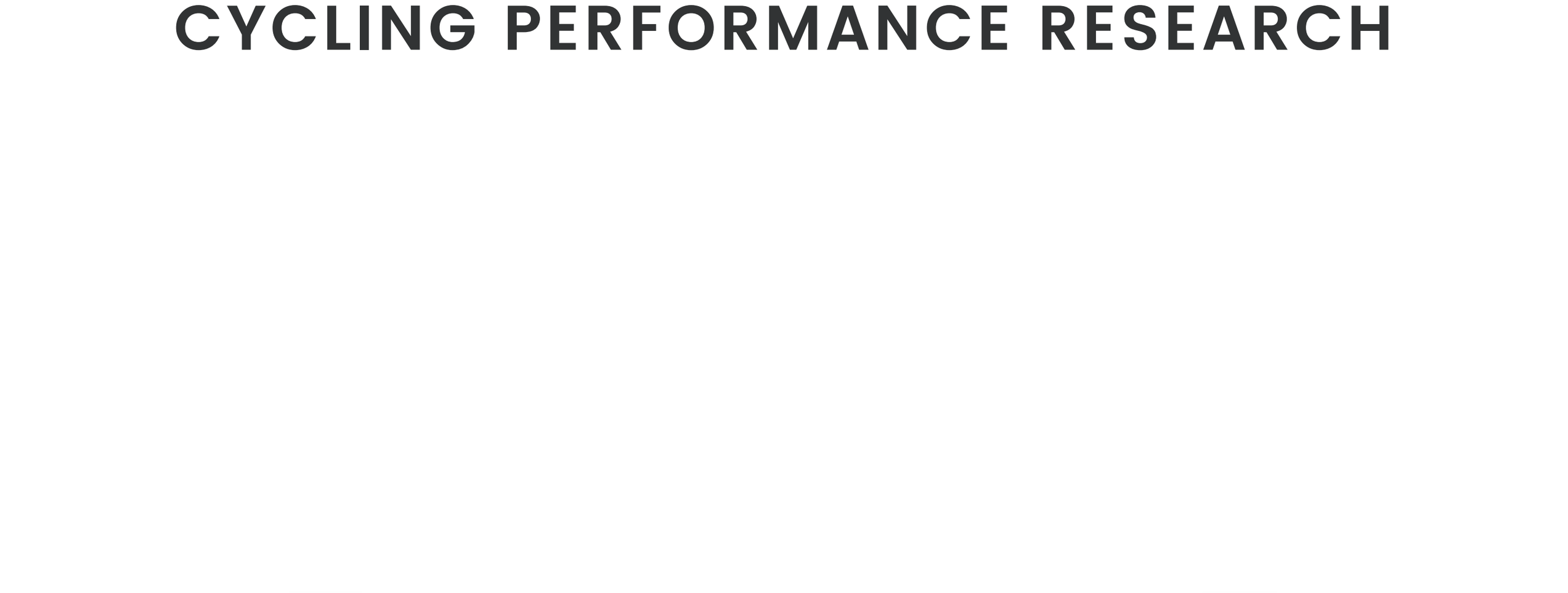
SEMIPRO CYCLING

MARCH 2021 | ISSUE #03

# CYCLING SCIENCE

DIGEST

## A MONTHLY SUMMARY OF THE LATEST CYCLING PERFORMANCE RESEARCH



# Contents

# How to read the digest

Page number

16

Classic

Section

Abstract

Link to abstract

Title

## The role of resistance exercise intensity on muscle fibre adaptations

Study details

**OBJECTIVE**

Although many training variables contribute to the performance, cellular and molecular adaptations to resistance exercise, relative intensity (% 1 repetition maximum [%1RM]) appears to be an important factor.

This review aimed to provide an examination of the role of resistance training load on adaption of human skeletal muscle.

As Fry says "Only when knowledge of muscle physiology and the appropriate application of training stimuli are combined can we hope to optimise the adaption process".

**WHAT THEY DID**

This review examines the scientific literature concerning the role of resistance exercise intensity on cellular and molecular adaptions of human skeletal muscle.

The author summarises and analyses data from numerous resistance exercise training studies that have monitored percentage fibre type, fibre type cross-sectional areas, percentage cross-sectional areas, and myosin heavy chain (MHC) isoform expression.

The review was limited to studies analysing the vastus laterlais muscle using muscle biopsies.

**WHAT THEY FOUND**

- Muscular hypertrophy responses to different relative training intensities follows a dose-response curve.
- There may be a threshold for optimal growth responses once intensity reaches 80% of 1RM. And maximal growth occurs with loads between 80% and 95% of 1RM.
- The optimal relative intensity range for muscular hypertrophy is 40% to 80% of 1RM.
- For endurance cyclists not wanting large levels of muscular hypertrophy, it is important to also include work at ≥80% 1RM because there are other physiological and performance reasons to train e.g. muscular strength or power.

Practical takeaways from study

## Practical Takeaways

Fry found that Fast Twitch recruitment begins at approximately 40% of maximum voluntary contraction (MVC) and peaks at ~ 80-85% MVC. Reminder: MVC is a measure of strength.

- These numbers were intended to be transferred across percentages of maximum repetitions when doing strength work. But it's also possible to use them for on the bike strength workouts using power prescriptions.

To understand how this works, we need to find an athlete's peak torque. We can calculate this using peak power and cadence. For example for an athlete that has a peak power output of 1300W (snd peak cadence of 130rpm) has a peak torque of 95 Newton meters. To prescribe strength intervals use the power that corresponds to 40-80% of peak torque. In this case 38-76 Newton meters. At 50rpm that's a power range of 200-400w.

- Once you have that information you can create interval durations that fit the athlete's ability and specificity requirements. For example, long strength endurance intervals at 40-50% of max torque might be 30-minute blocks (max 3 x 30 minutes total) at 200-250w @ 50rpm. Or shorter intervals hill reps at 80-85% of max torque might be 6 x 4-minute blocks at 400-425w @ 50rpm.

## Damian's Comments

"I have used this study for many years to quantify my power prescriptions for on bike strength and strength endurance work. A quick calculation can keep an athlete in their personal hypertrophy range - and not waste their training time on guesses.

Also, having a personal range helps to measure progress (see below) and helps with motivation. Give this a try the next time you are prescribing strength endurance intervals."

**Session 1**

| Torque Nm/kg Nm/kg | Torque Nm Nm | % of Peak Torque % % |
|---|---|---|
| 0.81 | 60 | 48 |
| 0.83 | 62 | 50 |
| 0.84 | 63 | 50 |
| 0.85 | 63 | 51 |
| 0.85 | 63 | 50 |
| 0.85 | 63 | 50 |
| 0.85 | 63 | 51 |
| 0.85 | 63 | 51 |

**Session 2**

| Torque Nm/kg Nm/kg | Torque Nm Nm | % of Peak Torque % % |
|---|---|---|
| 1.01 | 75 | 60 |
| 1.11 | 82 | 65 |
| 1.11 | 82 | 65 |
| 1.10 | 81 | 65 |
| 1.10 | 81 | 65 |
| 1.10 | 81 | 65 |
| 1.08 | 80 | 64 |
| 1.10 | 81 | 65 |

Reviewers comments on the study

Related links to learn more about the topic

**Want to learn more?**
Check these out...

SEMIPRO Cycling

SEMIPRO CYCLING

# Welcome

If you're reading this right now, then I am seriously honoured you decided to invest in yourself and join SEMIPRO+. I am extremely thankful for every single member who chooses to join us on our relentless quest to get cyclists the right advice at the right time. Without you, this would simply not be possible; so thank you.

