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Cluster Sets - Current Methods for Introducing Variations into Training Sets

By

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Traditional Sets: Performance Responses

• In as little as 5-9 maximal contractions:
  – ↓ in maximal force
  – ↓ in maximal RFD

• As the number of repetitions increases within a set it can be expected that there will be a:
  – ↓ in Movement Velocity
  – ↓ in Power Output
  – ↓ in Maximal Force
  – ↓ in Technical Proficiency

• Higher volume sets will depict a greater decline in these parameters than shorter sets

With >5 repetitions there is a significant reduction in Peak Power during leg presses performed at 10RM Loads.

Figure 1. Peak power output profiles (average for n = 6 subjects) for each exercise during the two experimental conditions: when exercise was 5 repetitions (open circles) and when exercise was 10 repetitions (filled circles). Boxes represent mean of the peak power output for the first and the second half of a set of 10 repetitions. *significant difference (P<0.01) between the first and the second 5 repetitions. Values are means ± SD.

doi:10.1371/journal.pone.0013486.g001

Traditional Set: Bioenergetic Responses

- As the length of the set increases there is an:
  - ↑ ATP turnover
  - ↑ ATP production from the phosphagen system
  - ↑ ATP production from glycogenolysis
  - ↑ Lactate release

- The length of the set increases the metabolic demand which appears to correspond with the performance decline

Traditional Sets: Multiple Set Response

Figure 1. Peak power output profiles (average for n = 6 subjects) for each exercise during the two experimental conditions: when exercise was 5 sets of 10 repetitions to failure (10REP; open circles), and when exercise was 10 sets of 5 repetitions not to failure (5REP; filled circles). Boxes represent mean of the peak power output throughout 50 repetitions for 10REP and 5REP. *significant difference (P<0.05) between 10REP and 5REP (pooled from 5 to 5 repetitions). Values are means ± SD.

doi:10.1371/journal.pone.0040621.g001

Traditional: Physiological Responses

The decline noted in performance capacity (force, velocity and/or power) may be a function of:

- **Metabolic Demand Causing:**
  - ↓[ATP]
  - ↓[PCr]
  - ↑[La]
  - ↓[glycogen]

- **Neuromuscular Fatigue Causing:**
  - ↑EMG activity of engaged muscles

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Traditional Sets: Physiological Rationale

Traditional Sets: Physiological Rationale

With ↓[ATP] there is a reduction in the ability to maintain Peak Power across a series of repetitions.
As muscle [La]↑ there is a ↓ in Peak Power Output as a % of the initial value

Traditional Sets: Neuromuscular Response


(b) EMG activity of the VL, TRD, CLU (n = 9).
*Significantly different than repetition 1 for respective CONDITION (p < 0.05).
†Significantly different than CLU (P < 0.05).
Traditional Sets: Neuromuscular Response

Squats: 10 sets of 10 reps @ 70% 1RM

Traditional Set: Technical Breakdown

Figure 1. The effects of a traditional set configuration (P0) on barbell displacement in the power clean. * = Significant differences in horizontal displacement between repetitions 1 and 6 ($P \leq 0.05$). (A–C) Average barbell displacement during repetitions 1 and 6 for sets 1, 2, and 3, respectively. m, metres

With technical exercises sizes, such as the Weightlifting movements the more repetitions completed in a traditional set the greater the technical breakdown.

Traditional Sets: Can We Modify Them?

• It is apparent that set structure results in changes to the acute performance and physiological responses.

Based upon this how can we modify the set structure to:

– Maintain performance across a series of sets?
– Maximize performance across a series of sets?
– Change the physiological stress created by a series of sets?
– Maintain technique during high volume sets?
Cluster Sets: History and Definition


  - Indicate that clusters are used during strength and strength/power phases of a periodized training plan.
  
  - Suggest doing sets of 2-6 reps with a loads >2-6RM with 20-30 sec rest between each rep to increase training intensity

A 2-6RM is ~83-95% of 1RM for most large mass exercises
Cluster Sets: History and Definition

• Verkoshansky and Siff (2009) define cluster sets as:
  – “…another form of interval training that requires one to perform one or more repetitions with a 10-20 second interval between each repetition or cluster of repetitions in an extended set. Characteristically, the minimum load is one’s 5RM and 4-6 repetitions are performed.”

