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July 10 – 13, 2013 | Las Vegas, NV

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

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Fort Worth, TX
• Definition
• Physiological Basis
• Early Research
• Acute Response to CLU
• Long Term Response to CLU
• Conclusions & Practical Application
• Questions

TOPICS
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)

Cluster Sets (CLU)

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PHYSIOLOGICAL BASIS
Past

Progressive decline in maximum isometric force during repeated tetani

fig. 1. Force records during fatigue produced by repeated short tetani in an isolated mouse flexor digitorum brevis (FDB) fiber; each tetanus appears as a vertical line. In the top panel, the phases of fatigue (see sect. vi) have been indicated. The bottom panel shows records from the same fiber fatigued in the presence of cyanide to inhibit mitochondrial oxidative phosphorylation. Stimulation protocol: 350-ms, 70-Hz tetani repeated every 4 s for 2 min, and the interval was decreased by $-20\%$ every 2 min (interval changes indicated by open triangles). Temperature was 25°C. [From Lännergren and Westerblad (268).]
Velocity Declines When Repetitions Performed Continuously

Significant reduction in velocity when the number of repetitions was over $\frac{1}{3}$ (34%) and $\frac{1}{2}$ (48%) of the total number of repetitions performed for bench press and back squat, respectively.


Fig. 1a and b Average bench press velocity changes during the course of submaximal single sets of repetitions to failure with different percentages of 1-RM (60, 65, 70, and 75%) in a bench press action. Values of bench press velocities are expressed in absolute values (a) and as a percentage of velocity of first repetition (b). See text for significant declines in average repetition speed within the loads.

Fig. 2a and b Average parallel squat velocity changes during the course of submaximal single sets of repetitions to failure with different percentages of 1-RM (60, 65, 70, and 75%) in a parallel squat action. Values of parallel squat velocities are expressed in absolute values (a) and as a percentage of velocity of first repetition (b). See text for significant declines in average repetition speed within the loads.
Present
Decrease in power output, recognizes that fatigue can result from a reduction in either force or velocity


Causes of Fatigue

- **Acidosis**
  - Disassociation of hydrogen ions from lactate often associated with decrease in force
  - Number of studies have demonstrated not the cause

- **Inorganic phosphate (Pi)**
  - Increases during contraction mainly from breakdown of PCr
  - Released in the transition from low force, weakly attached state, to high force state, strongly attached state
  - Research limited

- **Adenine diphosphate (ADP)**
  - Increases during repeated contractions coincident with PCr depletion
  - Partial recovery of shortening velocity linked to removal of ADP by enzyme action or diffusion
  - Experiments on skinned fibers show a major inhibitory effect on velocity of shortening


Time course of PCr resynthesis is fairly rapid

Fig. 1
The time courses of PC resynthesis during recovery from 6 min exhaustive dynamic exercise (filled circles and continuous line) and isometric contraction sustained at 66 % MVC to fatigue (open circles and dashed line). The number of observations made during recovery from the dynamic exercise was 7 at 6 s, 4 at 2 min, 4 at 4 min, 6 at 8 min and 7 at 20 min; and during recovery from the isometric exercise was 6 at 6 s, 3 at 15 s, 4 at 30 s, 6 at 1 min, 5 at 2 min and 5 at 4 min. The vertical bars (where shown) indicate ± one S.D. about the mean.

Hypothetical Model

- Haff et al. (2003) presented first hypothetical model in scientific literature
- Later suggested inclusion 15-30 second rest would allow partial replenishment of PCr
- Debate on the cause of fatigue still exists
- Current theories all suggest inclusion of 15-30 seconds rest would enhance the ability to maintain both
  - Force
  - Velocity


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

Figure 2—Protocol for fatigue experiment.

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 \( \times \) week\(^{-1} \)
  - 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

Figure 4—Mean increases in isometric strength for the no-rest, rest and control groups. Graph is of means ± SE, adjusted by analysis of covariance. The rest and no-rest groups both differed significantly from the control group (*P < 0.001), but not from each other (P = 0.145).

