

Science behind high-intensity interval training (HIT) in endurance sports

INN
Inland Norway University of Applied Sciences

Bent Rønnestad
bent.ronnestad@inn.no

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Intro → Short vs. long intervals: – acute responses → Programming → long intervals → Short vs. long intervals: –training adaptations → Training → structure

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A review of 59 training studies concluded that the increase in VO_{2max} was positively related to training intensity in the range of 50–100% VO_{2max} (Wenger & Bell 1986)

Training time $\geq 90\% VO_{2max}$ can be a good criteria to judge the effectiveness of the training program to improve aerobic fitness (Thevenet et al. 2007, EJAP, 99:133–142; Midgley et al. 2006, Sports Med, 36: 117–132; Turnes et al. 2016, EJAP, 116:161-9; Buchheit & Laursen 2013, Sports Med, 43:313-328).

Several reviews have supported the superior efficacy of training at or near VO_{2max} (Bacon et al. 2013, PLoS One, 8: e73182; MacInnis & Gibala 2017, J Physiol, 595:2915-2930; Milanovic et al. Sports Med, 2015, 45:1469-81; Laursen & Jenkins 2002, Sports Med, 32:53-73; Midgley & Mc Naughton 2006, JSMP, 46:1-14; Midgley et al. 2006, Sports Med, 36:117-132; Turnes et al. 2016, EJAP, 116:161-9; Buchheit & Laursen 2013, Billat 2001, Sports Med, 31:13-31; Wenger & Bell 1986, Sports Med, 3:346-50)

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Training time $\geq 90\% VO_{2max}$ can be a good criteria to judge the effectiveness of the training program to improve aerobic fitness

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Different interval formats

(Buchheit & Laursen 2013, Sports Med, 43:313-328)

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Are there acute differences between multiple short intervals and long intervals in time $\geq 90\%$ $\dot{V}O_{2max}$?

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Multiple short intervals vs. long intervals

5 min 5 min 5 min 5 min

13 x 30/15 s

VS.

All-out; ~same work interval duration

Tid i økten (minutter)

bent.romnestad@inn.no

(Almqvist et al. 2020)

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Multiple short intervals vs. long intervals

5 min 5 min 5 min 5 min

13 x 30/15 s

27±7 years, 180±5 cm, 75±3 kg, $\dot{V}O_{2max}$ 73±7ml/kg/min, W_{max} 461±26 W

All-out; ~same work interval duration

Tid i økten (minutter)

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(Almqvist et al. 2020)

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Multiple short intervals vs. long intervals

Rate of perceived exertion (6-20) & Blood lactate concentration (mmol/L)

Same effort

4x5 min 3x13x30/15

4x5 min mean power = 367 +/- 23 W
30/15 mean power = 415 +/- 27 W

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(Almqvist et al. 2020)

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Multiple short intervals vs. long intervals

Time above 90% of $\dot{V}O_{2max}$ (sec)

#

30-15 4x5 min


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(Almqvist et al. 2020)

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Induces multiple short intervals larger time $\geq 90\%$ $\dot{V}O_{2max}$ than long intervals when mean power output is similar during the work intervals?




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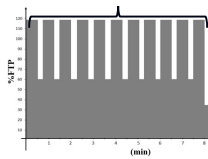
Intro → Short vs. long intervals: acute responses → Programming long intervals → Short vs. long intervals: training adaptations → Training structure

Induces multiple short intervals larger time $\geq 90\%$ $\dot{V}O_{2max}$ than long intervals when mean power output is similar during the work intervals?

N=19 ($\varphi=11, \sigma=8$)
 Age: 20.6 ± 3.9 yrs
 Body mass: 66.9 ± 7.2 kg
 $\dot{V}O_{2max}$: 70.4 ± 10.4 mL/min/kg
 W_{max} : 390 ± 68 W, 5.9 ± 1.0 W/kg
 $Power_{40-min}$: 269 ± 50 W, 4 W/kg



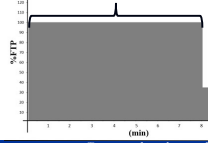
100% 40-min all-out



6x8min

VS.

100% 40 min all-out



6x8min


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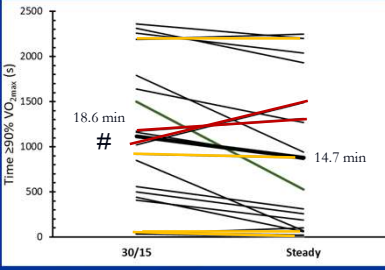
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Time $\geq 90\%$ $\dot{V}O_{2max}$ (s)



18.6 min # 14.7 min

30/15 Steady

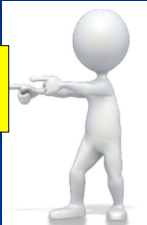
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Induces multiple short intervals larger time $\geq 90\%$ $\dot{V}O_{2max}$ than long intervals when mean power output is similar during the work intervals?

Multiple short intervals can give longer time above $90\% \dot{V}O_{2max}$ than long intervals, even when similar mean power output



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Applying the research




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Can we do something with the long intervals to increase the time $\geq 90\%$ $\dot{V}O_{2max}$?




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If we start long intervals with a high intensity and a subsequent reduction, would we then achieve a longer time $\geq 90\% \text{VO}_{2\text{max}}$?

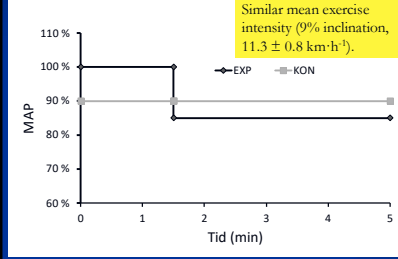


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6x5 min intervals; start high, go lower vs. steady



Similar mean exercise intensity (9% inclination, $11.3 \pm 0.8 \text{ km}\cdot\text{h}^{-1}$).