  A 5RM is ~86% of 1RM for most large mass exercises

• Extensive Clusters:
  – “…involves 4-6 repetitions with ones 4-6RM, with 10 seconds rest between each cluster.”

  A 4-6RM is ~83-90% of 1RM for most large mass exercises

• Intensive Clusters:
  – “…involves 4-6 sets of of only one repetition with 75-90% of 1RM, with about a 20 second rest between repetitions for 4-6 repetitions.”

Cluster Sets: History and Definition

• How we have defined cluster sets:
  – **Cluster Set**: a set in which there is 15-45 s between individual repetitions or groups of repetitions

• Cluster-Set Sub-Types:
  – **Undulating Cluster Sets**: a cluster set in which resistance is increased in a pyramid fashion
  – **Ascending Cluster Sets**: a cluster set in which resistance is increased across the set

• Other set structures that are often referred to as cluster sets are what could be termed a(n):
  – **Extended Set**: this where a very long set is created from what might be 3 traditional sets. In this structure there is rest after individual reps or groups of reps but only 1 defined set
  – **Rest-Pause Set**: this is when you perform as many reps as you can then rest for 15-45 s and then complete more reps to failure

Cluster Sets: Basic Set Structures

At its most simplistic format the addition of 20 s of inter-repetition rest into a set of 5 would create a basic cluster set that allows for better quality repetitions to be performed with higher intensities. Note the defined set structure.

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Sets: Classic Performance Targets

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Sets: Supporting Research

- In 2003, we examined 3 set structures during the clean pull which included the following:
  - **Traditional Set:**
    - 5 repetitions at 90% of 1RM Power Clean
    - 5 repetitions at 120% of 1RM Power Clean
  - **Cluster Set:**
    - 5 repetitions at 90% of 1RM Power Clean with 30 s Inter-repetition rest
    - 5 repetitions at 120% of 1RM Power Clean with 30 s Inter-repetition rest
  - **Undulating:**
    - 5 repetitions with 30 s Inter-repetition rest with variable loads per repetition average intensity of 90% 1RM
    - 5 repetitions with 30 s Inter-repetition rest with variable loads per repetition average intensity of 120% 1RM

Cluster Set: Strength/Power

![Graph showing barbell velocity during multiple set configurations at 120% of 1RM. * = significant difference $p < 0.02$. ** = significant difference $p < 0.001$. *** = significant difference $p < 0.01$.]

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

Cluster Sets: More Complex Set Structures

Cluster sets 3 x (6/1): 6 repetitions broken into single repetitions with 20s inter-repetition rest interval

Cluster sets 3 x (6/2): 3 clusters of 2 repetitions broken with 20s rest intervals between clusters

Cluster sets 3 x (6/3): 6 repetitions broken into clusters of 3 repetitions with 20s inter-repetition rest interval

More complex cluster set structures can be created by modifying the number of repetitions contained in the cluster

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Sets: Effect of Configuration

  - Exercise:
    - Jump Squat with 40kg
  - Set Structures: a total of 4 sets of 6 repetitions were examined with each of 4 set structures
    - Time to complete sets was equalized resulting in variable cluster set rest intervals which may reduce the effectiveness of the cluster set
      - Changes the recovery time between clusters which could impact metabolic recovery rates and thus performance markers

Figure 1 — Traditional and four cluster loading set structures.
Cluster Sets: Effect of Configuration

Power output and velocity decline: Cluster sets 1 rep < 2 rep < 3 rep < traditional sets

less reduction in movement velocity and power output with smaller clusters even though rest interval between clusters was less

Cluster Sets: Effect of Configuration

- The effect of the cluster set structure may impact the ability to maximize movement velocity across the set during explosive exercises.
  - Cluster sets of 1: demonstrate the greatest maintenance of velocity, force and power

Variation in cluster set structures by breaking sets of 6 into clusters of 1, 2, or 3 can result in different performance and physiological responses.

Match the cluster to the periodized goals.

Cluster Sets: Effect Rest Duration

- Factors that may impact the recovery rate between individual repetitions or clusters of repetitions includes
  - Length of Inter-repetition rest
    - 15 sec into recovery peak force generating capacity returns to ~79.7% of initial capacity
    - Rest intervals may allow for resynthesis of ATP and PCr
    - Shorter rest intervals create reduce the ability to recovery between repetitions

Cluster Sets: Effect Rest Duration


6 reps @ 80% 1RM Power Clean

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).