Figure 3—Mean increases in dynamic strength for the no-rest, rest and control groups. Graph is of means ± SE, adjusted by analysis of covariance. All pair-wise comparisons of group means were significant (*P < 0.001).
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
    - 6 to 10 repetitions
    - 6 stations
- Intervention
  - TRD
  - 1 second IRR
  - 2 second IRR

TABLE II.—Initial and final strength (kg; M±SD).

<table>
<thead>
<tr>
<th>Group</th>
<th>Bench press *</th>
<th></th>
<th>Leg press **</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>%gain</td>
<td>Initial</td>
<td>Final</td>
</tr>
<tr>
<td>C</td>
<td>68.9± 9.2</td>
<td>70.2±10.9</td>
<td>±2</td>
<td>160.3±49.1</td>
<td>158.2±54.1</td>
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<tr>
<td>E₁</td>
<td>68.9±10.6</td>
<td>85.9±11.9</td>
<td>+25</td>
<td>193.6±57.8</td>
<td>301.8±60.1</td>
</tr>
<tr>
<td>E₂</td>
<td>62.7±8.5</td>
<td>81.4±10.4</td>
<td>+30</td>
<td>150.9±23.9</td>
<td>176.4±23.9</td>
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<tr>
<td>E₃</td>
<td>79.1±15.8</td>
<td>97.5±12.0</td>
<td>+23</td>
<td>159.1±34.1</td>
<td>181.8±25.7</td>
</tr>
</tbody>
</table>

*F₃, ₄s = 23.9  E₁, E₂, E₃>C  (p≤.05);  **F₃, ₄s = 22.2  E₁>E₂, E₃>C  (p≤.05).

TABLE III.—Initial and final PWC₁₇₀  (Watts; M±SD).

<table>
<thead>
<tr>
<th>Group</th>
<th>Arm-cranking *</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>%gain</td>
</tr>
<tr>
<td>C</td>
<td>119±29</td>
<td>116±28</td>
<td>—3.2</td>
</tr>
<tr>
<td>E₁</td>
<td>126±30</td>
<td>128±21</td>
<td>+1.6</td>
</tr>
<tr>
<td>E₂</td>
<td>120±24</td>
<td>125±28</td>
<td>+3.7</td>
</tr>
<tr>
<td>E₃</td>
<td>145±31</td>
<td>157±33</td>
<td>+8.5</td>
</tr>
</tbody>
</table>

*F₃, ₄s = 3.18  E₁=E₂>E₃>C  (p<.05).

Greater physical work capacity following training in CLU
No difference in strength gains
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⁻¹
  - 9 weeks
  - Leg extension exercise
  - ~73% 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
- 6RM Bench press determination
- Power output during 1 set of 6 repetitions (TRD)
- Protocols (equated for time)
  - CLU Singles = 20 seconds IRR
  - CLU Doubles = 50 seconds ISR
  - CLU Triples = 100 seconds ISR

<table>
<thead>
<tr>
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<th>RS</th>
<th>X</th>
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<th>X</th>
<th>20</th>
<th>X</th>
<th>20</th>
<th>X</th>
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<td>46</td>
<td>69</td>
<td>92</td>
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<table>
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<td>CT</td>
<td>56</td>
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<table>
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<th>100</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>CT</td>
<td>109</td>
<td>118</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1.** Work:rest intervals (s) for the Singles (6 × 1 repetition), Doubles (3 × 2 repetition), and Triples (2 × 3 repetition) groups. RS—X = a repetition sequence followed by a rest period(s) for each intervention. CT— = cumulative time(s) for the intervention.

Near Linear Decrease

**Figure 2.** Mean power output (SD) associated with 6RM training. All power outputs are significantly different from each other.
Greater Power Output During Bench Press

**TABLE 3.** Mean total power output (SD), percentage change, range, and t-test (p-value) for continuous, Singles, Doubles and Triples loading schemes.

