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COMPARATIVE EFFECTS OF ISOMETRIC AND ISOKINETIC STRENGTHENING EXERCISES ON QUADRICEPS MUSCLE STRENGTH, ENDURANCE, AND FUNCTIONAL PERFORMANCE IN HEALTHY ADULTS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT:

Background: Isometric and isokinetic strengthening exercises are widely used in clinical rehabilitation and sports conditioning, yet direct comparative evidence in healthy populations remains limited.

Objective: To compare the effects of 8-week isometric and isokinetic strengthening exercise programs on quadriceps muscle strength, endurance, and functional performance in healthy young adults.

Methods: A single-blind, randomized controlled trial with 300 healthy adults (150 per group) aged 18-40 years was conducted at Hi-Tech Medical College & Hospital, Bhubaneswar. The isometric group performed multi-angle static contractions (30°, 60°, 90° knee flexion), while the isokinetic group trained at constant angular velocities (60°/s and 180°/s) using a Biodex System 4 Pro dynamometer. Assessments included quadriceps peak torque (primary outcome), muscle endurance, functional tests (Timed Up-and-Go, 30-Second Sit-to-Stand), and subjective measures. Data were analyzed using mixed-model repeated measures ANOVA with between-group comparisons.

Results: At Week 8, isokinetic training produced significantly greater quadriceps peak torque improvements (46.2 Nm gain vs. 28.5 Nm; $p<0.001$) with a large effect size (Cohen's $d=0.89$). Muscle endurance improved 43% in the isokinetic group versus 30% in the isometric group ($p<0.001$). Functional performance improvements were consistently superior in the isokinetic group: 23.2% vs. 16.8% TUG improvement ($p=0.002$) and 37.8% vs. 25.5% STS improvement ($p=0.001$). Strong correlations ($r=0.71$-0.76) demonstrated direct transfer of strength gains to functional capacity.

Conclusion: Isokinetic training produced 62% greater quadriceps strength improvements compared to isometric training, with superior gains in endurance and functional performance. However, isometric training retains substantial clinical value for early-stage rehabilitation and joint protection. A phased, integrated approach optimizes rehabilitation outcomes.

KEYWORDS:

STRENGTH TRAINING, ISOKINETIC EXERCISE, ISOMETRIC EXERCISE, QUADRICEPS MUSCLE, FUNCTIONAL PERFORMANCE, RANDOMIZED CONTROLLED TRIAL, MUSCLE ENDURANCE, REHABILITATION.

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1. INTRODUCTION

The quadriceps femoris muscle group represents the primary extensor of the knee joint and is essential for fundamental activities including walking, stair climbing, and maintaining balance and postural stability. Optimal quadriceps strength is a prerequisite for functional independence and plays a critical protective role against musculoskeletal disorders such as patellofemoral pain syndrome and knee osteoarthritis.

Muscle strengthening techniques are scientifically classified based on contraction type: isometric (static tension without joint movement), isotonic (dynamic contractions against constant load), and isokinetic (dynamic contractions at constant angular velocity).Both isometric and isokinetic modalities are extensively utilized in clinical rehabilitation and athletic conditioning. however, direct comparative evidence in healthy populations remains limited, with most research focused on clinical or pathological cohorts.

Isometric exercise is characterized by minimal equipment requirements, joint protection through absence of movement, and excellent accessibility in resource-limited settings. Conversely, isokinetic training, utilizing specialized computerized dynamometers, provides maximal muscle loading throughout the full range of motion through automatic resistance adjustment. Prior comparative studies have produced conflicting findings

and have been limited by small sample sizes, heterogeneous methodologies, and incomplete assessment batteries.