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. ψ = Significantly different from P20. β = Significantly different from P40 (p ≤ 0.05).

P0=0 IRR; P20=20s IRR, P40=40s IRR
Cluster Sets: Effect Rest Duration

6 reps @ 80% 1RM Power Clean

Figure 7. A–C. Effect of 0 (P0), 20 (P20) and 40 (P40) seconds of IRR rest on peak velocity for each of the six repetitions during each set. Results are presented as percent change from the first repetition of the first set. * = significantly different from the first repetition of P0. # = significantly different from the first repetition of P20. @ = significantly different from the first repetition of P40. y = P0 significantly different from P20. b = P0 significantly different from P40. Y = P20 significantly different from P40 (p ≤ 0.05).

P0=0 IRR; P20=20s IRR, P40=40s IRR

Cluster Sets: Effect Rest Duration

6 reps @ 80% 1RM Power Clean

Figure 5. A–C. Effect of 0 (P0), 20 (P20) and 40 (P40) seconds of IRR rest on peak power for each of the six repetitions during each set. Results are presented as percent change from the first repetition of the first set. * = significantly different from the first repetition of P0. # = significantly different from the first repetition of P20. @ = significantly different from the first repetition of P40. y = P0 significantly different from P20. b = P0 significantly different from P40. ψ = P20 significantly different from P40 (p ≤ 0.05).

P0=0 IRR; P20=20s IRR, P40=40s IRR

Cluster Sets: Effect Rest Duration

Figure 2. The effects of a cluster set configuration with 20 seconds inter-repetition rest (P20) on barbell displacement in the power clean. (A–C) Average barbell displacement during repetitions 1 and 6 for sets 1, 2, and 3, respectively. m, metres.

Figure 3. The effects of a cluster set configuration with 40 seconds inter-repetition rest (P40) on barbell displacement in the power clean. * = Significant differences in horizontal displacement between repetitions 1 and 6 ($P \leq 0.05$). (A–C) Average barbell displacement during repetitions 1 and 6 for sets 1, 2, and 3, respectively. m, metres.

Cluster Sets: Modern Performance Targets

Haff et al. Prof Strength and Cond 12: 12-17, 2008.

Hypertrophy ? Strength/Power Endurance → Velocity → Power → Cluster Set
Cluster Sets: Strength/Power-Endurance

- How might cluster sets impact strength/power endurance?
  - Creating higher repetition sets (>6 reps) with various cluster models can increase metabolic stress and work load
  - Similar to a high intensity interval model the cluster set can be used to engage in high intensity efforts for an increased volume
  - If using weightlifting derivatives there is the possibility of technique maintenance over the duration of the set structure.

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Sets: Strength/Power-Endurance

Test Exercise: 3 sets of 12 repetitions of back squats performed at 60% 1RM
Subjects: 12 strength trained males (back squat = 1.9± 0.23 kg/kg bm)

Cluster Sets: Strength/Power-Endurance

Cluster Sets: Strength/Power-Endurance

![Graph showing Velocity and Power Decline](image)

Cluster Sets: Strength/Power-Endurance

Both set structures used an intensity of 70% of 1RM

Figure 1. Set configurations for traditional (TRD) and cluster (CLU) sets.

Cluster Sets: Strength/Power-Endurance

**Table 3.** Concentric time under tension (in seconds) collapsed by training status across sets.*†

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<th>Repetition</th>
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<th>CLU</th>
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<td>0.92 ± 0.02†</td>
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<td>1.20 ± 0.04</td>
<td>1.04 ± 0.03§</td>
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<td>1.20 ± 0.05</td>
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<td>10</td>
<td>1.34 ± 0.06</td>
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*TRD = traditional sets; CLU = cluster sets.
†Values are means ± SE.
‡Significant difference between conditions (p < 0.10).
§Significant difference between conditions (p ≤ 0.05).


