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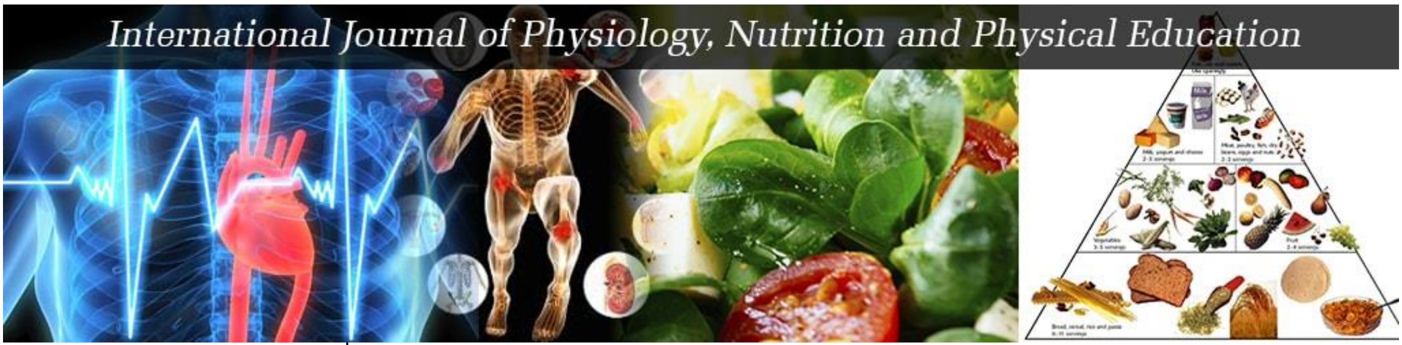

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Effects of core strength training and yogasana practices on muscular fitness of school students

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Abstract
The aim of this study to examined how a 12-week core strength training program and a yogasana intervention affected muscular strength and endurance in school-aged adolescents. 195 students whose age 15-19 years were randomly assigned to a Core Strength Training Group (CRG), a Yogasana Practices Group (YG), or a Control Group (CG). From there 65 subjects were randomly select for per group. Muscular strength and endurance for upper- and lower-body were measured before and after the intervention using push-ups, static wall squat, sit-ups, and plank. One-way ANCOVA showed significant group differences in all fitness measures (p<0 .001). Post-hoc tests revealed that CRG attained the greatest gains overall, with YG also significantly outperforming CG. For example, CRG performed on average 7.90 more push-ups than CG (p<.001) and 3.13 more than YG (p<.001). Similarly, CRG increased sit-up endurance by 12.29 reps more than CG (p<.001) and 6.20 more than YG (p<.001). These results indicate that both interventions significantly improve adolescents' muscular fitness, with core training yielding the largest effects.

Keywords: Core strength, yogasana practices, muscular strength, muscular endurance, adolescents, fitness training

Introduction

Adolescence is a critical period for physical development, marked by rapid musculoskeletal growth and heightened neuroplasticity, which underscores the importance of targeted interventions to enhance muscular fitness (Malina*et al.*, 2015) [12]. Muscular fitness encompassing muscular strength and muscular endurance is a cornerstone of functional mobility, athletic performance, and injury prevention (Faigenbaum *et al.*, 2016) [6]. Robust muscular fitness in adolescence not only supports participation in physical activities but also establishes lifelong health trajectories by reducing risks of obesity, metabolic disorders, and musculoskeletal injuries (Ortega *et al.*, 2008) [14]. Despite its significance, global trends indicate declining muscular fitness among adolescents, attributed to sedentary lifestyles and inadequate physical education curricula (Tomkinson *et al.*, 2019) [19]. This decline necessitates evidence-based interventions to revitalize youth fitness paradigms.