**So, what's special in this month's issue?**

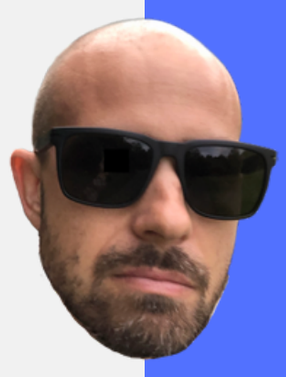
1. We added two new reviewers this month to round out perspectives from a coach, scientist, and athlete. Actually, all reviewers are coaches which helps make sure the practical takeaways work for coaches and athletes. We are also going to sit down and record a conversation on some of this month's articles - so keep an eye out on the podcast feed for that.

2. There were no strength papers of note this month. I will be looking hard to find some for the next issue as it is an underserved part of athlete preparation and maintenance.

Thanks for reading, and for being a member :)

Damian





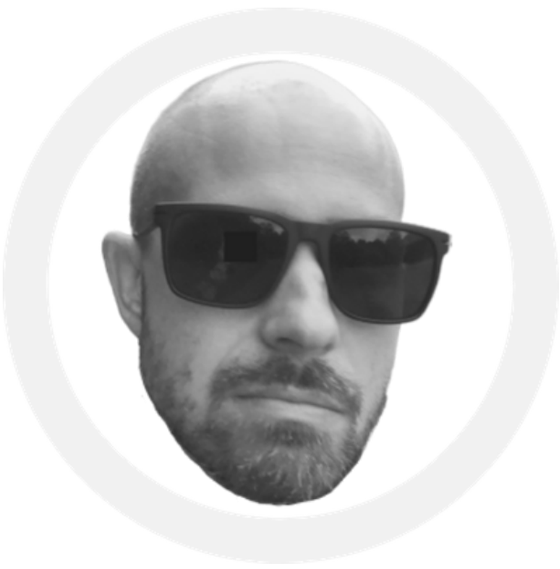

## Damian Ruse

**Founder and Head Coach of SEMIPRO Cycling**

Damian is an elite cycling coach and cycling science educator and has worked in the field of sports performance for over 8 years, helping athletes get the best out of themselves. Damian coaches professional, elite, and amateur athletes and has been the Performance Director of a top Australian road cycling team. Damian is also a lifelong cyclist, riding and racing bikes for over 28 years.

# Meet your experts

## The Coach



### Damian Ruse

**Founder and Head Coach of SEMIPRO Cycling**

Damian has a Batchelor of Psychology from the University of New England and is an elite cycling coach and cycling science educator and has worked in the field of sports performance for over 8 years, helping athletes get the best out of themselves. Damian coaches professional, elite, and amateur athletes and has been the Performance Director of a top Australian road cycling team. Damian is also a lifelong cyclist, riding and racing bikes for over 28 years.

## The Scientist

### Jason Boynton Ph.D

**Sport Scientist & Cycling Coach**

Jason Boynton has a PhD is Exercise and Sport Science and is a USA Cycling level 1 certified coach. Jason is also a published researcher in the area of cycling performance. Jason earned his Ph.D. at Edith Cowan University in Perth, Australia. His academic supervisors were Associate Professor Chris Abbiss, Dr. Paolo Menaspà (Cycling Australia), and Associate Professor Jeremiah Peiffer. His thesis research investigated the effects of environmental temperature on high-intensity interval training.

## The Athlete

### Cyrus Monk

**FUll-time Athlete with a Bachelor of Exercise Science**

Cyrus has a Bachelor of Science with a Physiology Major from the University of Melbourne and is now a full-time athlete with UCI Professional cycling team EvoPro Racing. As a former U23 Australian champion Cyrus knows how to get the best out of himself.

# Performance

This month’s top research on cycling performance

## Five weeks of heat training increases haemoglobin mass in elite cyclists

Rønnestad, B., et al. Experimental Physiology. 106 (1), 2021.

## Preliminary study on crosswind aerodynamics for a group of road race cyclists

Kraemer, P., et al. SN Applied Sciences 3 (3), 2021.

## Intermittent post-exercise sauna bathing improves markers of exercise capacity in hot and temperate conditions in trained middle-distance runners

Kirby, N.V., et al. European Journal of Applied Physiology. 121 (2), 2021.

## Effects of including sprints during prolonged cycling on hormonal and muscular responses and recovery in elite cyclists

Almquist, N. W., et al. Scandinavian Journal of Medicine & Science in Sports. 31 (3), 2021.

Abstract

# Five weeks of heat training increases haemoglobin mass in elite cyclists

### OBJECTIVE

Endurance training is widely known to increase haemoglobin mass (Hbmass) and thus improve oxygen carrying capacity during exercise. This effect is often augmented in professional athletes through training in extreme environments, most commonly at high altitude, which has been shown to increase EPO release and red blood cell production.

Often training or living at high altitude provides logistical challenges for athletes. An alternative option to increase Hbmass, such as heat training, could be more practical.Many previous heat training studies have failed to show a significant Hbmass in comparison to a control. This may be due to the intervention only occuring long enough to increase in blood plasma volume (often the primary objective) but perhaps not long enough to allow for changes in red blood cell production.

This study aimed to determine whether haemoglobin mass and red blood cell volume increase in elite cyclists training in a hot environment for five weeks compared to a control group training at normal temperature for the same period.

### WHAT THEY DID

Twenty-three male elite cyclists ( = 76.2 ± 7.6 ml min-1 kg-1) were prescribed 1 h of regular light exercise (45% of power output at 4 mmol l-1 [La-]) in a heat chamber 5 times per week for 5 weeks.

Cyclists were assigned to HEAT (n = 11; HEAT; 37.8 ± 0.5°C; 65.4 ± 1.8% humidity) or CON (n = 12; 15.5 ± 0.1°C; 25.1 ± 0.0% humidity) training groups. Hbmass was determined before and after the intervention period in conjunction with an extensive exercise test protocol (conducted at 16–19°C).

During the training intervention there were no differences between HEAT and CON in mean weekly duration and intensity of the endurance training.

### WHAT THEY FOUND

- HEAT increased (P < 0.05) Hbmass by 42 g from 893 ± 78 to 935 ± 108 g whereas Hbmass remained unchanged (+6 g) in CON.

  The greater increase in Hbmass in HEAT, however, did not manifest in a greater increase in (225 ± 274 ml min-1 in HEAT and 161 ± 202 ml min-1 in CON).

- While HEAT reduced (P < 0.05) lactate levels during some of the submaximal exercise tests, there were no statistical differences between groups for other performance markers.