Variable		mean \pm SD
Age	years	23,3 \pm 3,5
Body height	cm	183 \pm 6
Body mass	kg	76,6 \pm 7
$\text{VO}_{2\text{max}}$	ml/min/kg	70,3 \pm 5,7
HR_{max}	beat/min	198 \pm 8
MAS	km/h	12,6 \pm 0,9
$\text{V}_{1,7}$	km/h	10,1 \pm 0,8

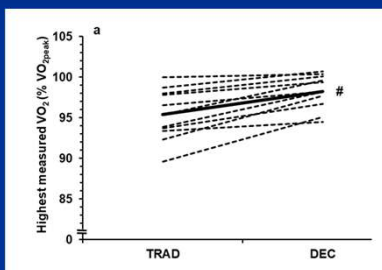
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(Rønnestad et al., 2019)

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

6x5 min intervals; start high, go lower vs. steady



	DEC	TRAD
Peak VO_2 (% $\text{VO}_{2\text{max}}$)	98,2%*	95,3%

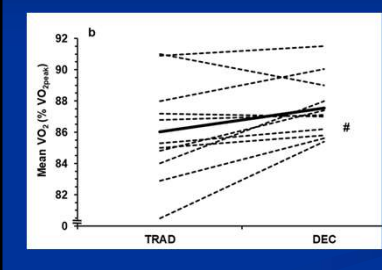
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(Rønnestad et al., 2019)

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

6x5 min intervals; start high, go lower vs. steady



	DEC	TRAD
Peak VO_2 (% $\text{VO}_{2\text{max}}$)	98,2%*	95,3%
Mean VO_2 (% $\text{VO}_{2\text{max}}$)	87,6%*	86,1%

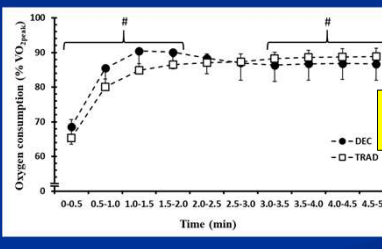
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(Rønnestad et al., 2019)

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

6x5 min intervals; start high, go lower vs. steady



	DEC	TRAD
Peak VO_2 (% $\text{VO}_{2\text{max}}$)	98,2%*	95,3%
Mean VO_2 (% $\text{VO}_{2\text{max}}$)	87,6%*	86,1%

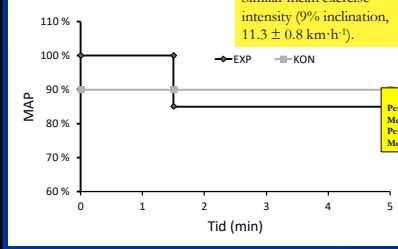
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(Rønnestad et al., 2019)

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6x5 min intervals; start high, go lower vs. steady



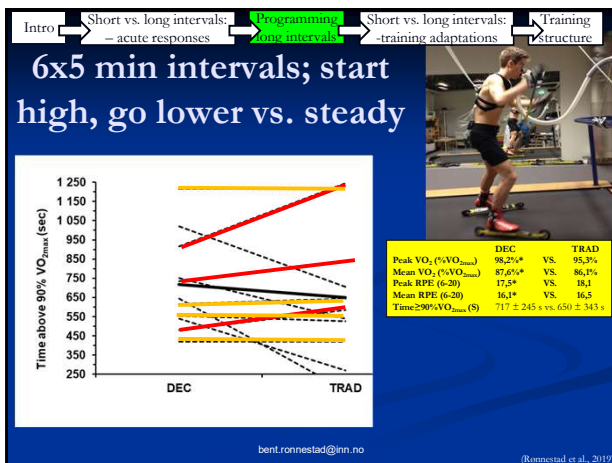
Similar mean exercise intensity (9% inclination, $11.3 \pm 0.8 \text{ km}\cdot\text{h}^{-1}$).

	DEC	TRAD
Peak VO_2 (% $\text{VO}_{2\text{max}}$)	98,2%*	95,3%
Mean VO_2 (% $\text{VO}_{2\text{max}}$)	87,6%*	86,1%
Peak RPE (6-20)	17,5*	18,1
Mean RPE (6-20)	16,1*	16,5

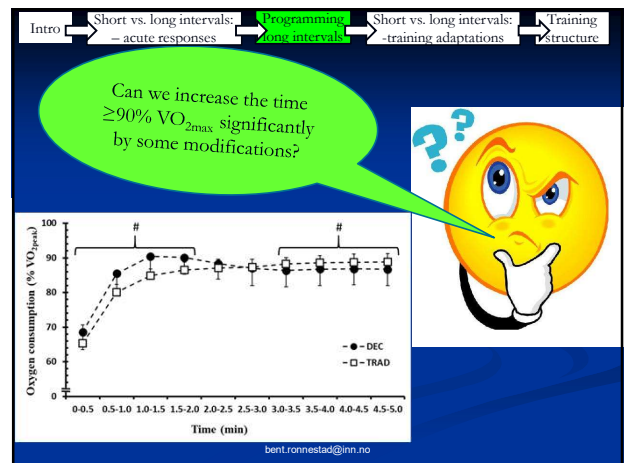
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(Rønnestad et al., 2019)

