Immunity, GI, Nutrient Absorption & Performance Benefits

Dr. Ralf Jäger, CISSN, FISSN, MBA
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The Gut-Muscle-Axis

- Can Probiotics improve athletic performance?
Nutritional Goals of Athletes

- **Increase Performance through nutrition**
  - **Ergogenic supplements** are defined as ingredients that have been shown to significantly enhance exercise performance (e.g., helps you run faster, lift more weight, …)
  - Nutritional practices that help prepare individuals to train and/or enhance recovery from exercise should also be viewed as ergogenic (enhancing performance in the long run).

- **Commonly used nutrients**
  - **Hydration** (water, electrolytes, betaine, glycerol, …)
  - **Macronutrients** (carbohydrates, protein, fat)
  - **Lean Body Mass-Strength-Power** (protein, creatine, HMB, phosphatidic acid, …)
  - **Endurance** (nitrates, choline, astaxanthin, …)
  - **Mental performance** (caffeine, L-theanine, phosphatidylserine, …)

Gut Bacteria Diversity Improves With Exercise

- **Clarke et al., 2014**
  - **Subjects:**
    40 professional athletes (BMI = 29) from an international rugby team compared with two groups of healthy male controls from the Cork region of Ireland (BMI ≤ 25, or BMI > 28).

  - **Results & Conclusion:**
    - Athletes also had a far higher diversity of gut bacteria -- 22 phyla, 68 families, and 113 genera compared with just 11 phyla, 33 families and 65 genera for controls with a low BMI, and 9 phyla, 33 families and 61 genera for controls with a high BMI.
    - High protein intake, as well as high levels of creatinine kinase, positively correlated with bacterial diversity, suggesting that **both diet and exercise are drivers of biodiversity.**
    - Athletes and low BMI group had high levels of *Akkermansia*, which has been linked in past studies with a decreased risk for obesity and systemic inflammation.

Probiotics have been shown to reduce the number, duration and severity of upper respiratory tract infections (URTI) and gastrointestinal (GI) distress in the general population and in at risk sub-groups such as the elderly or children attending care centers.

- 90-day administration of a multi-strain synbiotic
  - L. *plantarum* (Probial LP02)
  - L. *rhamnosus* (Probial LR04)
  - B. *lactis* (Probial BS01)

- in 237 healthy volunteers resulted in a significant reduction of
  - the length of URTIs (-1.96 days)
  - the severity of URTIs

Infections in Athletes – High Risk Group

- Infection risk and exercise workload follow a J-Shape
  - Moderate intensity exercise reduces infection risk
  - **High intensity** exercise increases infection risk

- Immune suppression in athletes worsens by
  - Psychological stress
  - Foreign travel
  - Disturbed sleep
  - Environmental extremes
  - Bad diet
  - Exposure to large crowds
  - Increases exposure to pathogens due to elevated breathing during exercise
  - …

Infections in Athletes – A Real Problem

- Out of 2,567 athletes at the 2010 Vancouver Winter Olympics
  - 7.2% reported an illness
  - 60% of illnesses were infections

- Out of 10,568 athletes at the 2012 London Summer Olympics
  - 7.2% reported an illness
  - 46% of illnesses were infections

- Chrissie Wellington
  2007: Ironman World Champion Hawai’i
  2008: Ironman World Champion Hawai’i
  2009: Ironman World Champion Hawai’i
  2010: Missed event due to an infection
  2011: Ironman World Champion Hawai’i

- Faris Al-Sultan
  2005: Ironman World Champion Hawai’i
  2007: Missed event due to an infection

**L. casei Shirota: Reduces Number of URTI Episodes**

- **48 men and women engaged in endurance-based physical activity**
  - Running, cycling, swimming, triathlon, team games, racquet sports
  - Average training load: 10hr/week (recreationally active to Olympic athlete)

- **4-month period of winter training and competition**
  - Number of URTI episodes was significantly lower (1.2 ± 1.0) in the probiotics group in comparison to control (2.1 ± 1.2)
  - The proportion of subjects who experienced 1 or more weeks with URTI symptoms was lower in the placebo group (control 0.90, probiotic 0.66).
  - Severity and duration of symptoms were not significantly different
  - Probiotic administration reduced days with gastrointestinal symptoms