RESEARCH OBJECTIVES:

1. To compare the effects of 8-week isometric and isokinetic strengthening exercise programs on quadriceps muscle strength (primary outcome: peak torque)
2. To evaluate secondary outcomes: muscle endurance, functional performance (mobility and power), and subjective training experiences
3. To assess the functional transfer of strength gains to real-world activities
4. To examine durability of adaptations at 4-week follow-up

2. METHODS

2.1 STUDY DESIGN

A single-blind, randomized controlled trial (RCT) with allocation concealment and blinded assessors was conducted in accordance with CONSORT guidelines.

2.2 PARTICIPANT POPULATION

Setting: Department of Physiotherapy, Hi-Tech Medical College & Hospital, Bhubaneswar, Odisha, India.
Recruitment Period: January 2025 - August 2025
Total Sample: 300 healthy adults (150 per group)

INCLUSION CRITERIA:

- Age 18-40 years
- Healthy without acute or chronic musculoskeletal conditions
- No lower limb injury within past 12 months
- No structured resistance training within past 6 months
- Physician clearance for moderate-intensity exercise
- Written informed consent obtained

EXCLUSION CRITERIA:

- Active knee pain or pathology
- History of knee surgery or meniscal injury
- Uncontrolled cardiovascular or metabolic conditions
- Current medication affecting muscle function (corticosteroids, anabolic agents)
- Pregnancy or recent major surgery
- Non-compliance predicted or inability to complete protocol

2.3 INTERVENTIONS

Isometric Group (n=150): Multi-angle quadriceps contractions at 30°, 60°, and 90° knee flexion angles; 70-80% perceived maximal voluntary contraction; 3 sets × 10 repetitions per angle per session; 5-7 second holds; 3 sessions per week.

Isokinetic Group (n=150): Bilateral knee extension/flexion at constant velocities (60°/s and 180°/s) using Biodex System 4 Pro dynamometer; maximal voluntary effort; 3 sets × 10 repetitions per velocity; 3 sessions per week.

3. OUTCOME MEASURES AND RESULTS

3.1 PRIMARY OUTCOME: QUADRICEPS PEAK TORQUE

Quadriceps strength was measured via handheld dynamometry at 60° knee flexion across four time points (Baseline, Week 4, Week 8, Week 12 follow-up).

Time point	Isometric (Nm)	Isokinetic (Nm)	p-value
Baseline	94.8 ± 12.3	95.2 ± 11.9	0.78
Week 4	108.5 ± 14.6	118.9 ± 15.2	<0.001
Week 8	123.3 ± 16.8	141.4 ± 18.7	<0.001
Week 12 Follow-up	121.2 ± 15.9	139.8 ± 18.2	<0.001
Gain (Baseline to Week 8)	28.5 Nm	46.2 Nm	<0.001

Table 1: Quadriceps Peak Torque Progression Across Study Timeline

3.2 SECONDARY OUTCOMES: MUSCLE ENDURANCE

Muscle endurance showed significant improvements in both groups with superior isokinetic gains:

Outcome	Isometric	Isokinetic	p-value
Baseline Repetitions	32.4 ± 8.2	33.1 ± 7.9	0.42
Week 8 Repetitions	42.1 ± 9.7	47.2 ± 10.3	<0.001
Improvement (%)	30%	43%	<0.001
Effect Size (Cohen's d)	1.05	1.42	-

Table 2: Muscle Endurance Improvements at 8 Weeks

4. FUNCTIONAL PERFORMANCE RESULTS

4.1 TIMED UP-AND-GO (TUG) PERFORMANCE

Figure 1: Figure 1: TUG Performance Improvements Over 8 Weeks. Isometric group showed 16.8% improvement while isokinetic group achieved 23.2% improvement. Both groups demonstrated consistent gains across 4-week intervals with continued improvement through follow-up.

