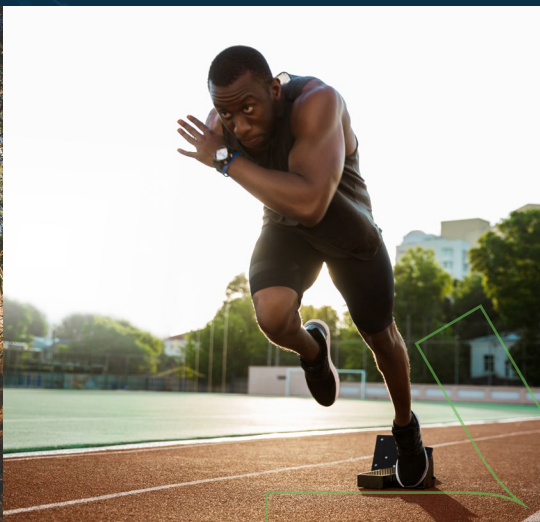




NuliGo[®] Lipids Trials White Paper



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1. WHAT ARE NULIGO® STRUCTURED LIPIDS?

Lipids are essential building blocks of life, found in every living cell. These compounds include fatty acids, triglycerides, phospholipids, and sterols. They play critical roles in storing and transporting energy, sending cellular signals, and forming the structural foundation of cell membranes.

NuliGo® lipids by Bunge represent a groundbreaking innovation in sports nutrition. Created through an enzyme-driven process, NuliGo® structured lipids combine medium-chain fatty acids (MCFAs) from palm kernel oil with long-chain fatty acids (LCFAs) from canola oil. These are recombined into new triglycerides – structured medium- and long-chain triglycerides (sMLCT) – where MCFAs and LCFAs are selectively re-attached to the same glycerol backbone. This unique structure blends the rapid energy release of MCFAs with the sustained energy of LCFAs, providing a balanced fuel source.

This balance makes NuliGo® structured lipids especially beneficial for athletes, as lipid (fat) oxidation is crucial in sustaining muscle energy during prolonged, sub-maximal exercise and muscle recovery.

Backed by decades of expertise, Bunge has explored structured MLCTs since the early 2000s in medical applications. The existing extensive clinical evidence supports our understanding of how NuliGo® sMLCTs deliver remarkable benefits.

ENERGY SOURCES: MCTs, LCTs, AND NULIGO® sMLCTs

	Medium-Chain Triglycerides (MCTs)	Long-Chain Triglycerides (LCTs)	NuliGo® Structured Medium- and Long-Chain Triglycerides (sMLCTs)
Definition	Made of three medium-chain fatty acids (MCFAs) attached to a glycerol backbone.	Made of three long-chain fatty acids (LCFAs) attached to a glycerol backbone.	Combine medium- and long-chain fatty acids (MCFAs ^[1] and LCFAs ^[2]) on the same glycerol backbone, offering both quick and sustained energy.
Absorption Mechanism	After digestion, MCFAs enter intestinal cells and are absorbed directly into the bloodstream. They are rapidly transported to the liver for processing.	LCFAs are absorbed into intestinal cells, packed into transport molecules called chylomicrons, and sent through the lymphatic system into the bloodstream.	Absorbed like LCTs, MCFAs and LCFAs are packed into chylomicrons, delivered through the lymphatic system, and sent to tissues like muscles for energy.
Metabolism Mechanism	MCFAs are processed in the liver, where they are converted into energy-rich molecules like ketone bodies. They do not directly supply energy to muscles.	LCFAs are delivered to muscle and fat tissues. ^[3] With the help of L-carnitine, LCFAs enter muscle cells' mitochondria, where they are slowly oxidized for long-term energy.	MCFAs in sMLCTs are quickly oxidized in muscle cells for rapid energy without needing L-carnitine. LCFAs are oxidized more slowly, providing sustained energy.
Role in Energy Supply	Ideal for quick energy in low-carb conditions (such as ketosis), their energy contribution outside ketosis supports liver functions, not direct muscle energy.	Provide steady, long-lasting energy, critical during sustained activities like endurance exercise.	Offer both rapid energy from MCFAs, which extends carbohydrate reserves, and sustained energy from LCFAs, supporting long-duration performance.