L. fermentum VRI-003: Reduces URTI Episodes & Severity

- 20 highly-trained male distance runners
  - Competing in events from 800m to marathon
  - Mean training mileage approx. 100km per week
  - $1.2 \times 10^{10}$ CFU L. fermentum VRI 003 per day for 4 months

- 4-month period of winter training
  - Probiotic administration reduced the number of days with URTI symptoms by more than half (30 days vs. 72 days)
  - Illness severity was lower during probiotic administration
  - No difference in running performance measures were observed

**L. fermentum**  PCC: Good for Male Athletes, but Females?

- 64 male, 35 female competitive cyclists and triathletes
- 11-week test period
- Performance measured on a cycle ergometer
  - Probiotic administration reduced severity and duration of respiratory illness and severity of GI symptoms in MALE athletes
  - Respiratory illness symptoms increased in FEMALES
  - No difference in performance measures were observed

**Source:** NP. West et al. *Lactobacillus fermentum* (PCC) supplementation and gastrointestinal and respiratory-tract illness symptoms: a randomised control trial in athletes. *Nutrition J* 2011, 10:30.
**L. rhamnosus GG: No Effect In Marathon Runners**

- A randomized, double-blind intervention study in 141 runners
- *L. rhamnosus* or placebo for three months leading into a marathon
- No significant difference in either respiratory tract illness, or GI symptom episodes, in the two weeks after the marathon


**L. casei DN-114001: No Effect During Combat Training**

- A randomized, double-blind intervention study in 47 French commando cadets during the French Commando training (3-week training followed by a 5-day combat course).
- *L. casei* DN-114001 or placebo during the three week training course
- No significant difference in respiratory tract illnesses.
- Probably too short to show any effect on URTI but did show that the probiotic was associated with improved maintenance of salivary IgA levels.

Probiotics and Swimmers (Design)

- **Salarkia et al., 2013**
  - **Subjects:** Young (13.8 ±1.8 years) female endurance swimmer
  - **Supplement:** L. *acidophilus* SPP, L. *delbrueckii bulgaricus*, B. *bifidum*, S. *salivarus thermophilus* yoghurt at 4×10^{10} CFU per day for 8 weeks. Yoghurt without probiotics was used as control.
  - **Measurements:**
    - *Performance*: aerobic fitness, 400-meter race time
    - Number of episodes and duration of *respiratory infections* and *digestive health*

Test of Aerobic Fitness

- **Harvard Step Test**
  - test requires minimal equipment and costs, and can be self-administered
  - athlete steps up and down on a 41 cm high bench for 3 minutes at a rate of 22 steps per minute (Salarkia et al).
  - heart rate is measured for 15 seconds immediately after finishing the test
  - VO$_2$max (ml/kg/min) can be calculated.

Probiotics and Swimmers (Results)

- Performance
  - Probiotic administration reduced 400m swim time by 3.9 seconds (control -0.5s, p=0.22)
  - Probiotic significantly increase aerobic fitness (VO$_2$max, 0.56 vs. 0.01, p<0.05)

Source: Salarkia et al. Effects of probiotic yogurt on performance, respiratory and digestive systems of young adult female endurance swimmers: a randomized controlled trial. MJIRI 2013, 27(3):141-146
Probiotics and Runners in the Heat (Design)

- Shing et al., 2014
  - **Subjects:**
    Ten trained, male runners (27 ± 2 years)
  - **Supplement:**
    45×10¹⁰ CFU of multistrain probiotic (L. *acidophilus* (7.4 bn), L. *rhamnosus* (15.55 bn), L. *casei* (9.45 bn), L. *plantarum* (3.15 bn), L. *fermentum* (1.35 bn), B. *lactis* (4.05 bn), B. *breve* (1.35 bn), B. *bifidum* (0.45 bn), S. *thermophilus*) per day for 4 weeks.
  - **Measurements:**
    - Performance: time-to-exhaustion (35°C, 40% humidity, 80% of their ventilatory threshold)
    - Gastrointestinal permeability
    - Cytokines (inflammation)
    - Heart rate, core temperature

