

COLD-WATER IMMERSION A VLIV NA REGENERACI A ADAPTACI NA ZÁTĚŽ

Regenerace a
kompenzace ve
sportu



COLD-WATER IMMERSION (CWI)

- Patří mezi kryoterapeutické metody
- Ponoření (částečné/celkové) do studené vody (~ 10–15 °C) po dobu 5- 20 minut
- Většinou následuje ihned po fyzické aktivitě
- Kontinuální/přerušované



CWI – (DOMNĚLÉ) FYZIOLOGICKÉ ÚČINKY

- ▶ Lokální vazokonstrikce a hydrostatický tlak
 - ▶ Snížení metabolické aktivity
 - ▶ Ovlivnění sekrece hormonů
 - ▶ Ovlivnění prokrvení



- ▶ Akutní snížení markerů svalového poškození a zánětů (?), redukce svalové bolesti, a udržení svalové funkce



- ▶ Zlepšení svalové regenerace (?)

Post-exercise Cold Water Immersion Effects on Physiological Adaptations to Resistance Training and the Underlying Mechanisms in Skeletal Muscle: A Narrative Review

[Aaron C. Petersen](#)^{1,*} and [Jackson J. Fyfe](#)²

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▶ Opravu CWI tlumí zánětlivou odpověď po RT?

- ▶ „Although cold exposure is commonly cited as reducing post-exercise inflammation, much of the evidence to support this comes from animal models of muscle injury or human eccentric exercise models, **which are not representative of typical resistance exercise due to the much greater muscle damage they induce.**“
- ▶ Indeed, studies investigating the inflammatory or immune cell response to resistance exercise show **either no effect** (Gonzalez et al., 2014a,b; Fragala et al., 2015; Jajtner et al., 2015; Yamane et al., 2015; Peake et al., 2017; Fuchs et al., 2020) **or a potentiated response** (Roberts et al., 2014; Jajtner et al., 2015; Fuchs et al., 2020) **due to CWI**, with only **one study reporting a decreased response** (Earp et al., 2019)

CO S TÍM ZÁNĚTEM?

Systematic Review | [Open Access](#) | [Published: 18 November 2015](#)

Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis


[Aryane Flauzino Machado](#), [Paulo Henrique Ferreira](#), [Jéssica Kirsch Micheletti](#), [Aline Castilho de Almeida](#), [Ítalo Ribeiro Lemes](#), [Franciele Marques Vanderlei](#), [Jayme Netto Junior](#) & [Carlos Marcelo Pastre](#) 

[Sports Medicine](#) **46**, 503–514 (2016) | [Cite this article](#)

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CWI VS SVALOVÁ BOLEST

Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis

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- ▶ Celkem vyhledáno 258 studií
- ▶ Do systematického přehledu zahrnuto 9 studií
- ▶ Kontrolní skupina (pasivní odpočinek)
- ▶ Jedna tréninková jednotka
- ▶ Aplikace CWI do 1 hodiny po zatížení
- ▶ Pouze jedna aplikace CWI

Rozdělení dle teploty vody

- Medián 12 °C
- „severe cold (5-10 °C)
- „moderate cold (11-15 °C)

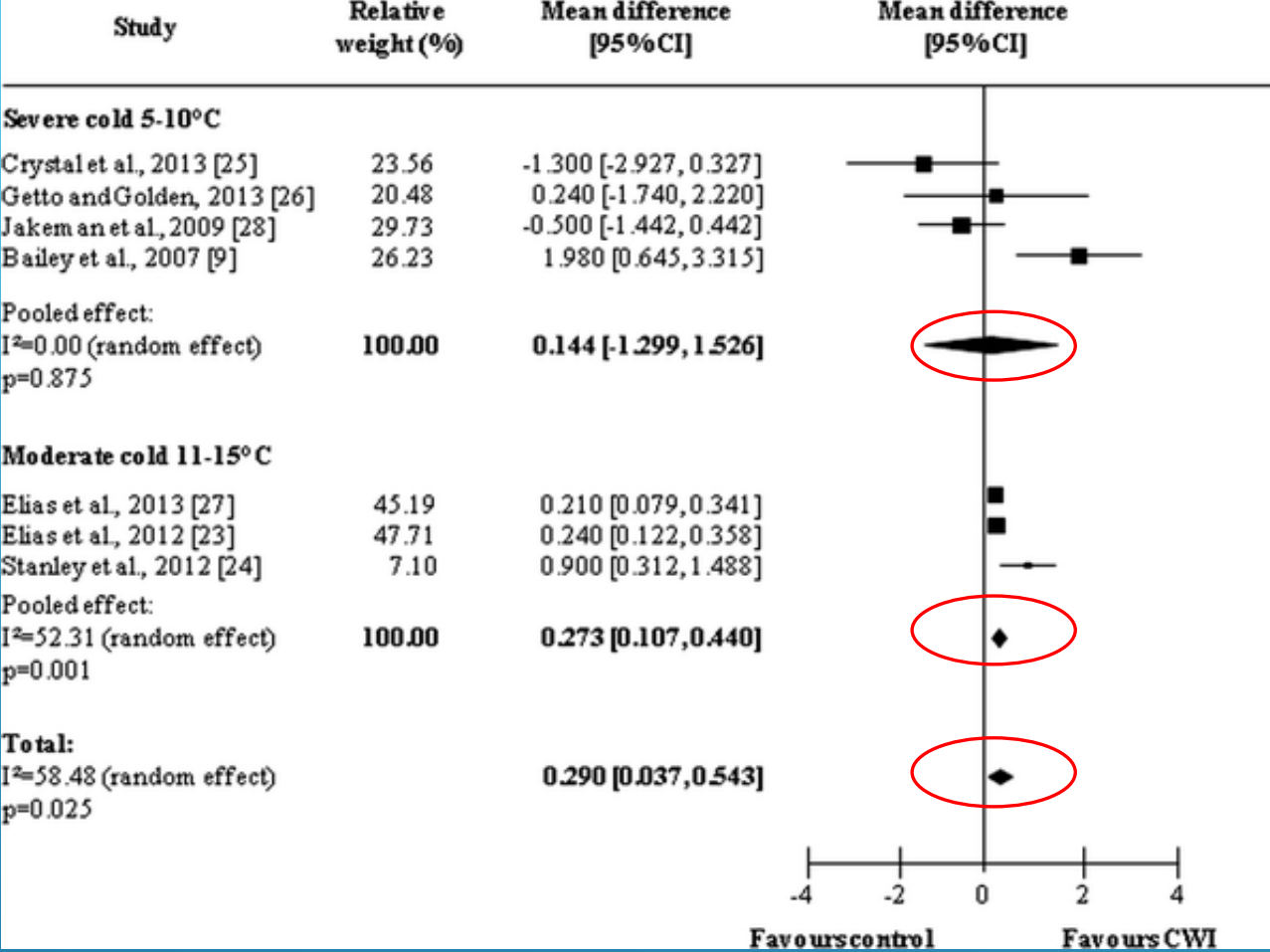
Rozdělení dle doby aplikace (ponoření)

