

Acute Rhodiola Rosea Intake Can Improve Endurance Exercise Performance

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Purpose: The purpose of this study was to investigate the effect of acute and 4-week Rhodiola rosea intake on physical capacity, muscle strength, speed of limb movement, reaction time, and attention. **Methods:** PHASE I: A double blind placebo-controlled randomized study ($n = 24$) was performed, consisting of 2 sessions (2 days per session). Day 1: One hour after acute Rhodiola rosea intake (R, 200-mg Rhodiola rosea extract containing 3% rosavin + 1% salidroside plus 500 mg starch) or placebo (P, 700 mg starch) speed of limb movement (plate tapping test), aural and visual reaction time, and the ability to sustain attention (Fepsy Vigilance test) were assessed. Day 2: Following the same intake procedure as on day 1, maximal isometric knee-extension torque and endurance exercise capacity were tested. Following a 5-day washout period, the experimental procedure was repeated, with the treatment regimens being switched between groups (session 2). PHASE II: A double-blind placebo-controlled study ($n = 12$) was performed. Subjects underwent sessions 3 and 4, identical to Phase I, separated by a 4-week R/P intake, during which subjects ingested 200 mg R/P per day. **Results:** PHASE I: Compared with P, acute R intake in Phase I increased ($p < .05$) time to exhaustion from 16.8 ± 0.7 min to 17.2 ± 0.8 min. Accordingly, VO_{2peak} ($p < .05$) and VCO_{2peak} ($p < .05$) increased during R compared to P from $50.9 \pm 1.8 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ to $52.9 \pm 2.7 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ (VO_{2peak}) and from $60.0 \pm 2.3 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ to $63.5 \pm 2.7 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ (VCO_{2peak}). Pulmonary ventilation ($p = .07$) tended to increase more during R than during P (R: $115.9 \pm 7.7 \text{ L/min}$; P: $114.8 \pm 7.7 \text{ L/min}$). All other parameters remained unchanged. PHASE II: Four-week R intake did not alter any of the variables measured. **Conclusion:** Acute Rhodiola rosea intake can improve endurance exercise capacity in young healthy volunteers. This response was not altered by prior daily 4-week Rhodiola intake.

Key Words: Rhodiola rosea, phytomedicine, endurance capacity, mental capacity

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Introduction

Adequate sports nutrition is an important means to enhance training adaptations and optimize exercise performance. Elite athletes, but also individuals involved in recreational sports activities, use nutritional supplements on top of their normal diet because they believe this may beneficially impact on their performance level. Indeed, for some supplements like carbohydrates, proteins (29), and creatine (30), there is sound scientific support for an “ergogenic” action. The available selection of “sports supplements” continuously increases, including a growing number of plant extract sports supplements. A plant that has attracted recent attention is *Rhodiola rosea* or golden root (14).

Rhodiola rosea occurs in arctic and mountainous regions throughout Europe, Asia, and America. Based on fragmentary research data, a number of beneficial effects have been attributed to the intake of *Rhodiola rosea* root extracts. These include stimulation of the central nervous system (12), enhancement of physical work performance (2), increased muscle strength (5), suppression of mental fatigue (7, 26), and prevention of high altitude sickness (10). Furthermore, *Rhodiola rosea* intake has also been claimed to have anticancer (28) and cardioprotective (18) properties. In fact, due to its observed ability to offer resistance against a variety of biological (4) and physical stressors (7, 26) and the absence of any severe adverse side effects (10, 23), *Rhodiola rosea* has been categorized as an “adaptogen”—that is, a substance that can facilitate adaptations to stress conditions, presumably including exercise. However, most if not all of these claims rely on fragmentary and poorly controlled research designs. In this respect, one recent scientific report showed (26) *Rhodiola rosea* ingestion ($100 \text{ mg} \cdot \text{day}^{-1}$, 20 days) to enhance physical work capacity (PWC 170). However, the methods and statistics used in this study are unclear and therefore the data unsure. Still, the potential of the presumed active compounds of *Rhodiola rosea*, notably salidroside and rosavin, to stimulate endorphin secretion (10, 27) provides a possible physiological mechanism for performance enhancement. Therefore, and also because *Rhodiola rosea* is becoming increasingly popular in athletic populations, it seems warranted to reinvestigate some of the previously described effects of *Rhodiola rosea* using a well-controlled experimental design. Thus, the primary aim of the present study was to investigate whether *Rhodiola rosea* intake can improve endurance exercise capacity and muscle strength. In addition, we also re-evaluated the effects of *Rhodiola rosea* on speed of limb movement, reaction time, and the ability to sustain attention.

