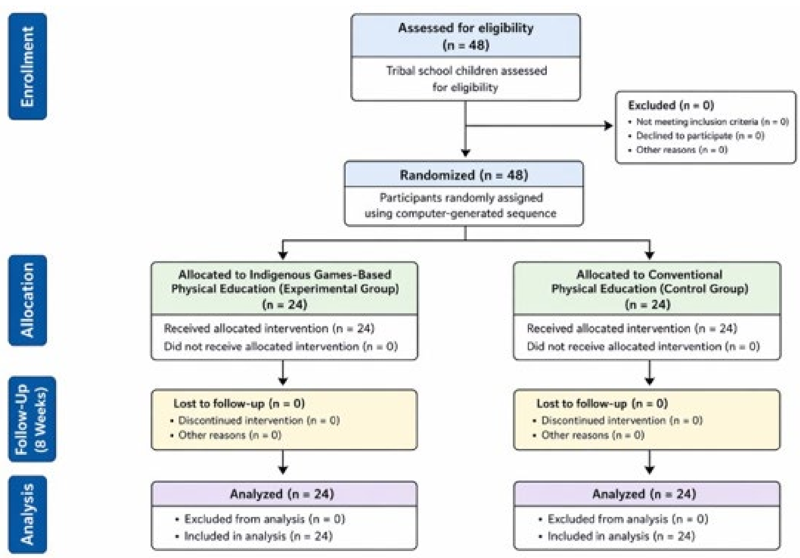


**Figure 2** CONSORT Flow Diagram of Participant Recruitment, Allocation, Follow-Up, And Analysis in the Randomized Controlled Trial.

### 5) Intervention Protocol

The intervention process lasted eight weeks, and the sessions were three times a week but on different days. The sessions were about 45 minutes long and had a standardized format consisting of a 10-minute warm-up, 30 minutes of main activity, and a 5-minute cool-down. The experimental group was exposed to an indigenous games-based physical education programme, which included kabaddi, kho-kho, and lagori activities, which were chosen due to their ability to produce multidirectional and high-intensity movement patterns. The programme was developed through a progressive overload strategy in three stages: familiarization (weeks 1-2), progression (weeks 3-5), and optimization (weeks 6-8). The intensity of training was manipulated by controlling the duration of the bouts, the rest periods, and the complexity of the tasks, and the total training load was measured by session rating of perceived exertion (sRPE). Table 1 provides detailed information on the structure of the session, the volume of training, and progression strategies. The control group maintained their usual physical education sessions, which included calisthenics and general fitness activities, but did not have a system of progression or variation in the form of a game.

**Table 1**

**Table 1 Indigenous Games-Based Physical Education Intervention Protocol (8 Weeks)**

| Phase (Weeks) | Frequency (sessions·week$^{-1}$) | Session Duration (min) | Intensity (sRPE*) | Content (Indigenous Games & Drills) | Volume / Structure | Progression Features |
|---|---|---|---|---|---|---|
| Familiarization (1–2) | 3 | 45 | 3–4 (moderate) | Basic rules and movement patterns; modified kabaddi, kho-kho, lagori; low-intensity tag and chase activities | 2–3 bouts × 5–6 min; 2–3 min passive rest between bouts | Emphasis on technique, safety, and spatial awareness; larger play areas; simplified rules |

| | | | | | | |
|---|---|---|---|---|---|---|
| Progression (3–5) | 3 | 45 | 5–6 (moderate–vigorous) | Standardized kabaddi, kho-kho, lagori; small-sided games; reactive drills (start–stop, change of direction) | 3–4 bouts × 6–8 min; 1–2 min rest between bouts | Increased bout duration; reduced rest; introduction of tactical constraints (time limits, scoring rules) |
| Optimization (6–8) | 3 | 45 | 7–8 (vigorous) | Competitive gameplay; full-rule formats; high-intensity chase/escape and evasion tasks; repeated sprint actions | 4–5 bouts × 8–10 min; ≤1 min rest between bouts | Maximal game intensity; smaller play areas; higher opponent density; decision-making under pressure |