Probiotics and Runners in the Heat (Results)

- Probiotic supplementation resulted in significant improvement of time-to-exhaustion run time:
  - Probiotic: 37:44 ± 2:42 (min:s)
  - Control: 33:00 ± 2:27 (min:s)

- Probiotic supplementation had no effect on:
  - Gastrointestinal permeability
  - Inflammation (cytokines)
  - Core temperature, heart rate
  - GI Health

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subjects</th>
<th>Supplementation</th>
<th>Exercise</th>
<th>Performance Benefit</th>
<th>Immune or GI Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clancy et al (2006)</td>
<td>18 healthy athletes, 9 fatigued athletes</td>
<td>L. <em>acidophilus</em>, capsules, $2 \times 10^{10}$ CFU per day for 4 weeks</td>
<td>No exercise intervention</td>
<td>Not assessed</td>
<td>T cell deficit was reversed following probiotic supplementation</td>
</tr>
<tr>
<td>Moreira et al (2007)</td>
<td>Non-elite Marathon runners (n=141)</td>
<td>L. <em>rhamnosus</em> (LGG), milk-based drink, $4 \times 10^{10}$ CFU per day for 12 weeks</td>
<td>Running (3-month training during pollen season &amp; 2003 Helsinki City Marathon)</td>
<td>Not assessed</td>
<td>No effects on symptoms of atopy or asthma</td>
</tr>
<tr>
<td>Kekkonen et al (2007)</td>
<td>Non-elite Marathon runners (n=141)</td>
<td>L. <em>rhamnosus</em> (LGG), milk-based drink, $4 \times 10^{10}$ CFU per day for 12 weeks</td>
<td>Running (3-month training &amp; 2003 Helsinki City Marathon)</td>
<td>Not assessed</td>
<td>No effect on respiratory infections or GI episodes, however, shortened GI stress post marathon.</td>
</tr>
<tr>
<td>Tiollier et al (2007)</td>
<td>French commandos cadets (n=47)</td>
<td>L. <em>casei</em>, milk-based drink during training</td>
<td>3-week training followed by a 5-day combat course.</td>
<td>Not assessed</td>
<td>No effect on respiratory tract infections</td>
</tr>
<tr>
<td>Cox et al (2010)</td>
<td>Elite male distance runners (n=20)</td>
<td>1.2$\times 10^{10}$ CFU <em>L. fermentum</em> VRI 003 per day for 4 months</td>
<td>Running (4-month of winter training)</td>
<td>No changes in running performance</td>
<td>Significant reduction in respiratory episodes and severity.</td>
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<tr>
<td>Martarelli et al (2011)</td>
<td>Active individuals (n=24)</td>
<td>L. rhamnosus, L. Paracasei $1 \times 10^9$ CFU per day for 4 weeks</td>
<td>4 weeks of intense physical activity</td>
<td>Not assessed</td>
<td>Blunting exercise induced oxidative stress.</td>
</tr>
<tr>
<td>Gleeson et al (2011)</td>
<td>Recreationally active endurance athletes (n=84)</td>
<td>L. casei Shirota (LGG), $1.3 \times 10^{11}$ CFU per day for 16 weeks</td>
<td>Running (4-month of winter training, normal training load)</td>
<td>Not assessed</td>
<td>Significant reduction in respiratory infections.</td>
</tr>
<tr>
<td>West et al (2011)</td>
<td>Competitive cyclists (n=80)</td>
<td>L. fermentum $1 \times 10^9$ CFU per day for 11 weeks</td>
<td>Cycling (winter training, normal training load)</td>
<td>No effect on peak power or VO$_2$ max</td>
<td>Significant reduction in respiratory infections (duration and severity) in males. No effect in females.</td>
</tr>
<tr>
<td>Välimäki et al (2012)</td>
<td>Marathon runners (n=127)</td>
<td>L. rhamnosus (LGG), $3 \times 10^{10}$ CFU per day for 12 weeks</td>