Most published studies with regard to the effects of *Rhodiola rosea* on physical performance relate to the effects of short-term intake (60–600 mg/d for 2 weeks to several months). However, the acute effects of *Rhodiola rosea* intake have remained largely unexplored. Therefore, the secondary aim of this study was to compare the acute and 4-week (200 mg/d for 4 weeks) effects of *Rhodiola rosea* intake.

Methods

Subjects

After they were informed in detail of all the experimental procedures to be undertaken, 24 healthy and physically active male ($n = 12$, 21.8 ± 0.3 year, 72.3 ± 2.4 kg) and female ($n = 12$, 20.2 ± 0.3 year, 59.4 ± 1.5 kg) students gave their written

informed consent. Exclusion criteria on admission were: (a) intake of any nutritional supplement within a period of 6 months prior to the start of the study, (b) consistent intake of any medication with the exception of oral contraceptives in the female subjects, and (c) any medical condition that might contra-indicate for endurance and/or strength exercise testing. Furthermore, subjects were asked to abstain from any medication during the period of the study and to avoid changes in their diet or level of physical activity. The Ethics Committee of the Faculty of Medicine of the K.U.Leuven approved the study protocol.

Study Protocol

The study consisted of two phases, with a 5-day washout period in between. Two weeks prior to the start of Phase I, the subjects reported to the laboratory to become familiar with the test procedures to be undertaken.

Phase I aimed to evaluate the acute effects of *Rhodiola rosea* intake on endurance exercise capacity, muscle strength, speed of limb movement, reaction time, and the ability to sustain attention. Therefore, a double-blind placebo-controlled crossover study ($n = 24$) was performed, which consisted of 2 experimental sessions (2 days per session) interspersed by a 5-day washout period. From the evening (10:00 PM) before the experiments until the end of each session, the subjects were asked not to consume alcohol- or caffeine-containing beverages. However, they were, in each phase of the study, not compelled to be fasted at commencement of the tests. The subjects reported to the laboratory between 7:30 AM and 15:30 PM to participate in the first session (day 1). Upon arrival, they were weighed and subsequently randomly assigned to either of two experimental groups (placebo vs. *Rhodiola rosea*). Subjects ingested two capsules containing either 350 mg starch (Placebo, P; male: $n = 6$, female: $n = 6$) or 100 mg of a *Rhodiola rosea* extract containing 3% rosavin and 1% salidroside (Finzelberg GmbH, Andernach, Germany) plus 250 mg starch (R; male: $n = 6$, female: $n = 6$). They were seated in a semi-supine position in a comfortable chair for a 1-hr period needed to obtain full intestinal absorption (7). Thereafter, speed of limb movement (test duration: ~15 min), reaction time (test duration: ~15 min), and the ability to sustain attention (test duration: ~30 min) were measured in this order and with no rest interval in between. On the next day (day 2), the subjects returned to the laboratory and received capsules according to the same procedure and time schedule as for day 1. After a 1-hr rest period, maximal isometric muscle strength (test duration: ~15 min) and endurance exercise capacity (test duration: ~30 min) were assessed. Following a 5-day washout period, the entire experimental procedure was repeated, with the treatment regimens being switched between the groups (experimental session 2).

Phase II aimed to evaluate the effects of 4-week *Rhodiola rosea* intake. Following a 5-day washout period after Phase I, a double-blind placebo-controlled study ($n = 12$) was performed over a 4-week period. Based upon the measurements of Phase I, subjects were assigned to either P ($n = 12$) or R ($n = 12$), with similar distributions for gender, endurance exercise capacity, maximal isometric muscle strength, and speed of limb movement. Subjects underwent two more experimental sessions (sessions 3 and 4), separated by a 4-week P/R supplementation period during which subjects ingested a P (350 mg starch) or R (100 mg *Rhodiola rosea* extract) capsule twice a day (9:00 AM and 2:00 PM). Experimental sessions 3 and 4

were identical to Phase I, which means that subjects received an acute P/R dose 1 hour before the start of each test series.

