

# What Is Really Known about Post-Exercise Recovery Methods?

Natalie Badowski Wu

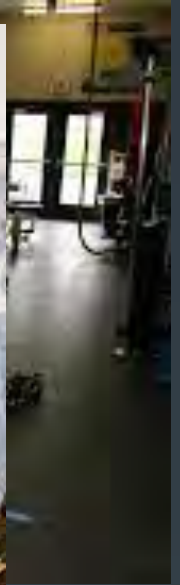
Stanford/Kaiser Emergency Medicine  
O'Connor Sports Medicine



# We Train Hard



© Kristyna Barbellio



# We Are Competitive





# Is There a Better Way to Recover?



# What is Recovery?

- A return to a normal state of health, mind, or strength (Oxford Dictionary)
- Bishop et al. (2008) define recovery as the ability to meet or exceed performance in a particular activity.
- Jeffreys (2005) lists factors of recovery:
  - Normalization of physiological functions (e.g. blood pressure, cardiac cycle)
  - Return to homeostasis (resting cell environment)
  - Restoration of energy stores (blood glucose and muscle glycogen)
  - Replenishment of cellular energy enzymes
- Recovery may include an active component (such as a post-workout walk) and/or a passive component (such as a post-workout massage treatment).



Recovery  
from injury



Recovery  
from training and racing

I will be focusing on recovery after training and racing

# Benefits of Better Recovery



## Adaptation

- Body to adapt to stress of exercise

## Repletion

- Repletion of energy stores

## Repair

- Tissue repair
- Removal of chemical buildup



Better training sessions in the future

Better competitive performance

# Conventional Thoughts on Recovery





# Recovery Methods



# Do These Methods Work?

- Is there any scientific evidence supporting the current recovery methods?
- Is there any benefit to these methods?
- Is there any harm?

# What I Want to Propose



The conventional thinking about recovery from exercise, training, and competition is outdated

*We need a paradigm shift and more research about what really works*

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- Pneumatic Compression
- Massage therapy

# What Will NOT Be Covered



- Elevation
- Electronic Interventions
- The effect of sleep
- Nutritional interventions
- PRP and injections

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- Pneumatic Compression
- Massage therapy



# ACTIVE RECOVERY



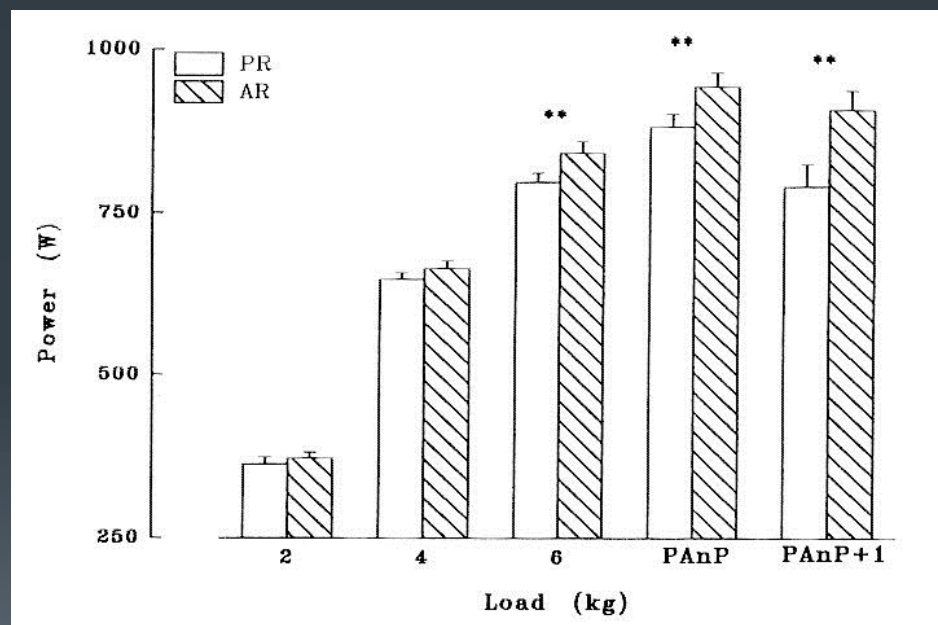
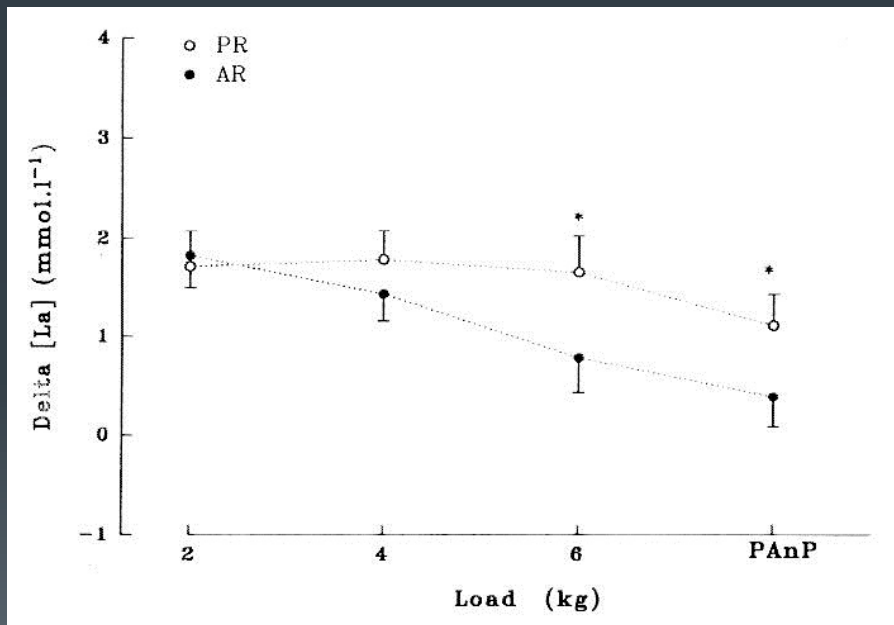
# What is Active Recovery?