### 6) Outcome Measures

All the tests were done a week prior to and after the intervention in standardized conditions. Field-based tests were used to measure physical performance. Speed was measured with the help of the 30 m sprint test (in seconds)(Sinclair et al., 2021), agility was measured with the help of the Illinois agility test (in seconds)(Singh et al., 2017), and lower-limb explosive power was measured with the help of the standing broad jump (in centimetres)(Ayala et al., 2017). The 20 m shuttle run test was used to estimate aerobic capacity with results given as the predicted $VO_2$max (ml·kg$^{-1}$·min$^{-1}$)(Petros et al., 2016).

To test the efficiency of movements, neuromechanical variables were measured. Reactive strength index (RSI) was determined by using jump height and ground contact time, and ground contact time (ms) was recorded using motion analysis programs that had been validated. The sprint and agility performance measures were used to calculate change-of-direction deficit (s)(Fernandes et al., 2020).

All the neuromechanical variables showed good reliability with intraclass correlation coefficients of more than 0.85. Standardized measures were used to assess psychosocial outcomes. A validated group interaction scale was used to measure social cohesion, a standardized motivation inventory was used to measure intrinsic motivation, and a physical activity enjoyment scale was used to measure enjoyment(Zarrett et al., 2021). Each of the questionnaires was given in the local language with proper explanations to make sure that the participants understood it.

### 7) Testing Standardization

A familiarization exercise was done for all the participants before baseline testing. All the assessments were done at the same time of day to reduce circadian variation. The participants were advised not to engage in vigorous activity 24 hours before testing and to have regular diets.

### 8) Statistical Analysis

IBM SPSS Statistics (version 25.0) was used to analyse data. Descriptive statistics were in the form of mean ± standard deviation. The Shapiro-Wilk test was used to test the normality of distribution, and the Levene test was used to test the homogeneity of variance. To test the between-group differences at the post-test with the control of the baseline values, a mixed-model analysis of covariance (ANCOVA) was conducted. Paired sample t-tests were used to analyse within-group changes. ANCOVA and pairwise comparisons were calculated using partial eta squared ($\eta^2$p) and Cohen's d, respectively. The statistical significance was determined at $p < 0.05$.

## 3. RESULTS

All the conditions were met: normality (Shapiro-Wilk, $p > .05$) and homogeneity of variance (Levene test, $p > .05$). Descriptive data are given in the form of mean + SD. None of the participants dropped out, and all participants who were randomized were used in the final analyses.

**Table 2**

**Table 2 Baseline Characteristics of Participants**

| Variable | Experimental (n = 24) | Control (n = 24) | *p* |
|---|---|---|---|
| | Mean ± SD | Mean ± SD | |
| Age (years) | 12.8 ± 1.4 | 13.0 ± 1.3 | .62 |
| Height (cm) | 148.5 ± 6.2 | 149.1 ± 5.9 | .71 |
| Body Mass (kg) | 40.2 ± 5.8 | 41.0 ± 6.1 | .65 |

| | | | |
|---|---|---|---|
| BMI (kg/m$^2$) | 18.2 ± 2.1 | 18.4 ± 2.3 | .74 |

**Note.** Values are presented as mean ± standard deviation. No significant baseline differences between groups (p > .05).

At baseline, there were no statistically significant differences in age, height, body mass, or body mass index (all p > .05) between the experimental and control groups, and thus, the groups were similar before the intervention (Table 2).