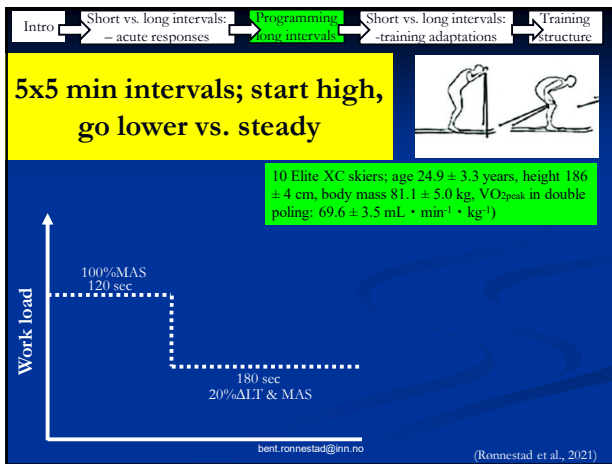
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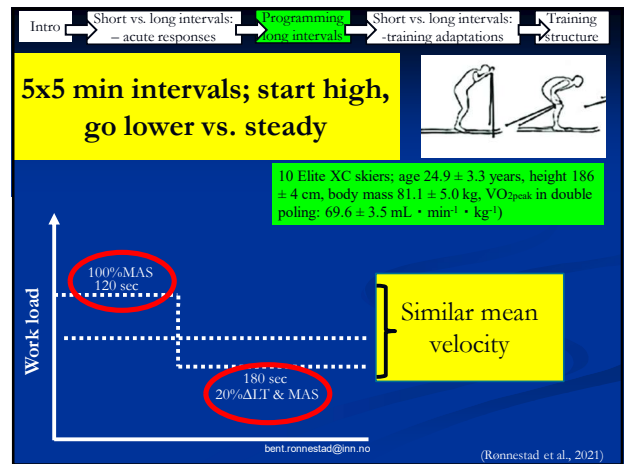
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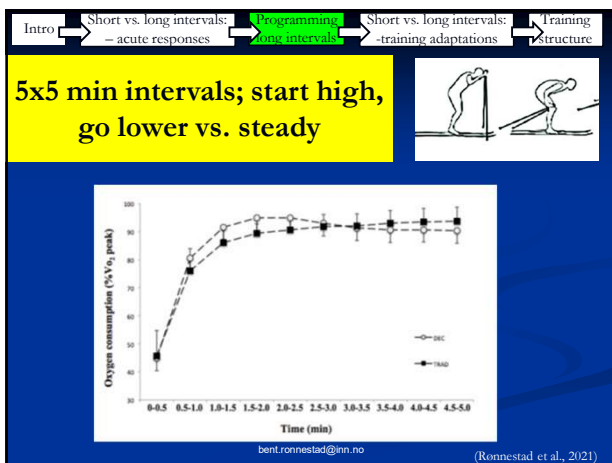
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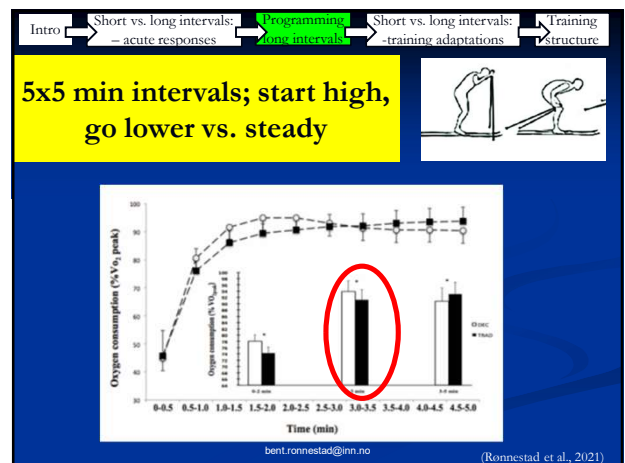
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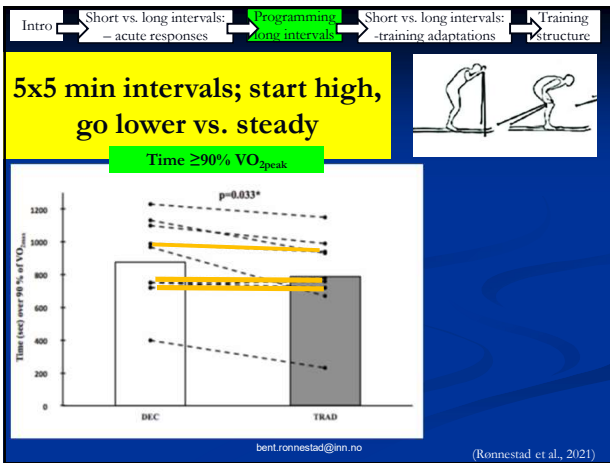
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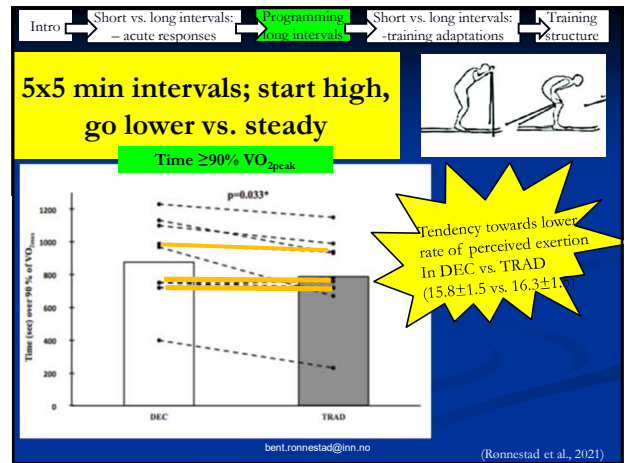
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If we start long intervals with a high intensity with a subsequent reduction, would we then achieve a longer time $\geq 90\%$ VO_{2max} ?

Yes, start high go lower seems to be a good supplement to the traditional approach, especially if we take into consideration the individual LT

bent.ronnestad@inn.no

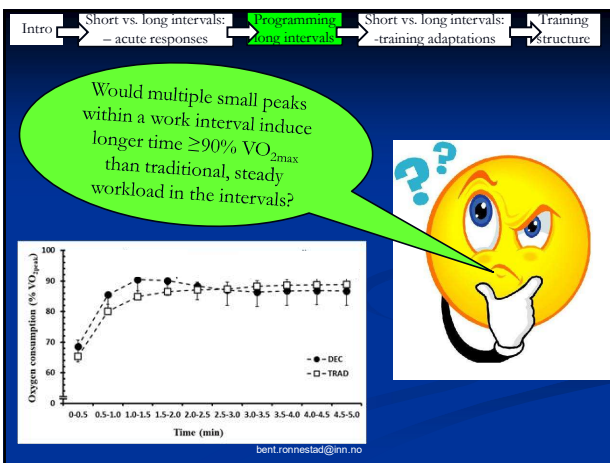
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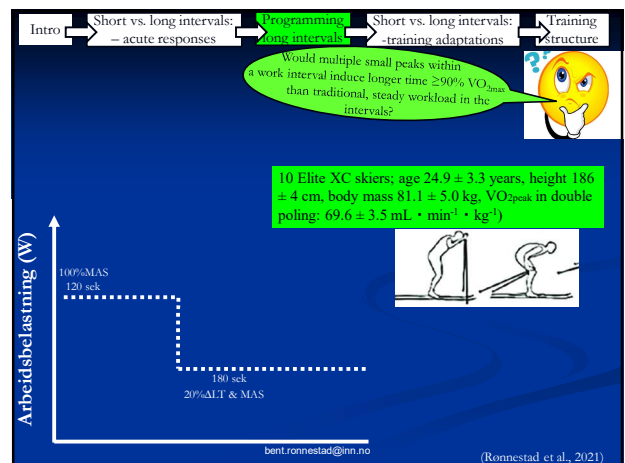
Applying the research

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Would multiple small peaks within a work interval induce longer time $\geq 90\%$ VO_{2max} than traditional, steady workload in the intervals?

