Inter-Repetition Rest (IRR), Intra-set Rest (ISR), and Cluster Sets (CLU): Evidence for Maximizing Muscular Power

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TOPICS

• Definition
• Physiological Basis
• Early Research
• Acute Response to CLU
• Long Term Response to CLU
• Conclusions & Practical Application
• Questions
DEFINITION

Inter-Repetition, Intra-Set, and Inter-Set Rest

- Inter-repetition rest (IRR)
  - Rest between repetitions
- Intra-set rest (ISR)
  - Rest between groups (clusters) of repetitions within a set
- Inter-set rest
  - Rest between sets

Cluster Sets (CLU)

Set which contains rest between each repetition (IRR) or cluster of repetitions (ISR)

Typically utilized at higher intensities (75-95% 1RM)

4-6 sets
Examples of Cluster Set Configurations

Traditional (TRD)

- Rep 1 → Rep 2 → Rep 3 → Rep 4 → Rep 5 → Rep 6 → 2 min → X 4

Cluster Sets (CLU)

- Rep 1 → Rep 2 → Rep 3 → Rep 4 → Rep 5 → Rep 6 → 2 min → X 4
- Rep 1 → Rep 2 → Rep 3 → Rep 4 → Rep 5 → Rep 6 → 2 min → X 4
- Rep 1 → Rep 2 → Rep 3 → Rep 4 → Rep 5 → Rep 6 → 2 min → X 4

PHYSIOLOGICAL BASIS

Past Progressive decline in maximum isometric force during repeated tetani
Velocity Declines When Repetitions Performed Continuously

Significant reduction in velocity when the number of repetitions was over ⅓ (34%) and ⅓ (48%) of the total number of repetitions performed for bench press and back squat, respectively.

Present
Decrease in power output, recognizes that fatigue can result from a reduction in either force or velocity.

Causes of Fatigue
- Acidosis
  - Accumulation of hydrogen ions from lactate often associated with decrease in force
  - Number of studies have demonstrated this result
- Inorganic phosphate (Pi)
  - Increase during contraction nearly from breakdown of PCr
  - Released in the transition from low force, weakly attached state, to high force state
- Research limited
- Adenosine diphosphate (ADP)
  - Increase during repeated contractions coincident with PCr depletion
  - Partial recovery of shortening velocity linked to removal of ADP by enzymes within or diffusion
  - Experiments on isolated fibers demonstrated inhibitory effect on velocity of shortening
Early Research Supports the Use of Cluster Sets

**EARLY RESEARCH**
Isometric Strength and CLU

- 9 (n = 9) Untrained subjects
- Exercise of elbow flexors
- Protocols
  - TRD
  - CLU 30 seconds IRR
- % Change in isometric strength

Less reduction in isometric force following CLU

Strength Training and CLU

- Forty-two (n = 42) untrained males and females
- Dynamic and isometric strength of elbow flexors
- Training
  - 3 days - week
  - 6 weeks
  - Exercise of elbow flexors
  - 6 to 10 sets of 6RM
- Protocol
  - TRD
  - CLU 30 seconds IRR
Strength Gains and CLU

- No difference in isometric strength
- Smaller gains in dynamic strength following training in CLU

![Graph showing strength gains and CLU]

Physical Work Capacity and CLU

- Fifty (n = 50) untrained males
- Bench press and leg press strength
- Physical work capacity at 170 beats·minute⁻¹ arm cranking exercise
- Training
  - 3 days·week⁻¹
  - 10 weeks
  - Circuit training
    - 3 sets
    - 4 to 10 repetitions
  - 6 stations
- Intervention
  - TRD
  - 1 second IRR
  - 2 second IRR


Greater physical work capacity following training in CLU
No difference in strength gains

![Table showing initial and final strength data]
Peak Isokinetic Torque and CLU

- Twenty-three (n = 23) recreationally active males and females with no history of lower body strength training
- Strength, isometric strength, angle-torque, and peak isokinetic torque
- Training
  - 3 days × week
  - Leg extension exercise
  - ~70% 1RM
- Intervention
  - TRD = 4 sets of 10 with 30 seconds inter-set rest
  - CLU = 4 sets of 10 with 30 seconds IRR and 30 seconds inter-set rest
  - Peak isokinetic torque


Greater high velocity strength gains following training in CLU
- Non-significant tendency (p<0.10) towards greater high velocity strength gains in CLU.
- Similar gains observed in all other variables measured

Early Study Limitations

- Relatively untrained subjects
- Use of single joint, isolation exercises
  - Unlikely these types of exercises utilized in athlete training programs
  - The ability to generate power is dependent on movement involved
- Studies sought to determine mechanism responsible for strength gains thus power not measured
Varying Exercise Types
Metabolic, Hormonal and Ratings of Perceived Exertion

ACUTE EFFECTS OF CLUSTER SETS

Traditional Resistance
Training Exercises
- Improvements in maximal power output of sport specific movements, but attributed to
  - Hypertrophy
  - Increased neural drive
- Limited to untrained or those with relatively low initial strength levels
  - Novice
  - Endurance athletes
- If greater velocities achieved could result in enhancement of muscular power long term

Bench Press Power Output
- Twenty-six (n = 26) elite junior male basketball and soccer players
- Used bench press determination
- Power output during 1 set of 6 repetitions (RM)
- Protocols (equated for time)
  - 6RM Singles = 30 second ISR
  - 6RM Doubles = 40 second ISR
  - 6RM Triples = 50 second ISR

Near Linear Decrease

![Graph showing near linear decrease in power output during repetitions.]