  There were, however, small to intermediate effect sizes favouring HEAT for lactate threshold power output (2.8 ± 3.9 vs. -0.4 ± 5.1% change, effect size (ES) = 0.34), gross economy in the fatigued state (0.19 ± 0.42 vs. -0.12 ± 0.49%-point change, ES = 0.52) and 15 min mean power (6.9 ± 8.4 vs. 3.4 ± 5.1% increase, ES = 0.22). This study demonstrates an increase in Hbmass and small to intermediate effect sizes on exercise variables in elite cyclists following a 5-week heat training intervention.

## **Practical** Takeaways

- This is more promising research for athletes, similarly to the previous study on saunas, as it provides a means of obtaining enhanced adaptations to aerobic training without travelling to high altitude for an extended period.

  Unfortunately, the improvements in the exercise test for the HEAT group were noted as trends rather than significant changes. The intervention fails to trump altitude training in terms of these performance benefits. However, for elite level cyclists a 3-4% increase in power output at threshold can translate to a 12-15W increase during sustained efforts. This could make all the difference in a time trial or mountain top finish - well worth the sweat.

- The authors' proposed underlying mechanism was that the increase in Hbmass would be preceded by an increase in plasma and hence reduction in haematocrit and that this would facilitate the synthesis of EPO according to the kidneys 'critmeter' function. This supports the premise behind continuing the heat training intervention for an extended period rather than the commonly used one to two week period.

  With five one-hour sessions per week required to elicit the increased haemoglobin it would be feasible for coaches to incorporate these low intensity heat training sessions immediately following a standard road training session.

## Cyrus' Comments

""This is the first study of its kind to demonstrate an increase in Hbmass as a result of heat training in elite athletes. We should hopefully see further research in the near future allowing insight into the time course for these effects to take place as well as other possible heat interventions leading to a similar physiological response.Frustratingly, the sauna study above did not measure Hbmass!!! It would be great to compare the two heat interventions and their effect on red blood cell production. There is definitely scope for a paper on this one. This particular study did not provide any iron supplements to either group. This is a little out of the ordinary for this type of study as lack of available iron has been shown to be a limiter for haemoglobin production. The author didn't mention this at any point so it may have been an oversight that prevented the subjects experiencing an even greater increase in Hbmass."

Abstract

# Preliminary study on crosswind aerodynamics for a group of road race cyclists

### OBJECTIVE

Watching any road race in the history of the sport involving crosswinds will quickly reveal that an echelon is the most efficient way for a group to maintain speed and minimise power output of each rider involved. The extent to which this is beneficial over a standard riding formation has not yet been analysed in depth, or at least not published in the scientific literature.

A 4-rider echelon is studied to point out the differences in drag and lateral forces experienced by a sheltered rider in the echelon and a guttered rider struggling against the wind behind the group.

### WHAT THEY DID

The study used steel model cyclists at the scale 1/32 of 5.5 cm high, 5.1 cm long, and 1.5 cm wide. The estimated frontal section of the model is S=5.5×10-4 m2. This corresponds to a 1.80 m high cyclist adopting a road race position on a classical road race bicycle and it is consistent with the values used in other road cycling aerodynamics studies.

Models were secured to a load cell placed on a rotatable plate so that angle of the wind and position of the riders in relation to wind angle could be manipulated (see figure). Force was measured in direction of flow and orthogonal to direction of flow.From these measurements, Cx (drag coefficient) and Cy (lateral force coefficient), were determined.

In order to make the analysis more intuitive the authors also provided the results in the real frame of reference, where wind direction relative to moving cyclist (αcw) is computed for a crosswind velocity Vcw=40 km/h and a cyclist velocity U = 40 km/h.

### WHAT THEY FOUND

- For yaw angles (αy) lower than 30° (αcw< 60°) it was found that that rider 4 experiences a drag 25% lower than that of rider 3 in a sheltered position. In other words, for these relatively small yaw angles, it is more beneficial to be behind the echelon than riding within it. With regard to the lateral forces, the values for rider 3 are barely lower than for rider 4; no significant disadvantage is identified for rider 4.Yet for αy>30° (αcw>60°) a sharp increase in the drag of rider 4 is observed whereas the drag of rider 3 continues to decrease. The same phenomenon is pointed out for the lateral forces. At 50° yaw, the guttered rider experiences the same forces globally as an isolated rider, whereas rider 3 is very well sheltered in the echelon, with drag and lateral forces of 29.6% and 20.6% of an isolated rider, respectively. The drag and lateral forces are therefore 3.4 and 4.9 times smaller than those of the guttered rider, respectively.

## **Practical** Takeaways

- In road cycling, the crosswind substantially impacts the races and leads to splits in the peloton when echelons are formed by the riders of professional teams. Professional cyclists and practical cycling experts know that a rider finding themself in the disadvantageous position of the guttered rider behind the echelon has to struggle against the crosswind and is very likely to get dropped.

  It was found that the position of the guttered rider really becomes disadvantageous in terms of both drag and lateral force only beyond a 30° yaw, whereas in the same crosswind conditions a sheltered rider in the echelon benefits from even larger drag and lateral force reductions. An echelon is consequently worth being adopted by a cycling team only beyond 30° yaw angles.

- In a noteworthy aside, the study found that a solo road cyclist has to produce more power at a 15° yaw crosswind than a cyclist riding as fast and facing a pure headwind with a similar velocity. A ‘block headwind’ is therefore not quite as bad as it gets.

The authors stress that the approximations of the experimental design—cyclist model, perforated grid, coarse geometry—affected the results and, therefore, they should be mainly considered as preliminary.

**Want to learn more?**
Check these out...

## Cyrus' Comments

""One could easily question the original need for this study given the abundance of evidence available from races supporting riding in a sheltered position within an echelon over the guttered position behind the echelon. Nonetheless, it provides interesting insight into the magnitude of benefit gained riding within an echelon in comparison to riding behind. It also may provide practical applications for team directors during Team Time Trials, using team radio, to organise their riders in a way most likely to minimise drag on sheltered riders.

Given this study investigated a simple three-rider echelon with one rider placed behind, it would be interesting to explore other formations (double/triple echelons) which often form in races and compare these."

Abstract

# Intermittent post-exercise sauna bathing improves markers of exercise capacity in hot and temperate conditions in trained middle-distance runners

**OBJECTIVE**

Active heat acclimation is known to increase exercise performance when competing in the heat. Various barriers (cost, logistics, disruption to training intensity, etc.) often prevent many athletes from partaking in active heat acclimation.

Despite post-exercise sauna use being increasingly prescribed to athletes, there is limited research showing ergogenic benefits to performance in temperate climate events. This study investigates whether intermittent post-exercise sauna bathing across three weeks of endurance training improves exercise heat tolerance and exercise performance markers in temperate conditions, compared to endurance training alone.

An additional aim was to determine whether exercise heat-tolerance would further improve following seven weeks post-exercise sauna bathing.

**WHAT THEY DID**

Twenty middle-distance runners (13 female; mean ± SD, age 20 ± 2 years, VO2max 56.1 ± 8.7 ml kg-1 min-1) performed a running heat tolerance test (30-min, 9 km h-1/2% gradient, 40 °C/40% relative humidity (RH); HTT) and temperate (18 °C) exercise tests (maximal aerobic capacity [VO2max], speed at 4 mmol L-1 blood lactate concentration ([La-]) before (Pre) and following three-weeks (3-Weeks) normal training (CON; n = 8) or normal training with 28 ± 2 min post-exercise sauna bathing (101–108 °C, 5–10%RH) 3 ± 1 times per week (SAUNA; n = 12). Six SAUNA participants continued the intervention for 7 weeks, completing an additional HTT (7-Weeks).