Tests during sessions 1 to 4 were performed at the same time of day and by the same investigator.

Experimental Procedures

Endurance Exercise Capacity. The exercise test was performed in an air-conditioned laboratory, with air temperature maintained at 19 °C. Endurance capacity was assessed using an incremental test on an electromagnetically braked bicycle ergometer (Jaeger, ER900). Initial workload was set at 60 W (6 min for warming up), after which workload was increased by 20 W/min until volitional exhaustion. During the test, pulmonary ventilation (V_e , L/min), oxygen uptake ($\dot{V}O_2$, ml/min/kg), and CO_2 output ($\dot{V}CO_2$, ml/min/kg) were continuously measured using a breath-by-breath ergospirometry system (Jaeger, Oxycon Alpha), which was calibrated prior to each experiment using gas mixtures of known composition. Throughout the test, cadence was fixed at 70–80 rpm. Blood lactate concentration was measured on capillary blood sampled from a hyperaemic (Forapin,) earlobe before the test, at min 10 and exactly 2 min after the point of volitional exhaustion. During the test, heart rate was continuously registered (Polar, Finland).

Muscle Strength. Maximal isometric knee-extension torque was assessed on an isokinetic dynamometer (Technogym,) that was instrumented with a torque transducer. After a 5-min standardized warm-up, the subjects performed three voluntary maximal isometric knee-extensions (3 s), interspersed by 1-min rest intervals, at a knee-angle of 60°. Maximal isometric torque (Nm) was calculated from the smoothed curve of the static torque. The better of 3 attempts was taken as the test result.

Speed of Limb Movement. The plate-tapping test aimed to evaluate the speed of repeated arm movement during a well-defined, semi-precise task. Subjects were requested to touch two 20-cm rubber discs alternately with the preferred hand as fast as possible, completing 25 full cycles. The discs were 80 cm apart (Eurofit test battery for physical fitness; 22). The test was performed twice with a 5-min rest interval in between, with the dominant hand and in the standing position. The time needed to complete 25 full cycles was recorded. The better of two attempts was taken as the test result.

Reaction Time. Subjects were seated in an isolated, quiet room in front of a computer display, with only the investigator being present. Limb reaction times for a simple auditory (buzzer) and visual (a white block presented on the middle of a computer screen) stimulus were measured. Stimulus exposure endured until subjects tapped a press button (space bar). The inter-stimulus interval was randomly varied from 2.5 to 4 s. Thirty stimuli were given. To exclude guessing, reaction times below 120 ms were omitted. Reaction time was measured as the average of the 10 fastest responses.

Sustained Attention. Subjects were seated in an isolated quiet room in front of a computer display. In order not to distract the subject, the investigator left the room. Subjects were asked to engage in a decision process based on sparse information about the stimulus. Every 4 s, a noise (XXXXXXX) or signal (one X was replaced by an A) stimulus was randomly presented for a very short duration until subjects completed 450 stimuli (8). The subjects were stepwise adapted to the stimulus

(training phase). Starting with stimulus duration of 1000 ms, the stimulus duration was decreased in steps of 200 ms less, until duration of 400 ms was reached. After the training phase, the stimulus duration in the actual test was set to be 100 ms. Sustained attention was expressed as d' , which expresses the ability of a subject to discriminate between noise and signal during the course of the test.

Statistical Analysis

There were no dropouts during Phase I. However, during Phase II, 1 male subject enrolled in R was excluded from the study for medical reasons not related to the study protocol. This subject was excluded from the statistical analysis of Phase II data.

Data were analyzed using Statistica® software (Statsoft Inc., Tulsa, OK, USA). Phase I data were analyzed using a paired t test. Phase II data were analyzed using a 2×2 (group [placebo, *Rhodiola rosea*] \times time [pre, post]) repeated measures ANOVA. When appropriate, Tukey's post hoc tests were applied. All data are presented as means \pm SE. A probability level of less than .05 was chosen as the threshold for acceptance of statistical significance.