<td>Running (3-months training period, marathon run)</td>
<td>Not assessed</td>
<td>No effects on serum LDL or antioxidant levels.</td>
</tr>
<tr>
<td>Lamprecht et al (2012)</td>
<td>23 endurance trained men (triathletes, runners, cyclists)</td>
<td>$1 \times 10^{10}$ CFU multispecies probiotic per day for 14 weeks</td>
<td>Normal training load</td>
<td>No effect on VO$_2$ max, maximum performance</td>
<td>Significant reduction in Zonulin (marker of gut permeability)</td>
</tr>
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<tr>
<td>Gleeson et al (2012)</td>
<td>Highly active individuals (n=66)</td>
<td>L. salivarius (LGG), 2×10^{10} CFU per day for 16 weeks</td>
<td>4-months of spring training (endurance-based physical activities)</td>
<td>Not assessed</td>
<td>No effect on frequency, severity and duration of respiratory infections.</td>
</tr>
<tr>
<td>Salarkia et al (2013)</td>
<td>Females endurance swimmer (n=46)</td>
<td>Multi-strain probiotic yoghurt 4×10^{10} CFU per day for 8 weeks</td>
<td>Swimming</td>
<td>Increase in aerobic fitness. No effect on swim times.</td>
<td>Significant reduction in respiratory and ear infections. No effect on GI episodes.</td>
</tr>
<tr>
<td>Charlesson et al (2013)</td>
<td>Male athletes (n = 8)</td>
<td>L. acidophilus, B. lactis, L. rhamnosus per day for 8 weeks</td>
<td>Normal training, Travelling to high risk travelers’ diarrhea countries</td>
<td>Not assessed</td>
<td>No effect on TD. 50% of all athletes reported TD symptoms.</td>
</tr>
<tr>
<td>West et al (2014)</td>
<td>Active individuals (n=465)</td>
<td>L. lactis BI-04 2×10^{10} CFU, or LA NCFM and B. lactis BI-07 5×10^{9} CFU/d for 150 days</td>
<td>Normal activity load (approx. 6 hours per week)</td>
<td>Not assessed</td>
<td>BI-04 reduced URTI frequency. BI-07+LA NCFM showed no effect.</td>
</tr>
<tr>
<td>Haywood et al (2014)</td>
<td>Highly-trained rugby union players (n=30)</td>
<td>L. gasseri 2.6×10^{12} CFU, B. bifidum and B. longum 0.2×10^{12} CFU/d for 4 weeks</td>
<td>Normal training load</td>
<td>Not assessed</td>
<td>Significant reduction in respiratory infections and GI episodes. No effect on severity.</td>
</tr>
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<tr>
<td>Shing et al (2014)</td>
<td>Male runners (n=10)</td>
<td>4.5×10^{10} CFU multispecies probiotic per day for 4 weeks</td>
<td>Normal training load</td>
<td>Significant increase in run time to fatigue in the heat</td>
<td>No effects on inflammation or GI markers.</td>
</tr>
<tr>
<td>Aghaee et al (2014)</td>
<td>Male athletes (n = 16)</td>
<td>Daily Probiotic for 30 days</td>
<td>Normal training load</td>
<td>Not assessed</td>
<td>Probiotics increase monocyte levels</td>
</tr>
<tr>
<td>Georges et al (2014)</td>
<td>Resistance-trained individuals (n=10)</td>
<td>Bacillus coagulans GBI-30, 6086 (BC30), 5×10^{9} CFU plus 20g of casein twice per day for 8 weeks</td>
<td>Periodized resistance training</td>
<td></td>
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<tr>
<td>Wilson et al (2014)</td>
<td>Resistance-trained individuals</td>
<td>Bacillus coagulans GBI-30, 6086 (BC30), 5×10^{9} CFU plus 20g of casein twice per day for 2 weeks</td>
<td>Intense Single Leg Training Bout</td>
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</tr>
</tbody>
</table>
Summary: the athletes’ immune system and probiotics