Rectal temperature (Trec), skin temperature (Tsk), and HR were measured continuously. Perceptual measures, which included ratings of perceived exertion (RPE), thermal comfort and thermal sensation, were obtained in the final min of the HTT. Sweat gland activity of the forearm and upper back were recorded immediately following the HTT. Estimated sweat loss was calculated as the difference between Pre- and post-HTT nude body mass.

On a separate visit, resting HR was assessed and venous blood was drawn for measurement of plasma vascular endothelial growth factor (VEGF) and serum EPO.

**WHAT THEY FOUND**

During the HTT, SAUNA reduced peak rectal temperature (Trec; - 0.2 °C), skin temperature (- 0.8 °C), and heart rate (- 11 beats min-1) more than CON at 3-Weeks compared to Pre (all $p < 0.05$). In temperate testing, SAUNA also improved VO2max (+ 0.27 L-1 min-1; $p = 0.02$) and speed at 4 mmol L-1 [La-] (+ 0.6 km h-1; $p = 0.01$) more than CON at 3-Weeks compared to Pre.

The SAUNA group exhibited a 54 ± 59% increase in sweat gland activity on the forearm, equating to a 22 active glands per cm2 greater increase than the CON group's 6 ± 17% reduction, at 3-Weeks as compared to Pre ($p < 0.01$, $d = 1.40$). Changes in sweat gland activity on the upper back were not different between groups.

The SAUNA group exhibited a 1 ± 1 scale point greater reduction in peak thermal sensation ($p = 0.02$) and a 2 ± 2 scale point greater reduction in peak thermal comfort ($p < 0.01$) during the HTT than the CON group at 3-Weeks as compared to Pre.No significant changes in resting HR, VEGF or EPO were observed between SAUNA and CON.Only peak Trec (- 0.1 °C; $p = 0.03$ decreased further from 3-Weeks to 7-Weeks in SAUNA (other physiological variables $p > 0.05$).

## Practical Takeaways

The study effectively confirms what many coaches and exercise physiologists had already expected: post-exercise saunas can be utilised as both an effective tool for heat acclimation as well as an ergogenic aid to benefit performance in temperate conditions.

These adaptations occur following ~10 intermittent exposures across three weeks. Extending the intervention to seven weeks appeared to have little additional benefit. This intermittent-style intervention is especially attractive as the flexible nature and minimal impact on normal training circumvent common challenges associated with more traditional active heat acclimation approaches.

While the study used sauna exposures across a number of weeks, similar benefits can be obtained over a shorter period using consecutive daily sauna exposure for ~10 days.

Many athletes may also experience difficulty staying in a >90°C environment continuously for 30 minutes, particularly if fatigued after training, so an alternative protocol which athletes may prefer is listed below.

1. 15 minutes in Sauna
2. 5 minutes out
3. 12.5 min in 5 min out
4. 10 min in

This gives a total of 37.5 min total exposure and a time commitment of around one hour in total for the athlete.

**Want to learn more?**
Check this out...

## Cyrus' Comments

"The study claims to be the first to demonstrate that post-exercise sauna bathing can induce thermoregulatory adaptations during exercise at an absolute fixed-workload. This is surprising given this has been a practise implemented for a number of years by various coaches and athletes to prepare for events in hot climates without disrupting a normal training schedule.

For me, the most encouraging findings of this study are the effects on performance even in temperate conditions. Intermittent post-exercise sauna bathing combined with endurance training on average improved VO2max by ~ 8%, running speed at 4 mmol L-1 [La-] by ~ 4%, and time to exhaustion by ~ 12%, all of which were significantly greater improvements than those exhibited by the CON group. These are some hefty gains to be made by trained athletes over a three week period - a great return for simply sitting in a room for half an hour...

I've personally utilised saunas on many occasions myself, particularly when preparing for the Australian Summer of Cycling. The 2018 U23 Australian Road Race Championships were contested in 40°C temperatures and I have it on very good authority that the entire podium of that race followed the same 2-week sauna protocol in the lead-up to the event. I'm never one to back a personal anecdote over solid science so it's great that this study has finally surfaced to further justify all the time spent in the hot box."

Abstract

# Effects of including sprints during prolonged cycling on hormonal and muscular responses and recovery in elite cyclists

**OBJECTIVE**

Competitions for elite level cyclists involves strenuous cycling exercise for long durations and distances. Over the course of these competitions, intensities can vary greatly from low-intensity aerobic exercise to all-out sprints with a considerable anaerobic component. This highlights the need to consider the greater scope of bioenergetic systems when prescribing training sessions for these athletes. Additionally, for the highly elite (i.e. professional cyclists) already at a high volume of training, or the time crunched amateur cyclist, attempting to increase performance by simply increasing the volume of low-intensity training (LIT) is simply not feasible. For these cases, and potentially others, increasing performance requires novel adjustments to training protocols. One of these adjustments could be the addition of sprint intervals to LIT.

In this study, researchers investigated the acute effects of integrated sprint and prolonged LIT on muscular and hormonal responses and recovery in elite cyclists. It was hypothesized that compared LIT alone (E) the addition of 30-second sprints into a 4-hour LIT session (E&S) would lead to increased messenger ribonucleic acid (mRNA) levels for genes associated with mitochondrial function and biogenesis, angiogenesis, ion transport, and protein turnover in the quadricep muscles, as well as increased hormonal responses.

**WHAT THEY DID**

This study was a follow-up of a previously published study (reference1 below). It included twelve male (26.2 ± 6.3 years of age, VO2max = 73.4 ± 4.0 mL/kg/min) that trained on average 13 ± 8 hours per week and did not perform sprint training on a regular basis. This was a randomized, work-matched, crossover study design, where participants visited the lab on four occasions. These sessions included a screening session (including a VO2max test), a familiarization of the exercise protocol, and lastly two sessions that randomly tested participants with the E or E&S experimental protocols. The E protocol, or 'control condition', consisted of LIT at 50% of VO2max for 4 hours (this intensity more or less what coaches and cyclists would refer to as "endurance pace" or Coggan's "zone 2"). The E&S protocol was divided into 1-hour long sections, where for the first 3 sections participants cycled at 50% of VO2max, and then at the 42-minute mark 3x 30-second sprints were performed 4 minutes apart (1 minute of rest followed by 3 minutes riding at 100 watts). The last 1-hour section of the E&S protocol was performed at 50% of VO2max. Both exercise protocols consisted of: a 10-minute warmup; muscle biopsies and blood draws pre-exercise, 20 minutes post-exercise, 3 hours post-exercise, and 24 hours post-exercise; and isokinetic leg extension testing pre-exercise, immediately post-exercise, and 24 hours post-exercise.

**WHAT THEY FOUND**

- The E&S protocol lead to augmented mRNA responses in muscle for markers of fat metabolism, angiogenesis, and muscle hypertrophy, while levels of mitochondrial biogenesis markers decreased compared to E. The authors claimed this represented a more pronounced change in muscle cells and supported their initial hypothesis.