Results

Experimental Parameters

Endurance Capacity (Table 1). Compared with P, acute R intake in Phase I increased ($p < .05$) time to exhaustion by 24 s on average. Accordingly, $VO_{2\text{peak}}$ and $VCO_{2\text{peak}}$ were ~5% higher ($p < .05$), whereas pulmonary ventilation tended to be higher ($p = .07$) during R than during P. Blood lactate values and heart rates were similar between conditions. During Phase II, which involved 4 weeks of P/R intake in between the pre- and posttest, blood lactate values before starting the exercise protocol were significantly lower in subjects who had been taking R. Other parameters remained unchanged.

Muscle Strength (Table 2). Compared with P, maximal isometric muscle strength was significantly changed neither by acute (Phase I) nor by 4-week R intake (Phase II).

Speed of Limb Movement (Table 2). Compared with P, plate tapping performance was similar in R both after acute (Phase I) and after 4-week (Phase II) intake.

Reaction Time (Table 2). Both visual and aural reaction time remained stable during Phase I and Phase II.

Sustained Attention (Table 2). Results for the sustained attention test were not different between P and R at any time in the study.

Compliance, Treatment Identification, Adverse Side Effects, and Body Weight

Compliance. To ensure compliance, subjects were asked to return the unused Phase II capsules. None of the subjects returned any capsules.

Treatment Identification. At the end of each phase, the subjects were asked whether they had any notion of the treatment received. At the end of Phase I (session

Table 1 Endurance Exercise Performance Following Acute and 4-Week Rhodiola Rosea Intake

| Variable | Phase 1 | Phase 2 | |
|--|--------------------------|--------------|------------------------|
| | | Pre | Post |
| Volitional exhaustion (min) | | | |
| Placebo | 16.8 ± 0.7 | 17.7 ± 1.0 | 17.6 ± 1.0 |
| Rhodiola rosea | 17.2 ± 0.8* | 17.1 ± 1.4 | 17.0 ± 1.4 |
| Pulmonary ventilation (L · min ⁻¹) | | | |
| Placebo | 115.9 ± 7.7 | 134.7 ± 13.3 | 128.8 ± 12.9 |
| Rhodiola rosea | 124.8 ± 7.7 [†] | 118.6 ± 11.2 | 121.6 ± 12.6 |
| Peak O ₂ uptake (ml · min ⁻¹ ◇ kg ⁻¹) | | | |
| Placebo | 50.9 ± 1.8 | 57.8 ± 3.3 | 57.0 ± 3.3 |
| Rhodiola rosea | 52.9 ± 2.7* | 54.5 ± 3.1 | 53.9 ± 3.5 |
| Peak CO ₂ output (ml · min ⁻¹ · kg ⁻¹) | | | |
| Placebo | 60.0 ± 2.3 | 68.5 ± 4.0 | 66.6 ± 4.4 |
| Rhodiola rosea | 63.5 ± 2.7* | 62.1 ± 3.6 | 60.3 ± 4.5 |
| Blood lactate (mmol · L ⁻¹) | | | |
| Placebo | | | |
| Start | 0.8 ± 0.1 | 1.9 ± 0.1 | 1.5 ± 0.2 [‡] |
| 10 min | 2.0 ± 0.2 | 2.3 ± 0.2 | 2.3 ± 0.4 |
| 2 after exhaustion | 7.7 ± 0.3 | 7.8 ± 0.6 | 8.4 ± 0.5 |
| Rhodiola rosea | | | |
| Start | 0.9 ± 0.1 | 1.8 ± 0.1 | 1.0 ± 0.1 |
| 10 min | 1.8 ± 0.2 | 2.2 ± 0.1 | 1.7 ± 0.3 |
| 2 after exhaustion | 7.8 ± 0.4 | 7.1 ± 0.6 | 6.6 ± 0.5 |
| Heart rate (beats · min ⁻¹) | | | |
| Placebo | | | |
| Start | 67 ± 2 | 65 ± 3 | 61 ± 3 |
| 6 min | 104 ± 3 | 101 ± 4 | 100 ± 5 |
| 10 min | 136 ± 5 | 138 ± 7 | 134 ± 6 |
| Exhaustion | 185 ± 2 | 187 ± 3 | 187 ± 3 |
| Rhodiola rosea | | | |
| Start | 65 ± 3 | 65 ± 4 | 65 ± 5 |
| 6 min | 98 ± 3* | 103 ± 5 | 103 ± 5 |
| 10 min | 134 ± 2 | 136 ± 7 | 141 ± 8 |
| Exhaustion | 186 ± 2 | 184 ± 4 | 187 ± 3 |