10 Elite XC skiers; age 24.9 ± 3.3 years, height 186 ± 4 cm, body mass 81.1 ± 5.0 kg, VO_{2peak} in double poling: 69.6 ± 3.5 mL \cdot min $^{-1}$ \cdot kg $^{-1}$

5x5 min intervals with similar mean velocity

bent.ronnestad@inn.no (Ronnestad et al., 2021)

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

Would multiple small peaks within a work interval induce longer time $\geq 90\%$ VO_{2max} than traditional, steady workload in the intervals?

15.0 min (Variable) vs. 13.1 min (TRAD)

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Would multiple small peaks within a work interval induce longer time $\geq 90\%$ VO_{2max} than traditional, steady workload in the intervals?

Oxygen consumption (% VO_{2peak}) vs. TIME (MIN:SEC)

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Would multiple small peaks within a work interval induce longer time $\geq 90\%$ VO_{2max} than traditional, steady workload in the intervals?

Yes! Then maybe another good supplement to the traditional approach?

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

Summary

- Multiple short intervals can give longer time above $90\%VO_{2max}$ than long intervals, even when similar mean power output
- Multiple small peaks within a work interval can induce longer time $\geq 90\%$ VO_{2max} than traditional, steady workload in the intervals
- Start high go lower seems to induce longer time $\geq 90\%$ VO_{2max} than steady workload, especially if we take into consideration the individual LT

Are there differences between "start high go lower" vs. multiple small peaks within a work interval vs. steady power intervals in time $\geq 90\%$ VO_{2max} ?

Similar effects?

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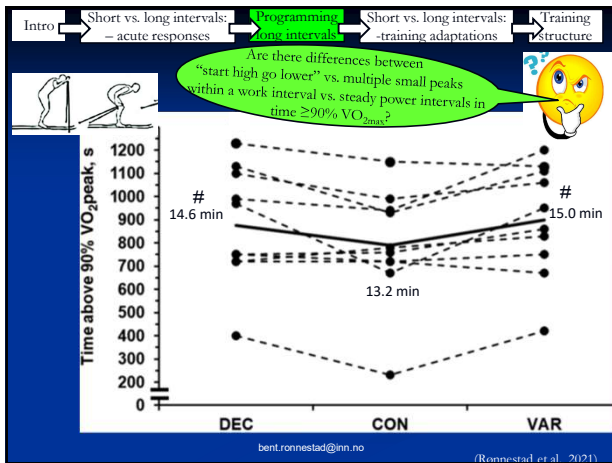
Are there differences between "start high go lower" vs. multiple small peaks within a work interval vs. steady power intervals in time $\geq 90\%$ VO_{2max} ?

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5x5min (VAR), 5x5min (steady), 5x5min (DEC)

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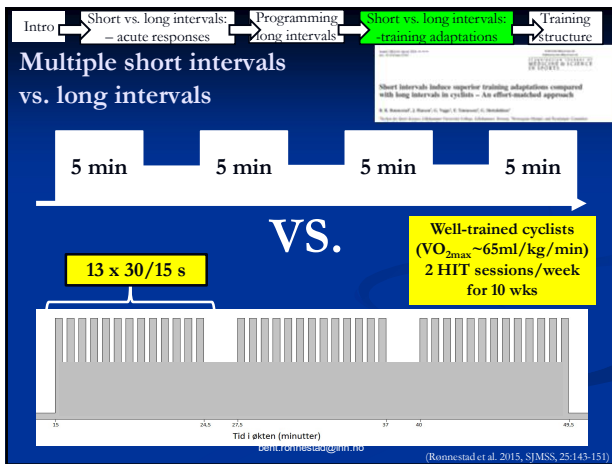
Summary:
The following alternative to traditional long intervals seems to acutely give longer time $\geq 90\%$ of VO_{2max} :

1. Multiple short intervals
2. Start high and go lower in intensity within a long work interval
3. Multiple small peaks within a long work interval

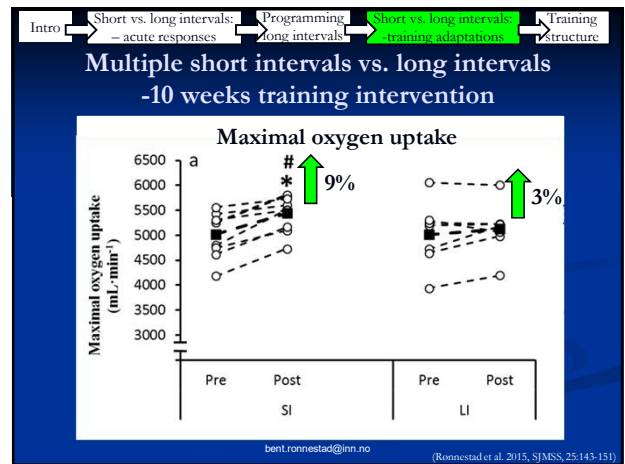
But will it lead to superior training adaptations??