**Figure 2.** Average velocity (m·s⁻¹) collapsed by training status across reps (A) and across sets (B). †Significantly different from set 1 in same condition (p ≤ 0.05); *Significant difference between conditions (p ≤ 0.05); #Significant difference between conditions (p < 0.10).
Cluster Sets: Strength/Power-Endurance

Traditional Sets: 60% 1RM

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Inter-Set Rest: 240 s  Intra-Set Rest: 0 s  Total Rest: 240 s

Cluster Sets 4: 75% 1RM

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<td>30</td>
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</table>
Inter-Set Rest: 240 s  Intra-Set Rest: 180 s  Total Rest: 420 s

Cluster Sets 2: 80% 1RM

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<tbody>
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</table>
Inter-Set Rest: 240 s  Intra-Set Rest: 450 s  Total Rest: 690 s

Selected loadings were equalized based upon relative RM. For example, 60% of 1RM = ~85% of 12RM, 75% of 1RM = ~85% of 4RM, and 80% of 1RM = ~85% of 2RM

Tufano and Haff (unpublished data)
The cluster sets allowed for heavier loads to be lifted but the overall power output of the sets was equal.

Tufano and Haff (unpublished data)
Cluster Sets: How/When Do We Use Them?

So it appears that cluster sets can change the training stimulus so we need to consider the following:

- What exercises should we use in our cluster sets?
- What sets and repetitions schemes could we use to create cluster sets?
- How do we manipulate rest intervals to change the training stress?
- What types of cluster sets can we create?
- How do we load cluster sets?
- How do we integrate cluster sets into our periodized training plan?
- Where do various cluster set structures belong in our periodized training plan?
Cluster Sets: Exercises & Training Target

**Strength/Power Endurance**
- Power Clean/Snatch
- Clean/Snatch Pulls
- Push Press
- Bench Press

**Hypertrophy**
- Back/Front Squat
- Flat/Incline Bench Press

**Strength/Power Focus**
- Snatch/Clean
- Power Clean/Snatch
- Clean/Snatch Pulls
- Push Press/Jerk

**Power Focus**
- Jump Squats
- Snatch/Clean
- Bench Throw
- Push Jerk
Cluster Sets:
Planning Sets and Repetitions

- **Strength/Power Endurance**
  - 1-5 sets
    - 8-12 Reps/set
      - 8/1, 8/2, 8/4
      - 9/1, 9/3
      - 10/1, 10/2, 10/5
      - 11/1
      - 12/2, 12/3, 12/4, 12/6

- **Hypertrophy**
  - 1-5 sets
    - 4-6 Reps/Set
      - 4/1, 4/2
      - 5/1
      - 6/1, 6/2, 6/3

- **Strength/Power**
  - 1-5 Sets
    - 4-6 Reps/Set
      - 4/1, 4/2
      - 5/1
      - 6/1, 6/2, 6/3

- **Power**
  - 1-5 Sets
    - 2-6 Reps/Set
      - 2/1
      - 4/1, 4/2
      - 5/1
      - 6/1, 6/2, 6/3

8/1 = 8 total repetitions divided into individual repetitions
8/2 = 8 total repetitions divided into 4 clusters of 2 repetitions
8/4 = 8 total repetitions divided into 2 clusters of 4 repetitions
Cluster Sets: How Do We Load Them?

- When Loading Cluster sets there are a couple of ways to go:
  - Lets say I am doing a total of 4 repetitions with clusters of 2 with 20 s between clusters and want a heavy load:
    - Base intensity off the total number of repetitions (i.e. 4 repetitions):
      - in this case it would be between 81-85% of 1RM (90-94% of 4RM)
    - Base intensity off the repetitions contained in the cluster (i.e. 2 repetitions):
      - In this case it would be 86-89% of 1RM (90-94% of 2RM)
Cluster Sets: Selecting the Rest Interval

Decreasing the rest interval between repetitions or clusters results in greater physiological stress and a shift toward strength or power endurance focus. Increasing the duration of rest will allow for more recovery and a focus on maximal movement velocity and power output.
Cluster Sets: Selecting the Rest Interval

Rest intervals between repetitions and clusters of repetitions can be modified in order to increase or decrease the physiological stress. This can be used to modulate the performance outcome.
Cluster Sets: Types Used for Strength/Endurance/Hypertrophy Focus

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<th>Type Of Cluster</th>
<th>Sets</th>
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<th>Reps</th>
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Intensity based off of a 1RM Power Clean of 140kg

General Guidelines:
- The greater the number of reps in the cluster the longer the rest interval needed between clusters.
- With Undulating Clusters the average intensity of the set should equal the targeted intensity for the exercise on that training day. In the above example this is 64% of 1RM

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Sets: Types Used for Strength/Power or Power Focus

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<th>Reps</th>
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Intensity Based off of a 1RM Power Snatch of 120 kg