Note. Data are means ± SE. (phase 1: $n = 24$; phase 2: P, $n = 12$ and R, $n = 11$). Following acute (phase 1) and before (Pre) and after (Post) 4-week (phase 2) placebo or Rhodiola rosea intake, subjects were engaged in an endurance exercise test. Initial workload was set at 60 W (6-min warm-up) after which workload was increased by 20 W/min until volitional exhaustion (min). Throughout the test, cadence was fixed at 70–80 rpm. See the Methods section for further details. * $p < .05$ compared to the corresponding placebo value. [†] $p = .07$ compared to the corresponding placebo value. [‡] $p < .05$ compared to the corresponding pre value.

Table 2 Speed of Limb Movement, Reaction Time, Sustained Attention, and Maximal Isometric Muscle Strength Following Acute and 4-Week *Rhodiola rosea* Intake

| Variable | Phase 1 | Phase 2 | |
|--|-------------|-------------|-------------|
| | | Pre | Post |
| Speed of limb movement (s) | | | |
| Placebo | 10.4 ± 2.4 | 10.0 ± 2.9 | 9.7 ± 1.9 |
| <i>Rhodiola rosea</i> | 10.2 ± 2.2 | 9.8 ± 3.0 | 9.7 ± 2.4 |
| Aural reaction time (ms) | | | |
| Placebo | 191 ± 3 | 185 ± 5 | 185 ± 5 |
| <i>Rhodiola rosea</i> | 190 ± 3 | 186 ± 6 | 189 ± 4 |
| Visual reaction time (ms) | | | |
| Placebo | 207 ± 3 | 197 ± 5 | 196 ± 6 |
| <i>Rhodiola rosea</i> | 209 ± 3 | 197 ± 7 | 204 ± 6 |
| Sustained attention (d') | | | |
| Placebo | 4.00 ± 0.29 | 4.24 ± 0.29 | 4.23 ± 0.34 |
| <i>Rhodiola rosea</i> | 3.94 ± 0.18 | 3.82 ± 0.28 | 4.25 ± 0.38 |
| Maximal isometric muscle strength (Nm) | | | |
| Placebo | 202 ± 11 | 204 ± 18 | 213 ± 19 |
| <i>Rhodiola rosea</i> | 204 ± 12 | 204 ± 20 | 209 ± 23 |

Note. Data are means ± *SE* (phase 1: $n = 24$; phase 2: P, $n = 12$ and R, $n = 11$) and are expressed in ms. Following acute (phase 1) and before (Pre) and after (Post) 4-week (phase 2) placebo or *Rhodiola rosea* intake, speed of limb movement (plate tapping test), aural (buzzer) and visual (a white block presented on a computer screen) reaction time, sustained attention (FePsy Vigilance Test), and maximal isometric force (knee-extension) were assessed. See the Methods section for further details.

2), 21 subjects responded that they were unsure about the treatment they received in the last experimental session, 2 erroneously answered to have taken P, and 1 correctly answered to have received R. During Phase II, 6 subjects reported to be unsure, 10 reported to have taken P (3 correct answers), and 8 reported to have taken R (5 correct answers) capsules. Thus, the fraction of correct treatment identifications was not significantly different from random assignment.

Adverse Side Effects. After each experimental session, subjects were asked as to whether they noticed any side effects that may be related to the intake of *Rhodiola rosea*. During Phase I, following placebo intake, 1 subject experienced strong headaches. No side effects were reported for the R treatment. During Phase II, 1 subject experienced some minor headaches during P treatment. During R, 1 subject suffered from moderate headaches, whilst another complained of insomnia.

