Effectiveness of Metronome-Paced Training for Rehabilitation of Knee Neuromuscular Control Deficiency

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BACKGROUND AND PURPOSE

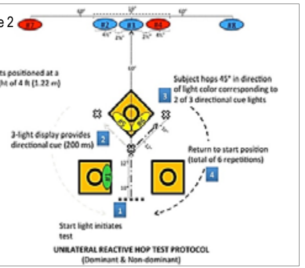
- Failure to restore post-surgical quadriceps and hamstrings strength can lead to joint degeneration and disability[1]
  - Quadriceps (QU) strength deficits of 5-40% have been reported to persist for up to 7 years post-surgery
  - Hamstrings (HS) strength deficits of 9-27% have been reported to persist for up to 3 years post-surgery
- The single-leg squat has been shown to improve neuromuscular control and proper biomechanics of the knee[2,3]
  - Imposes demand that can improve fine motor control and enhance co-contraction of QU and HS
- Metronome training has been shown to modify corticospinal control mechanisms that improve dynamic stability[4]
  - Modulation of presynaptic inhibition believed to affect relative activation levels of antagonistic muscle groups
- The purpose of this study was to assess the potential benefits of metronome-paced single-leg squat progressive resistance exercise to increase quadriceps and hamstrings performance in individuals with a history of knee injury

PARTICIPANTS AND PROCEDURES

- 6 college students (22 ±1.7 years); 5 female (169.16 ±7.75 cm; 69.38 ±8.14 kg) and 1 male (187.96 cm; 80.51 kg)
  - Inclusion criteria: previous knee surgery (>6 months prior) and history of high school sport participation
- Baseline and post-intervention assessments included muscle performance and reactive agility measures
  - Quadriceps and hamstrings performance assessed using isokinetic dynamometer (Figure 1)
    - Biodex System 2™ (Biodex Medical Systems Inc., Shirley, NY)
      - Concentric performance assessed at 60°/sec for 5 repetitions for both extremities
        - Peak Torque (N·m), Average Power (W), and Total Work (N·m)
  - Unilateral Reactive Hop (URH) assessed with wireless programmable light system (Figure 2)
    - FitLight Trainer™ (FITLight Corp., Aurora, Ontario); Reaction Time (RT) and Response Accuracy (RA)
      - Participants respond to color of illuminated array of lights by performing 45° unilateral hop to right or left
      - One familiarization trial of 4 repetitions; one recorded trial of 6 repetitions performed on each extremity
- 4-week single-leg squat exercise program utilized weighted bar and mirror for visual performance feedback
  - Single-leg squat performed only on involved limb for 3 sets of 8-12 repetitions for 3-4 sessions per week
    - Concentric and eccentric phases each lasted 3 seconds (metronome used to time exercise)
  - Program initiated with bar weighing 4.1 kg (9 lb); progression to 5.5 kg (12 lb) and 10.9 kg (24 lb)
    - Resistance level maintained until 12 repetitions possible with proper squat technique to ~70-90° of knee flexion
- Repeated measures analysis of variance performed to assess effect of intervention on performance measures
  - Pre- and post-intervention changes assessed for uninvolved and involved extremities
  - Pre- to post-intervention changes in bilateral performance deficits were assessed
    - Standardized response mean (SRM) calculated to represent magnitude of change[5]
      - Small SRM = 0.2 – 0.5; Moderate SRM = 0.5 – 0.8; Large SRM = ≥ 0.8

Figure 1

Figure 2



RESULTS

- No statistically significant pre- to post-test differences found for any variables ($p < .05$)
  - URH RT: Involved Δ=29 ms faster (1109 → 1080); Uninvolved Δ=109 ms slower (1114 → 1223)
  - URH RA: Involved Δ=5% poorer (94 → 89); Uninvolved Δ=3% better (94 → 97)
  - Peak Torque (N·m): Uninvolved QU Δ=0.36; Involved HS Δ=9.92
  - Average Power (W): Uninvolved QU Δ=2.31; Involved HS Δ=5.55; Uninvolved HS Δ=4.37
  - Total Work (N·m): Involved QU Δ=142.7; Uninvolved QU Δ=40.5; Involved HS Δ=42.6; Uninvolved HS Δ=50.2
- Marginally significant pre- to post-test differences for some variables (p = .05 - .10)
  - Peak Torque: Involved QU Δ=20.65 (t_5=2.01, p=.10); Uninvolved HS Δ=4.86 (t_5=2.45, p=.06)
  - Average Power: Involved QU Δ=18.72 (t_5=2.23, p=.08)
- No significant differences in pre- to post-test bilateral performance deficits were identified (Figures 3 & 4)
- Standardized response means revealed large effects for all isokinetic variables (Tables 1-3)

Figure 3

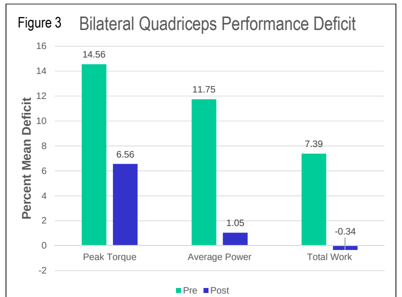


Figure 4

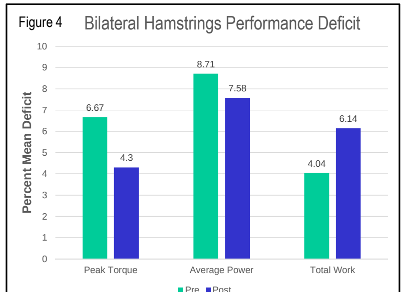


Table 1. Peak Torque Change (N·m)

Extremity – Muscle Group	Mean	Standard Deviation	SRM
Uninvolved Quadriceps	1.37	0.07	19.57
Involved Quadriceps	1.50	0.15	10.00
Uninvolved Hamstrings	1.41	0.04	35.25
Involved Hamstrings	1.45	0.30	4.83

Table 2. Average Power Change (W)

Extremity – Muscle Group	Mean	Standard Deviation	SRM
Uninvolved Quadriceps	0.88	0.09	9.99
Involved Quadriceps	0.99	0.11	9.24
Uninvolved Hamstrings	0.91	0.08	11.19
Involved Hamstrings	0.92	0.10	9.48

Table 3. Total Work Change (N·m)

Extremity – Muscle Group	Mean	Standard Deviation	SRM
Uninvolved Quadriceps	1.14	0.13	8.77
Involved Quadriceps	1.53	0.23	6.65
Uninvolved Hamstrings	1.44	0.18	8.00
Involved Hamstrings	1.41	0.25	5.64

CLINICAL RELEVANCE

- Despite small sample size and lack of statistical significance, SRM values for isokinetic measures were substantial
  - Large SRM values observed for uninvolved QU & HS, which apparently resulted from involved extremity training
- Single-leg squat training paced by metronome may induce beneficial adaptations within the central nervous system
  - Improved isokinetic performance symmetry suggests that post-surgical neural inhibition can be overcome
- Although definitive conclusions cannot be drawn, the metronome-paced single-leg squat exercise performed with visual feedback appears to facilitate a beneficial neuromuscular adaptation for improved dynamic knee stability

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