- Completing a workout at a low intensity
- Performing an activity outside of one's usual sport to allow blood movement and a mild increase in HR
- Theoretically helps by:
  - Reducing residual muscle fatigue
  - Removal of lactic acid
  - Allows a mental break



# Physiological Data

Ahmaidi et al. (1996) found active recovery (AR) decreased blood lactate concentration and allowed higher anaerobic power compared to passive recovery (PR)



# Passive vs Active Recovery Studies

Studies in other sports:

- Alpine Ski Racers (White et al 2015): 3 minute walk recovery vs passive standing between runs
- Cycling (Lopez et al 2014): Wingate tests with active or passive recovery on ergometer
- Strength training (Lopes et al 2014): Bench press with active vs passive recovery on lactate and power performance

**Active recovery promotes faster lactate clearance  
and better anaerobic efforts in all studies**

White GE, Wells GD. J Strength Cond Res. 2015 Mar;29(3):800-6.

Lopez EI, Smoliga JM, Zavorsky GS. Res Q Exerc Sport. 2014 Dec;85(4):519-26.

Lopes FA, Panissa VL2 Julio UF, Menegon EM, Franchini E. J Hum Kinet. 2014 Apr 9;40:161-9.

# Limitations



- Studies are all done with the next interval immediately following the active recovery session
- Anaerobic sports
- Long term or competition effects not noted

# Passive vs Active Recovery: Any Conclusions?



- Trend that active recovery can help with lactate clearance
- Likely can benefit spurts of anaerobic activity
- Seems to be more beneficial than complete rest between training and before competition (anecdotal evidence)
- However a lot of unanswered questions:
  - Does active recovery benefit aerobic sports that induce considerable muscle damage? (i.e. a 30 mile training run)
    - Does it help flush out waste products or would it just induce more muscular damage
  - What are the long term effects of active recovery? Does it matter?
  - What are the long term effects of active recovery (such as a taper) before competition?

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- Pneumatic Compression
- Massage therapy

# Cryotherapy



# What is Cryotherapy?



Application of cooling to skin above muscle to:

- Temporarily reduce muscle temperature
- Stimulate vasoconstriction
- Inhibit pain

**Does cryotherapy have a role in recovery?**

# Cryotherapy: Rat Studies



- Two studies in rats using crush injury:
  - Schaster et al (2007) found reduced intramuscular pressure, reduced adhering granulocytes, reduced tissue damage and myonectosis at 24 hours
  - Takagi et al (2011) found early reduction in muscle degeneration and leukocyte infiltration but detrimental long term effects (2-4 weeks out) leading to delay in muscle generation (delays in cell-induced repair, larger collagen deposits, decreased macrophage activation)
- Other limitations: animal study, crush injury vs overuse, larger human limbs (can only cool to 25C)



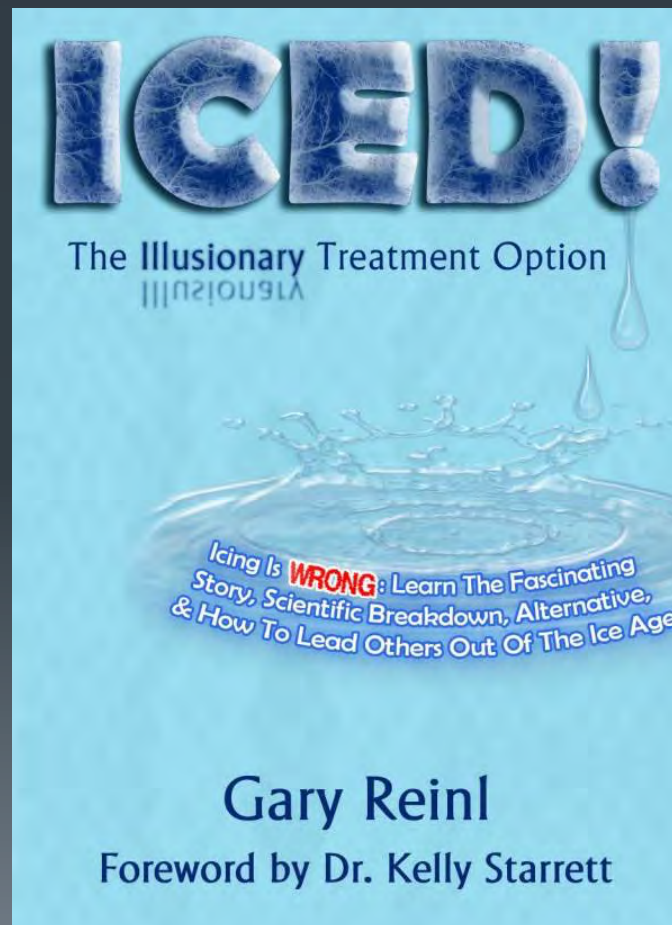
# Cryotherapy: Human Studies

- Many studies across different sports:
  - Rugby: no restorative effect for muscle function tests nor on blood markers of muscle damage
  - Cycling: increased anaerobic contribution but not clear on power output
  - Resistance Training: increased work load on subsequent sessions
  - High Intensity Exercise: no difference between cryotherapy and placebo
  - Running: No change in lactate, VO<sub>2</sub>, or running economy