Compared to E, blood growth hormone and sex hormone binding globulin (SHBG) for E&S were slightly reduced immediately after exercise, while other hormones changed in similar manners across the two protocols immediately and 3 hours post-exercise. Isokinetic knee extension torque measures were completely restored 24 hours after both E&S and E demonstrating similar rates of recovery.

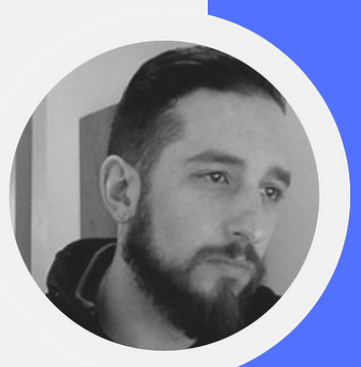
## **Practical** Takeaways

- Due to the fact that this study measured molecular markers and hormones, when it comes to practical application, it runs into many of the similar issues of the carbohydrate restriction study by Ramos et al. that I summarized earlier in this digest. In other words, great for building hypotheses and determining mechanisms, but less certain than the findings of a training study with a significantly higher increase in performance. What advantage this study had over Ramos et al. was the high level of fitness for the participants, making the findings more applicable than if participants were merely 'healthy' and 'actively fit'.

  Based on the findings of this study I would not say either mode of training, either E or E&S, was superior to one or the other- just unique in their own way. With that said, I would argue that these findings provide some level of evidence that E and E&S are both important to incorporate into the training of elite endurance athletes.

- One finding that was interesting to me for the E&S protocol, was the reduction of levels of mitochondrial biogenesis markers decreased compared to E. This coincides with previous research that has shown decreases on mitochondrial biogenesis in the presence of muscle acidosis. The previously published paper for this study demonstrated higher lactate levels during the E&S protocol compared to E after the sprints were performed. This would have coincided with an increased muscle acidosis which could have potentially been a factor leading to the reduction of mitochondrial biogenesis markers for the E&S protocol.
  One slight issue I had with this study was the use of an isokinetic torque test to determine the level of recovery 24 hours post protocol. I think my preference for a test of recovery would have been that of some kind of aerobic test (e.g. a submaximal test) in conjunction with the isokinetic test. I think this would have provided a more robust demonstration of post exercise recovery.

**Want to learn more?**
Check this out...



## Jason's Comments

""I really liked that this study had well-trained cyclists in the 20-something range as participants. I think, other than real-life pros, that is as close to the gold standard for cycling participants that you can get. Speaking from experience, securing that kind of participant cohort requires a number of factors coming together.

I'll also take a moment to note the last author, Bent R. Rønnestad. He's one of these researchers whose name you can type into a search engine and you will be guaranteed a plethora of excellent papers investigating cycling performance.

If you are seeking more information about optimizing endurance training of elite cyclists with the inclusion of sprints during low-intensity exercise, the author of this paper, Nicki Winfield Almquist, has their complete thesis (which includes all of his papers to date published from his thesis) available on Researchgate. The link is provided."

# Technology & Profiling

This month's top research on technology and profiling

## Heart-Rate Variability Recording Time and Performance in Collegiate Female Rowers

Sherman, S. R., et al. International Journal of Sports Physiology and Performance (Ahead of Print), 2021.

## Oxynet: a collective intelligence that detects ventilatory thresholds in cardiopulmonary exercise tests

Zignoli, A., et al. European Journal of Sport Science. 2021.

## Continuous sweat lactate monitoring system with integrated screen-printed MgO-templated carbon-lactate oxidase biosensor and microfluidic sweat collector

Shitanda, I., et al. Electrochimica Acta. 368, 2021.

Abstract

# Heart-Rate Variability Recording Time and Performance in Collegiate Female Rowers

### OBJECTIVE

Heart-rate variability (HRV) is a reflection of cardiac autonomic modulation of the heart and is expressed by nonlinear and complex oscillations that occur between successive heart beats.

HRV as a measure is utilized by athletes and coaches to monitor autonomic function for insights into performance and recovery. HRV has an advantage in that it is simple and easy to measure through noninvasive means. The root mean square of successive R-R intervals (RMSSD) is the preferred HRV measure for athletic populations in the field.

The preferred time to acquire a HRV measurement is upon waking, in order to limit physiological perturbations. However, it is difficult to ensure athlete compliance for unsupervised and home-based measures. Recording of athlete measures (e.g. HRV) on site with coaching and sport science staff (e.g. prior to practice) helps to increase athlete compliance.

Therefore, this study sought to investigate whether HRV measures (specifically RMSSD) for female rowers taken prior to practice were as reliable as waking HRV measures. Additionally, these researchers sought to determine the association of HRV measures with performance outcomes in this population.

### WHAT THEY DID

This study recruited a total of 31 National Collegiate Athletic Association Division I rowers and monitored them for 6 consecutive days.

Two seated RMSSD measurements (one upon waking and the other at morning practice; T1 and T2, respectively) were taken at least 3 times via a smartphone application. On separate days during the week, participants performed 2000-m time-trial and distance covered in 30 minutes tests on a rowing ergometer.

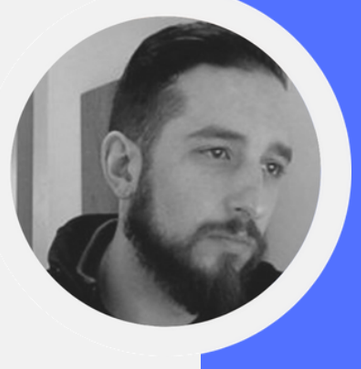
Participants were also ranked within the team through objective and subjective means by the coaching staff.

### WHAT THEY FOUND

- T1 and T2 HRV measures had a strong agreement with each other, demonstrating HRV measures taken upon waking and later in the morning both have valid potential for monitoring the measure in athletes.
- However, HRV measures from either timepoint were not correlated with performance outcomes from either of the rowing tests. The investigators hypothesized that this was potentially due to a lack of variability in training load over the week large enough in magnitude to elicit changes to autonomic function in the tested athlete population.

## **Practical** Takeaways

- This study demonstrates HRV measures later in the morning can be as valid as HRV taken upon waking. However, my recommendation would be to pick one method/time point for measuring HRV and sticking with it, only supplementing one for the other on the rare occasion. In practical and chronological terms, it makes the most sense to me to still make the best attempt to diligently measuring HRV upon waking. Then, in the unfortunate circumstance you miss an upon waking HRV measure, you can now know measuring HRV later in the morning (after at least a 1-minute rest) is not the worst thing in the world. But again, for the sake of maximizing accuracy of individualized measures, it is best to keep things consistent as possible.



## Jason's Comments

""The interest in HRV for endurance athletes seems to have been recently reinvigorated. If I was to take a guess, a large part of this effect has to be due to the increased prevalence of wearable devices such as Whoop, Oura, and OmegaWave.

Indeed, I have had multiple conversations about HRV with other athletes, coaches, and sport scientists. I'm pretty excited to see where this technology takes us in terms of load modelling and training prescription in both the professional and amateur cyclist space."