- Medián 14 minut
- „short immersion“ (5-10 minut)
- „medium immersion (11-15 minut)
- „longer immersion“ (16-20 minut)

Okamžitý a „pozdní“ efekt aplikace

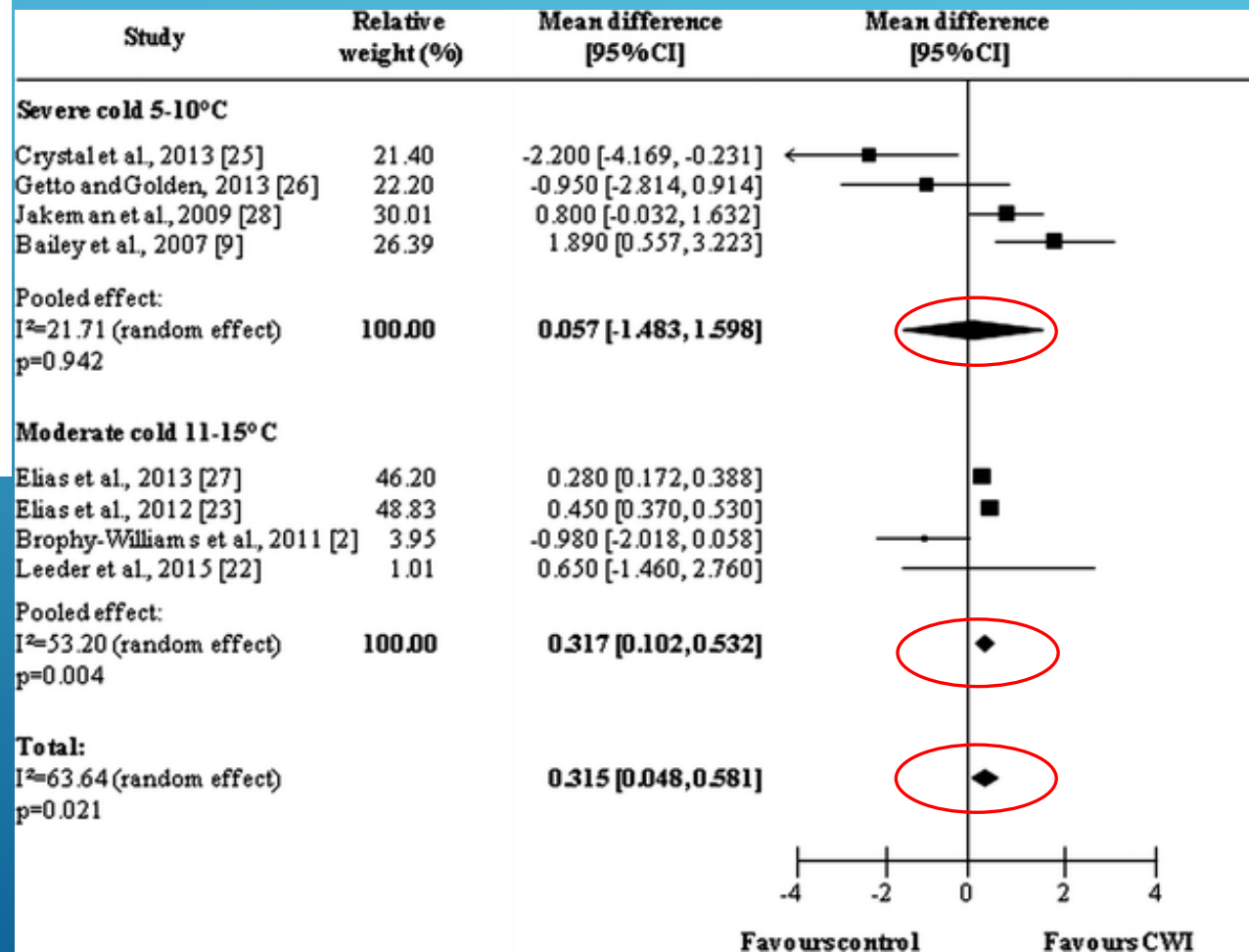
- Do 24 hodin od aplikace
- Po 24 hodinách od aplikace