Core strength training and yogasana practices represent two distinct yet complementary approaches to improving muscular fitness. Core strength training, emphasizing dynamic and isometric exercises targeting the trunk and limb muscles, enhances stability, power transmission, and neuromuscular coordination (Hibbs *et al.*, 2008) [10]. Conversely, yogasana integrates controlled postures and breathe work to improve flexibility, balance, and proprioception, fostering holistic muscular engagement (Ross & Thomas, 2010) [16]. While prior studies validate the efficacy of core training in boosting strength and endurance (Prieske *et al.*, 2016) [15] and yogasana in enhancing flexibility and mental well-being (Hagen &Nayar, 2014) [9], comparative research on their differential impacts on upper- *and* lower-body muscular fitness remains scarce. Most existing studies focus on isolated muscle groups or adult populations, neglecting adolescents' unique physiological and developmental needs (Smith *et al.*, 2021) [18]. Furthermore, limited evidence exists on the longitudinal effects of 12-week interventions, a duration critical for inducing hypertrophic and neural adaptations (American College of Sports Medicine [ACSM], 2018) [2].

This study addresses these gaps by examining the effects of a 12-week core strength training program and yogasana regimen on upper and lower body muscular strength and endurance in school students. The primary objectives were to compare the efficacy of core training and yogasana in improving muscular fitness across distinct anatomical regions, and to establish foundational evidence for integrating these modalities into school-based physical education programs. By employing standardized assessments, the findings aim to inform educators, coaches, and policymakers on optimizing training protocols to combat sedentary and foster physically resilient youth populations.

Selection of Subjects

This randomized controlled trial involved 195 adolescents aged 15-19 years; both genders, selected from a population of approximately 3,000 students at Islamganj High Madrasah in Nadia District, West Bengal, India. A stratified random sampling method was employed to ensure proportional representation across age groups and genders. Eligibility criteria included enrolment in grades IX-XII with absence of musculoskeletal injuries or chronic medical conditions, and written informed consent from both participants and their parents/guardians. Students meeting these criteria were pooled, and a computer-generated randomization sequence (using SPSS v25) assigned them to one of three groups: Core Strength Training Group (CRG; *n* = 65), Yogasana Practices Group (YG; *n* = 65), or Control Group (CG; *n* = 65). The Control Group followed the standard school curriculum without additional interventions. Approval was obtained from the Institutional Review Board of Department of Physical Education University of Kalyani.

Criterion Measured: Muscular fitness was evaluated through four standardized tests administered in a controlled indoor sports facility under the supervision of trained researchers to ensure procedural consistency. First, upper-body strength was assessed using the Standard Push-Up Test (McColl, 2019) [13]. Second, lower-body isometric strength was measured via the Wall Squat Test (Wood, 2019) [21]; time sustained (seconds) was recorded using a digital stopwatch, with a protractor ensuring proper knee alignment. Third, core endurance was evaluated using the Sit-Up Test (Kevi *et al.*, 2013) [11]. Finally, lower-body endurance was assessed via the Plank Test. All tests were preceded by a 48-hour familiarization session to minimize learning effects.

Research Framework & Protocol

This study employed a randomized controlled experimental design, with participants randomly allocated to three groups. Pre-test data were collected over one week in June 2023 using standardized muscular fitness assessments under controlled environmental conditions. Test-retest reliability was established for all measures through a pilot study conducted one-week prior, ensuring instrument consistency (Kevi *et al.*, 2013) [11]. The CRG underwent a 12-week progressive Core Strength Training program (3 days/ 2 sessions/week, 30-45 minutes/session), incorporating exercises such as planks, bird-dogs, and core twists. The Yogasana Practices Group followed a structured yogasana protocol (3 days/ 2 sessions/week, 30-45 minutes/session), performing sequences like Tadasana, Bhujangasana, Sarvangasana and others emphasizing whole-body alignment and breath control. The Control Group continued their regular school activities without additional training. Post-tests were conducted in September 2023 under identical environmental and procedural conditions as pre-tests. Certified fitness trainers and yoga instructors supervised all sessions to ensure adherence to protocols.

Statistical Analysis

Data were analyzed using SPSS version 25. Each fitness outcome was analyzed with one-way ANCOVA. Effect sizes were reported as partial η^2. Post hoc pair wise comparisons were done with Bonferroni adjustment. Significance was set at $p<0.05$.