<table>
<thead>
<tr>
<th></th>
<th>Singles</th>
<th>Doubles</th>
<th>Triples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total power output for continuous 6RM (W)</td>
<td>1,383 (374)</td>
<td>1,252 (368)</td>
<td>1,361 (246)</td>
</tr>
<tr>
<td>Total power output for 6 repetitions (W)</td>
<td>*1,765 (300)</td>
<td>*1,619 (276)</td>
<td>*1,816 (436)</td>
</tr>
<tr>
<td>Mean change (%)</td>
<td>21.6</td>
<td>22.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Range (%)</td>
<td>-23.4–41.1</td>
<td>3.1–39.1</td>
<td>-10.9–43.6</td>
</tr>
<tr>
<td>t-test (p-value)</td>
<td>-2.9 (0.02)</td>
<td>-4.2 (0.01)</td>
<td>-3.5 (0.01)</td>
</tr>
</tbody>
</table>

* Significantly different from continuous 6RM 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 stimuli that results in an increased power output during performance of Olympic weightlifting movements would hypothetically elicit 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 seconds IRR
  - Undulating CLU (UND) = 1 set of 5 repetitions with 30 second IRR
- Intensity
  - 90% 1RM
  - 120% 1RM

Figure 4. Experimental design.

Figure 1. Theoretical velocity and displacement model for a traditional set.

Figure 2. Theoretical velocity and displacement model for a cluster set.

Figure 3. Theoretical velocity and displacement model for an undulating set.

Figure 5. Barbell displacement during multiple set configurations at 90% of 1RM.

Figure 6. Barbell displacement during multiple set configurations at 120% of 1RM. * = significant difference $p < 0.02$. ** = significant difference $p < 0.03$. *** = significant difference $p < 0.01$.

Figure 7. Barbell velocity during multiple set configurations at 90% of 1RM. * = significant difference $p < 0.02$. ** = significant difference $p < 0.03$. *** = significant difference $p < 0.01$.

Figure 8. Barbell velocity during multiple set configurations at 120% of 1RM. * = significant difference $p < 0.02$. ** = significant difference $p < 0.001$. *** = significant difference $p < 0.01$. 

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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

Greater Peak Velocity and Peak Displacement During Clean Pull
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 7.3% 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)

Table I. The effects of cluster set configurations on peak vertical displacement.

<table>
<thead>
<tr>
<th>Repetition</th>
<th>P0</th>
<th>P20</th>
<th>P40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td>Set 3</td>
</tr>
<tr>
<td>1</td>
<td>1.02 ± 0.02</td>
<td>1.01 ± 0.02</td>
<td>1.02 ± 0.02</td>
</tr>
<tr>
<td>6</td>
<td>0.94 ± 0.02*</td>
<td>0.94 ± 0.02*</td>
<td>0.94 ± 0.02*</td>
</tr>
</tbody>
</table>

Note: Values are mean ± s. P0, traditional set configuration. P20, cluster set configuration with 20 seconds inter-repetition rest. P40, cluster set configuration with 40 seconds inter-repetition rest. * = Significantly different from repetition 1. Values are reported in metres (m).
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

**Figure 4.** Effect of 0 (P0), 20 (P20), and 40 (P40) seconds of interrepetition rest (IRR) on peak velocity during each of the 6 repetitions. Results are presented as percent change from the first repetition of each set and averaged across all 3 sets. * = Significantly different from the first repetition. ψ = Significantly different from P20. β = Significantly different from P40 (p ≤ 0.05).
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

Figure 2. Effect of 0 (P0), 20 (P20), and 40 (P40) seconds of interrepetition rest (IRR) on peak power during each of the 6 repetitions. Results are presented as percent change from the first repetition of each set and averaged across all 3 sets. * = Significantly different from the first repetition. $\psi$ = Significantly different from P20. $\beta$ = Significantly different from P40 ($p \leq 0.05$).
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 (n = 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 3 minutes inter-set rest
  - CLU Singles = 4 sets of 6 with 12 seconds IRR and 2 minutes inter-set rest
  - CLU Doubles 4 sets of 3 doubles with 30 seconds ISR
  - CLU Triples = 4 sets of 2 triples with 60 seconds ISR and 2 minutes inter-set rest


Figure 1 — Traditional and four cluster loading set structures.
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

Figure 4 — Mean (± SD) repetition peak velocity of the center of mass for each set configuration. *Significantly different from control ($P < .05$).