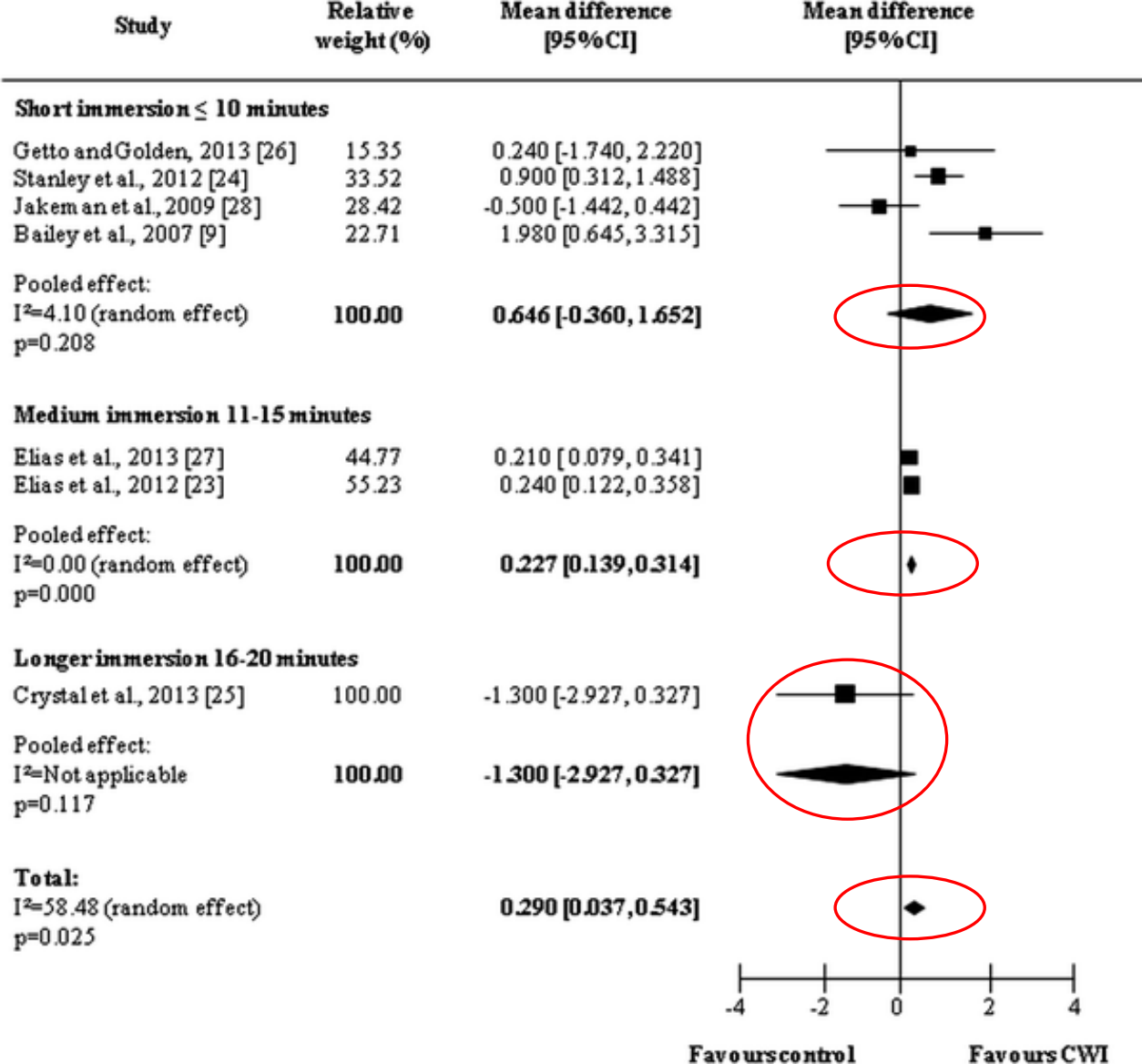


Teplota vody

Pozdní efekt



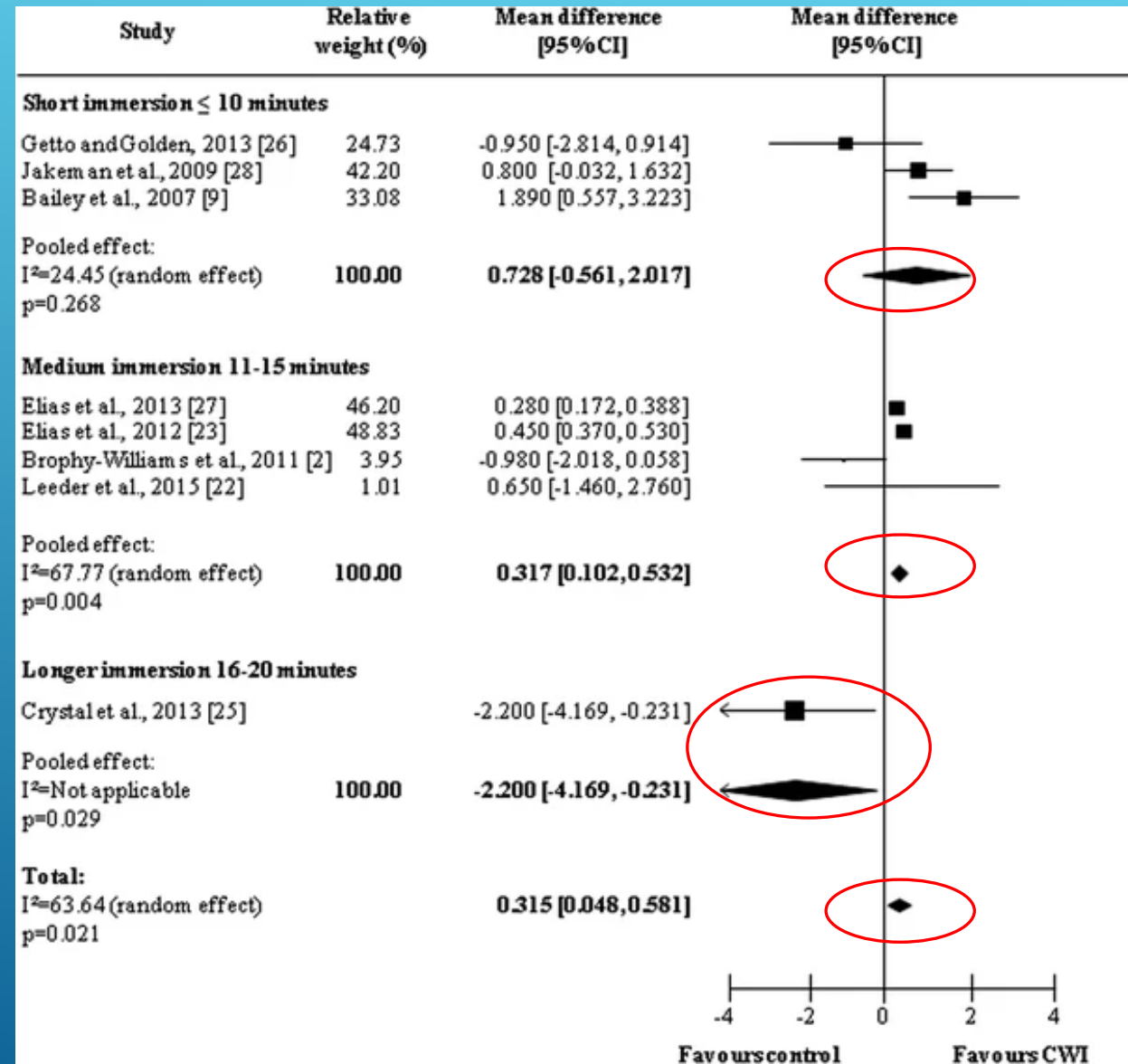
Okamžitý efekt



Okamžitý efekt

Délka ponoření

Pozdní efekt






- ▶ Nezávisle na čase a teplotě, CWI produkovalo **obecně pozitivní výsledky** co se týče okamžitého i pozdního efektu
- ▶ CWI ve vodě v rozmezí **11 – 15 °C** vedlo k výraznější redukci svalové bolesti po fyzické aktivitě
- ▶ **11-15 minut** byl optimální čas CWI pro úlevu od svalové bolesti
- ▶ Ačkoliv byl výsledek favorizující CWI statisticky významný, tzv. **effect size byl „malý“** (v reálné situaci zlepšení ~ 5 %)

KLÍČOVÁ ZJIŠTĚNÍ

Effects of cold water immersion after exercise on fatigue recovery and exercise performance-- meta analysis

Feiyan Xiao^{1*}Anastasiia V. Kabachkova¹Lu Jiao¹Huan Zhao²Leonid V. Kapilevich^{1,3}

	0H	24H	48H
CMJ	↓ 	— † Temp<10°C †; Part —	—
DOMS	↓ 	— † Temp —; Part —	— † Temp —; Part —
RPE	↓ 	—	—
CK	—	↓	—
Lactate	— † Temp —; Part —	↓	↓
CRP	—	—	—
IL-6	—	—	—

↓ = significantly decrease in CWI, groups, compared with CON, groups; † = significantly increase in CWI, groups, compared with CON, groups; — = insignificant difference between CWI, and CON, groups; † = heterogeneity present between CWI, and CON, groups; Temp = CWI, temperatures; Part = CWI, of different body parts; CMJ , countermovement jump; DOMS, delayed-onset muscle soreness; RPE , rating of perceived exertion; CK , creatine kinase; CRP = C-Reactive protein; IL-6 , Interleukin 6.