Result and Discussion

The study's outcomes are presented through two analytical frameworks: Table 1 summarizes pre- and post-intervention descriptive statistics with mean and *SD* for muscular fitness variables across all groups, while Table 2 details the results of one-way ANCOVA and Bonferroni post hoc comparisons, adjusting for baseline differences.

Table 1: Pre Post session descriptive characteristics of all variables

Variables	CG		CRG		YG	
	Pre	Post	Pre	Post	Pre	Post
UBS	17.28±4.65	15.32±4.35	30.23±7.93	35.22±8.24	27.05±6.40	29.14±6.44
LBS	44.71±12.08	41.72±12.53	86.07±32.42	105.82±39.63	78.19±31.84	94.07±31.38
UBSE	19.66±5.16	17.06±5.34	33.52±9.60	41.98±8.99	31.66±9.13	34.09±8.94
LBSE	48.09±11.16	44.8±11.65	100.06±34.85	122.46±40.4	72.89±24.36	92.76±27.82

(UBS: Upper Body Strength, LBS: Lower Body Strength, UBSE: Upper Body Strength Endurance, LBSE: Lower Body Strength Endurance)

Table 1 present's pre and post-intervention descriptive statistics for muscular fitness variables across the Control Group (CG), Core Strength Training Group (CRG), and Yogasana Practices Group (YG).The CRG demonstrated the largest improvement in UBS, reflecting a 16.5% increase, while the YG showed modest gains with 7.7% increase. In contrast, the CG exhibited a decline -11.3%, underscoring the efficacy of structured interventions. The higher post-test variability in CRG suggests individual differences in responsiveness to resistance-based training.CRG participants achieved substantial gains in LBS 22.9%, outperforming YG 20.3%. Both experimental groups surpassed the CG, which declined. The wider post-test SD in CRG (39.63) highlights heterogeneity in lower-body adaptation, potentially due to baseline fitness disparities. The CRG improved markedly in UBSE approximately 25.2%, whereas YG showed minimal gains 7.7%. The CG's performance deteriorated, reinforcing the necessity of targeted training for endurance enhancement. CRG and YG exhibited comparable improvements in LBSE 22.4% and 27.3%. The CG declined, emphasizing the role of inactivity in regressing muscular stamina. Notably, post-test standard deviations increased in CRG for LBS and LBSE, suggesting divergent responsiveness to core training. Conversely, YG's reduced variability in UBSE implies more uniform adaptations to yogasana.

Table 2: ANCOVA and Post hoc of all variables

Variables	*F (2;191)*	*η²*	*CG*		*CRG*
			CRG	*YG*	*YG*
UBS	86.63**	0.48	7.90**	4.77**	3.13**
LBS	38.29**	0.29	23.04**	19.12**	3.92
UBSE	234.37**	0.71	12.29**	6.1**	6.20**
LBSE	55.66**	0.37	22.92**	21.84**	1.08

** Significant at 0.01 level

The one-way ANCOVA, controlling for baseline scores, revealed statistically significant differences among groups for all muscular fitness variables ($p<0.01$). A large treatment effect was observed. Post hoc comparisons indicated that the Core Strength Training Group (CRG) significantly outperformed both the Control Group and the Yogasana Practices Group. YG also surpassed CG, though to a lesser extent. These results underscore core strength training's specificity in enhancing upper-body resistance capacity. A moderate-to-large effect was identified. CRG demonstrated superior gains compared to CG and YG. However, the difference between CRG and YG was non-significant, suggesting both interventions comparably enhance lower-body strength, likely due to shared neuromuscular demands in squat-based movements.

The largest effect size was observed for UBSE. CRG exhibited substantial improvements over CG and YG, while YG also surpassed CG. The CRG's dominance highlights the efficacy of progressive core strength training in sustaining repetitive upper-body efforts. A moderate effect emerged. CRG and YG both outperformed CG, with no significant difference between the two experimental groups. This parity suggests yogasanas isometric holds and core strength training's dynamic exercises similarly enhance lower-body stamina.