Abstract

# Oxynet: a collective intelligence that detects ventilatory thresholds in cardiopulmonary exercise tests

**OBJECTIVE**

The problem of the automatic determination of the first and second ventilatory thresholds (VT1 and VT2) from cardiopulmonary exercise test (CPET) still leads to controversy. The reliability of the gold standard methodology (i.e. expert visual inspection) feeds into the debate and several authors call for more objective automatic methods to be used in the clinical practice. In this study, they used cloud computing, crowdsourcing and computer-assisted techniques.

The resulting database was used to train and test a machine learning (i.e. a convolutional neural network) algorithm.

The aim of this paper is to present the Oxynet project, and therefore the potential of a collaborative approach to solve the problem of ventilatory thresholds detection in CPET.

**WHAT THEY DID**

The researchers created a crowdsourcing web-application, to collect data and then train and test new artificial intelligence algorithms and a web application that automatically detects the ventilatory thresholds in new uploaded CPET files, snd a website (oxynet.net) with a single landing-page was created to redirect the users to the web applications and for advertising the project.

This is how they crowdsourced a dataset of 1245 CPET files from both healthy subjects and patients and with different incremental protocols. This dataset was then used to train the neural network adopted in this study to automatically detect ventilatory thresholds.

**WHAT THEY FOUND**

- The ventilatory thresholds values obtained with the neural network were strongly associated with the VT values estimated with the visual inspection analysis.
- The neural network was able to detect the ventilatory thresholds with an average mean absolute error of 178 (198) mlO2/min (11.1%, r=0.97) and 144 (149) mlO2/min (6.1%, r=0.99), for VT1 and VT2 respectively.
- The performance of the neural network in detecting VT1 deteriorated in case of individuals with poor aerobic fitness.

## **Practical** Takeaways

- In the last digest, we discussed the new method for detecting VT1 using the short-term scaling exponent alpha1 of detrended fluctuation analysis (DFA a1). This might be a useful way to measure VT1, but even this method might have difficulty detecting VT2. As Bruce Rogers, lead author of the previous study mentions, there are some big hurdles to jump for a VT2/FTP correlation. There is the known effect of artifact correction as well as possible device bias. Although they will be looking at it soon. The point being, that any technology that can not only estimate VT! and VT2 and do it accurately will be a welcome addition to the training space.
- At the date of publication, the tools developed by the researchers are available to use at http://oxynet.net/. It does not look like it is available to the public but there might be a chance to email the group and be a contributor and also use the CPET Interpreter.

## Damian's Comments

""Projects like this show not only the potential of the technology but how large-scale change in sports science could occur in the future.

This type of collective intelligence system outperformed isolated experts in ventilatory thresholds detection. This is encouraging for accuracy and time-saving in the field.

Also, as in similar projects that use neural networks, the quality and quantity of the data are some of the most important factors. Corwod sourcing helps this but collecting a larger number of VT1 examples certified by a community of experts is not a simple task.

Once this problem is solved, this project may be rolled out for clinical use."

Abstract

# Continuous sweat lactate monitoring system with integrated screen-printed MgO-templated carbon-lactate oxidase biosensor and microfluidic sweat collector

### OBJECTIVE

Chemical biomarkers in bodily fluids, such as blood, saliva, and sweat, are more challenging to quantify with wearable sensors. For instance, lactate, which is produced during the breakdown of glucose in the absence of oxygen in tissues. When lactate is released into the bloodstream, part of it is eliminated through sweat. This means that a wearable chemical sensor could measure the concentration of lactate in sweat to give a real-time picture of the intensity of exercise or the condition of muscles. Although lactate-measuring wearable sensors have already been proposed, most of them are composed of materials that can cause irritation of the skin. To address this problem, this team of scientists in Japan recently carried out this study to bring us a more comfortable and practical sensor.

### WHAT THEY DID

To develop the sensor the team first focused on the sensing mechanism that they would employ. Most lactate biosensors are made by immobilizing lactate oxidase (an enzyme) and an appropriate mediator on an electrode. A chemical reaction involving lactate oxidase, the mediator, and free lactate results in the generation of a measurable current between electrodes -- a current that is roughly proportional to the concentration of lactate. A tricky aspect here is how to immobilize the enzyme and mediator on an electrode. To do this, the scientists employed a method called "electron beam-induced graft polymerization," by which functional molecules were bonded to a carbon-based material that can spontaneously bind to the enzyme. The researchers then turned the material into a liquid ink that can be used to print electrodes. This last part turns out to be an important aspect for the future commercialization of the sensor.

### WHAT THEY FOUND

- In this study, we successfully developed a sensing system for the continuous monitoring of lactate in sweat.

## **Practical** Takeaways

- Continuous sweat lactate monitoring technology will be a gamechanger for real-time monitoring of efforts on the road. Both for training and racing. This technology is not without its issues. So it is important to be aware of the challenges this technology faces.

  A recent paper released (linked below) investigated whether relations between blood and sweat sodium, chloride, potassium, ammonia, lactate and glucose would exist within the ranges that are usually found during submaximal exercise in healthy individuals.

  Twelve trained individuals (nine males, three females; age = 25 ± 4 years; height = 181.0 ± 7.8 cm; body mass = 74.3 ± 10.7 kg; VO2max = 52.2 ± 9.4 mL kg-1 min-1) participated in this study. They did a VO2max and maximum heart rate ramp test and on another day did 30 min at 60% HRmax, 20 min at 70% HRmax, 20 min at 80% HRmax.

  Results?

  Overall concentrations of lactate were consistently higher in sweat compared to blood ($P < 0.001$)and there were significant main effects of exercise intensity on blood lactate concentrations ($P = 0.007$).

- The majority of correlations between blood and sweat composition were non-significant.

  There were no significant correlations between blood and sweat lactate at any exercise intensity for both locations ($r \leq 0.31$, $P > 0.05$).

  In addition, overall sweat lactate concentrations considerably exceeded blood lactate concentrations.

- Such findings show that sweat composition is at least partly independent of blood composition. This has to be taken into consideration when aiming to use sweat as non-invasive alternative for blood measurements during exercise.

**Want to learn more?**
Check this out...

## Damian's Comments

""The interesting thing about this new sensor was detection limits of the sensor and its operating range for lactate concentrations was confirmed to be suitable for investigating the "lactate threshold".

Real-time monitoring of the lactate threshold will help optimise the training at all intensities.

With any luck, the progress made in this study will help develop the field of wearable chemical sensors, but there are many challenges before this is a reality."

# Nutrition

This month's top research on nutrition

## Assessing Overall Exercise Recovery Processes Using Carbohydrate and Carbohydrate-Protein Containing Recovery Beverages

Russo, I., et al. Frontiers in Physiology, 12 (1), 2021.

## Sodium bicarbonate improves sprint performance in endurance cycling

Dalle, S., et al. Journal of Science and Medicine in Sport, 24 (3), 2021.

## Carbohydrate restriction following strenuous glycogen-depleting exercise does not potentiate the acute molecular response associated with mitochondrial biogenesis in human skeletal muscle

Ramos, C. et al., European Journal of Applied Physiology (2021)

Abstract

# Assessing Overall Exercise Recovery Processes Using Carbohydrate and Carbohydrate-Protein Containing Recovery Beverages


**OBJECTIVE**

Over the past decade, studies have meticulously investigated the optimal nutritional approach for isolated goals, such as, the replacement of energy substrate and body water losses, and repair of damaged tissues (e.g., skeletal muscle), leading to the development of generalized recommendations for each element of exercise recovery.