The Effects of Regular Cold-Water Immersion Use on Training-Induced Changes in Strength and Endurance Performance: A Systematic Review with Meta-Analysis

[Elvis S. Malta](#), [Yago M. Dutra](#), [James R. Broatch](#), [David J. Bishop](#) & [Alessandro M. Zagatto](#) 

Sports Medicine **51**, 161–174 (2021) | [Cite this article](#)

2218 Accesses | **4** Citations | **194** Altmetric | [Metrics](#)

- ▶ Celkem vyhledáno 697 studií
- ▶ Do systematického přehledu zahrnuto 8 studií
- ▶ Kontrolní skupina (pasivní odpočinek, aktivní odpočinek)
- ▶ Vliv CWI na adaptaci na silový/vytrvalostní trénink

Study or Subgroup

Weighting

Std. Mean Difference
IV, Fixed, 95%CIStd. Mean Difference
IV, Fixed, 95%CI**IRM (kg)**

Roberts et al. [23] (Knee extension)

6.9 %

-1.73 [-2.77; -0.70]

Fyfe et al. [24] (Bench press)

7.6 %

0.28 [-0.71; -0.70]

Fyfe et al. [24] (Leg press)

7.7 %

0.06 [-0.92; 1.04]

Roberts et al. [23] (Leg press)

7.9 %

-1.17 [-2.14; -0.21]

Frohlich et al. [5] (Knee extension)

16.1 %

-0.27 [-0.95; 0.40]

Subtotal (95% CI)**46.1 %****-0.50 [-0.90, -0.10]**Test for overall effect: $Z = 2.45$ ($P = 0.01$)**Maximal isometric strength (kg)**

Yamane et al. [36] (Wrist-flexion)

5.0 %

-1.41 [-2.63; -0.20]

Yamane et al. [28] (Wrist-flexion; part-IV)

7.6 %

-0.12 [-1.10; 0.86]

Roberts et al. [23] (Knee extension)

8.1 %

-1.09 [-2.04; -0.13]

Yamane et al. [28] (Wrist-flexion; part-III)

10.3 %

-0.34 [-1.19; 0.50]

Subtotal (95% CI)**31.0 %****-0.65 [-1.14; -0.17]**Test for overall effect: $Z = 2.63$ ($P = 0.009$)**Strength endurance (n. Lifts)**

Yamane et al. [36] (Wrist-flexion)

6.3 %

-0.62 [-1.70; 0.46]

Yamane et al. [28] (Wrist-flexion; part-IV)

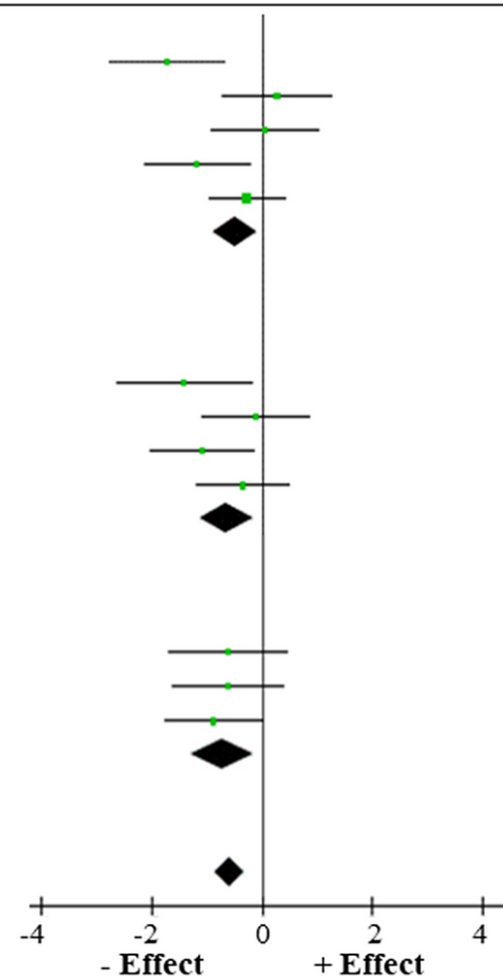
7.2 %

-0.62 [-1.63; 0.39]

Yamane et al. [28] (Wrist-flexion; part-III)

9.4 %

-0.88 [-1.76; 0.01]

Subtotal (95% CI)**22.9 %****-0.73 [-1.29; -0.16]**Test for overall effect: $Z = 2.51$ ($P = 0.01$)**Total (95% CI)****100.0 %****-0.60 [-0.87; -0.33]**Test for overall effect: $Z = 4.33$ ($P < 0.0001$)**Ballistic efforts (N and Nm·s⁻¹)**

Fyfe et al. [24] (Ballistic push-up)

25.9 %

-0.04 [-1.02; 0.94]

Fyfe et al. [24] (CMJ)

25.7 %

-0.21 [-1.19; 0.78]

Fyfe et al. [24] (SJ)