- **Strenuous exercise suppresses the immune system, resulting in**
  - decreased performance during competition
  - missed events
  - slower recovery
  - reduced training intensity and/or frequency

- **Intervention studies in athletes with probiotics show**
  - strain-specific benefits
    - sport specific?
    - intensity specific?
    - gender specific?
    - optimal and minimal duration of supplementation?
    - Probiotics aid travelers diarrhea

- **Studies have yet to show direct benefit on performance**
Protein and Exercise

Protein supplementation has been shown to increase muscle protein synthesis in response to exercise in a dose-dependent manner and approximately 20g protein are needed to...

- Increase Lean Body Mass (LBM)
  - Increase Strength
  - Increase Power
- Speed up Recovery
  - Reduce fatigue
- Recommended protein intake for athletes (high quality protein):
  - 1.2 to 1.7 g/kg/d
  - Sedentary adults: 0.8 to 0.9 g/kg/d

US SPORTS NUTRITION MARKET
- **SIZE:** $4.7 billion (60% world share).
- **GROWTH:** 7% annually.
- **CATEGORY:** Protein-based (90%).
Probiotics Increase Amino Acid Absorption from Protein

- Bacillus coagulans GBI-30, 6086 (GanedenBC\textsuperscript{30}) has been shown to aid protein digestion in an \textit{in vitro} model (TIM-1).

- Human Study: Randomized, double-blind, placebo-controlled, crossover clinical trial.

- Healthy subjects consumed
  - Whey Protein or
  - Whey Protein plus 1 billion CFU Bacillus coagulans GBI-30, 6086.
  - for 2 weeks.

- Probiotics increased amino acid absorption.

Protein and Muscle Protein Synthesis (MPS)

- There are 20 total amino acids, comprised of 9 essential amino acids (EAAs) and 11 non-essential amino acids (NEAAs).
- EAAs alone stimulate as much protein synthesis as a whole protein with the same EAA content.
- Research shows BCAAs were able to stimulate skeletal MPS to the same degree as all 9 EAAs.
- When examined further, only leucine was able to stimulate MPS independently.
- Leucine range for optimal MPS 1.7-3.5g (leucine alone does not work).

Leucine Content in Different Protein Sources

- Leucine content of different protein sources and grams of protein needed to yield 3g of leucine
Probiotics and Protein: Potential Benefits

Increased leucine appearance in the blood through probiotics results in

- Reduced quality differences between plant (lower in leucine) and animal proteins
- Reduced serving sizes of animal protein

* needs further clinical validation
Probiotics and Resistance Training: 1st Pilot Study

- Georges et al., 2014
  - **Subjects:**
    Ten male. Resistance-trained athletes (22 ± 2 years)
  - **Supplement:**
    Bacillus coagulans GBI-30, 6086 (BC30), 5×10⁹ CFU plus 20g of casein twice per day for 8 weeks.
  - **Training:**
    - Full-body resistance training
    - 4-times per week
  - **Measurements:**
    - Power (vertical jump, peak)
    - Strength
    - Body composition
    - GI Health
    - Infections

### Probiotics and Resistance Training (Design)

- **Full body workouts, 4-times per week for 8 weeks**
  - Hypertrophy (8-12 RM loads with 60 seconds rest)
  - Strength (1-5 RM loads with 3-5 minutes rest)