To date, however, recovery guidelines have failed to consider the impact of exercise-induced gastrointestinal syndrome (EIGS) on regulation of nutrient availability via gastrointestinal integrity and functional responses and (or) the restoration of immunocompetency in response to immunosuppressive exercise.

With this in mind, the current study aimed to investigate the impact of a carbohydrate- and protein-containing flavored dairy beverage and a non-nitrogenous carbohydrate electrolyte beverage on overall and integrative markers of acute recovery following an exercise stress known to perturb many aspects of physiological and metabolic homeostasis.

**WHAT THEY DID**

The study compared the impact of two different, but commonly consumed, beverages on integrative markers of exercise recovery following a 2 h high intensity interval exercise (i.e., running 70–80% V̇O2max intervals and interspersed with plyometric jumps).

Recreationally trained participants (n = 9 males, n = 5 females) consumed a chocolate flavored dairy milk beverage (CM: 1.2 g carbohydrate/kg BM and 0.4 g protein/kg BM) or a carbohydrate-electrolyte beverage (CEB: isovolumetric with 0.76 g carbohydrate/kg BM) after exercise, in a randomized-crossover design.

The recovery beverages were provided in three equal boluses over a 30 min period commencing 1 h post-exercise. Muscle biopsies were performed at 0 h and 2 h in recovery. Venous blood samples, nude BM and total body water were collected before and at 0, 2, and 4 h recovery. Gastrointestinal symptoms and breath hydrogen (H2) were collected before exercise and every 30 min during recovery. The following morning, participants returned for performance assessment.

**WHAT THEY FOUND**

- In recovery, breath H2 reached clinical relevance of >10 ppm following consumption of both beverages, in adjunct with high incidence of gastrointestinal symptoms (70%), but modest severity.
- Blood glucose response was greater on CEB vs. CM ($P < 0.01$). Insulin response was greater on CM compared with CEB ($P < 0.01$).

Escherichia coli lipopolysaccharide stimulated neutrophil function reduced on both beverages (49%).

Phosphorylated glycogen synthase kinase 3 (p-GSK-3β)/total-GSK-3β was greater on CM compared with CEB (indicative of increase glucose uptake within cell; $P = 0.037$); however, neither beverage achieved net muscle glycogen re-storage.

Phosphorylation of mTOR was greater on CM than CEB ($P < 0.001$). Fluid retention was lower ($P = 0.038$) on CEB (74.3%) compared with CM (82.1%).Physiological and performance outcomes on the following day did not differ between trials.


## Practical Takeaways

- Flavored dairy milk beverages have gained popularity within the sport and exercise community due to the close alignment with current recovery nutrition guidelines surrounding protein and carbohydrate intake post-exercise. Anecdotally, however, some resistance persists due to the belief that dairy products will induce greater gastrointestinal discomfort. Findings from the present study dispel this notion.

  Athletes are advised to consume small and frequent doses of nutritional composition equivalent to 1.2 g/kg BM carbohydrate and 0.4 g/kg BM protein over the 1–2 h acute recovery time period, and return to habitual dietary patterns thereafter.

  It is noted that the nutritional composition of the recovery beverage is inconsequential within the context of overall nutritional intake over a 24 h window, and does not influence subsequent performance 24 h after the initial exercise bout. However, the acute clinical (i.e., minimizing gastrointestinal burden, stimulating neutrophil function toward clearance of tissue debris, endotoxins and luminal-derived pathogenic agents, reduced risk of illness and soft tissue injury) and physiological (i.e., maximized nutrient absorption and hydration, substrate provision for repletion of skeletal muscle glycogen, and substrate and anabolic stimulus for skeletal muscle repair and adaptation) implications of immediate consumption of small and frequent boluses of a dairy milk beverage is likely to provide a cumulative advantage within an extended training regime.

**Want to learn more?**
Check this out...

## Cyrus' Comments

"Effects of a nutritional intervention on recovery are notoriously much more difficult to assess than effects on performance. This study combatted this by analysing a wide range of parameters involved in various aspects of the recovery process.The results largely confirm that the regularly prescribed combination of carbohydrates and protein soon after exercise is superior in accelerating the recovery process to carbohydrates alone.A common trend among professional cyclists of avoiding dairy due to potential GI discomfort was not supported by this study. However, no participants in this study reported any history of lactose intolerance and this is something which should obviously be accounted for, particularly when involving athletes from different ethnicities.The authors also noted large individual discrepancies between participants in the physiological response to each nutritional intervention. Unfortunately, this means that for many athletes it will remain a game of trial and error to find a recovery beverage that is easily digested and enhances the recovery process."

Abstract

# Sodium bicarbonate improves sprint performance in endurance cycling

**OBJECTIVE**

Oral sodium bicarbonate intake (NaHCO3) may improve performance in short maximal exercise by inducing metabolic alkalosis. However, it remains unknown whether NaHCO3 also enhances all-out performance at the end of an endurance competition.

The present study investigated whether stacked sodium bicarbonate loading in the hours before and during a prolonged endurance exercise bout, can result in a higher HCO3- concentration by the time high anaerobic capacity is needed to be successful in a final all-out exercise bout or sprint. The authors hypothesized that stacked NaHCO3 loading by increasing extracellular buffer capacity can improve performance in a short all-out exercise bout at the end of a 3-h simulated cycling race.

**WHAT THEY DID**

Eleven trained male cyclists (22.3 (18.3–25.3) years; 73.0 (61.5–88) kg; VO2max: 63.7 (57–72) ml kg-1 min-1) ingested either 300 mg kg-1 body weight NaHCO3 (BIC) or NaCl (PL). NaHCO3 or NaCl was supplemented prior to (150 mg kg-1) and during (150 mg kg-1) a 3-h simulated cycling race with a 90-s all-out sprint (90S) at the end.

The race simulation consisted of six consecutive 30-min blocks during which exercise intensity was varied per 5-min intervals between 60 and 90% of LT taken from the preliminary testing.

Capillary blood samples were collected for determination of blood pH, lactate and HCO3- concentrations.

The design was a double-blind randomized placebo-controlled cross-over study.

**WHAT THEY FOUND**

- NaHCO3 intake improved mean power during 90S by ~3% (541 ± 59 W vs. 524 ± 57 W in PL, p = 0.047, Cohen's D = 0.28, medium).
- Peak blood lactate concentration and heart rate at the end of 90S were higher (p < 0.05) in BIC (16.2 ± 4.1 mmol l 1, 184 ± 7 bpm) than in PL (12.4 ± 4.2 mmol l-1, 181 ± 5 bpm). NaHCO3 ingestion increased blood [HCO3-] (31.5 ± 1.3 vs. 24.4 ± 1.5 mmol l-1 in PL, p < 0.001) and blood pH (7.50 ± 0.01 vs. 7.41 ± 0.03 in PL, p < 0.05) prior to 90S.

## **Practical** Takeaways

- For the first time, it is shown that sodium bicarbonate loading prior to and during a simulated cycling race improves a 90-sec all-out sprint at the end of the race. This provides new opportunities for endurance athletes (e.g. road cyclists) to diversify a nutritional ergogenic aid previously only used in shorter events (prologues, time trials, track racing) to use in a wider range of events.