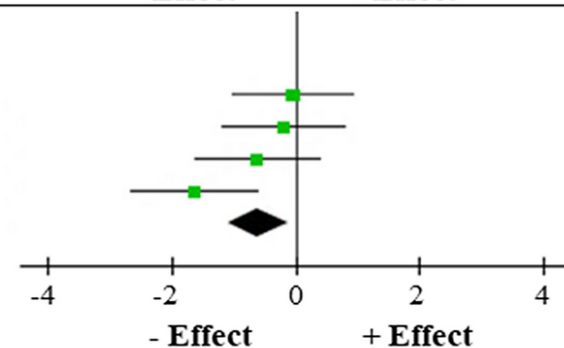
24.4 %

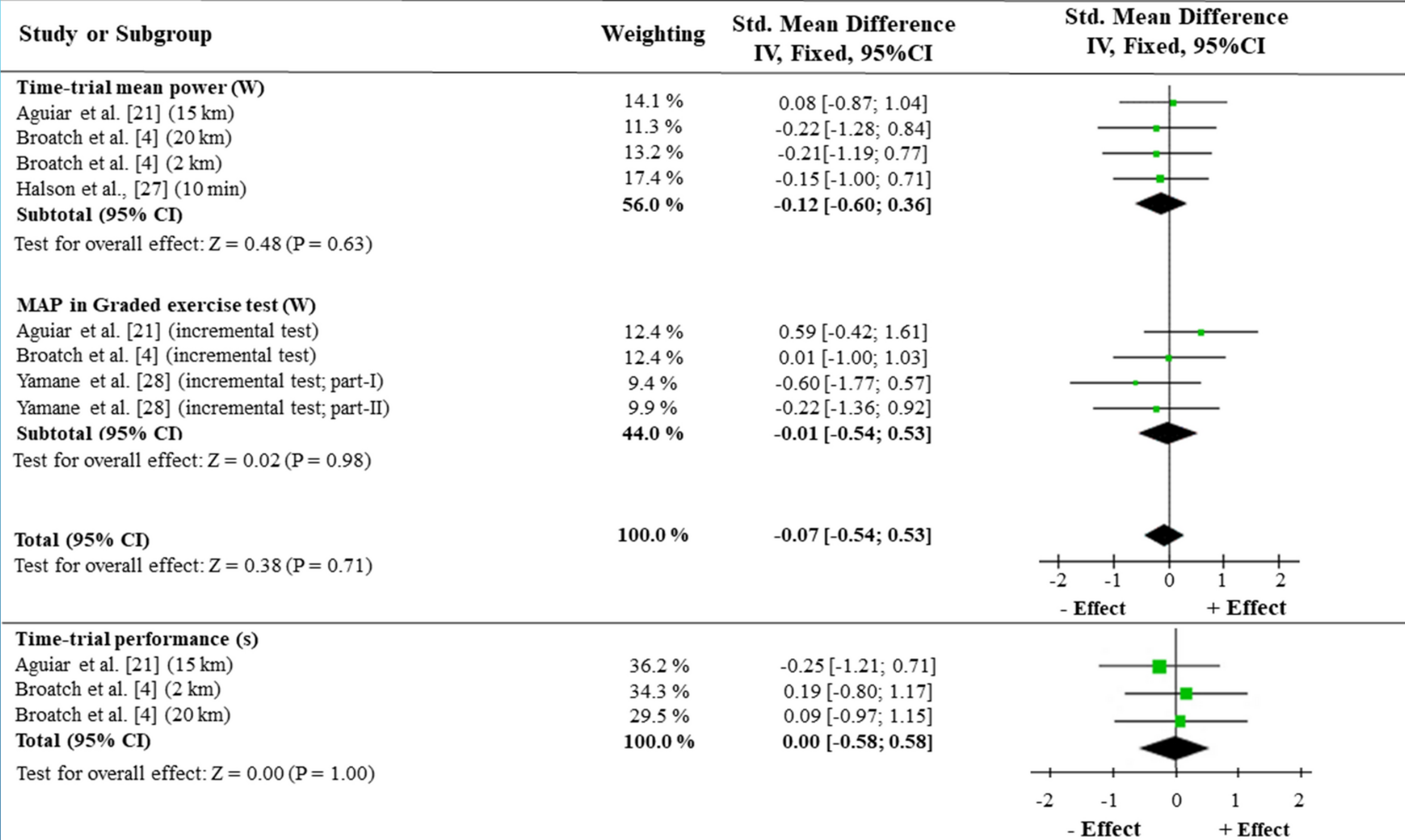
-0.62 [-1.63; 0.39]

Roberts et al. [23] (Knee extension)

24.0 %

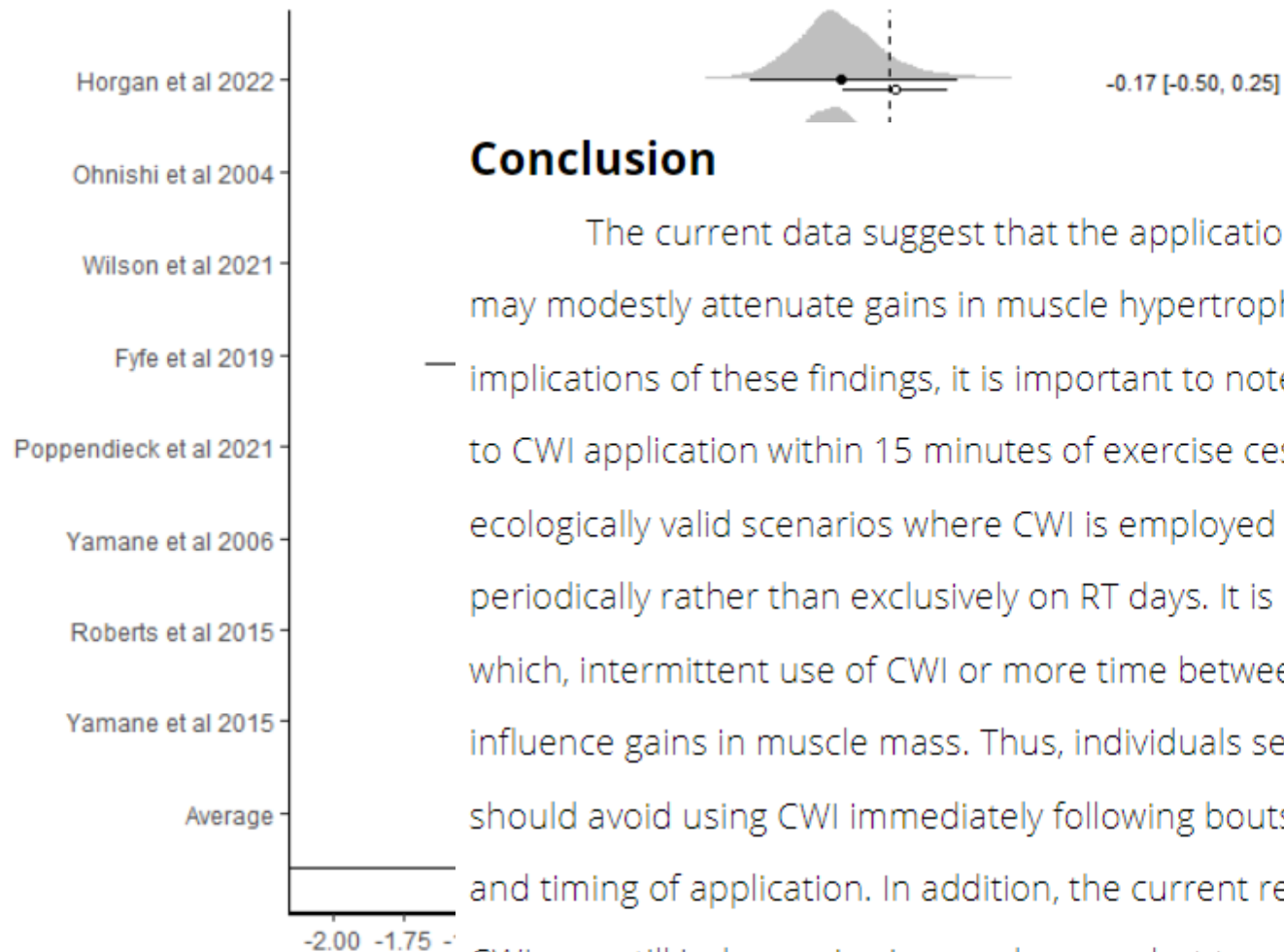
-1.65 [-2.66; -0.63]