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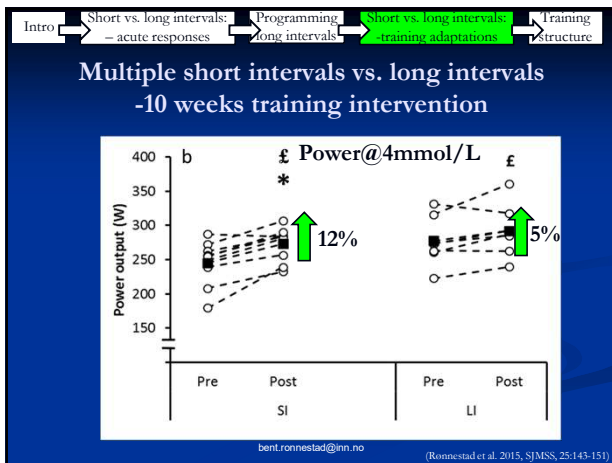
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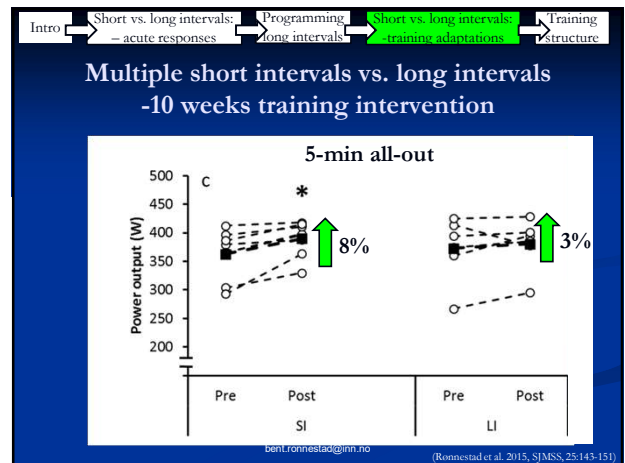
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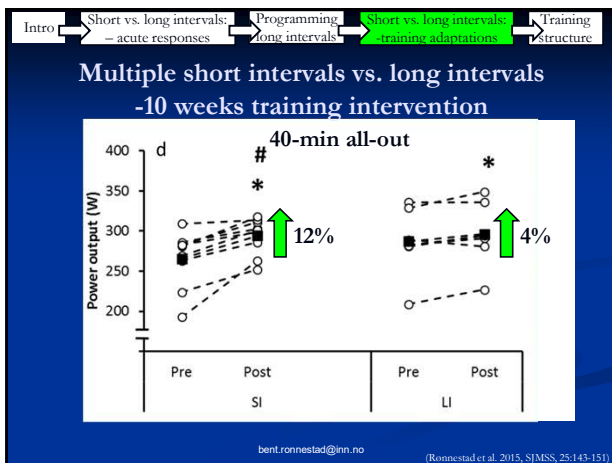
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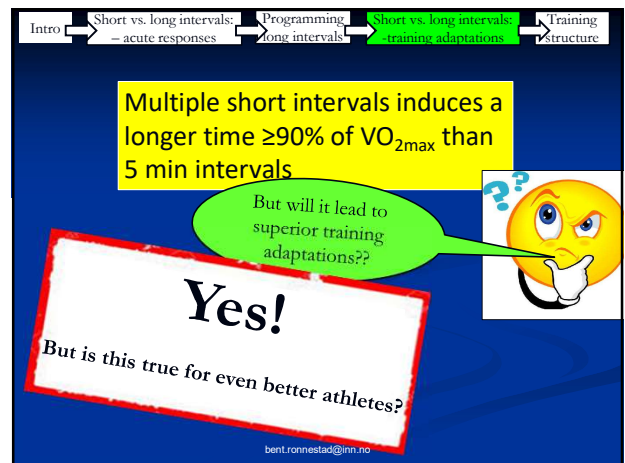
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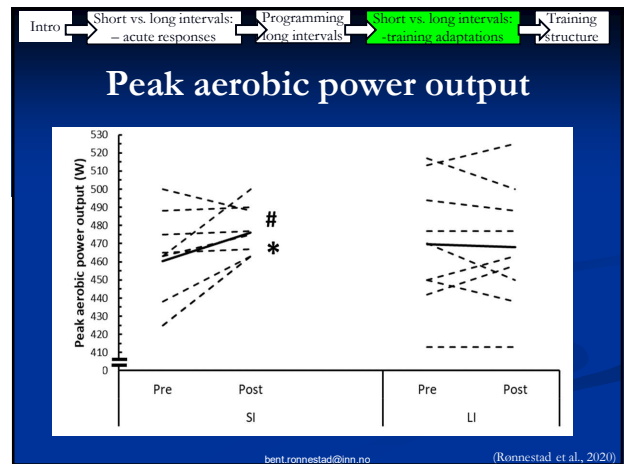
Multiple short intervals vs. long intervals -even better cyclists

3 HIT sessions per week for 3 weeks with 5 days after last HIT before post-test

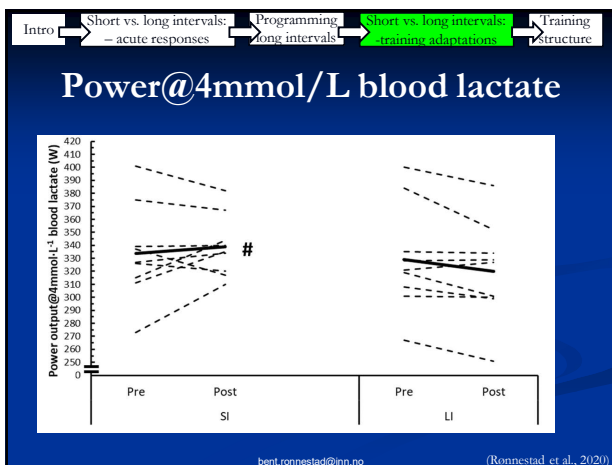
	30/15	4 x 5 min
Age (years)	24±4	25±5
Height (cm)	184±3	182±4
Body mass (kg)	75.2±3.6	74.5±5.1
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	73±3	74±4
W_{max} (W)	460±26	468±39
20 min all-out power (W)	343±31	348±32

bent.ronnestad@inn.no (Rønnestad et al., 2020)

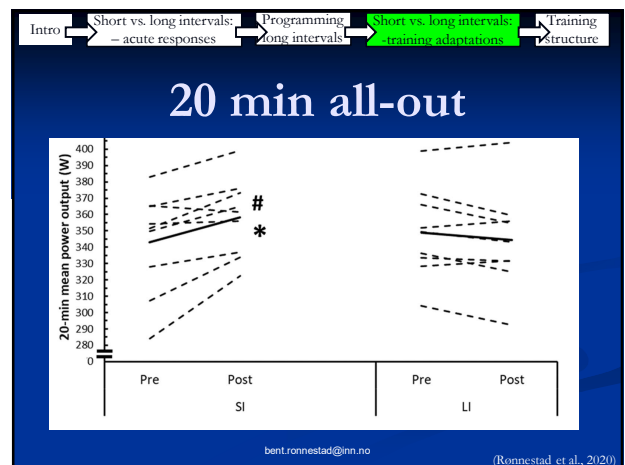
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Multiple short intervals induces a longer time $\geq 90\%$ of VO_{2max} than 5 min intervals

Yes!
But is this true for even better athletes?