Stacked sodium bicarbonate loading of 0.3 g/kg body mass prior to and during cycling did not elicit gastrointestinal disturbances. Attention is required to ensure the dosage is kept small but regular in order to avoid GI upset. The combination of NaHCO3 with a high-carbohydrate meal can facilitate the development of blood alkalosis as well as reduce the incidence of GI symptoms.

The authors noted that much of the prior research surrounding sodium bicarbonate effects on short duration exercise performance have failed to show benefits in untrained individuals.

Further research is required in endurance type events to elicit whether the performance benefits shown in this study are also reflected in untrained individuals.Coaches and athletes should test the supplementation protocol on training sessions before its application in competition.

## Cyrus' Comments

"This may prove to be a breakthrough study for the use of bicarbonate supplementation as an ergogenic aid in endurance events. Many sports (road cycling, open water swimming, cross country skiing, running) are decided by a high intensity anaerobic effort at the completion of a long distance aerobic effort. If a 3% increase in power output for this type of effort can be supported by subsequent studies we could see many athletes adding NaHCO3 to their bidons in the future.A real bike race often plays out quite differently to the mock race used in the testing protocol of this study design. The regular accelerations well over LT, typical of a road race, may result in more utilisation of the NaHCO3 buffer prior to the final decisive sprint. Thus the amount of bicarbonate ingested in this study may then not be enough to provide significant performance benefit, more research required!"

Abstract

# Carbohydrate restriction following strenuous glycogen-depleting exercise does not potentiate the acute molecular response associated with mitochondrial biogenesis in human skeletal muscle

### OBJECTIVE

The investigators in this study wanted to determine if carbohydrate (CHO) restriction could be an effective metabolic regulator of endurance exercise-induced muscle adaptations after cycling exercise that was strenuous enough to deplete muscle glycogen stores.

Previous research investigating this question utilized prolonged moderate-intensity continuous cycling exercise to deplete CHO levels. This previous research found no difference in gene expression related to mitochondrial biogenesis or oxidative metabolism between post-exercise CHO restricted or CHO enriched states.

However, in the current study, it was hypothesized post-exercise CHO restriction may induce increased gene expression related to mitochondrial biogenesis or oxidative metabolism after a combination of both moderate-intensity continuous cycling and repeated sprint exercise.

### WHAT THEY DID

This study was a follow-up of a previously published study (referenced below). It included 8 healthy active male participants (18 to 40 years) in a randomized crossover design study. The experiment included three visits to the laboratory. During the first visit a graded exercise test was utilized to determine VO2max and individualized intensity for the exercise protocol in the two subsequent sessions.

During lab visits, 2 & 3 an exercise protocol consisting of a 8-10 minute warm-up (1 W/kg), 60 minutes of continuous cycling exercise at 60% VO2max, and 6x 30-second all-out sprints separated by 4 minutes were performed.

Muscle biopsies were conducted prior to exercise, 2-3 minutes post-exercise, and 3 hours post-exercise. Participants consumed post-exercise, in a randomized session order, a beverage containing either a CHO beverage or a placebo every 15 minutes for 150 minutes.

Lab visits 2 & 3 were separated by 4 weeks. Muscle biopsies were used to assess levels of muscle glycogen levels and levels of gene expression associated with mitochondrial biogenesis and oxidative metabolism.

### WHAT THEY FOUND

- The researchers conducting this study found no difference in the increase of PGC1A and PDK4 mRNA levels (i.e. molecular indicators) for the CHO restricted and CHO enriched conditions.

  Additionally, post exercise for the CHO enriched condition, the researchers observed significantly higher levels of muscle glycogen (3 hours), rates of muscle glycogen re-synthesis (3 hours), and blood glucose concentration (30-180 minutes).

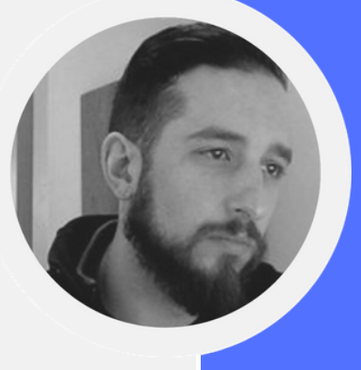
- However, while these results were significant, they were not necessarily novel. The magnitude of the increase for PGC1A mRNA observed in this study after combined continuous cycling and repeated sprint exercise was much higher than what was observed in previous studies utilizing moderate-intensity, or high-intensity interval exercise. However, comparing results across independent studies has to come with a caveat because of the variations in outcomes that can be caused by different methods and participants.

## **Practical** Takeaways

While interesting research, firm practical takeaways for the endurance athlete are limited for this study. I would argue the reason for this is due to couple reasons. 1). This is study did not utilize trained endurance athletes. This is always something to be aware of when seeking research to apply to your endurance training. The use of 'healthy' participants vs. endurance trained doesn't necessarily negate the findings of study, but it does add a factor of relevance. I would argue that trained participant factor of relevance is going to be especially important when looking at gene expression after an endurance training session. 2). Examining molecular factors and then interpreting positive results as real-world performance improvements is almost always going to be problematic. For example, as the authors of this study pointed out, increased levels of mRNA transcription (i.e. what was measured in this study) does not necessarily mean increased translation (i.e. protein production). Had these researchers found a difference in gene expression between the CHO enriched and CHO restricted protocols, best practice would have been to follow-up with a training study to see if the difference in gene expression actually translated to improved endurance performance. In other words, molecular studies are really good for hypothesis building, determining mechanisms, and seeking some level of truth in lieu of a proper training study, but they should be taken with a grain of salt when being considered for the applied world.

- With the issues above noted, based on the findings of this study and related studies, there appears to be a lack of compelling evidence that would support any molecular benefits to restricting CHO consumption. And therefore, restricting or 'forgetting' your CHO intake after a workout shouldn't be seen as a way to somehow stimulate boosts in endurance performance; unless of course there ends up being strong training study findings with trained endurance athletes contrasting this claim.
  So basically for me, this study is just another reminder to make sure you consume your CHO after exercise. Hopefully, that is already current best practice utilized by most coaches and athletes.

**Want to learn more?**
Check these out...



## Jason's Comments

"I included this article mostly as an exercise to examine a paper studying a molecular outcome post exercise so coaches and athletes not familiar with the inner workings of cellular and molecular can have a better idea of what things they need to consider when interpreting and translating their results in a real-world applied sense.

I also included this paper specifically because it had negative results (i.e. results that do not support the hypothesis). Negative results often get under published in the scientific world, but they are very important to the overall process- especially when making decisions in the applied world. You could always find a positive study to back-up your thoughts on an aspect training, but what is important is what the body of literature says, not just one study. So negative results are definitely important to consider in the applied world when consider what actions to take. This also gets into the concept of regressing to the mean, but I will let Derek Muller from Veritasium explain that (link to the video provided)."

# Thanks for reading

Next issue will be published on the first of next month.

If you liked all the great content, then make sure to share it and spread the knowledge to your friends and colleagues who you know will also find it useful!

Cheers!
Damian

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