**Table 3**

**Table 3 Pre- and Post-Intervention Physical Performance Variables**

| Variable | Group | Pre-Test Mean ± SD | Post-Test Mean ± SD | Δ Change | % Change |
|---|---|---|---|---|---|
| 30 m Sprint (s) | Experimental | 5.82 ± 0.34 | 5.41 ± 0.30 | −0.41 | −7.0% |
| | Control | 5.79 ± 0.36 | 5.70 ± 0.35 | −0.09 | −1.5% |
| Agility (s) | Experimental | 18.4 ± 1.2 | 16.9 ± 1.1 | −1.5 | −8.1% |
| | Control | 18.2 ± 1.3 | 17.8 ± 1.2 | −0.4 | −2.2% |
| Broad Jump (cm) | Experimental | 142.5 ± 12.3 | 158.6 ± 13.1 | 16.1 | 11.30% |
| | Control | 143.1 ± 11.9 | 147.2 ± 12.5 | 4.1 | 2.90% |
| $VO_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$) | Experimental | 38.2 ± 3.5 | 43.6 ± 3.8 | 5.4 | 14.10% |
| | Control | 38.5 ± 3.7 | 40.1 ± 3.6 | 1.6 | 4.10% |

**Note. Δ =** mean change (post – pre). Negative values indicate improvement for time-based variables.

After 8 weeks of intervention, the experimental group showed significant changes in all the variables of physical performance in comparison with the control group (Table 3). Sprint performance at 30 m or more significantly increased in the experimental group (Δ = -0.41 s; -7.0%), but only insignificant changes were found in the control group (Δ = -0.09 s; -1.5%). Agility performance also followed the same trend, as there was a significant decrease in the completion time in the experimental group (Δ = -1.5 s; -8.1%) and a slight increase in the control group (Δ = -0.4 s; -2.2%). The explosive power, measured with the standing broad jump, showed significant improvement in the experimental group (Δ = +16.1 cm; +11.3%), whereas the control group experienced a slight improvement (Δ = +4.1 cm; +2.9%). The experimental group (Δ = +5.4 mlkg-1min-1; +14.1%) showed a significant increase in aerobic capacity (VO2max) compared to a small increase in the control group (Δ = +1.6 mlkg-1min-1; +4.1%).

**Table 4**

**Table 4 Pre- and Post-Intervention Neuromechanical Variables**

| Variable | Group | Pre-Test Mean ± SD | Post-Test Mean ± SD | Δ Change | *p* |
|---|---|---|---|---|---|
| Reactive Strength Index | Experimental | 1.21 ± 0.18 | 1.48 ± 0.20 | 0.27 | < .001 |
| | Control | 1.19 ± 0.17 | 1.26 ± 0.18 | 0.07 | .08 |
| Ground Contact Time (ms) | Experimental | 312 ± 28 | 276 ± 25 | −36 | < .001 |
| | Control | 309 ± 30 | 300 ± 27 | −9 | .09 |
| COD Deficit (s) | Experimental | 0.78 ± 0.09 | 0.65 ± 0.08 | −0.13 | < .001 |
| | Control | 0.77 ± 0.10 | 0.73 ± 0.09 | −0.04 | .07 |

**Note. COD =** change-of-direction. Δ = mean change (post – pre).

The experimental group showed significant improvements in neuromechanical efficiency (Table 4). Reactive Strength Index (RSI) improved (Δ = +0.27; p < .001), and this means that the stretch shortening cycle functions improved, but the control group did not experience any significant change (Δ = +0.07; p =.08). The experimental group had a significant reduction in ground contact time (Δ = -36 ms; p <.001), indicating an increase in neuromuscular responsiveness. Conversely, the control group showed a small and non-significant decrease (Δ = -9 ms; p =.09). Likewise, change-of-direction (COD) deficit also showed a significant improvement in the experimental group (Δ = -0.13 s; p <.001), whereas the control group did not show any statistically significant change (Δ = -0.04 s; p =.07).