**Weak evidence overall and no clear conclusions**  
**Suggestion of dependence on temperature**

# The Anti-Ice Movement

- Against the use of ice as a recovery tool for athletes and active people
- The theory: “healing cannot occur without inflammation”



# Cryotherapy: Any Conclusions?

- Benefits:
  - Short term pain control
  - Short term inflammation control
  - Possible advantage in situations with quick resumption of activity
- No effect
  - Many studies suggesting no effect or equal to placebo
  - Not cold enough?
  - Not long enough?
  - Not the right scenario?
- Potential Harm
  - Slows the normal regenerative function of the inflammatory reaction
  - Can lead to further injury when numb
  - Can possibly be detrimental to long term muscle recovery

**Possible short term benefits, no performance advantage, and suggestion of long-term detriment**

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- Pneumatic Compression
- Massage therapy

# Compression Wear



# Compression Gear



- The use of wearable garments to apply compression to specific parts of the body
- Theoretically, this
  - Accelerates blood flow
  - Helps the body get rid of lactic acid and other metabolic wastes
  - Gets more oxygen to your muscles
  - Decreases muscle soreness
  - Speeds recovery
  - Improves subsequent performance

Is there any scientific evidence to support these claims?

# Compression Gear



- Many, many studies of variable methodology
- Will present a select few

# Physiological Data

- Measured venous pressure measurement via 18 gauge cannula in dorsal vein of foot with and without elastic compression
- Findings: elastic compression does not increase blood flow but does make the veins less compliant
- Theoretically compression shunts more blood through the deep venous system

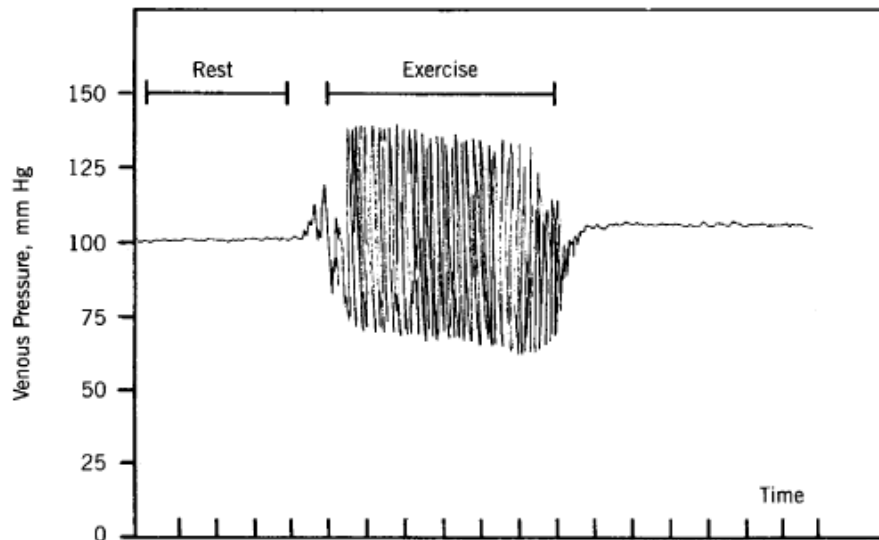
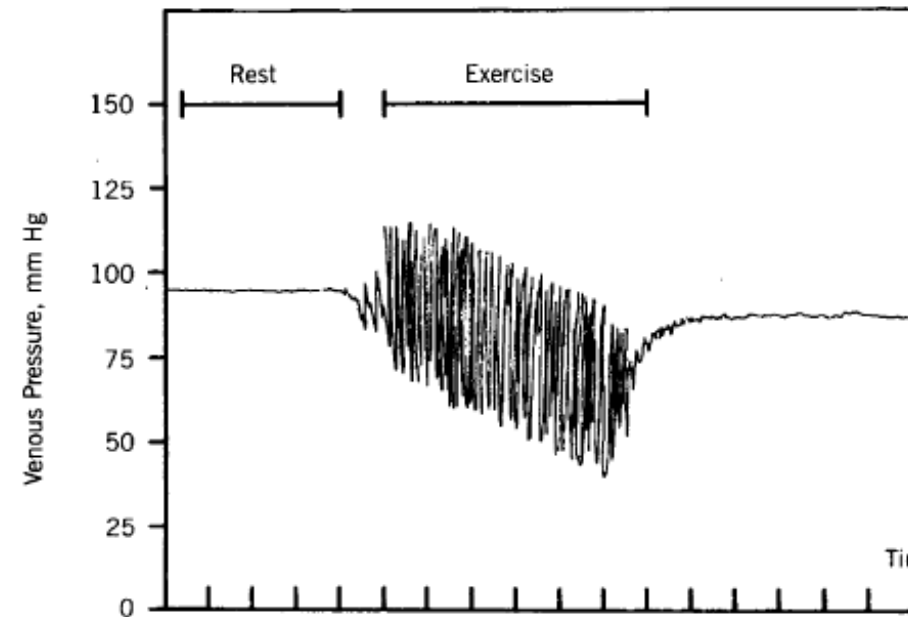


Fig 2.—Representative venous pressure trace from patient with postphlebotic limb. Top Figure shows values without elastic compression, while in bottom Figure elastic compression has been applied. Amplitude of pressure swing and peak systolic pressure are lessened following application of elastic compression.