“[This] lipid fuel technology[...] will make a huge difference in fueling during sport performance.”

– Mathieu Van Der Poel, professional cyclist, six-time Cyclo-cross World Champion, UCI Road World Champion, and UCI Gravel World Champion



2. EXPLORING THE POTENTIAL OF NULIGO® STRUCTURED LIPIDS

Many athletes have tested NuliGo® structured lipids in real-world conditions and reported noticeable performance improvements. In field trials conducted by Bunge among 52 field testers, 41 experienced positive results.

FIELD TESTING AND CLINICAL TRIALS

The positive feedback from field tests, combined with compelling testimonials from athletes who experienced improved performance and recovery, encouraged further research to deepen the understanding of NuliGo®'s sMLCTs potential. To build on the promising results, additional research conducted in controlled settings was launched to validate initial findings.

Endurance Performance: Field tests revealed that 93% of athletes tolerated NuliGo® lipids well, and 78% reported feeling better than average. Based on these results, researchers conducted a double-blind, placebo-controlled cross-over trial to test endurance improvements in competitive triathletes.

Muscle Recovery: Field testing also showed that 62% of athletes experienced improved recovery, and 23% reported reduced soreness. These results led to a clinical trial investigating muscle performance and recovery in healthy individuals.

These trials support the hypothesis that NuliGo® lipids enhance endurance and muscle recovery, helping athletes perform at their best. By blending real-world insights with rigorous scientific testing, NuliGo structured lipids are reinforced as a key innovation in performance nutrition.

MATS P., COMPETITIVE CYCLIST, SHARED:

"I tested LiFT® a number of times. Each time the result was the same — I noticed that I had more 'surplus.' [...] Normally, after a threshold training, I am really empty, and the journey back home is a survival journey. However, not this time. I felt surprisingly fresher, taking this with the same carbohydrates (80g/h)."

ERIC E., COMPETITIVE ULTRA-RUNNER, NOTED:

"Last weekend, I used LiFT® [with NuliGo® lipids] for the first time during an ultra-trail run (80km/2400d+ in 8h35'). [...] I applied LiFT® in combination with my carbohydrate intake for best results. Remarkably, I did not notice a 'drain' of energy toward the end of the race. I also experienced significantly less muscle pain in the quadriceps and calves in the days after the race."



3. POWER CYCLISTS TRIAL

A randomized, double-blind, placebo-controlled cross-over trial was conducted by Bunge, in partnership with 4GOLD to evaluate the effects of NuliGo® sMLCTs on endurance and performance in cyclists and triathletes. The trial was conducted using Lipid Fuel Technology (LiFT®) by 4GOLD, a flavored oil powered by NuliGo® sMLCTs and designed for endurance athletes. It included 20 healthy, non-smoking athletes (18 males and 2 females) aged 16 to 45. The cross-over design, in which each athlete is tested under both NuliGo® lipids and placebo conditions, ensures a properly controlled comparison between the two treatments.

The study involved three visits to an exercise lab, each spaced at least seven days apart to allow for full recovery. The structure was as follows:

Visit 1: Familiarization Phase

Athletes completed baseline measurements and were introduced to the study protocols.

Visit 2: Experimental Test 1

Participants underwent their first testing session under controlled conditions.

Visit 3: Experimental Test 2

Participants returned for their second testing session under the same controlled conditions.

This design ensured accurate comparisons between the effects of NuliGo® structured lipids and the placebo, providing robust data on its impact on athletic performance.

3.1 FAMILIARIZATION

During the first visit, athletes underwent a medical screening with a sports physician. They then completed a graded cycling test on an ergometer to determine key performance metrics:

Maximal Exercise Ability (Wmax)

Functional Threshold Power (FTP)

Peak Oxygen Uptake (VO2 max)

3.2 EXPERIMENTAL TEST 1

For the first test, athletes were randomly assigned to either the NuliGo® Group or the Placebo Group.