**Figure 2.** Mean power output (SD) associated with 60sJ training. All power outputs are significantly different from each other.

Greater Power Output During Bench Press

**Table 1.** Mean total power output (SD) percentage change, range, and trend p value for continuous, singles, doubles, and triples training effects.

<table>
<thead>
<tr>
<th>Rep 1</th>
<th>Rep 2</th>
<th>Rep 3</th>
<th>Rep 4</th>
<th>Rep 5</th>
<th>Rep 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singles</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
</tr>
<tr>
<td>Doubles</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
</tr>
<tr>
<td>Triples</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
<td>1,300 (100)</td>
</tr>
</tbody>
</table>

* Significantly different from continuous JRM total power output.

- All CLU had net effect of ↑total power output by 21-25% over TRD
- No significant difference between CLU groups
- All CLU configurations equally advantageous at intensities of 6RM or ~85% 1RM

Olympic Weightlifting Exercises

- Often prescribed due to the similarity in movement patterns and the relationship between power output between these lifts and those of athletic movements.
- Thus, any training stimulus that results in an increased power output during performance of Olympic weightlifting movements would hypothetically eliciting further improvements in power output during athletic movements.


Clean Pull Barbell Velocity and Displacement

- Thirteen (n = 13) male athletes all having competed in Olympic weightlifting
- Testing and study protocol integrated into training schedule
- 1RM clean pull determination
- Velocity, displacement, and power during clean pull

Protocols
- TRD = 1 set of 5 repetitions
- CLU = 1 set of 5 repetitions with 30-second IR
- Undulating CLU (UND) = 1 set of 5 repetitions with 30-second IR

Intensity
- 90% 1RM
- 120% 1RM


Greater Peak Velocity and Peak Displacement During Clean Pull

- CLU resulted in greater peak velocity at 90 and 120% 1RM
- CLU resulted in greater barbell displacements at 120% 1RM and approached significance at 90% 1RM
- Trend observed whereas, peak velocity declined with each successive repetition using traditional set
- No difference in peak power between TRD and CLU protocols
Power Clean Technique

- Ten (n = 10) male recreational weightlifters
- 1 RM Power clean determination
- Horizontal and vertical displacement during multiple sets of power clean
- Optimal load or 80% 1RM
- 3 Sets of 6 repetitions with 3 minutes inter-set rest
  - TRD = No IRR (PO)
  - CLU = 20 seconds IRR (P20)
  - CLU = 40 seconds IRR (P40)


Greater Maintenance of Vertical Displacement Over Successive Repetitions During Power Clean

- Peak vertical displacement decreased -2% from repetition 1 to repetition 6 with PO
- No differences in peak vertical displacements from repetition 1 to repetitions 6 in either IRR (P20 or P40)

Power Clean Peak Force, Velocity, and Power

- Ten (n = 10) male recreational weightlifters
- 1 RM Power clean determination
- Peak force, velocity, and power during multiple sets
- Optimal load or 80% 1RM
- 3 Sets of 6 repetitions with 3 minutes inter-set rest
  - TRD = No IRR (PO)
  - CLU = 20 seconds IRR (P20)
  - CLU = 40 seconds IRR (P40)
Greater Peak Force During Power Clean

- Peak force from repetition 1 to repetition 6
  - -7.34% PO
  - -2.67% P20
  - 0.04% P40
- Similar trend observed when evaluating individual sets

Greater Peak Velocity During Power Clean

- Peak velocity from repetition 1 to repetition 6
  - -10.21% PO
  - -3.76% P20
  - -1.70% P40
- Again, similar trends observed when evaluating individual sets

Greater Peak Power Output During Power Clean

- Peak power from repetition 1 to repetition 6
  - -7.51% PO
  - -2.56% P20
  - -1.81% P40
- Summary
  - Largest decrements observed in force, velocity and power occurred with PO
  - No significant differences observed between P20 and P40
  - Similar results observed over each set and repetitions per set

Summary

- Largest decrements observed in force, velocity and power occurred with PO
- No significant differences observed between P20 and P40
- Similar results observed over each set and repetitions per set
Ballistic Exercises

- Greater improvements in ability to generate maximal power output during sports specific movements
- Not limited to training with optimal load, thus both low- and high-load training demonstrate improvements in maximal power output
- Recommended for training for enhancement of muscular power output


Ballistic Jump Squats Peak Force, Velocity, and Power

- Twenty (+ 20) professional and semi-professional rugby players
- Peak force, velocity, and power during 40 kg ballistic jump squats