**Table 5**

**Table 5 Pre- and Post-Intervention Psychosocial Variables**

| Variable | Group | Pre-Test Mean ± SD | Post-Test Mean ± SD | Δ Change | Cohen's *d* |
|---|---|---|---|---|---|
| Social Cohesion | Experimental | 3.1 ± 0.5 | 4.2 ± 0.4 | 1.1 | 1.85 |
| | Control | 3.0 ± 0.6 | 3.3 ± 0.5 | 0.3 | 0.45 |
| Motivation | Experimental | 3.4 ± 0.6 | 4.5 ± 0.5 | 1.1 | 1.70 |
| | Control | 3.5 ± 0.5 | 3.8 ± 0.6 | 0.3 | 0.50 |
| Enjoyment | Experimental | 3.2 ± 0.5 | 4.6 ± 0.4 | 1.4 | 2.10 |
| | Control | 3.3 ± 0.6 | 3.7 ± 0.5 | 0.4 | 0.60 |

Note. Δ = mean change (post – pre). Effect sizes interpreted as small (0.2), moderate (0.5), and large (≥0.8).

The experimental group showed significant positive changes in psychosocial variables after the intervention (Table 5). The level of social cohesion improved significantly (Δ = +1.1), and the effect size (Cohen d = 1.85) was large, in contrast to a small improvement in the control group (Δ = +0.3; d = 0.45). Intrinsic motivation and enjoyment also increased more significantly in the experimental group (Δ = +1.1 and +1.4, respectively), which both had large effect sizes (d = 1.7-02.10). Conversely, the control group only had small to moderate improvements in these measures. Between-Group Differences (ANCOVA).

**Table 6**

**Table 6 ANCOVA Results for Post-Test Between-Group Comparisons**

| Variable | F | *p* | Partial $\eta^2$ | Effect Size |
|---|---|---|---|---|
| 30 m Sprint | 18.42 | < .001 | 0.29 | *Large* |
| Agility | 21.35 | < .001 | 0.32 | *Large* |
| Broad Jump | 16.88 | < .001 | 0.27 | *Large* |
| $VO_2$max | 19.76 | < .001 | 0.3 | *Large* |
| Social Cohesion | 24.11 | < .001 | 0.35 | *Very Large* |
| Motivation | 20.54 | < .001 | 0.31 | *Large* |

**Note.** ANCOVA adjusted for baseline values. Partial $\eta^2$ is interpreted as small (0.01), medium (0.06), and large (≥0.14).

The results of the analysis of covariance, which adjusted the values of the baseline, showed statistically significant between-group differences at post-test in favour of the experimental group in all outcome variables (Table 6). Large effect sizes were observed for sprint performance ($\eta^2p$ = 0.29), agility ($\eta^2p$ = 0.32), broad jump ($\eta^2p$ = 0.27), and $VO_2$max ($\eta^2p$ = 0.30). Between-group effects were also significantly high in psychosocial variables, especially social cohesion ($\eta^2p$ = 0.35), which was the biggest effect. The results of all ANCOVAs were statistically significant ($p < .001$), which shows that the indigenous games-based intervention was superior to traditional physical education. Figure 3 shows the percentages of change (Δ%) of outcome variables.