Haff et al. Prof Strength and Cond 12: 12-17, 2008.
Cluster Set: Example Training Sessions

Table 5: Example Cluster Set Implementation during a Basic Strength Phase of Training.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets x Repetitions</th>
<th>Set Type</th>
<th>Intensity</th>
<th>% 1-RM</th>
<th>Inter-Repetition Rest Interval(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Snatch Warm-up</td>
<td>3 x 10</td>
<td>Traditional</td>
<td>30</td>
<td>22%**</td>
<td>0</td>
</tr>
<tr>
<td>Clean Grip Shrugs</td>
<td>3 x 5</td>
<td>Traditional</td>
<td>193</td>
<td>133%</td>
<td>*</td>
</tr>
<tr>
<td>Power Clean</td>
<td>3 x 5/1</td>
<td>Undulating Cluster</td>
<td>(130, 134, 138, 133, 130)</td>
<td>133</td>
<td>92%</td>
</tr>
<tr>
<td>Clean Pull</td>
<td>3 x 5</td>
<td>Traditional</td>
<td>174</td>
<td>120%</td>
<td>*</td>
</tr>
<tr>
<td>Clean Grip RDL</td>
<td>3 x 5</td>
<td>Traditional</td>
<td>151</td>
<td>104%</td>
<td>*</td>
</tr>
</tbody>
</table>

Note: Max Power Clean = 145 kg; Max Power Snatch = 135 kg; RDL = Romanian Deadlift; * = based upon maximum power clean. A 2-3 minute rest interval is employed between each set.

Table 7: Example Cluster Set Implementation during a Strength-Power Phase of Training.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets x Repetitions</th>
<th>Set Type</th>
<th>Intensity</th>
<th>% 1-RM</th>
<th>Inter-Repetition Rest Interval(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Squats</td>
<td>3 x 3</td>
<td>Traditional</td>
<td>100</td>
<td>50%</td>
<td>0</td>
</tr>
<tr>
<td>Power Clean</td>
<td>1 x 3/1</td>
<td>Ascending Cluster</td>
<td>115, 120, 125</td>
<td>86%</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>1 x 3/1</td>
<td>Ascending Cluster</td>
<td>120, 125, 130</td>
<td>89%</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>1 x 3/1</td>
<td>Ascending Cluster</td>
<td>125, 130, 135</td>
<td>93%</td>
<td>30</td>
</tr>
<tr>
<td>Push Jerk*</td>
<td>3 x 3</td>
<td>Traditional</td>
<td>120</td>
<td>89%</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Max Power Clean = 140 kg; Max Back Squat = 200 kg; Max push jerk = 135 kg. A 2-3 minute rest interval is employed between each set. * = front squat first repetition of each set.

Haff et al. Prof Strength and Cond 12: 12-17, 2008.

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JULY 6-9, 2016 • NEW ORLEANS, LA • HYATT REGENCY
Cluster Sets: Integration into Training Plan

Table 1. Tulane Yearly Periodization Program

Cluster Sets: Team Sport Model

• The implementation of cluster sets results in the set taking longer to complete as a result of the increased rest provided between repetitions or groups of repetitions.
  – This can be problematic in team sports where there is often limited time allotted for training
  – How can we use clusters in a group setting to get the benefit of the cluster set, but not the negative impact of extended time to perform the exercise?
Thank You!!

• **Most Important Collaborator:**
  - Erin “The Coach” Haff, MA, mTOR Barbell Club and Australian Weightlifting Federation

• **Post-Graduate Research Students:**
  - Lynne Munroe (Ph.D. Candidate)
  - Barry Horgan (Ph.D. Candidate)
  - Grant Rowe (Ph.D. Candidate)
  - James Tufano (Ph.D. Candidate)
  - Jenny Conlon (Ph.D. Candidate)
  - Harry Banyard (Ph.D. Candidate)

• **International Collaborators:**
  - Dr. Laurent Seitz, French Rugby League
  - Dr. Charles Dumke, UMONT.
  - Dr. Travis Triplett, ASU.
  - Dr. Kejo Häkkinen, University of Jyväskulä
  - Dr. Simon Walker, University of Jyväskulä
  - Dr. Dale Chapman, Australian Institute of Sport
  - Dr. Shona Halson, Australian Institute of Sport

Special Thanks to:

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Very few people come into your life and completely change your path Doc Stone change my life!! Thank you for all you have done and do Doc!