NuliGo® Samples: 15 ml doses of 4GOLD's LiFT® containing 13g of NuliGo® lipids (~9 g sMLCTs)

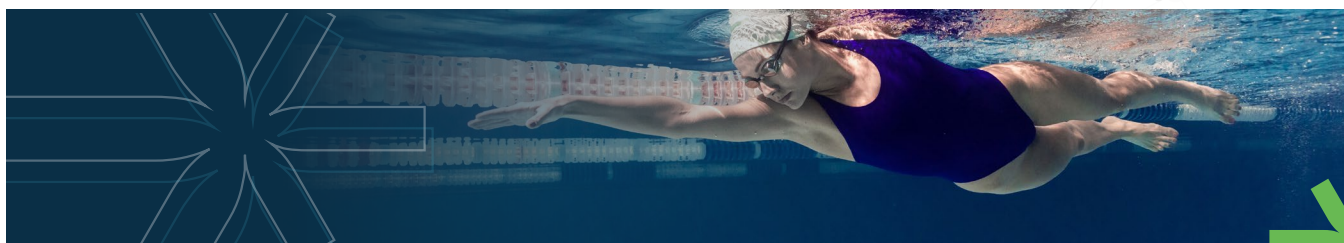
Placebo Samples: 15 ml doses of canola oil, designed to mimic the flavor, appearance, and texture of NuliGo® lipids

This double-blind design ensured that neither the athletes nor the exercise lab staff knew who were under NuliGo® lipids or placebo conditions. Testing was divided into two phases: pre-loading at home and testing day at the lab.

PRE-LOADING (DAY BEFORE TESTING)

Athletes took one dose of either NuliGo® lipids or the placebo with breakfast and another with dinner.





TESTING DAY

Athletes took another dose with breakfast before heading to the lab. Testing included two key phases:

3.2A PRE-EXHAUSTION PERIOD

One hour after the first dose, athletes cycled for two hours at 55% of their functional threshold power (FTP), established during the familiarization test.

During this period, athletes consumed:

- A second dose of NuliGo® lipids or placebo with a carbohydrate drink^[4] after 30 minutes.
- A third dose with a carbohydrate drink after 90 minutes.

Every 20 minutes, the following were recorded:

- **Blood lactate levels:** measured through earlobe samples.
- **Heart rate:** using heart rate belts and measured in bpm.
- **Power output:** using the bike ergometer and measured in watts.

3.2B ALL-OUT PERIOD

Immediately following the two-hour pre-exhaustion phase, athletes transitioned to a one-hour all-out cycling test.

Athletes consumed a fourth dose of NuliGo® lipids or placebo with a carbohydrate drink at the start of this phase.

Every 20 minutes, the following were recorded:

- Blood lactate levels
- Heart rate
- Power output

3.3 EXPERIMENTAL TEST 2

After a one-week washout period with no treatment, athletes returned for a second experimental test.

Cross-Over Design: Athletes who received a placebo in Test 1 were given NuliGo® lipids in Test 2, and vice versa.

Double-Blind Protocol: Neither the athletes nor the researchers knew who received NuliGo® or the placebo in each test.

The athletes followed the same pre-loading, dosing, and cycling protocols as in Test 1. This design ensured a direct comparison of NuliGo® versus the placebo for each athlete.

3.4 RESULTS

The trial demonstrated that NuliGo® lipids significantly enhanced performance compared to the placebo. Athletes showed:

Higher average power output: They sustained more power during all-out cycling.

Lower average heart rate: Their hearts worked more efficiently under intense effort.

Delayed lactate build-up: NuliGo® lipids helped slow the rise in lactate levels, which is typically associated with fatigue during high-intensity exercise.

These results aligned with positive feedback from field trials, confirming NuliGo® sMLCTs as an effective energy supplement for athletes.