**Figure 3**

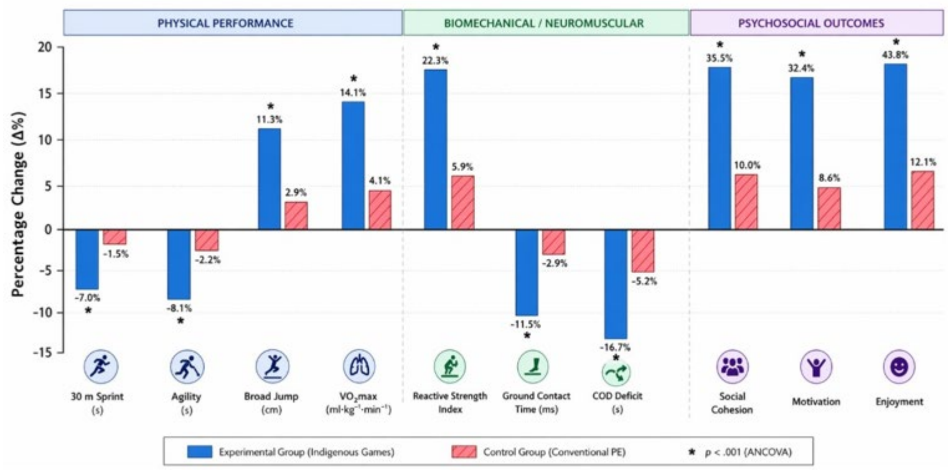


**Figure 3** Percentage Change (Δ%) in Physical Performance, Neuromechanical, and Psychosocial Outcomes

Indigenous games-based physical education programme led to statistically significant and practically significant changes in physical performance, neuromuscular efficiency, and psychosocial outcomes as compared to conventional physical education. The similarity of these effects in several domains with large effect sizes underscores the effectiveness of culturally-based, game-based interventions in fostering holistic development among tribal school children.

## 4. DISCUSSION

The present study examined the impact of an eight-week indigenous games-based physical education program on physical performance, neuromechanical efficiency, and psychosocial outcomes among tribal school children. The main conclusion was that the intervention yielded statistically significant and consistent improvements in all domains measured, with moderate-to-large effect sizes in favour of the experimental group. These findings suggest that game-based and culturally-based activities can be used as an effective and scalable alternative to traditional physical education among this group of people.

### 1) Physical Performance Adaptations

There were significant improvements in sprint speed, agility, lower-limb strength, and aerobic capacity after the intervention. The extent of the change in agility (−8.1) and sprint performance (−7.0) indicates that the repeated exposure to multidirectional and high-intensity motions inherent in indigenous games resulted in significant changes in acceleration, deceleration, and change-of-direction capacity(Akıncı & Ateş, 2023; Larsen et al., 2017). These results are in line with those of game-based and small-sided training paradigms, which show that intermittent and high-intensity actions enhance neuromuscular and metabolic conditioning.

The increase in standing broad jump performance (+11.3) reflects greater lower-limb explosive power, probably due to repeated jumping, lunging, and rapid propulsion exercises inherent in exercises like kabaddi and kho-kho. Equally, the positive change in the estimated $VO_2max$ (+14.1) indicates a positive change in cardiorespiratory fitness, which can be explained by the intermittent nature of gameplay, where aerobic and anaerobic energy systems are concurrently challenged(Pujari & Rathore, 2023). Taken together, these findings help sustain the assumption that indigenous games have the ability to simulate the physiological requirements of formal training and remain ecologically valid and engaging(Akbar et al., 2020).

### 2) Neuromechanical Adaptations

A notable strength of the present study is the incorporation of neuromechanical measures, which give an idea of the mechanisms that drive performance improvements. The large rise in the index of reactive strength and a decrease in ground contact time suggest greater efficiency of the stretch-shortening cycle. These changes imply enhanced neuromuscular coordination and enhanced ability to store and reuse elastic energy in dynamic movements(Meszler et al., 2019).

Moreover, the decrease in change-of-direction deficit indicates the increase in movement efficiency in the directional transitions. The unpredictable and open skill of indigenous games must have necessitated constant adaptations in body posture, use of force, and timing, thus developing motor control strategies. Such environments encourage adaptive movement solutions as opposed to linear or pre-planned drills, which are crucial to functional athletic performance(Duarte et al., 2022; Hussain & Cheong, 2022; Strafford et al., 2018). These results are relevant to the existing literature as they show that activities with cultural roots can not only affect the performance outcomes but also the biomechanical efficiency behind them.

**3) Psychosocial Outcomes**

Besides physical and neuromechanical positive changes, the intervention also resulted in significant psychosocial variable improvements, such as social cohesion, intrinsic motivation, and enjoyment. The enormous effect sizes of these outcomes highlight the holistic effect of indigenous games. Cooperation, communication, and common goals are inherent to these activities and can enhance interpersonal relationships and group dynamics(Louth & Jamieson-Proctor, 2018; Moloi et al., 2021).

The gains of motivation and enjoyment are especially applicable to school-based settings, where participation is a decisive factor of long-term involvement. Culturally familiar and inherently rewarding, indigenous games can help to increase the desire of students to engage actively in physical education(Mo et al., 2023). This is in line with the modern educational views, which stress the learner-centred methods and the incorporation of culturally relevant content to enhance the learning outcomes.