Figure 6 — Mean (± SD) repetition peak force for each set configuration.
• 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

Greater Power Output During Ballistic Jump Squats
CMVJ Height and SLJ Distance


Figure 1. Procedural order for the three data collection sessions.
Table I. HRE training protocols

<table>
<thead>
<tr>
<th>Exercise</th>
<th>TS protocol</th>
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<th>CS protocol</th>
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<tbody>
<tr>
<td></td>
<td>Tempo</td>
<td>Load</td>
<td>Volume</td>
<td>Intra-set rest</td>
<td>Inter-set rest</td>
<td>Volume</td>
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<td>Clean pull (CP)</td>
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<td>75%</td>
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<td>3 × 2</td>
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<td>3 × 2</td>
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<td></td>
<td>62-67%</td>
<td>1 × 10</td>
<td>0</td>
<td>2 min</td>
<td>Blood draw</td>
<td>5 × 2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Inter-set</td>
<td></td>
<td></td>
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<td>Back squat (BS)</td>
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<td>55%</td>
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<td></td>
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<td>1 × 4</td>
<td>0</td>
<td>2 min</td>
<td>2 × 2</td>
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<td></td>
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<td>0</td>
<td>2 min</td>
<td>5 × 2</td>
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<td>1 × 10</td>
<td>0</td>
<td>2 min</td>
<td>5 × 2</td>
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<td>62-67%</td>
<td>1 × 10</td>
<td>0</td>
<td>Blood draw</td>
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<td>Inter-set</td>
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<tr>
<td>Circuit 1</td>
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<td>65%</td>
<td>10</td>
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<td>40% 1RM</td>
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<td>30 s</td>
<td>10 ea</td>
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<td>10</td>
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<td>30 s</td>
<td>30 s ea</td>
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<td>BP</td>
<td>20/AMRP</td>
<td>0</td>
<td>30 s</td>
<td>20/AMRP</td>
</tr>
</tbody>
</table>

aThree-way plank = full front plank, full-side plank (right), full-side plank (left) performed consecutively before 30-s rest taken.
bTriceps extension was the only exercise performed for two instead of three sets. Final set was for as many reps as possible (AMRP).
Jump performance better sustained with CLU
Metabolic and Hormonal Response

Figure 1. Procedural order for the three data collection sessions.
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 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)

Fig. 2 Average RPE for each set. *Significantly different from set 1 (p ≤ 0.05). \( \beta \)Significantly different from set 2 (p ≤ 0.05)


Lower RPE with CLU

Fig. 1 Average RPE for each IRR protocol. P0 = 0 s IRR, P20 = 20 s IRR, P40 = 40 s IRR. *Significantly different from P40 (p ≤ 0.05)

Fig. 3 Average RPE for each set of each IRR protocol. P0 = 0 s IRR, P20 = 20 s IRR, P40 = 40 s IRR. *Significantly different from set 1 (p ≤ 0.05). †Significantly different from set 2 (p ≤ 0.05)
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
- Number of investigations have supported use of mixed methods approach

**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
- 1RM Back squat predicted (2-6RM lift)
- Peak force, velocity, and power of ballistic jump squats with 0, 20, 40, and 60 kg
- Training
  - 2 days · week⁻¹
  - 8 weeks
  - Mixed methods approach
  - Periodized
- Intervention
  - TRD
  - CLU