O'Donnell TF Jr, Rosenthal DA, Callow AD, Ledig BL. Effect of elastic compression on venous hemodynamics in postphlebotic limbs. JAMA. 1979 Dec 21;242(25):2766-8.



# Elastic Compression in Running Recovery

- Lower lactate with GCS worn during treadmill and ergometer and recovery
  - **Point: Lower lactate because kept in muscles or because cleared better?**
  - Berry, M.J., R.G. McMurray. 1987. Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. J Phys Med 66(3):121-32.
- Reduction in delayed-onset muscle soreness 24 hours post 10km trail
- Difference in the frequency and location of soreness
  - Ali, A., M.P. exercise. J
- Higher capillary blood flow
  - 20 mmHg increased StO<sub>2</sub> by 3.3 %
  - Ménétrier A1, Mourot L, Bouhaddi M, Regnard J, Tordi N. Compression sleeves increase tissue oxygen saturation but not running performance. Int J Sports Med. 2011 Nov;32(11):864-8. doi: 10.1055/s-0031-1283181. Epub 2011 Nov 3.
- Less muscle soreness with CS, possible strength improvement, trivial or unclear differences for CK and IL-6
  - Bieuzen F1, Brisswalter J, Easthope C, Vercruyssen F, Bernard T, Hausswirth C. Effect of wearing compression stockings on recovery after mild exercise-induced muscle damage. Int J Sports Physiol Perform. 2014 Mar;9(2): 256-64. doi: 10.1123/ijsp.2013-0126. Epub 2013 May 22.

Overall: Reduction in DOMs, possible increase in tissue oxygenation and decrease in lactate, but no benefit to performance

and after

ce

# Elastic Compression in Other Sports

## ■ Cycling

- Less decrease in max power, lower lactate, lower pain sensation
- 10/12 thought increased performance, but no measured performance gain
- Chatard, J.C., D. Atlaoui, J. Farjanel, F. Louisy, D. Rastel, C.Y. Guezennec. 2004. Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. *Eur J Appl Physiol* 93(3):347-52.

## ■ Netball/Basketball

- No difference CK, LDH, thigh girth, perceived soreness, and no difference in test performance.
- Women: CS attenuated CK at 24 hours and the perception of muscle soreness
- Davies, V., K.G. Thompson, S.M. Cooper. 2009. The effects of compression garments on recovery. *J Strength Cond Res* 23(6):1786-94.

## ■ Strength Exercise:

- The EC30 stockings produced the lowest levels of fatigue
- Miyamoto, N., K. Hirata, N. Mitsukawa, T. Yanai, Y. Kawkami. 2011. Effect of pressure intensity of graduated elastic compression stocking on muscle fatigue following calf-raise exercise. *J Electromyogr Kinesiol* 21(2):249-54.

No performance gains but possible decreased muscle soreness  
and decreased fatigue

Questions about effect of gender and level of compression

# Compression: Any Conclusions?

- Does the use of wearable garments to apply compression to specific parts of the body have any benefit?
- Does NOT accelerate blood flow (O'Donnell et al)
- May help the body get rid of lactic acid and other metabolic wastes (Berry et al. , Davies for women)
- May show some oxygenation benefit (Menetrier)

Decreases muscle soreness  
NO evidence that it speeds recovery or improves  
subsequent performance

# Compression: Any Conclusions?

- Benefits:
  - Reduction in delayed muscle soreness
  - Reduction in perceived soreness
  - Possible decreased lactate
- Questionable:
  - No clear evidence for attenuation of other markers of muscle damage (CK, IL-6)
  - No clear performance benefit
- Potential Harm:
  - No real harm measured or discussed
- Considerations:
  - Small group sizes 9-28
  - Effect of bias
  - Mostly male – is there a gender difference?
  - Compression vs Graduated compression?
  - Calf compression vs thigh vs whole body compression?
  - Specificity of effect? (ex. Bieuzen et al.)
  - Does level of compression matter? (Miyamoto et al)
  - Actual pressure on subjects is not always measured

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- **Pneumatic Compression**
- Massage therapy

# Pneumatic Compression



# Pneumatic Compression



- An inflatable garment for the arm, leg, trunk, or chest that fills with air and intermittently inflates and deflates to provide cyclic compression
- Thought to:
  - Increase venous return
  - Increase lymphatic return
  - Alleviate soreness
  - Improve function of fatigued muscles
  - Help accelerate training
  - Help improve performance

Is there any data behind pneumatic compression?

# Hospital SCDs and Physiological Data

- Sequential compression devices (SCDs)= origin of pneumatic compression
- Hospital use: venous stasis, post-operative cases, and lymphedema.



- Pneumatic compression at intermediate setting increases:
  - Venous velocity
  - Muscle blood flow
  - Subcutaneous mean tissue flow
- Highest setting decreased venous velocity and subcutaneous tissue flow and did not further increase muscle blood flow

Lawrence D, Kakkar VV. Graded, static, external compression of the lower limb: a physiological assessment. Br J Surg. 1980 Feb;67(2):119-21.