Effect sizes (η^2) ranged from moderate (0.29) to large (0.71), per Cohen's (1988) [4] conventions, indicating clinically meaningful improvements. The Bonferroni correction mitigated Type I error risks across multiple comparisons, reinforcing result reliability.

These findings align with resistance training principles, where specificity and progressive overload drive strength adaptations (ACSM, 2018). Yogasana's comparable lower-body gains may stem from enhanced motor unit synchronization and stability (Coulson *et al.*, 2013) [5].

Discussion

The findings demonstrate distinct neuromuscular and physiological adaptations elicited by core strength training and yogasana practices, contextualized by exercise specificity and baseline fitness levels. Below, interpret the mechanisms underlying improvements for each variable, supported by empirical and theoretical evidence.

The CRG's superior gains in UBS (16.5% vs. YG: 7.7%) align with principles of progressive resistance training, where dynamic overload stimulates hypertrophy in the pectoralis major and triceps brachii via mechanotransduction pathways (Schoenfeld, 2010) [17]. Core exercises like planks and push-ups impose high mechanical tension on upper-body muscles, activating mTORsignaling and protein synthesis (West *et al.*, 2021) [20]. In contrast, yogasana's isometric postures (e.g., ChaturangaDandasana) prioritize endurance over maximal strength, limiting hypertrophic adaptations (Hagen &Nayar, 2014) [9]. The CG's decline (-11.3%) mirrors global trends of adolescent sedentarism eroding musculoskeletal health (Tomkinson *et al.*, 2019) [19].

Both CRG (+22.9%) and YG (+20.3%) exhibited significant LBS improvements, attributable to shared neuromuscular demands. Core training's squats and lunges enhance quadriceps cross-sectional area through eccentric-concentric cycles; while yogasana's Utkatasana (chair pose) improves motor unit recruitment via sustained isometric contractions (Granacher *et al.*, 2016) [8]. The non-significant CRG-YG difference ($p>.05$) suggests that neural adaptations—such as increased rate coding and synchronization—dominate early-stage strength gains, irrespective of exercise modality (Aagaard *et al.*, 2002) [1].

CRG's marked UBSE superiority (+25.2% vs. YG: +7.7%) reflects metabolic adaptations, including increased mitochondrial density and lactate threshold elevation in the deltoids and trapezius (Bishop *et al.*, 2011) [3]. High-repetition core exercises (e.g., mountain climbers) enhance oxidative capacity through AMPK activation, delaying fatigue (Hawley *et al.*, 2014). Yogasana's slower tempo and submaximal intensity likely insufficiently stress type II muscle fibers, limiting endurance gains (Ross & Thomas, 2010) [16].

The comparable LBSE improvements in CRG (+22.4%) and YG (+27.3%) stem from divergent mechanisms. Core strength training's dynamic squats improve capillary density and glycogen storage in the quadriceps, enhancing aerobic endurance (MacInnis&Gibala, 2017). Conversely, yogasana's prolonged holds (e.g., Virabhadrasana II) boost mitochondrial efficiency via PGC-1α upregulation, facilitating sustained ATP production (Gautam *et al.*, 2021) [7]. These findings underscore that endurance adaptations are modality-agnostic when metabolic thresholds are adequately challenged.

The CRG's dominance in strength-related metrics underscores the value of resistance principles (progressive overload, specificity) for adolescent athletic development. Conversely, yogasana's parity in LBSE highlights its utility for disciplines prioritizing stamina over power. The CG's regression emphasizes the urgency of integrating structured physical activity into school curricula to counteract sedentarism. Future research should explore genetic (e.g., ACTN3 polymorphisms) and neuroendocrine (e.g., IGF-1 levels) mediators of training responsiveness.

Conclusion

This study found that 12 weeks of core strength training significantly boosts upper-body strength and endurance in adolescents, while yoga improves lower-body stamina. Both programs outperformed the control group, which showed declines in fitness, highlighting the risks of inactivity. Schools should combine core exercises for sports needing power (e.g., swimming) and yoga for activities requiring flexibility (e.g., dance). Future studies should explore how to sustain these benefits long-term and tailor workouts to individual needs.

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