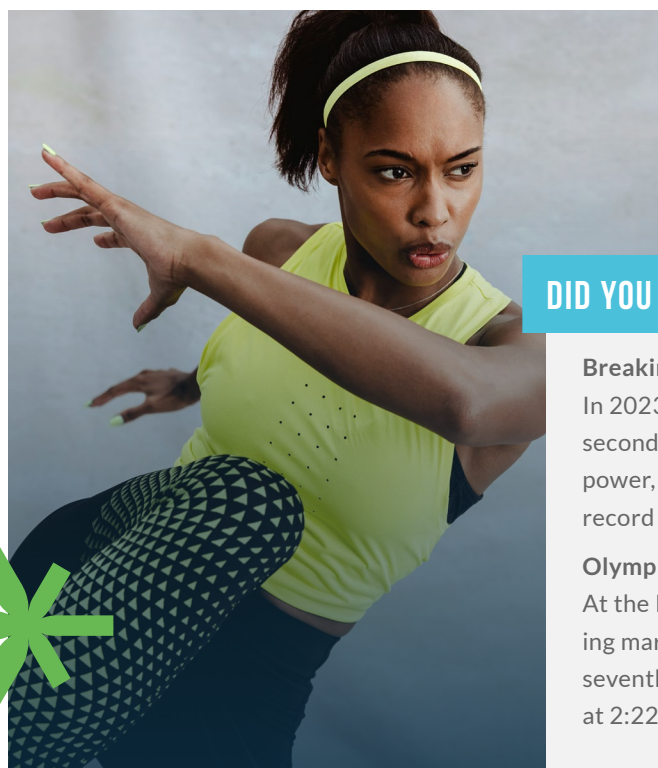
3.4A INCREASED POWER OUTPUT

NuliGo® sMLCTs improved performance for 85% of athletes (17 out of 20). Compared to the placebo, athletes experienced:

Average power increase: +2.4%
($p < 0.005$, paired t-test)

Median power increase: +1.7%
($p < 0.0025$, Wilcoxon test)

These results translate to an increase of 4.0–5.7 watts, highlighting NuliGo® sMLCTs as a reliable supplemental energy source for sustained and intense efforts.



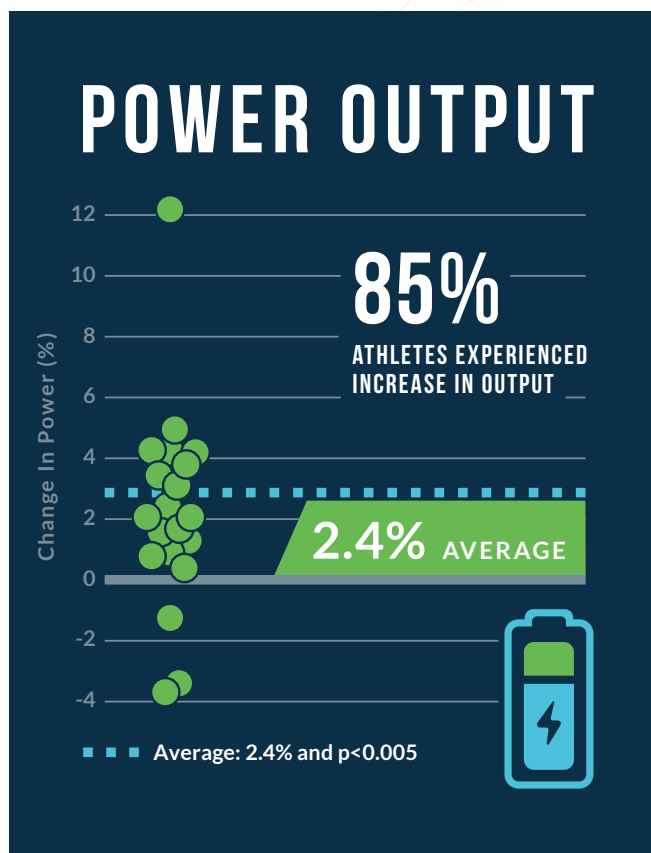
DID YOU KNOW

Breaking Records:

In 2023, Sifan Hassan ran the Chicago Marathon in 2:13:44 — the second-fastest women's marathon time ever. With just 2% more power, she could have shaved off 2.84 minutes, breaking the world record of 2:11:53 set by Tigist Assefa in Berlin that same year.

Olympic Gold Shift:

At the Paris Olympics, Sifan Hassan won gold with a record-breaking marathon time of 2:22:55. If Delvin Meringor, who placed seventh at 2:24:56, had 2% more power, she could have finished at 2:22:05—winning gold and setting a new Olympic record.