### TABLE 2. Training program for traditional training group.*

<table>
<thead>
<tr>
<th>Week</th>
<th>Core lifts</th>
<th>Reps</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
<th>Reps</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
<th>Reps</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
<th>Load (%1RM)</th>
<th>Rest (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 2</td>
<td>Front squat</td>
<td>8</td>
<td>80</td>
<td>180</td>
<td>8</td>
<td>80</td>
<td>180</td>
<td>6</td>
<td>85</td>
<td>180</td>
<td>6</td>
<td>85</td>
<td>180</td>
<td>6</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>3 and 4</td>
<td>Back squat</td>
<td>8</td>
<td>80</td>
<td>180</td>
<td>8</td>
<td>80</td>
<td>180</td>
<td>6</td>
<td>85</td>
<td>180</td>
<td>6</td>
<td>85</td>
<td>180</td>
<td>6</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>5 and 6</td>
<td>Box squat</td>
<td>7</td>
<td>80</td>
<td>180</td>
<td>5</td>
<td>85</td>
<td>180</td>
<td>5</td>
<td>85</td>
<td>180</td>
<td>5</td>
<td>90</td>
<td>180</td>
<td>6</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>7 and 8</td>
<td>Back squat</td>
<td>6</td>
<td>80</td>
<td>180</td>
<td>5</td>
<td>85</td>
<td>180</td>
<td>4</td>
<td>90</td>
<td>180</td>
<td>4</td>
<td>95</td>
<td>180</td>
<td>3</td>
<td>95</td>
<td>180</td>
</tr>
</tbody>
</table>

*Reps = repetitions; RM = repetition maximum.

### TABLE 3. Training program for cluster training group.*†

<table>
<thead>
<tr>
<th>Week</th>
<th>Core lifts</th>
<th>Clusters × reps</th>
<th>Load (%1RM)</th>
<th>Rest (clusters/sets)</th>
<th>Clusters × reps</th>
<th>Load (%1RM)</th>
<th>Rest (clusters/sets)</th>
<th>Clusters × reps</th>
<th>Load (%1RM)</th>
<th>Rest (clusters/sets)</th>
<th>Clusters × reps</th>
<th>Load (%1RM)</th>
<th>Rest (clusters/sets)</th>
<th>Clusters × reps</th>
<th>Load (%1RM)</th>
<th>Rest (clusters/sets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 2</td>
<td>Front squat</td>
<td>1 × 6</td>
<td>80</td>
<td>0/180</td>
<td>2 × 3</td>
<td>80</td>
<td>30/120</td>
<td>2 × 3</td>
<td>85</td>
<td>30/120</td>
<td>2 × 3</td>
<td>85</td>
<td>30/120</td>
<td>2 × 3</td>
<td>90</td>
<td>30/120</td>
</tr>
<tr>
<td></td>
<td>Clean pull</td>
<td>1 × 6</td>
<td>80</td>
<td>0/180</td>
<td>2 × 3</td>
<td>80</td>
<td>30/120</td>
<td>2 × 3</td>
<td>85</td>
<td>30/120</td>
<td>2 × 3</td>
<td>85</td>
<td>30/120</td>
<td>2 × 3</td>
<td>90</td>
<td>30/120</td>
</tr>
<tr>
<td>3 and 4</td>
<td>Back squat</td>
<td>1 × 5</td>
<td>80</td>
<td>0/180</td>
<td>1 × 5</td>
<td>85</td>
<td>0/180</td>
<td>1 × 2, 90</td>
<td>20–30</td>
<td>1 × 2</td>
<td>95</td>
<td>20–30</td>
<td>1 × 3</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clean pull</td>
<td>1 × 5</td>
<td>90</td>
<td>0/180</td>
<td>1 × 5</td>
<td>95</td>
<td>0/180</td>
<td>1 × 3</td>
<td>120</td>
<td>120</td>
<td>1 × 3</td>
<td>120</td>
<td>120</td>
<td>1 × 3</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>5 and 6</td>
<td>Box squat</td>
<td>1 × 6</td>
<td>80</td>
<td>0/180</td>
<td>1 × 6</td>
<td>85</td>
<td>0/180</td>
<td>3 × 1</td>
<td>90</td>
<td>10/120</td>
<td>3 × 1</td>
<td>90</td>
<td>10/120</td>
<td>3 × 1</td>
<td>95</td>
<td>10/120</td>
</tr>
<tr>
<td></td>
<td>Power clean</td>
<td>1 × 6</td>
<td>80</td>
<td>0/180</td>
<td>1 × 6</td>
<td>85</td>
<td>0/180</td>
<td>3 × 1</td>
<td>90</td>
<td>10/120</td>
<td>3 × 1</td>
<td>90</td>
<td>10/120</td>
<td>3 × 1</td>
<td>95</td>
<td>10/120</td>
</tr>
<tr>
<td>7 and 8</td>
<td>Back squat</td>
<td>1 × 5</td>
<td>80</td>
<td>0/180</td>
<td>1 × 4</td>
<td>80</td>
<td>0/180</td>
<td>1 × 3</td>
<td>90</td>
<td>0/180</td>
<td>2 × 2</td>
<td>20/120</td>
<td>2 × 2</td>
<td>10</td>
<td>20/120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jump squat</td>
<td>2 × 2</td>
<td>20</td>
<td>20/120</td>
<td>2 × 2</td>
<td>20</td>
<td>20/120</td>
<td>3 × 1</td>
<td>90</td>
<td>0/180</td>
<td>2 × 2</td>
<td>20</td>
<td>20/120</td>
<td>3 × 1</td>
<td>95</td>
<td>20/120</td>
</tr>
</tbody>
</table>