Total (95% CI)**100.0 %****-0.61 [-1.11; -0.11]**Test for overall effect: $Z = 2.40$ ($P = 0.02$)



- ▶ CWI zmírňuje tréninkem navozené zlepšení maximální síly a silové vytrvalosti
- ▶ V rámci silových schopností, CWI negativně ovlivnilo všechny ukazatele (1RM max, svalová vytrvalost, ballistický výkon – síla měřena během výskoku, rate of force development)
- ▶ CWI nemá vliv na tréninkem indukované zvýšení aerobního výkonu

HLAVNÍ ZJIŠTĚNÍ



Conclusion

The current data suggest that the application of CWI immediately following bouts of RT may modestly attenuate gains in muscle hypertrophy. When considering the practical implications of these findings, it is important to note that the results of this analysis apply solely to CWI application within 15 minutes of exercise cessation, which may not accurately reflect ecologically valid scenarios where CWI is employed several hours post-RT and/or implemented periodically rather than exclusively on RT days. It is unknown as to whether, or the degree to which, intermittent use of CWI or more time between RT sessions and CWI application may influence gains in muscle mass. Thus, individuals seeking to maximize muscle hypertrophy should avoid using CWI immediately following bouts of RT and further consider the frequency and timing of application. In addition, the current results suggest that RT in combination with CWI may still induce gains in muscle mass, but to a lesser degree compared to RT alone. These findings may have practical implications for athletes looking to limit RT-induced gains in muscle mass (e.g. distance runners). Further research is needed to understand the effects of different frequencies and timing strategies of CWI on RT-induced muscular adaptations, especially in resistance trained individuals and endurance athletes.

Figure 2: Bayesian forest plot illustrating effect sizes directly comparing resistance training (CWI + RT). Positive values favor resistance training (CWI + RT) and negative values favor resistance training (RT alone). The plot shows individual study estimates and a pooled average estimate based on all effects sizes included, the raw estimate, the raw estimate value and 95% credible intervals for the raw estimates and sampling variability. The plot illustrates uncertainty in the pooled

- ▶ **Potlačení aktivity** satelitních buněk a klíčových enzymů zapojených v signální kaskádě mTOR
- ▶ **Snížení zabudování** aminokyselin do kosterního svalstva
- ▶ **Potlačení a zpomalení** nástupu odezvy testosteronu po tréninku (?)
- ▶ Zvýšení bazálních hodnot **degradace svalových proteinů**
- ▶ **Potlačení** ribozomální biogeneze

Independent, corroborating evidence continues to accumulate that post-exercise cooling diminishes muscle adaptations to strength training

Jonathan M. Peake ✉

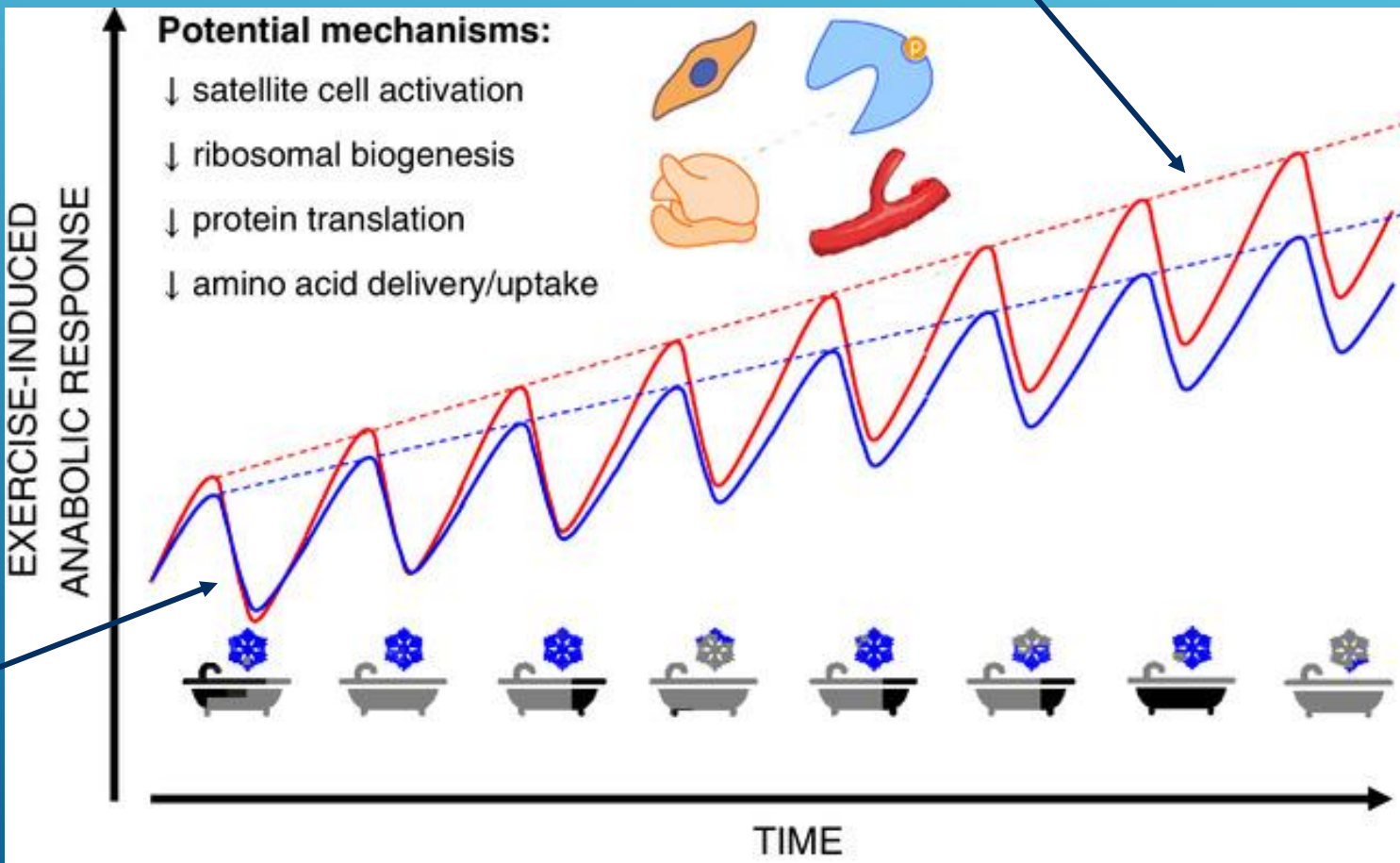
First published: 25 December 2019 | <https://doi.org/10.1113/JP279343> | Citations: 3