But will it lead to superior training adaptations??

Yes!
But is this true for a short HIT microcyclus?

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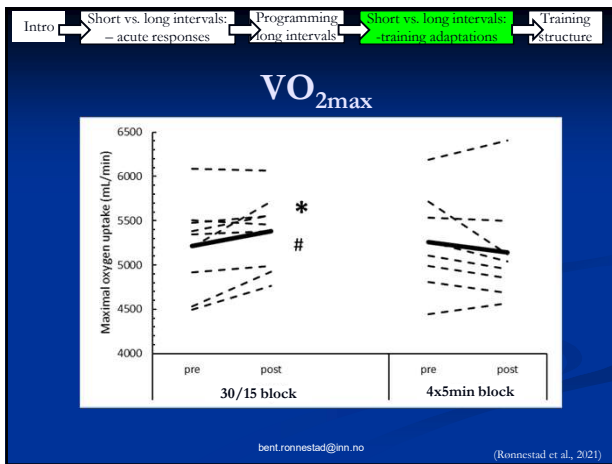
5 HIT sessions in a week (6 x 5 min) in 6 days
VS.
5 HIT sessions in a week (5 series á 12 x 30 sec work period with 15 sec recovery)

Both groups tested on the 6th day after last HIT session. Standardized and similar training in between

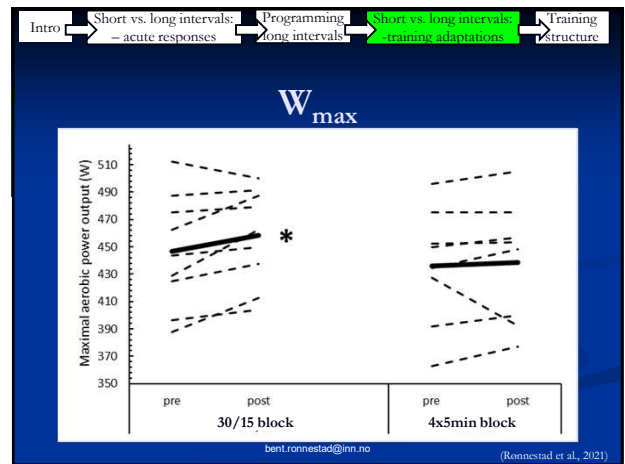
Each work interval should have a rate of perceived exertion between 17 and 19 on Borg 6-20 RPE scale

bent.ronnestad@inn.no (Ronnestad et al., 2021)

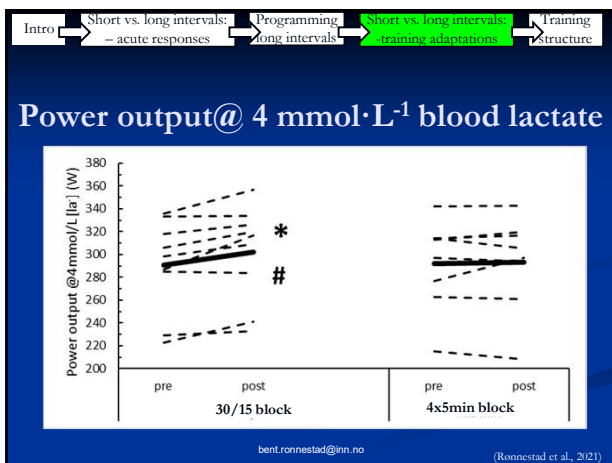
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Multiple short intervals induces a longer time $\geq 90\%$ of VO_{2max} than 5 min intervals

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Yes!
But is this true for a short HIT microcyclus?

Yes!

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: training adaptations → Training structure

Summary

- Multiple short intervals can give longer time above 90%VO_{2max} than long intervals, even when similar mean power output
- Multiple small peaks within a work interval can induce longer time ≥90% VO_{2max} than traditional, steady workload in the intervals
- Start high go lower seems can induce longer time ≥90% VO_{2max} than steady workload, especially if we take into consideration the individual LT
- Indications that isoeffort multiple short intervals can give larger adaptations than longer intervals

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Practical application of a 30/15 session

- Work intensity ≈ mean work rate during 5-6 min all-out
- Recovery ≈ moderate work intensity
- Number of intervals in a serie ≈ >9
- Number of series ≈ 3-4

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: training adaptations → Training structure

Practical application of a 30/15 session

- Work intensity ≈ mean work rate during 5-6 min all-out
- Recovery ≈ moderate work intensity
- Number of intervals in a serie ≈ >9
- Number of series ≈ 3-4

Borg scale

- No exertion at all
- Extreme light
- Very light
- Light
- Somewhat hard
- Hard (Heavy)
- Very hard
- Extremely hard
- Maximal exertion

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Applying the Borg scale

- 6 - Ekstremt lett
- 7 - Svært lett
- 8 - Lett
- 9 - Litt anstrengende
- 10 - Anstrengende
- 11 - Svært anstrengende
- 12 - Ekstremt anstrengende
- 13 - Maksimalt anstrengende
- 14 - 15 - 16 - 17 - 18 - 19 - 20

bent.romnestad@inn.no

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: training adaptations → Training structure

Summary

- Multiple short intervals can give longer time above 90%VO_{2max} than long intervals, even when similar mean power output
- Multiple small peaks within a work interval can induce longer time ≥90% VO_{2max} than traditional, steady workload in the intervals
- Start high go lower seems can induce longer time ≥90% VO_{2max} than steady workload, especially if we take into consideration the individual LT
- Indications that isoeffort multiple short intervals can give larger adaptations than longer intervals

Training Tool Box

bent.romnestad@inn.no

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Training Tool Box

It's important to monitoring individual responses to the training and find the right way at the right time for each individual athlete

bent.romnestad@inn.no

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bent.ronnestad@inn.no

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

Weekly organization of HIT sessions

In general, it can be argued that the traditional way of implementing HIT is to regularly perform ≈ 2 HIT sessions per week interspersed with low and moderate intensity endurance training