KEY FINDINGS:

- Baseline TUG (Isometric): 11.8 ± 1.2 seconds
- Baseline TUG (Isokinetic): 11.9 ± 1.1 seconds
- Week 8 TUG (Isometric): 9.8 ± 0.9 seconds (16.8% improvement, $p = 0.002$)
- Week 8 TUG (Isokinetic): 9.1 ± 0.8 seconds (23.2% improvement, $p = 0.002$)

4.2 30-SECOND SIT-TO-STAND (STS) PERFORMANCE

Figure 2: Figure 2: 30-Second Sit-to-Stand Repetition Gains. Isometric training improved STS performance by 25.5% while isokinetic training achieved 37.8% improvement. The isokinetic advantage was consistent across all measurement intervals and maintained at 4-week follow-up.

KEY FINDINGS:

- Baseline STS (Isometric): 16.2 ± 2.1 repetitions
- Baseline STS (Isokinetic): 16.5 ± 2.0 repetitions
- Week 8 STS (Isometric): 20.3 ± 2.4 repetitions (25.5% improvement, $p = 0.001$)
- Week 8 STS (Isokinetic): 22.7 ± 2.6 repetitions (37.8% improvement, $p = 0.001$)

5. COMPARATIVE ANALYSIS AND STRENGTH TRANSFER

5.1 COMPARATIVE STRENGTH GAINS

Figure 3: Comparative Peak Torque Gains (Newton-meters). Isokinetic training demonstrated significantly superior strength development with 46.2 Nm gain compared to isometric training's 28.5 Nm gain ($p<0.001$). This represents a 62% greater improvement in the isokinetic group.

5.2 CORRELATION ANALYSIS: STRENGTH-FUNCTION TRANSFER

Functional Test	Isometric Group (r)	Isokinetic Group (r)	Interpretation
TUG Performance	0.71*	0.74*	Strong positive correlation
STS Repetitions	0.76*	0.78*	Strong positive correlation
Endurance Test	0.68*	0.72*	Moderate-to-strong correlation

Table 3: Pearson Correlation Coefficients: Peak Torque vs. Functional Outcomes (* $p<0.001$)

6. EFFECT SIZE AND CLINICAL SIGNIFICANCE

Figure 4: Figure 4: Cohen's d Effect Sizes Across Primary and Secondary Outcomes. Isokinetic training demonstrated large to very large effect sizes across all measures (d=0.89-1.42), while isometric training showed moderate to large effects (d=0.72-1.05).

7. DURABILITY OF STRENGTH GAINS (4-WEEK FOLLOW-UP)

Measure	Week 8	Week 12 (Follow-up)	% Retention
Isometric Peak Torque (Nm)	123.3 ± 16.8	121.2 ± 15.9	98.3%
Isokinetic Peak Torque (Nm)	141.4 ± 18.7	139.8 ± 18.2	98.9%
Isometric STS Reps	20.3 ± 2.4	19.8 ± 2.3	97.5%
Isokinetic STS Reps	22.7 ± 2.6	22.2 ± 2.5	97.8%

Table 4: Strength Retention at 4-Week Detraining Follow-up (>96% Retention in Both Groups)

8. DISCUSSION

This randomized controlled trial provides robust evidence that isokinetic training produces 62% greater quadriceps strength improvements compared to isometric training in healthy young adults. The superior efficacy of isokinetic exercise aligns with biomechanical principles of maximal resistance throughout full range of motion. However, isometric training retains substantial clinical value, particularly for early-stage rehabilitation and joint protection.

Strong correlations between strength gains and functional performance improvements ($r = 0.71 - 0.78$) demonstrate that laboratory-measured strength increases translate meaningfully to real-world functional capacity. The durability of strength adaptations at 4-week follow-up (>96% retention) suggests substantial physiological integration of training effects.

Clinical Implications: A phased, integrated approach combining isometric exercises for early mobilization with progressive isokinetic training optimizes rehabilitation outcomes while minimizing joint stress.

9. CONCLUSION

Isokinetic training produced significantly superior quadriceps strength, muscle endurance, and functional performance improvements compared to isometric training in healthy adults. Both modalities demonstrated excellent safety profiles and training adherence. A phased rehabilitation approach incorporating both techniques based on recovery stage and individual tolerance offers optimal clinical outcomes.

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