Body Weight. There were no significant changes for body weight throughout the study. In the total group of subjects, body weights were 66.2 ± 2.0 kg (session 1), 66.1 ± 1.9 kg (session 2), 66.1 ± 2.0 kg (session 3), and 66.1 ± 2.0 kg (session 4).

Discussion

The aim of the present study was to evaluate the effects of acute and 4-week *Rhodiola rosea* intake on endurance exercise capacity, muscle strength, speed of limb movement, reaction time, and the ability to sustain attention. The primary finding is that acute *Rhodiola rosea* intake (200 mg) increased endurance capacity during an incremental exercise test to volitional exhaustion on a bicycle ergometer. Time to exhaustion on average increased by ~3% (range, -3.2% to +9.7%), and this was accompanied by a similar increase of oxygen uptake and CO₂ output rate at peak exercise (~exhaustion). However, peak lactate concentration was not different between experimental conditions.

It is tempting to speculate about the possible physiological mechanism underlying the beneficial effect of acute *Rhodiola rosea* intake on endurance exercise capacity. The supplement used in the current study, notably *Rhodiola rosea*, contains a high fraction of the phenylpropanoid rosavin and the phenylethanol salidroside (9, 13, 24). These molecules are believed to be the “active” compounds of the plant extract by their presumed ability to stimulate the synthesis, transport, and receptor activity of monoamines (16, 27), and opioid receptors and peptides such as β -endorphins (10, 16; for reviews see 5, 10). It is well known that high intensity endurance exercise often is associated with discomfort and pain (6, 20). Hence, one’s ability to perform exhaustive exercise at least partly depends on tolerance to pain and discomfort. It has been repeatedly shown that the endogenous opioid system is involved in the modulation of pain tolerance (11). Accordingly, opioid antagonism by the administration of naloxone not only resulted in markedly impaired endurance exercise capacity (19, 25) but, in addition, also abolished the favorable effect of *Rhodiola rosea* intake on heart contractility (15). However, since research trying to elucidate the underlying mechanisms that explain the effects of *Rhodiola rosea* intake is scarce and very fragmentary (16), it remains to be investigated whether the rosavin and salidroside content in *Rhodiola rosea* extract truly can stimulate endorphin action during exercise, either by enhancing endorphin secretion or by increasing sensitivity of the central nervous system to endorphins. Contrary to its effect on endurance, *Rhodiola rosea* intake did not impact on muscle strength. This is compatible with the fact that stimulation of endorphin secretion is not a factor to impact on performance during a very short maximal effort (3 s), such as the assessment of maximal isometric muscle force on an isokinetic dynamometer as used in the present study.

Most CNS stimulants such as caffeine and amphetamines lead to a temporary effect that fades upon repeated intake (1, 17). Accordingly, 4 weeks of *Rhodiola rosea* administration at a rate of 200 mg/d clearly did not alter the ergogenic effect of acute *Rhodiola rosea* intake.

There are some literature data to indicate that *Rhodiola rosea* intake reduces non-specific fatigue and improves mental work capacity assessed through a series of self-evaluation tests evaluating mood, mental discomfort, need for sleep and sleep pattern (26), and an extensive test battery evaluating aural and visual short-term memory (7), respectively. However, for any of these studies, the reproducibility

and validity of the tests used is unclear. In the present study, aural and visual reaction time, speed of limb movement and the ability to sustain attention were measured using well validated tests such as the plate-tapping test contained in the Eurofit test battery for physical fitness (22) and the Fepsy Vigilance test (3, 21). However, neither acute nor 4-week *Rhodiola* intake beneficially impacted on either performance in the plate-tapping test, aural and visual reaction time, or the Fepsy Vigilance test. Thus, in the conditions of the current study, *Rhodiola* intake clearly did not improve vigilance or mental alertness.

It is concluded that acute *Rhodiola rosea* intake (200 mg) can improve endurance exercise capacity in young healthy volunteers. This response was not altered by prior daily 4-week *Rhodiola* intake.

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