TESTIMONIES

Power output results in this trial are consistent with reports from athletes during field-testing of NuliGo® LiFT®:

"I am preparing myself for the Marathon of Antwerp on the 22nd of October. I use LiFT® on my long-distance trainings since two weeks. The overall feeling is better, I run faster and can keep my pace easier. It feels like you have more power and that gives me the right mindset to reach my goal." —Cathy S., marathon runner

"I have been riding with LiFT® for a few weeks now. Especially for the longer days on the bike to get those higher wattages to the end, I felt the difference." —Bram dL., cyclist

CHANGE IN ENERGY OUTPUT PER HEARTBEAT

4.6%

AVERAGE INCREASE IN ENERGY OUTPUT PER HEARTBEAT

Energy output per heartbeat (Joules/heartbeat)

80 | | | | | 84 | | | | | 88

87.9 J/BEAT

84.0 J/BEAT

Significance: $p < 0.0005$

NuliGo® lipids

Placebo

3.4B DECREASED HEART RATE

70% of athletes (14 out of 20), when taking NuliGo® structured lipids, showed lowered heart rates compared to when they took the placebo.

Average decrease: -1.7% ($p < 0.0025$, paired t-test)

Median decrease: -3.0% ($p < 0.0025$, Wilcoxon test)

This reduction in heart rate is particularly notable because it occurred alongside an increase in power output. Key findings include:

Energy output per heartbeat:

- **Average increase:** +4.6% or from 84.0 (placebo) to 87.9 (NuliGo®) J/heartbeat ($p < 0.0005$, paired t-test)
- **Median increase:** +10% or from 83.0 (placebo) to 91.3 (NuliGo®) J/heartbeat ($p < 0.0005$, Wilcoxon test)

These results show that NuliGo® sMLCTs enabled athletes to produce more power with less strain on their hearts, increasing energy efficiency by 5-10% (or 3.9–8.3 joules per heartbeat). For endurance sports, where energy economy is crucial, this improvement can lead to prolonged performance and greater stamina.

DURATION OF EFFECTS

The heart rate reduction was most significant during the first 20 and 40 minutes of the all-out effort period ($p < 0.005$ and $p < 0.01$, respectively). By 60 minutes, the effect diminished ($p > 0.1$) as heart rates neared maximum levels and athletes approached exhaustion. This outcome aligns with the effect of a supplemental lipid energy source, which is more efficient at sub-maximal effort levels, i.e., prior to exhaustion.

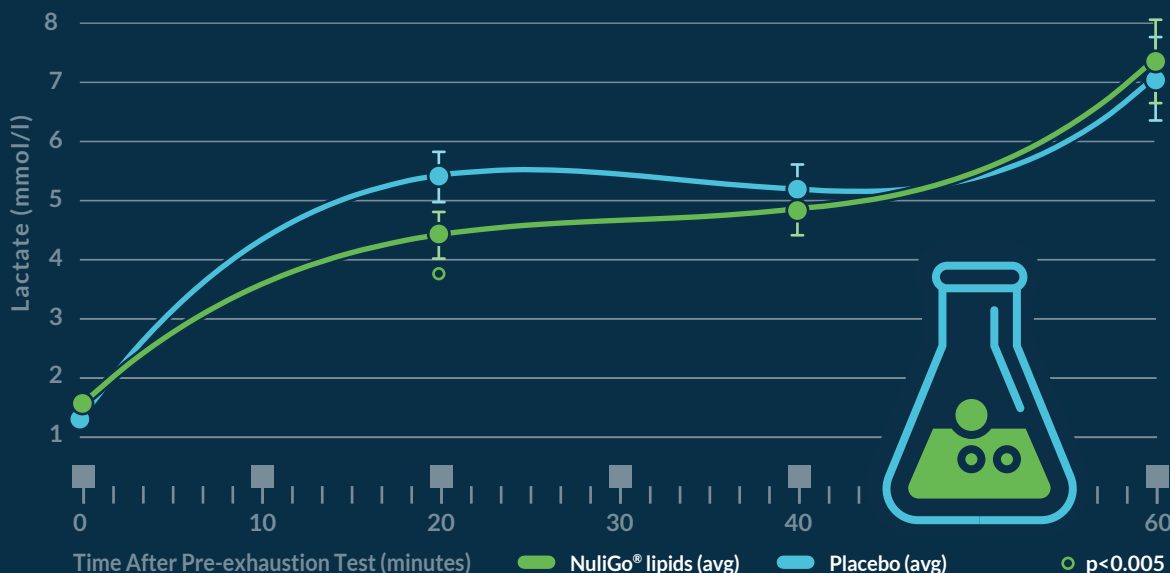
TESTIMONIES

The effect on heart rate observed in this trial is consistent with reports from athletes during field-testing of NuliGo® LiFT®:

"I started using LiFT® during my endurance workouts [...]. I noticed a significant difference during the efforts (heart rate remained lower during longer efforts) as well as during recovery. Suddenly, two heavy training days that used to be seriously draining became much more bearable [...]. This made it possible to increase my training capacity in terms of duration, which also put my performance on an upward curve." —Ward vL., competitive triathlete

"I early tested LiFT® and used it in trainings and races for over a year now. The first time I used it on a long endurance ride (5h) and the fifth hour felt like it was just my first. I could really keep going. I immediately pushed my best 3h values ever. The fatigue just never hit that day. I've had similar experiences afterwards during trainings and races. I don't think I would start a race without LiFT® anymore." —Thomas, competitive gravel and road cyclist

LACTATE ACCUMULATION OVER TIME



3.4C DELAYED LACTATE ACCUMULATION

Lactic acid, or lactate, builds up in muscles during intense exercise, contributing to fatigue and soreness. Given the two-hour pre-exhaustion phase before the one-hour all-out effort in this trial, some lactate accumulation was expected before the all-out section.

However, athletes who consumed NuliGo® structured lipids showed significantly lower lactate levels during the early stages of the all-out effort period:

At 20 minutes:

- **Average decrease:** -18.3% ($p < 0.005^{[5]}$, paired t-test)
- **Median decrease:** -29.3% ($p < 0.01^{[5]}$, paired Wilcoxon test)

This delayed lactate accumulation suggests that NuliGo® sMLCTs helped athletes maintain performance longer by reducing early muscle fatigue.

DURATION OF EFFECT

The reduction in lactate was most significant at 20 minutes into the all-out effort. By 40 and 60 minutes, the difference was no longer statistically significant, as lactate levels naturally rose closer to exhaustion. This aligns with the effects of a supplemental lipid energy source, which delays time to exhaustion but has minimal impact once exhaustion occurs.

TESTIMONIES

Athletes in the field also reported less muscle fatigue and soreness when taking NuliGo® LiFT®:

"I used it for longer (3h+) and more intense rides (Tempo+). I applied it within the ride. For me, it was like a booster. The fatigue in the muscles disappeared and I could ride stronger." —Ralf R., competitive cyclist

"Have tested LiFT® several times. Both on flat and hilly rides. It is especially on hilly courses that LiFT® comes into its own. The legs don't get tired, you can cope with one slope after another. There is no acidification and the dreaded hunger pangs do not appear." —Mitch V., competitive cyclist

4. MUSCLE DAMAGE POST-EXERCISE TRIAL

This trial investigated the effects of NuliGo® structured lipids on muscle performance and recovery after exercise-induced muscle damage. It was a double-blind, randomized, placebo-controlled study involving 38 healthy, recreationally active women (ages 18–35) who were non-smokers. Participants were divided into two groups:

NuliGo® Group (n=19 ^[6]): Received 9 ml doses of NuliGo® oil (~6 g sMLCTs).	Placebo Group (n=19 ^[6]): Received 9 ml doses of a 50/50 mix of canola oil and traditional MCT oil to mimic NuliGo® oil's composition and fatty acids profile.
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The study lasted seven days and included a pre-loading phase, five lab visits, and follow-up assessments.

PROTOCOL

Day	Phase	Description
1	Visit 1	Consent, initial assessments (height, weight, body composition), randomization, and protocol familiarization
2-3	Pre-Loading	Participants consumed one dose (9 ml) of their assigned treatment twice daily for two days
4	Visit 2	Baseline testing, muscle-damaging exercise, and immediate post-exercise testing
5	Visit 3	Follow-up testing 24 hours after exercise
6	Visit 4	Follow-up testing 48 hours after exercise
7	Visit 5	Follow-up testing 72 hours after exercise





4.1 EXPERIMENTAL TESTING (VISIT 2)

PRE-EXERCISE ASSESSMENTS

Before exercise, subjects were tested for:

Muscle performance: torque (in N x m) produced upon eccentric knee extension measured with isokinetic dynamometry at different times after movement onset (25-250 milliseconds).