# Pneumatic Compression: Exercise Studies

- Only 2 studies outside of the hospital setting!
- Eccentric exercise (single leg jumps) followed by 30 min of Normatec
  - No difference in total work completed, dynamometry measures, CK values
  - Cochrane DJ, Booker HR, Mundel T, Barnes MJ. Does intermittent pneumatic leg compression enhance muscle recovery after strenuous eccentric exercise? *Int J Sports Med.* 2013 Nov;34(11):969-74. doi: 10.1055/s-0033-1337944. Epub 2013 Apr 19.
- Eccentric exercise (hand weights) followed by pneumatic compression
  - Decreased circumference and stiffness, especially day 2 and 3
  - Strength was not affected
  - Chleboun GS, Howell JN, Baker HL, Ballard TN, Graham JL, Hallman HL, Perkins LE, Schauss JH, Conatser RR. Intermittent pneumatic compression effect on eccentric exercise-induced swelling, stiffness, and strength loss. *Arch Phys Med Rehabil.* 1995 Aug;76(8):744-9.

Pneumatic compression offers no advantage for work completed, dynamometry, blood values or strength but may help with stiffness and swelling

# Pneumatic Compression: Any Conclusions?

- Very little data
- Benefits:
  - Increased blood flow
  - Decrease circumference – less swelling?
  - Decrease stiffness
- No data or evidence:
  - Alleviate impaired muscle function
  - Help accelerate training
  - Help improve performance
- Questions:
  - Effect on endurance exercise, sports, competition
  - Ideal pulse pressure and pulse time
  - Sequencing of compression (peristaltic vs sequential)
  - Will it help one recover faster and compete sooner?

# What Will Be Covered



- **Rest?**

- Rest (passive) vs. active recovery

- **Ice?**

- Cryotherapy (aka ice baths)

- **Compression?**

- Compression wear
- Pneumatic Compression
- **Massage therapy**

# Massage



# Massage



- Massage is the pressing, rubbing, and manipulation of muscles and joints with the hands
- Thought to:
  - Improve circulation
  - Reduce stress
  - Decrease muscular pain
  - Enhance lymphatic flow
  - Aid in recovery from exercise and competition
  - Enhance sports performance

# Massage: Physiological Effects

## ■ Blood Flow

- No difference in peak torques up to 96 hours post, no difference in arterial or venous blood velocity (doppler US), reduced level of DOMS
- Tiidus PM, Shoemaker JK. Effleurage massage, muscle bloodflow and long-term post-exercise strength recovery. *Int J SportsMed.* 1995;16(7):478–83.

## ■ Lactate

- Less forearm blood flow and impaired lactate and H<sup>+</sup> removal from muscle with massage
- Wiltshire EV, Poitras V, Pak M, et al. Massage impairs post-exercise muscle blood flow and “lactic acid” removal. *Med Sci Sports Exerc.* 2010;42(6):1062–71.

## ■ Proprioception

- EMG: increased activation of gastrocnemius, increased proprioception as measured with ankle joint, not knee joint
- No significant change in lactate
- Shin MS1, Sung YH.. Effects of massage on muscular strength and proprioception after exercise-induced muscle damage. *J Strength Cond Res.* 2014 Sep 15. [Epub ahead of print]

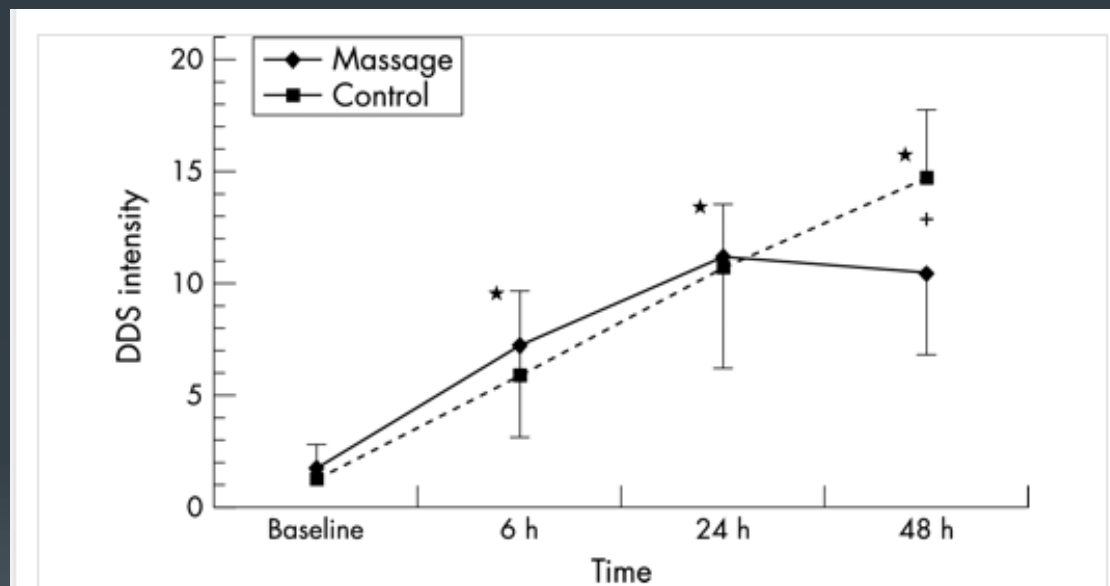
No benefit in blood flow, lactate clearance, or strength but increases in muscle activation, proprioception and reduction in DOMS

# Massage: Greatest benefit for DOMS

- Delayed onset muscle soreness

- No differences in peak torque, ROM, neutrophils, unpleasantness of soreness and mood. However, lower intensity of soreness with massage at 48h.

- Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Br J Sports Med.* 2003;37(1): 72-5



- Replicated in other studies

- Farr et al. : Massage after downhill walking reduced soreness at 24 hours

- Farr T, Nottle C, Nosaka K, et al. The effects of therapeutic massage on delayed onset muscle soreness and muscle function following downhill walking. *J Sci Med Sport.* 2002;5(4): 297–306.

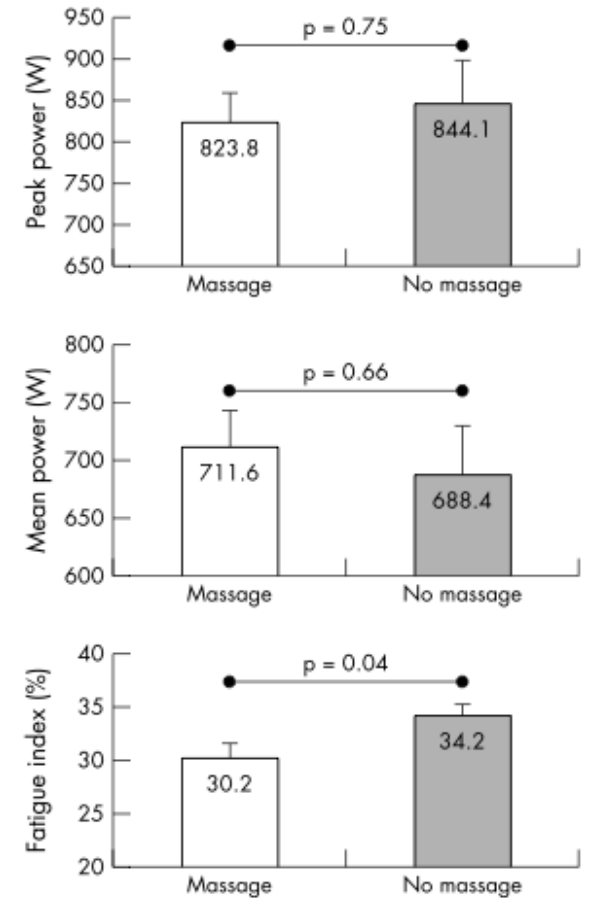
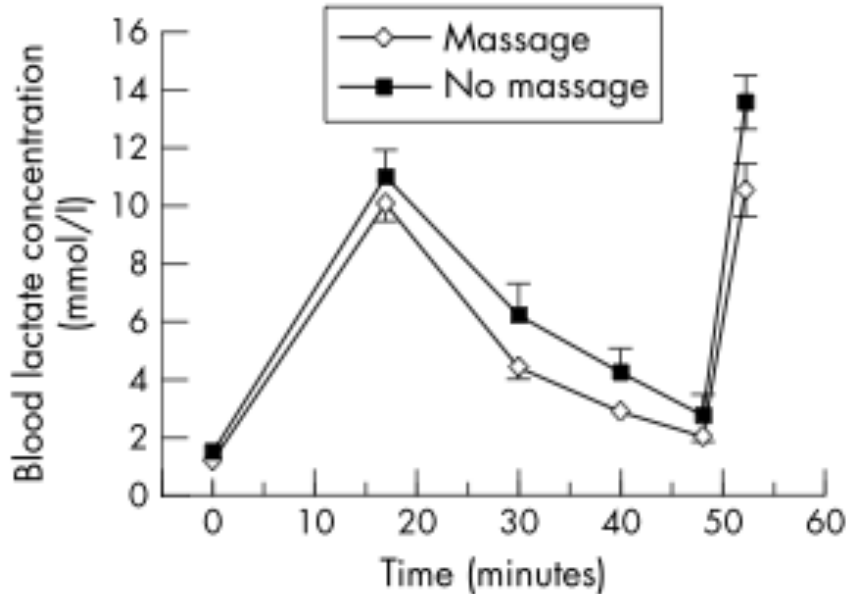
- Zainuddin et al. 30% reduction in DOMS and reduced swelling with arm flexion exercise, but no difference in strength

- Zainuddin Z, Newton M, Sacco P, et al. Effects of massage on delayed-onset muscle soreness, swelling, and recovery of muscle function. *J Athl Train.* 2005;40(3):174–8

# Massage: Performance Recovery

- Cycling Performance:
  - No difference in maximum power, mean power, or lactate
  - Lower fatigue index

Robertson A, Watt JM, Galloway SD. Effects of leg massage on recovery from high intensity cycling exercise. Br J Sp





# Massage: Performance Recovery

## ■ Running Performance:

- No change of muscle strength loss, swelling, or soreness
- Subjective findings of decreased pain and soreness in massaged leg
- Dawson LG, Dawson KA, Tiidus PM. Evaluating the influence of massage on leg strength, swelling, and pain following a half-marathon. *J Sports Sci Med.* 2004 Nov 1;3(YISI 1):37-43. eCollection 2004.

## ■ Potential Harm

- Underwater jet massage vs control over a one week period
- Findings: Serum myoglobin increased more than during control week
- Viitasalo JT, Niemela K, Kaappola R, et al. Warm underwater water-jet massage improves recovery from intense physical exercise. *Eur J Appl Physiol Occup Physiol.* 1995;71(5):431-8.

No benefit of power, strength, or performance but  
decreased fatigue and soreness

Question of possible muscle damage?