*Reps = repetitions; RM = repetition maximum.
†Repetitions are expressed as number of clusters × number of repetitions in each cluster, rest is expressed in seconds with the first number denoting rest between clusters and the second number rest between sets.
Smaller strength gains following training with CLU

- 18.3% vs. 14.6% with TRD and CLU, respectively
- However, effect sizes were large for both interventions (1.0-2.2)


<table>
<thead>
<tr>
<th>Load</th>
<th>Traditional</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back squat 1RM (kg)</td>
<td>203.2 ± 16.6</td>
<td>240.1 ± 25.0†‡</td>
</tr>
<tr>
<td>Peak power (W)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg</td>
<td>4,696.6 ± 460.6</td>
<td>4,789.6 ± 433.8</td>
</tr>
<tr>
<td>20 kg</td>
<td>4,325.5 ± 531.6</td>
<td>4,531.1 ± 432.3</td>
</tr>
<tr>
<td>40 kg</td>
<td>4,147.1 ± 539.6</td>
<td>4,168.7 ± 411.5</td>
</tr>
<tr>
<td>60 kg</td>
<td>3,942.6 ± 604.3</td>
<td>4,048.8 ± 504.6</td>
</tr>
<tr>
<td>Peak velocity (m·s⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg</td>
<td>2.18 ± 0.16</td>
<td>2.19 ± 0.15</td>
</tr>
<tr>
<td>20 kg</td>
<td>1.88 ± 0.16</td>
<td>1.92 ± 0.15</td>
</tr>
<tr>
<td>40 kg</td>
<td>1.65 ± 0.16</td>
<td>1.65 ± 0.15</td>
</tr>
<tr>
<td>60 kg</td>
<td>1.46 ± 0.17</td>
<td>1.48 ± 0.16</td>
</tr>
<tr>
<td>Peak force (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 kg</td>
<td>2,358.6 ± 140.2</td>
<td>2,410.6 ± 144.1</td>
</tr>
<tr>
<td>20 kg</td>
<td>2,518.8 ± 185.1</td>
<td>2,553.4 ± 149.3</td>
</tr>
<tr>
<td>40 kg</td>
<td>2,677.5 ± 189.6</td>
<td>2,671.7 ± 124.3</td>
</tr>
<tr>
<td>60 kg</td>
<td>2,837.8 ± 198.9</td>
<td>2,880.9 ± 155.1‡</td>
</tr>
</tbody>
</table>

RM = repetition maximum.
†Significant within group difference pretraining to posttraining.
‡Significant difference between traditional and cluster posttraining.
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)