<table>
<thead>
<tr>
<th>MONDAY DAY 1 (Strength)</th>
<th>WEDNESDAY DAY 2 (Back and Biceps Hypertrophy)</th>
<th>THURSDAY DAY 3 (Leg Hypertrophy)</th>
<th>SATURDAY DAY 4 (Chest-Shoulders-Triceps Hypertrophy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press (7 sets)</td>
<td>Pull-ups (7 sets)</td>
<td>Squats (6 sets)</td>
<td>Bench press (6 sets)</td>
</tr>
<tr>
<td>Squats (7 sets)</td>
<td>Seated cable rows (7 sets)</td>
<td>Leg press (6 sets)</td>
<td>Cable cross-over (6 sets)</td>
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<tr>
<td>Deadlift (7 sets)</td>
<td>Semi-supinated pull down with straight arm (7 sets)</td>
<td>Leg extensions (7 sets)</td>
<td>Military press (5 sets)</td>
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<tr>
<td>Leg raise (3 sets)</td>
<td>Reserve barbell curl (7 sets)</td>
<td>Leg curl (7 sets)</td>
<td>Lateral raise (5 sets)</td>
</tr>
<tr>
<td>Weighted crunch (3 sets)</td>
<td>Dumbbell curl (7 sets)</td>
<td>Calf raise (7 sets)</td>
<td>Triceps pushdown (5 sets)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shrugs (6 sets)</td>
<td>French press (5 sets)</td>
</tr>
</tbody>
</table>

- Full body workouts, 4-times per week for 8 weeks
  - Hypertrophy (8-12 RM loads with 60 seconds rest)
  - Strength (1-5 RM loads with 3-5 minutes rest)
Probiotics and Resistance Training (Design)

Bench Press  Leg Press  Military Press  Barbell Curls

Pull-ups  Bent Over Rows  Barbell Extensions
Probiotics and Resistance Training (Results)

- Probiotic supplementation showed a trend to increase vertical jump power (p=0.10)

- Probiotic supplementation might have positive effect on
  - Fat mass
  - Peak Power

- Probiotic supplementation had no effect on:
  - Lean Body Mass
  - Strength

Probiotics and Resistance Training: 2nd Pilot Study

Wilson et al., 2014

- **Subjects:** Resistance-trained athletes
- **Supplement:** Bacillus coagulans GBI-30, 6086 (BC30), $5 \times 10^9$ CFU plus 20g of casein twice per day for 2 weeks.
- **Training:** Damaging Single-Leg Exercise
- **Measurements:**
  - Markers of Muscular Damage
  - Perceived Recovery
  - Soreness
  - Performance
- **Results**: Might Decreased Recovery Time, Soreness
  - Might Reduced Muscle Damage
  - Might Improved Performance

* Need to be validated in larger study

The Competition

- Immune support in athletes
  - Baker’s yeast beta-glucan
  - Significantly reduces URTIs in marathon runners
  - Better overall health and decreased confusion, fatigue, tension, and anger, and increased vigor compared to control

- Protein absorption
  - Digestive enzymes
  - Blend of digestive proteases from *Aspergillus niger* and *Aspergillus oryzae*
  - Significantly increased amino acid appearance in the blood (AUC)


The Present – And So It Begins

Probiotics begin to flex their muscle in the sports nutrition market

By Stephen DANIELLS, 21-Jun-2012

“There has been controversy surrounding the benefits of probiotics in healthy people, including athletes, during the last years.”

Related tags: Probiotics, Sports nutrition, Immunity, Protein
Related topics: Probiotics, Research, Probiotics & prebiotics, Energy, Gut/digestive health, Immune support, Sports nutrition

The potential benefits of probiotic ingredients in sports nutrition products may extend beyond immune support, as emerging evidence suggests a potential to enhance protein utilization.
The Bright Future

- Probiotics have been linked to numerous benefits relevant for athletes
  - Normalize age related drops in testosterone levels: body composition
  - Increase neurotransmitter synthesis (acetylcholine): endurance, explosiveness
  - Reduce cortisol levels: body composition
  - Reduce inflammation: recovery
  - Improve mood: performance
  - ...

HUGE OPPORTUNITIES FOR GAINS AND GROWTH
Special Thanks To

Prof. Dr. Jacob M. Wilson, Ryan Lowery

Our Research Sponsors and Partners

Our Dedicated Subjects
Dr. Ralf Jäger, FISSN, CISSN, MBA

- Certified Sport Nutritionist (CISSN)
- Fellow of the International Society of Sports Nutrition (FISSN).
- Lead author on numerous scientific and lay press articles, including research on Creatine, PS, HMB, PA, Probiotics
- Associate Editor, Editorial Board Member of the JISSN
- Contact: ralf.jaeger@inrenovo.com