# Massage: Any Conclusions?

- Benefits:
  - Alleviate muscle soreness
  - Reduce muscular stiffness
  - Improve perception of recovery
- Questionable:
  - Benefit to muscle function
  - Benefit to recovery
- Potential Harm:
  - Immediately after: may induce harm
  - Create muscle damage?
- Other considerations:
  - What is the optimal timing?
  - What is the best type of massage?
  - What duration?
  - Methodical flaws: standardization of prior exercise, influence of diet

# Conventional Thoughts on Recovery



# Do These Methods Work?



- Is there any scientific evidence supporting the current recovery methods?
- Is there any benefit to these methods?
- Is there any harm?

# Is there any scientific evidence supporting the current recovery methods?

- There is some research on all methods
- However:
  - Small group sizes
  - Variations in methodology
  - Potential confounding factors
- Unknown effect of:
  - Bias
  - Gender
  - Age
  - Timing
  - Duration

# Is there any benefit to these methods?

- Active recovery
  - Spurts of anaerobic activity
  - Lactate clearance
- Cryotherapy
  - Short term pain and inflammation control
  - Situations requiring quick resumption of activity
- Elastic Compression
  - Reduction in perceived soreness
- Pneumatic Compression
  - Increased blood flow
  - Decreased circumference
  - Decreased stiffness
- Massage therapy
  - Decreased muscle soreness
  - Improved perception of recovery

No method has shown a clear benefit to training or performance!

# Is there any harm?

- Active recovery
  - Potential for further muscle damage?
- Cryotherapy
  - Potential slowing of normal regenerative inflammatory reaction
  - Potential further injury
  - Potential detriment to long term muscle recovery
- Elastic Compression
  - Question of slowed waste removal
- Pneumatic compression
  - Very little current evidence- potentially not measured?
- Massage
  - Potential to create more muscle damage if done too soon?

Most evidence for damage with cryotherapy,  
questionable in active recovery or massage

# General Conclusions



- The area of recovery is still young and there is so much more to learn
- Recover method of choice may depend on:
  - Activity type
  - Activity duration
  - Age
  - Sex
  - Timing
  - Individual factors



# Paradigm Shift



**C A M**

**Compression Activity Message**

# Our Study



## Investigation of Popular Recovery Techniques for Ultramarathon Recovery

- How can ultrarunners recover faster to be able to compete sooner and better in subsequent races?
- First study post ultramarathon recovery study
- Goal: 80 participants
- Requirements:
  - WSER 2015 runner
  - Willing to participate in either massage vs pneumatic compression vs control with no other post-race recovery modalities
  - Subjective scores: pre and post race log of subjective soreness and fatigue
  - Functional measures: 2 pre-race timed 400 meter runs, 2 post-race
  - CK measure
- Receive “race rat” T-shirt on sign up and WSER jacket on completion and
- Help contribute to science and exercise medicine
- Interested? Contact me, Natalie Wu : [nbadowski@gmail.com](mailto:nbadowski@gmail.com)

# Thank You!



Any Questions?

# References

(in order of appearance in presentation)

- Ahmaidi S, Granier P, Taoutaou Z, Mercier J, Dubouchaud H, Prefaut C. Effects of active recovery on plasma lactate and anaerobic power following repeated intensive exercise. *Med Sci Sports Exerc.* 1996 Apr;28(4):450-6.
- 
- White GE, Wells GD. The effect of on-hill active recovery performed between runs on blood lactate concentration and fatigue in alpine ski racers. *J Strength Cond Res.* 2015 Mar;29(3):800-6. doi: 10.1519/JSC.0000000000000677.
- 
- Lopez EI, Smoliga JM, Zavorsky GS. The effect of passive versus active recovery on power output over six repeated wingate sprints. *Res Q Exerc Sport.* 2014 Dec;85(4):519-26. doi: 10.1080/02701367.2014.961055.
- 
- Lopes FA, Panissa VL2 Julio UF, Menegon EM, Franchini E. The effect of active recovery on power performance during the bench press exercise. *J Hum Kinet.* 2014 Apr 9;40:161-9. doi: 10.2478/hukin-2014-0018. eCollection 2014.
- 
- Schaster KD, Disch AC, Stover JF, Lauffer A, Bail HJ, Mittlmeier T. Prolonged superficial local cryotherapy attenuates microcirculatory impairment, regional inflammation, and muscle necrosis after closed soft tissue injury in rats. *Am J Sports Med.* 2007;35:93-102.
- 
- Takagi R, Fujita N, Arakawa T, Kawada S, Ishii N, Miki A. Influence of icing on muscle regeneration after crush injury to skeletal muscle in rats. *J Appl Physiol.* 2011;110:382-8.
- 
- Tiidus PM. Alternative treatments for muscle injury: massage, cryotherapy, and hyperbaric oxygen. *Curr Rev Musculoskeletal Med.* 2015 Feb 28. [Epub ahead of print]
- 
- Takeda M, Sato T1, Hasegawa T1, Shintaku H1, Kato H1, Yamaguchi Y2, Radak Z3. The effects of cold water immersion after rugby training on muscle power and biochemical markers. *J Sports Sci Med.* 2014 Sep 1;13(3):616-23. eCollection 2014.
- 
- Stanley J, Peake JM, Coombes JS, Buchheit M. Central and peripheral adjustments during high-intensity exercise following cold water immersion. *Eur J Appl Physiol.* 2014 Jan;114(1):147-63. doi: 10.1007/s00421-013-2755-z. Epub 2013 Oct 25.
- 
- Halson SL, Bartram J, West N, Stephens J, Argus CK, Driller MW, Sargent C, Lastella M, Hopkins WG, Martin DT. Does hydrotherapy help or hinder adaptation to training in competitive cyclist? *Med Sci Sports Exerc.* 2014 Aug;46(8):1631-9. doi: 10.1249/MSS.0000000000000268.
- 
- Fröhlich M, Faude O, Klein M, Pieter A, Emrich E, Meyer T. Strength training adaptations after cold-water immersion. *J Strength Cond Res.* 2014 Sep;28(9):2628-33. doi: 10.1519/JSC.0000000000000434.