(e.g. Sandbakk et al. 2016, MSSE, 48, 1091-100; Sandbakk & Holmberg 2017, IJSP, doi: 10.1123/ijssp.2016-0749; Seiler 2010, IJSP, 5,276-291; Tonnessen et al. 2014, PLoS ONE 9: e101796)

bent.ronnestad@inn.no

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Weekly organization of HIT sessions

In general, it can be argued that the traditional way of implementing HIT is to regularly perform ≈ 2 HIT sessions per week interspersed with low and moderate intensity endurance training

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An alternative is a high concentration of specialized workloads during a short period

(Issurin 2016, Sports Med, 46:329-38)

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A HIT microcyclus of 7-17 days increases performance related variables in semi-professional soccer players, male cyclists, professional tennis players, junior triathletes, elite junior alpine skiers

Breil et al. 2010, EJAP, 109:1077-1086; Clark et al. 2014, PLoS ONE 9(12): e115308; Fernandez-Fernandez et al. 2015, JSSM, 14:783-91; Ronnestad et al. 2017, JSS, 35, 1392-1395; Storen et al. 2012, 26, 2705-2711; Wahl et al. 2014, JSSM, 13:259-65; Wahl et al. 2013, JSOR, 27:1384-93.

bent.ronnestad@inn.no

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A HIT microcyclus of 7-17 days increases performance related variables in semi-professional soccer players, male cyclists, professional tennis

How is the adaptations if total HIT stimulus is similar and only the organization of HIT sessions into microcycles is the difference?

Interesting and useful knowledge

...Likely due to a larger HIT dose than the control group or difficult to interpret due to lack of a control group?

bent.ronnestad@inn.no

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HIT micocycles with mantaining focus

Scand J Med Sci Sports 2012; 42: 1111-1116
doi: 10.1111/jms.12016

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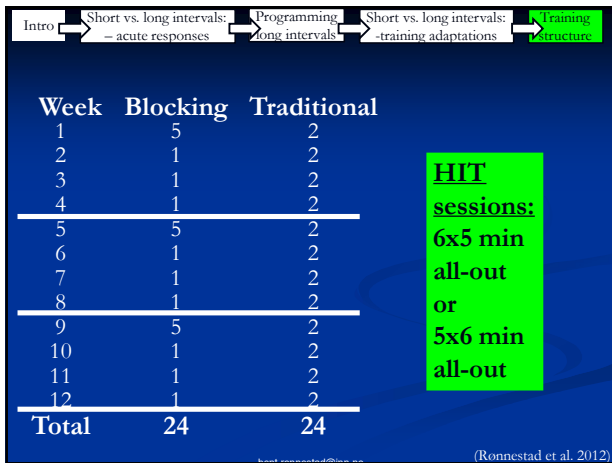
Effects of 12 weeks of block periodization on performance and performance indices in well-trained cyclists

B. R. Ronnestad¹, S. Ellefsen¹, H. Nygaard¹, E. E. Zacharoff¹, O. Vikmoen¹, J. Hansen¹, J. Hallén²

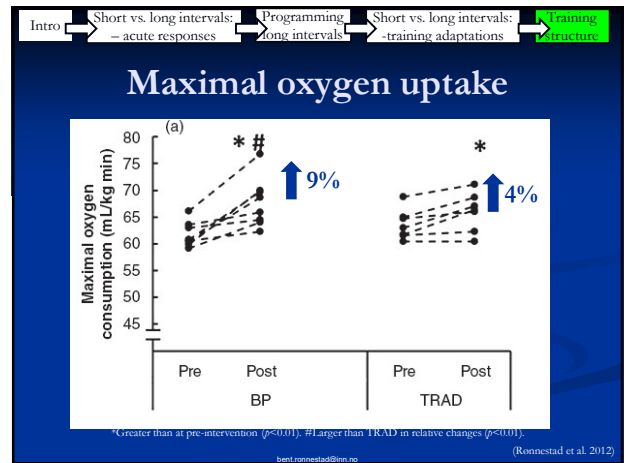
¹Section for Sport Science, Lillehammer University College, Lillehammer, Norway; ²Department of Physical Performance, Norwegian School of Sport Sciences, Oslo, Norway

Corresponding author: Bent R. Ronnestad, Section for Sport Science, Lillehammer University College, PB. 952, 2604 Lillehammer, Norway; Tel: +04761288153; Fax: +47 61288200; E-mail: bent.ronnestad@il.no

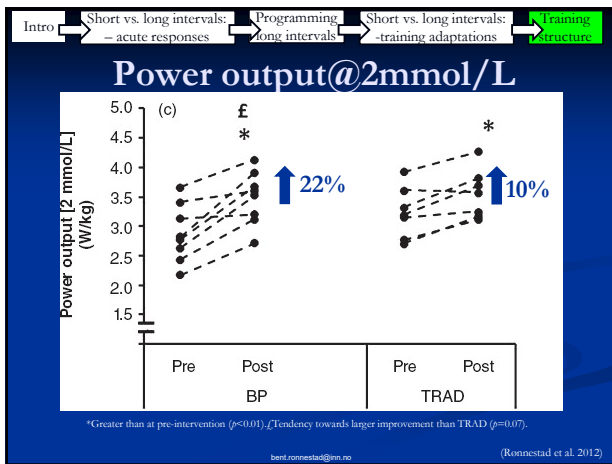
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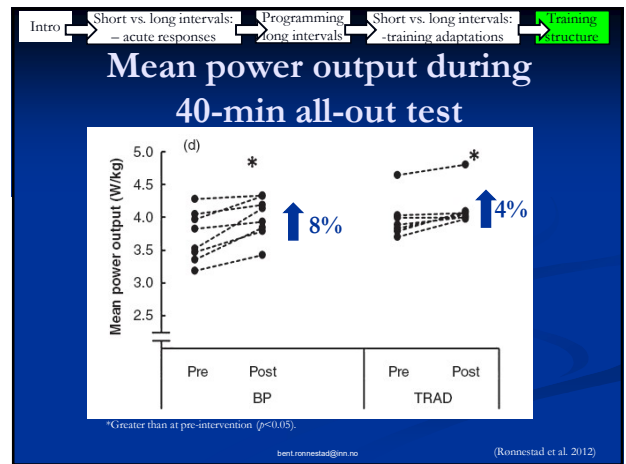
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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → HIT Training structure