Protocols
- TRD = 4 sets of 6 repetitions with 5 minutes inter-set rest
- CLI Singles = 4 sets of 6 with 12 seconds MM and 2 seconds rest between each repetition
- CLI Doubles = 4 sets of 6 doubles with 12 seconds MM and 3 minutes inter-set rest
- CLI Triples = 4 sets of 6 triples with 12 seconds MM and 3 minutes inter-set rest


Peak Force and Velocity

- Peak force and velocity decreased from repetition 1 to all subsequent repetition in TRD
- No difference in velocity from repetition 1 to any other repetition in the Singles
Greater Power Output During Ballistic Jump Squats

- TRD resulted in greatest percent decrease in peak power from repetition 1 (6.0 to 11.8% repetitions 3-6)
- Peak power significantly lower for TRD compared to all IRR and cluster set configurations for repetitions 5 and 6 with large effect sizes

CMVJ Height and SLJ Distance

Table 1. IRR training protocol

<table>
<thead>
<tr>
<th>Set</th>
<th>Volume</th>
<th>Intermittent min</th>
<th>Volume</th>
<th>Intermittent min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>2 min</td>
<td>1.2 - 1.5</td>
<td>15 s</td>
<td>1.7</td>
</tr>
<tr>
<td>7-10</td>
<td>2 min</td>
<td>1.2 - 1.5</td>
<td>15 s</td>
<td>1.7</td>
</tr>
<tr>
<td>11-14</td>
<td>2 min</td>
<td>1.2 - 1.5</td>
<td>15 s</td>
<td>1.7</td>
</tr>
<tr>
<td>15-18</td>
<td>2 min</td>
<td>1.2 - 1.5</td>
<td>15 s</td>
<td>1.7</td>
</tr>
</tbody>
</table>

- *Significant with standard deviation noted before % for set number.
- *Significant with standard deviation noted before % for set number.
- *Significant with standard deviation noted before % for set number.
- *Significant with standard deviation noted before % for set number.
Jump performance better sustained with CLU

Metabolic and Hormonal Response

Lower Lactate Values Following CLU

- Blood lactate was significantly lower immediately following performance of CLU
- No differences existed between protocols in GH or C
Power Clean Ratings of Perceived Exertion and Power Output

- Ten (n = 10) male recreational weightlifters
- 1 RM Power clean determination
- RPE and power output during multiple sets of power clean
- Optimal load on 80% 1RM
- 3 Sets of 6 repetitions with 3 minutes inter-set rest
  - TRD = no IR (P0)
  - CLU = 20 seconds IRR (P20)
  - CLU = 40 seconds IRR (P40)


Lower RPE with CLU

Greater Power Output Associated with Lower RPE with CLU

- TRD results in significant decreases in power
- No difference between CLU protocols
- RPE related to decline in power output
LONG TERM RESPONSE TO CLU

- Recommended approach when attempting to maximize power output
- Greater transfer of training effect
- Use of both low-load high velocity movements and high-load training

**Mixed Methods Approach to Power Training**

**Back Squat 1RM and Ballistic Jump Squats Peak Force, Velocity, and Power Following Training**
- Eighteen (n = 18) elite male rugby union players
- 3RM back squat predicted (2-4RM 1RM)
- Peak force, velocity, and power of ballistic jump squats with 0, 20, 40, and 60 kg

**Training**
- 2 days/week
- 3 sets
- Mixed methods approach
- Periodized

**Intervention**
- TRD
- CLU
Smaller strength gains following training with CLU

- 18.3% vs. 14.6% with TRL and GCL, respectively

- However, effect sizes were large for both interventions (1.0-2.2)
Authors suggested CLU possibly beneficial for improving jump squat power and velocity.

**SUMMARY & PRACTICAL APPLICATION**

Compared to TRD, CLU Result in ....

- Greater total power output during bench press (6RM or ~85% 1RM)
- Greater force, velocity, power, and vertical displacement during Olympic weightlifting exercises <90%, and greater peak velocity and displacement when ≥ 90% 1RM
- Maintenance of technique over successive sets and repetitions
- Greater power output during ballistic jump squats
- Better maintenance of jump height and distance
- Less reliance on anaerobic glycolysis
- Similar hormonal responses
- Lower RPE
- Smaller gains in strength
Practical Application

When to use....

• Hypertrophy
  - Traditional & Olympic
    – Ideal intensity (close to optimal loading)
    – Maintains form while improving velocity and power output

• Strength/Power
  - Traditional and Olympic
    – Allows ability to maintain intensity
    – Mixed methods approach
      • Low-load high velocity
      • High-load high velocity
      • TRD and CLU

• Power
  - Traditional and Olympic
    – Greater velocity and power with form maintenance
    – Mixed methods approach
      • Low-load
      • High-load

When to use judgment....

• Strength phase
  – However, advanced athletes may benefit from use of CLU with ballistic movements

• Other non-power related training
  (i.e. high intensity volume training)

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QUESTIONS