# References

- White GE, Rhind SG, Wells GD. The effect of various cold-water immersion protocols on exercise-induced inflammatory response and functional recovery from high-intensity sprint exercise. *Eur J Appl Physiol*. 2014 Nov;114(11):2353-67. doi: 10.1007/s00421-014-2954-2. Epub 2014 Jul 30.
- Dunne A, Crampton D, Egaña M. Effect of post-exercise hydrotherapy water temperature on subsequent exhaustive running performance in normothermic conditions. *J Sci Med Sport*. 2013 Sep;16(5):466-71. doi: 10.1016/j.jsams.2012.11.884. Epub 2012 Dec 14.
- O'Donnell TF Jr, Rosenthal DA, Callow AD, Ledig BL. Effect of elastic compression on venous hemodynamics in postphlebotic limbs. *JAMA*. 1979 Dec 21;242(25):2766-8.
- Berry, M.J., R.G. McMurray. 1987. Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. *J Phys Med* 66(3):121-32.
- Ali, A., M.P. Caine, B.G. Snow. 2007. Graduated compression stockings: Physiological and perceptual responses during and after exercise. *J Sports Sci* 25(4):413-419.
- Ménétrier A1, Mourot L, Bouhaddi M, Regnard J, Tordi N. Compression sleeves increase tissue oxygen saturation but not running performance. *Int J Sports Med*. 2011 Nov;32(11):864-8. doi: 10.1055/s-0031-1283181. Epub 2011 Nov 3.
- Bieuzen F1, Brisswalter J, Easthope C, Vercruyssen F, Bernard T, Hausswirth C. Effect of wearing compression stockings on recovery after mild exercise-induced muscle damage. *Int J Sports Physiol Perform*. 2014 Mar;9(2):256-64. doi: 10.1123/ijsspp.2013-0126. Epub 2013 May 22
- Chatard, J.C., D. Atlaoui, J. Farjanel, F. Louisy, D. Rastel, C.Y. Guezennec. 2004. Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. *Eur J Appl Physiol* 93(3):347-52.
- Davies, V., K.G. Thompson, S.M. Cooper. 2009. The effects of compression garments on recovery. *J Strength Cond Res* 23(6):1786-94.
- Miyamoto, N., K. Hirata, N. Mitsukawa, T. Yanai, Y. Kawkami. 2011. Effect of pressure intensity of graduated elastic compression stocking on muscle fatigue following calf-raise exercise. *J Electromyogr Kinesiol* 21(2):249-54.
- Lawrence D, Kakkar VV. Graduated, static, external compression of the lower limb: a physiological assessment. *Br J Surg*. 1980 Feb;67(2):119-21.
- Cochrane DJ, Booker HR, Mundel T, Barnes MJ. Does intermittent pneumatic leg compression enhance muscle recovery after strenuous eccentric exercise? *Int J Sports Med*. 2013 Nov;34(11):969-74. doi: 10.1055/s-0033-1337944. Epub 2013 Apr 19.

# References

- Chleboun GS, Howell JN, Baker HL, Ballard TN, Graham JL, Hallman HL, Perkins LE, Schauss JH, Conatser RR. Intermittent pneumatic compression effect on eccentric exercise-induced swelling, stiffness, and strength loss. *Arch Phys Med Rehabil.* 1995 Aug;76(8):744-9.
- Tiidus PM, Shoemaker JK. Effleurage massage, muscle bloodflow and long-term post-exercise strength recovery. *Int J SportsMed.* 1995;16(7):478–83.
- Wiltshire EV, Poitras V, Pak M, et al. Massage impairs post-exercise muscle blood flow and “lactic acid” removal. *Med Sci Sports Exerc.* 2010;42(6):1062–71.
- Shin MS1, Sung YH.. Effects of massage on muscular strength and proprioception after exercise-induced muscle damage. *J Strength Cond Res.* 2014 Sep 15. [Epub ahead of print]
- Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Br J Sports Med.* 2003;37(1): 72-5
- Farr T, Nottle C, Nosaka K, et al. The effects of therapeutic massage on delayed onset muscle soreness and muscle function following downhill walking. *J Sci Med Sport.* 2002;5(4): 297–306
- Zainuddin Z, Newton M, Sacco P, et al. Effects of massage on delayed-onset muscle soreness, swelling, and recovery of muscle function. *J Athl Train.* 2005;40(3):174–8
- Dawson LG, Dawson KA, Tiidus PM. Evaluating the influence of massage on leg strength, swelling, and pain following a half-marathon. *J Sports Sci Med.* 2004 Nov 1;3(YISI 1):37-43. eCollection 2004.
- Robertson A, Watt JM, Galloway SD. Effects of leg massage on recovery from high intensity cycling exercise. *Br J Sports Med.* 2004;38(2): 173–6.
- Viitasalo JT, Niemela K, Kaappola R, et al. Warm underwater water-jet massage improves recovery from intense physical exercise. *Eur J Appl Physiol Occup Physiol.* 1995;71(5):431–8.