Journal of Sport Sciences, 2015, 33(1), 1-8
doi:10.1080/02643758.2014.941848

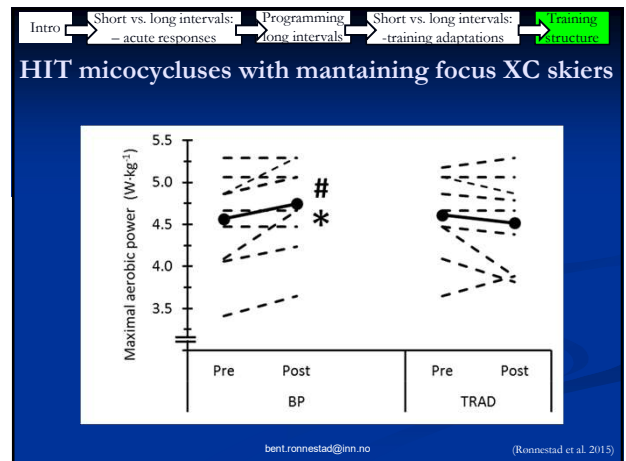
5-week block periodization increases aerobic power in elite cross-country skiers

B. R. Rønnestad¹, J. Hansen¹, V. Thyff¹, T. A. Bakken¹, Ø. Sandbakk¹

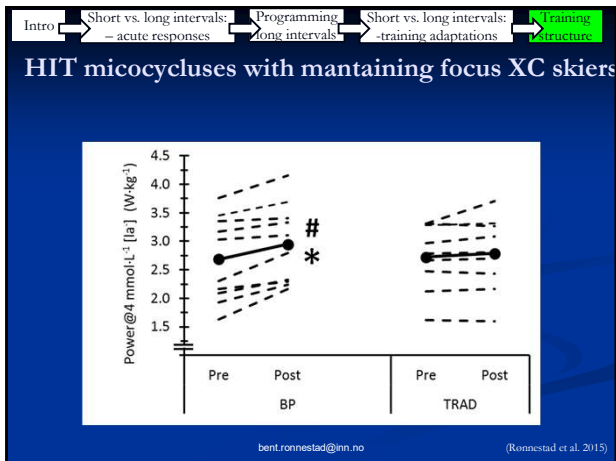
¹Section for Sport Sciences, Lillehammer University College, Lillehammer, Norway; ²Center for Elite Sports Research, Department of Neuroscience, Norwegian University of Science and Technology, Trondheim, Norway

Corresponding author: Ben R. Rønnestad, PhD, Lillehammer University College, PB. 952, 2604 Lillehammer, Norway.
Tel: +47 61284193, Fax: +47 61286200, E-mail: ben.ronnestad@hvl.no

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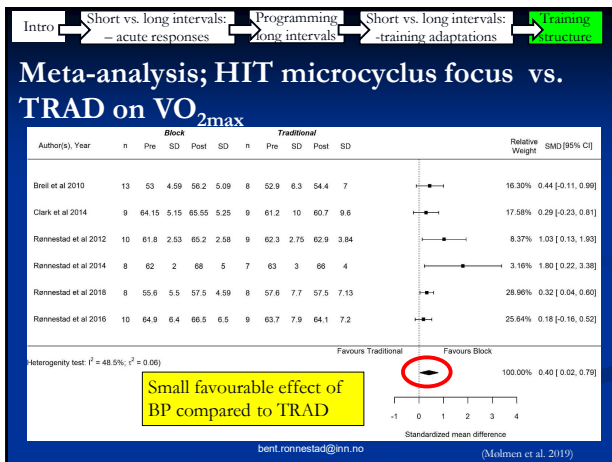
Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

How is the adaptations if total HIT stimulus is similar and only the organization of HIT sessions into microcycles is the difference?

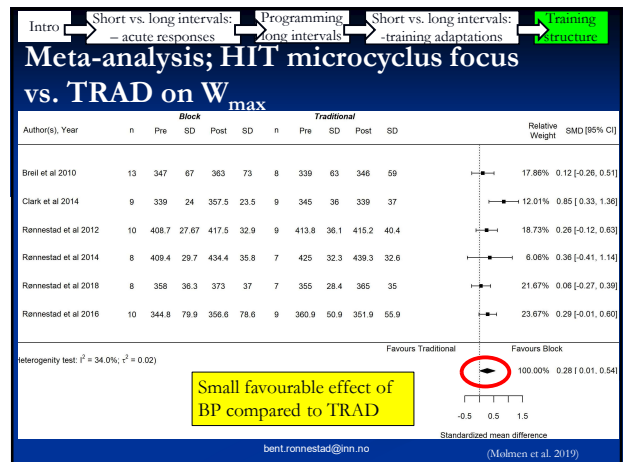
HIT microcycles *can* induce larger adaptations than more traditional organization despite similar total volume and intensity. The efficacy is supported by a meta-analysis.....

bent.ronnestad@inn.no

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Summary:
The following alternative to traditional long intervals seems to acutely give longer time ≥90% of VO_{2max}:

- Multiple short intervals
- Start high and go lower in intensity within a long work interval
- Multiple small peaks within a long work interval

Indications that isoeffort multiple s workrelief ratio can give larger time higher exercise intensity) and superior longer interval

BP can induce larger adaptations than Larger uncertainty about the long-term and cross-over studies indicate larger TRAD periodization (Ronnestad et al. Solli et al. 2019, Garcia-Pallarés et al. 2018)

Training Tool Box

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Intro → Short vs. long intervals: - acute responses → Programming long intervals → Short vs. long intervals: -training adaptations → Training structure

ional long intervals seems to VO_{2max}:
intensity within a long work interval

Multiple short intervals with a 2:1 time above 90% VO_{2max} (and prior adaptations compared to intervals

It's important to monitoring individual responses to the training and find the right way at the right time for each individual athlete


an TRAD in the short term. arm effects, but single-case and similar effects as TRAD s, Storen et al. 2012, Solli et al. fanchado et al. 2018)

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Thanks for the attention!



bent.ronnestad@inn.no