Vertical jump performance: power (in watts) and velocity (in m/s), during a counter-movement vertical jump, measured with a linear transducer attached to the subject's waist. Data not shown.^[7]

MUSCLE-DAMAGING PROTOCOL

Participants performed 8 sets of 10 eccentric knee extensions on a leg extension machine designed for more controlled movement. To ensure consistency and precision, participant's torsos and the tops of their legs were strapped into the machine. Ideally, this setup minimizes extraneous movement, providing a controlled environment to isolate the quadriceps. The protocol required participants to extend their knees as hard as possible at a 90° angle, effectively inducing controlled muscle damage.

IMMEDIATE POST-EXERCISE TESTING

Immediately after the muscle-damaging protocol, subjects repeated the muscle performance and vertical jump assessments to compare with their pre-exercise baselines.

Subjects consumed their second daily dose of NuliGo® lipids or placebo after the testing.

4.2 FOLLOW-UP TESTING (VISITS 3–5)

Participants continued taking two daily doses of their assigned treatment for three days after the muscle-damaging protocol. Scientists monitored the athletes' recovery through assessments at 24, 48, and 72 hours post-exercise.

4.3 BASELINE CONSIDERATIONS

Torque measurements during eccentric knee extensions, assessed using isokinetic dynamometry, can vary significantly, as do power and velocity during vertical jumps. These variations depend on factors such as strength, training level, and pain tolerance after muscle damage. To accurately evaluate the effects of the muscle damage protocol, it is crucial to use paired data (comparing each subject's performance to their own baseline) and baseline-normalized (relative) data for group comparisons. Without accounting for baseline variability, meaningful conclusions cannot be drawn.

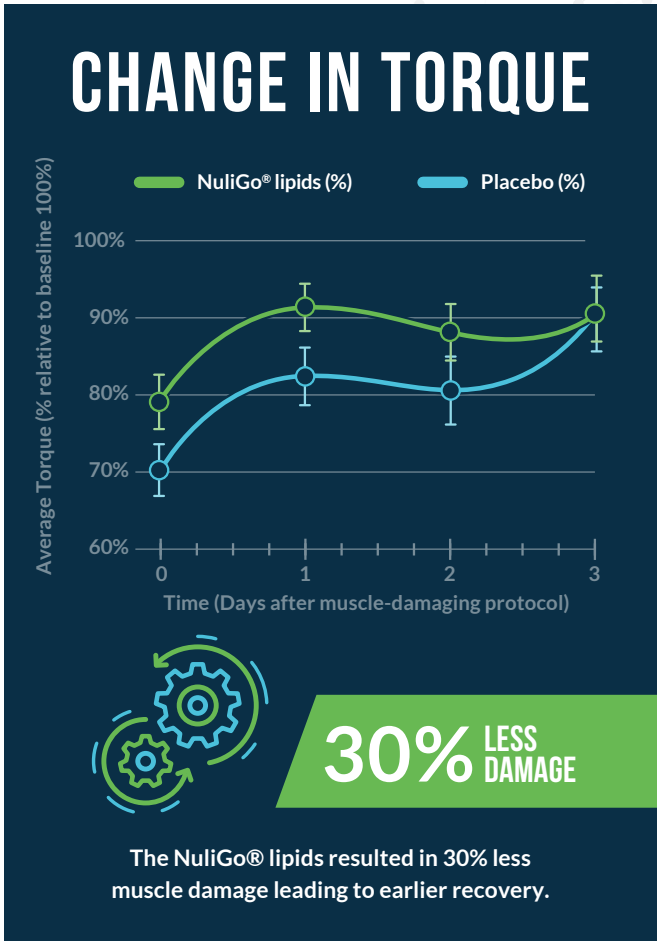
Additionally, torque measurements show greater variability at the onset of leg movement, particularly in the first milliseconds, due to mechanical noise. To address this, we used the average torque values recorded at 200 and 250 milliseconds after movement onset.