Trajektorie nárůstu síly a hypertrofie (long-term)

Systematic Review | Published: 04 November 2020
 The Effects of Regular Cold-Water Immersion Use on Training-Induced Changes in Strength and Endurance Performance: A Systematic Review with Meta-Analysis
 Elvis S. Malta, Yago M. Dutra, James R. Broatch, David J. Bishop & Alessandro M. Zagatto ✉
Sports Medicine 51, 161–174 (2021) | Cite this article
 2218 Accesses | 4 Citations | 194 Altmetric | Metrics

MOŽNÉ MECHANISMY

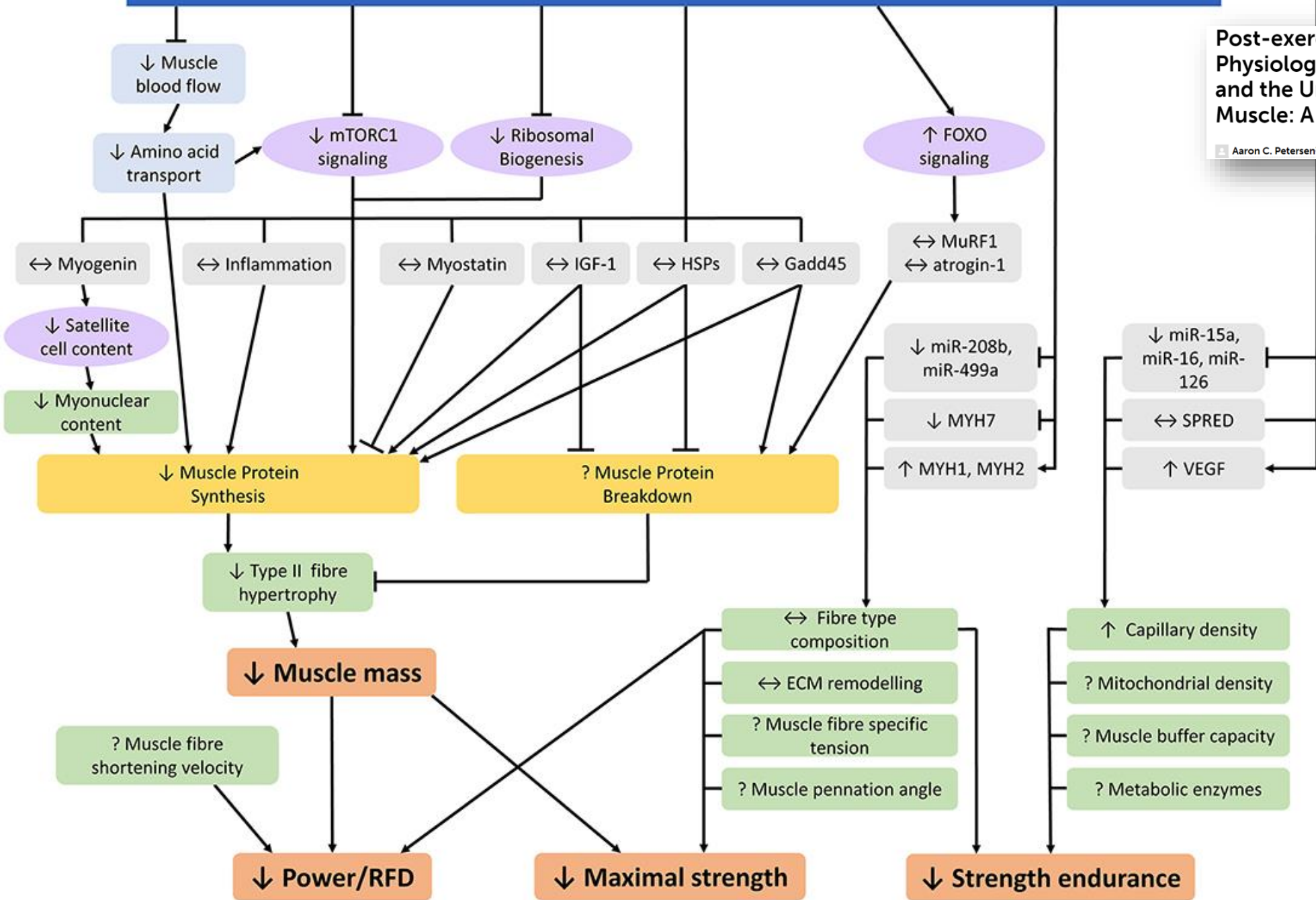
Akutní odezva



Resistance Exercise + Cold-Water Immersion

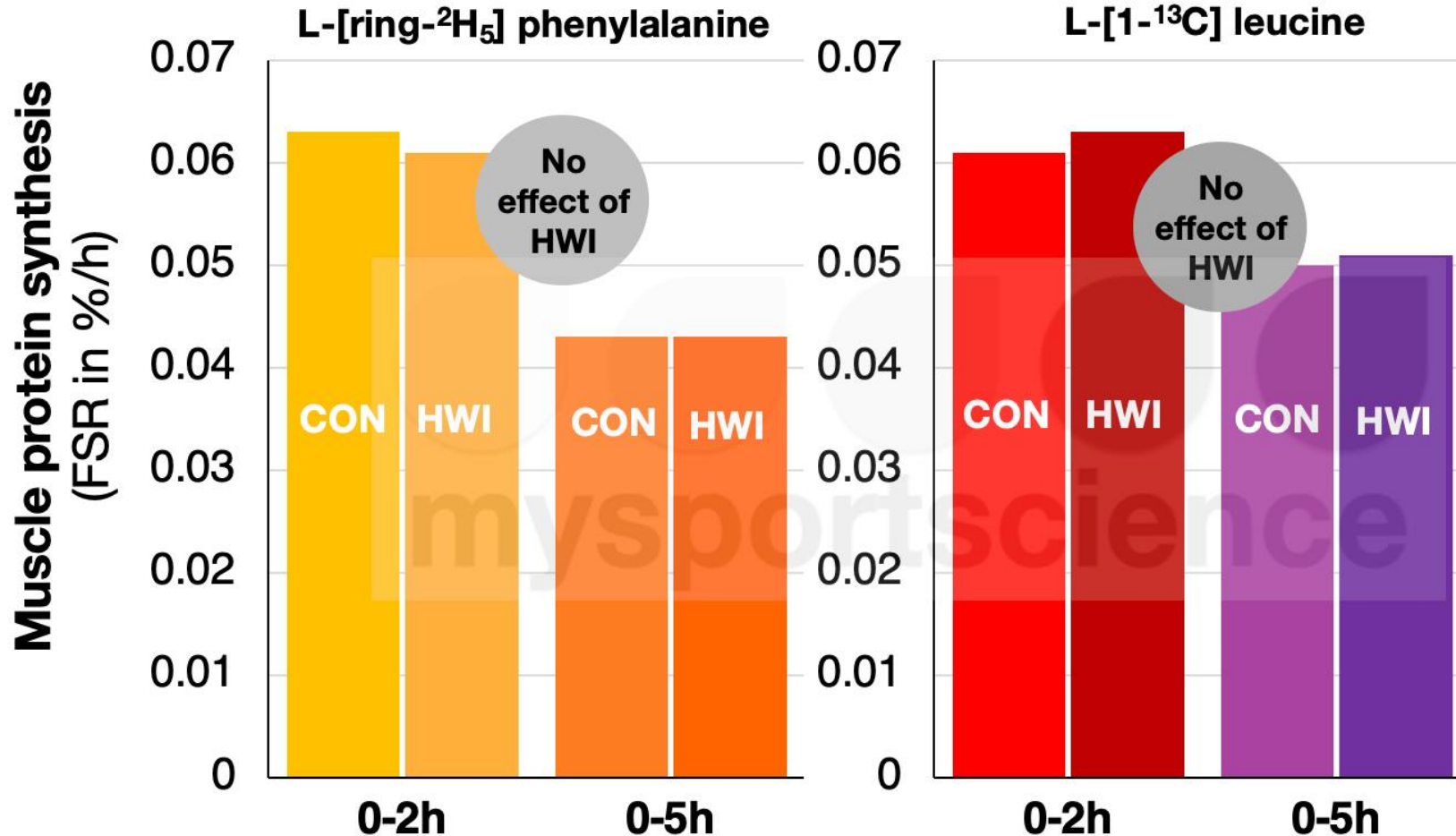
Post-exercise Cold Water Immersion Effects on Physiological Adaptations to Resistance Training and the Underlying Mechanisms in Skeletal Muscle: A Narrative Review