**4) Integration with Theoretical Frameworks**

The results obtained may be viewed in the context of the ecological dynamics theory, which assumes that movement behaviour is the result of the interaction of the individual, task, and environmental constraints. Native games offer a diverse and abundant movement experience, which is unpredictable and requires decisions. These conditions support perception-action coupling and the development of motor skills in a flexible manner. In motor learning terms, the variability of these activities could increase skill transfer and retention through exploration and problem-solving(Dhawale et al., 2017; Seifert et al., 2018). The simultaneous enhancement of physical, neuromechanical, and psychosocial domains underscores the integrative quality of the approach, which explains its applicability to the overall development of youth.

**5) Practical Implications**

The results of this research have significant implications for the practice of physical education, especially in tribal and resource-constrained environments. Indigenous games are a low-cost, culturally relevant, and scalable intervention that can be easily integrated into school curricula. Their low equipment needs and flexibility ensure that they can be used in a variety of learning settings. Such activities, when included in formal physical education programmes, can potentially enhance physical fitness, as well as social inclusion and cultural continuity(Williams & Pill, 2019). These findings have empirical implications for educators and policymakers to develop context-specific curricula that can be in line with local traditions and still achieve current health and performance goals.

**6) Strengths and Limitations**

The main advantage of the current study is its randomized controlled design and a multidimensional assessment model, which includes physical, neuromechanical, and psychosocial outcomes. This multi-faceted method increases the internal validity as well as the practical relevance of the findings. Nevertheless, some shortcomings must be recognized. The sample was restricted to a particular tribal group, which can limit the external validity of the findings. Also, the intervention period, though adequate to achieve meaningful adaptations, does not give information on long-term retention or the sustainability of long-term effects. Further studies are encouraged to use longitudinal designs, sample sizes, and more diverse samples, and include follow-ups to determine the long-term effects.

Overall, the present study shows that indigenous games-based physical education is a promising intervention to enhance physical performance, neuromechanical efficiency, and psychosocial well-being in tribal school children. The incorporation of culturally significant movement practices into the organized educational environments is a promising way of attaining not only health-related but also developmental results.

## 5. CONCLUSIONS

An eight-week physical education programme based on indigenous games generated a remarkable effect on physical performance, neuromechanical efficiency, and psychosocial outcome of tribal school children. The intervention resulted in better improvements in speed, agility, power, aerobic capacity, and movement efficiency, as well as improved social cohesion, motivation, and enjoyment compared to traditional physical education. These results validate the usefulness of culturally relevant, game-based interventions as a viable and scalable intervention in fostering holistic growth in physical education in schools. The integration of indigenous games into school-based physical education may also support cultural preservation while promoting inclusive and sustainable health-oriented educational practices.

## ETHICS APPROVAL

This study was approved by the Institutional Research Ethics Committee of the Hindustan Institute of Technology and Science (Deemed to be University), Chennai, India (Approval No.: HITS/CRC/004/20603034), and conducted in accordance with the Declaration of Helsinki (2013 revision). Written informed consent and parental consent (for participants under 18 years) were obtained.

## AVAILABILITY OF DATA AND MATERIALS

The datasets of this study are available from the corresponding author upon reasonable request.

## AI TRANSPARENCY

In the preparation of this manuscript, the authors used Jenni AI as an assistive tool for language editing, paraphrasing, and improving clarity. All AI-assisted content was critically reviewed, verified, and edited by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the work.

## AUTHOR CONTRIBUTIONS

Deepak J S contributed to conceptualization, data collection, methodology, statistical analysis, manuscript drafting, and final approval of the manuscript.

Dr. D. Harigaran supervised the study, contributed to study design, manuscript review, editing, and final approval of the manuscript.

## CONFLICT OF INTERESTS

None.

## ACKNOWLEDGMENTS

None.

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