4.4 RESULTS

The paired comparison of torque values — within each subject, before and after the muscle-damaging protocol — showed that both NuliGo® and Placebo groups were affected by the protocol. However, baseline-normalized data showed that subjects in the NuliGo® Group experienced a significantly lower reduction in torque after the muscle-damaging protocol than those in the Placebo Group. These results suggest that NuliGo® sMLCTs may help mitigate muscle damage during strenuous exercise.

Average torque decrease after muscle damage^[8]:

- Placebo Group: -29.7% (or 70.3% of baseline; $p<0.0000005^{[9]}$)
- NuliGo® Group: -20.8% (or 79.2% of baseline; $p<0.0001^{[9]}$)
- 30% lower reduction in torque in the NuliGo® Group ($p<0.05$, t-test)



At 24, 48, and 72 hours post muscle-damaging exercise, subjects in the NuliGo® group showed a non-significant reduction in torque compared to baseline. On the other hand, the Placebo Group continued to show a significant decrease in torque that only became statistically indistinguishable from the baseline after 72 hours.

Average torque decrease from 24 to 72 hours after muscle damage: ^[8]		
	NuliGo® Group	Placebo Group
24hr	-7.7% (or 92.3% of baseline, NS ^[9])	-17.0% (or 83.0% of baseline; $p<0.00005^{[9]}$)
48hr	-11.1% (or 88.9% of baseline, NS ^[9])	-18.9% (or 81.1% of baseline; $p<0.0005^{[9]}$)
72hr	-8.6% (or 91.4% of baseline, NS ^[9])	-8.5% (or 91.5% of baseline, NS ^[9])

FIELD TEST TESTIMONIAL

Feedback from real-world use supports these findings:

“It was amazing. Used it during this year’s Dodentocht [100 km], and it was really helpful. Didn’t feel tired at all, only one day of sore muscles, and completed the run in less than 12 hours. Truly amazing!” –Laurens B., competitive ultra runner

NOTES

- [1] MCFAs in NuliGo® are only fatty acids with 8 and 10 carbons (C8:0 and C10:0). Although fatty acids with 12 carbons (C12:0 or lauric acid) are considered, in some products and literature, MCFAs, their absorption and distribution within the body is more like that of LCFAs.
- [2] LCFAs in NuliGo® are mostly unsaturated fatty acids with 18 carbons with 2/3 of them oleic acid (C18:1).
- [3] LCFAs are also present in plasma and accessible to tissues when released from adipose cells into the bloodstream.
- [4] Carbohydrate drink with 40g highly-branched cyclic dextrin (HBCD), and 20g palatinose.
- [5] Statistical significance defined as $p < 0.017$ ($p < 0.05$ adjusted to account for three comparisons using Bonferroni's correction).
- [6] Out of 20 subjects in each group, 19 were considered for analysis. One subject in each group produced constantly increasing torque values relative to the baseline, including after the muscle damage protocol. Those subjects were discarded. Muscle performance data for one NuliGo® Group subject was left out due to torque data collection issues (no data collected at multiple time points). Muscle performance: NuliGo® Group $n=18$, Placebo Group $n=19$. Jump performance: NuliGo® Group $n=19$, Placebo Group $n=19$.
- [7] Vertical jump performance was highly variable without significant results in both the NuliGo® and Placebo groups.
- [8] Comparisons using medians instead of averages render the same results.
- [9] Paired t-test p-values shown. Statistical significance defined as $p < 0.00625$ ($p < 0.05$ adjusted to account for 8 comparisons using Bonferroni's correction). One-way repeated measures ANOVA using post-hoc paired t-tests with Bonferroni's correction renders the same results.

CONTACT US

Through Nuligo® structured lipids, Bunge is at the forefront of innovation in sports nutrition, delivering advanced solutions for performance and recovery. We collaborate with fitness nutrition and supplement manufacturers and organizations supporting elite athletes to explore the benefits of Nuligo® sMLCTs for muscle performance and recovery pre-, post-, and intra-workout.

In 2025, we will launch new studies, including a field trial focused on hybrid athletes to explore further the impact of NuliGo® structured lipids on muscle performance, recovery, and more. This research will provide invaluable insights for athletes and brands alike.

Join us in shaping the future of sports nutrition. Contact us today to stay up to date, learn more about our research or to discuss collaboration opportunities:

Email: Nutrition@bunge.com

Website: Nuligo.com/Contact

NuliGo →[®]