Aaron C. Petersen^{1*} and Jackson J. Fyfe²



Cíl	Chronická aplikace CWI	Akutní aplikace CWI
Nárůst svalové hmoty	Pravděpodobně negativní efekt	---
Nárůst svalové síly (maximální, explozivní, vytrvalostní)	Pravděpodobně negativní efekt	---
Nárůst vytrvalostní výkonnosti	Pravděpodobně bez efektu	---
Zmírnění svalové bolesti	---	Pravděpodobně pozitivní efekt

Effect of hot water immersion after exercise on muscle protein synthesis



No effects on protein synthesis of hot water immersion (HWI) after exercise despite an increase in muscle temperature and blood flow



Active recovery vs hot- or cold-water immersion for repeated sprint ability after a strenuous exercise training session in elite skaters

Robert Solsona, Thibaut Méline, Fabio Borrani, Roméo Deriaz, Jérôme Lacroix, Tom Normand-Gravier, ...show all

Received 04 Feb 2023, Accepted 09 Aug 2023, Published online: 18 Sep 2023

“ Cite this article

<https://doi.org/10.1080/02640414.2023.2259267>



CWI VS. HWI VS. ACTIVE RECOVERY

- ▶ 12 bruslařů (7M,5Ž)
- ▶ Crossover design
- ▶ Aplikace mezi tréninky (90 minut přestávka)
 - ▶ Vyčerpávající bruslařský trénink > opakované cyklistické sprinty
- ▶ HWI 20 min ($41.1 \pm 0.5^{\circ}\text{C}$), CWI 15 min ($12.1 \pm 0.7^{\circ}\text{C}$), 15 min AR

- ▶ Average power output was slightly but significantly higher for AR ($767 \pm 179 \text{ W}$) and HWI ($766 \pm 170 \text{ W}$) compared to CWI ($738 \pm 156 \text{ W}$) ($p = 0.026$, $d = 0.18$). No statistical difference was observed between the conditions for both lactatemia and rating of perceived exertion. Furthermore, no significant effect of recovery was observed on the fatigue index calculated from the repeated sprint cycling exercises ($p > 0.05$). Finally, a positive correlation was found between the average muscle temperature measured during the recoveries and the maximal power output obtained during cycling exercises. In conclusion, the use of CWI in between high-intensity training sessions could slightly impair the performance outcomes compared to AR and HWI.

Active recovery vs hot- or cold-water immersion for repeated sprint ability after a strenuous exercise training session in elite skaters

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„All things are poison and nothing is without poison; only the dose makes a thing not a poison“ Paracelsus

- ▶ Hypotéza o příznivém působení nízké úrovně stresu na organismus
- ▶ Dochází k posílení stávajících obranných mechanismů organismu → podpora schopnosti odolávat většímu stresu
- ▶ Cvičení → stres (metabolický, mechanický, oxidativní) → aktivace mechanismů vedoucích k adaptaci
- ▶ CWI za účelem snížení tréninkem indukovaných zánětlivých procesů → možné negativní ovlivnění adaptace (zánětlivé mediátory a reaktivní formy kyslíku = signální molekuly)

HORMEZE

Influence of acetaminophen and ibuprofen on skeletal muscle adaptations to resistance exercise in older adults

Todd A. Trappe,[✉] Chad C. Carroll, Jared M. Dickinson, Jennifer K. LeMoine, Jacob M. Haus, Bridget E. Sullivan, Jonah D. Lee, Bozena Jemiolo, Eileen M. Weinheimer, and Chris J. Hollon

- ▶ Určitým modulátorem efektu může být věk jedince
- ▶ Studie Trappe et al. (2011)
 - ▶ Jedinci 60-85 let
 - ▶ Odporový trénink (3x týdně, 12 týdnů)
 - ▶ Placebo vs. protizánětlivé léky (3x denně)
 - ▶ Nárůst síly
 - ▶ Placebo ↑ protizánětlivé léky ↑ ↑
 - ▶ Hypertrofie
 - ▶ Placebo ↑ protizánětlivé léky ↑ ↑

HORMEZE

High doses of anti-inflammatory drugs compromise muscle strength and hypertrophic adaptations to resistance training in young adults

M Lilja ^{1 2}, M Mandić ^{1 2}, W Apró ³, M Melin ^{1 2 4}, K Olsson ^{1 2}, S Rosenberg ⁵,
T Gustafsson ^{1 2}, T R Lundberg ^{1 2}

▶ Studie Lilja et al. (2018)

- ▶ Jedinci 18-35 let
- ▶ Odporový trénink (8 týdnů, 20 tréninků)
- ▶ Ibuprofen (3x denně 1 200 mg – obdobně jako ve studii na minulém slidu)
- ▶ Svalová síla
 - ▶ Ibuprofen ↑ placebo ↑ ↑
- ▶ Hypertrofie
 - ▶ Ibuprofen ↑ placebo ↑ ↑

HORMEZE