

Effects of One Week Juice Fasting on Lipid Metabolism: A Cohort Study in Healthy Subjects

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Key Words

Fasting · Vegetable juices · Cholesterol · Nonesterified fatty acids · Lipoproteins · Insulin

Summary

Objective: We investigated the effects of a popular modified juice fasting program on lipid metabolism. **Volunteers and Methods:** 5 healthy, nonobese, male volunteers fasted for 8 days. Daily energy intake was limited to 150–300 kcal/d solely as carbohydrates (vegetable and fruit drinks). Physical activity was maintained as before. At baseline, on days 2, 3, and 8 during fasting, and on days 2 and 8 after fasting, serum lipids, lipoproteins, and insulin were investigated. **Results:** Juice fasting resulted in bi-phasic changes: Until day 2 and 3 triacylglycerols (TG), very low-density lipoprotein apolipoprotein B (VLDL apo B), and insulin decreased by 52, 51, and 65% respectively, while nonesterified fatty acids (NEFA), low-density lipoprotein (LDL) apo B, and LDL cholesterol increased by 363, 38, and 35%. Between day 3 and 8 NEFA increased; TG and insulin increased as well, but remained below baseline values, and LDL cholesterol normalized. After 8 days juice fasting significant changes ($p < 0.05$) compared to the baseline were found only for free cholesterol (–10%), phospholipids (–14%), apo AI (–9%), apo AII (–11%), insulin (–42%), C-peptide (–57%), and NEFA (+535%, $p = 0.0001$). Total cholesterol decreased by 9% (n.s.) after 8 days. One week after the ending of fasting all parameters returned to normal. **Conclusion:** Contrary to total fasting and fasting with limited physical activity, 8 days juice fasting without limitation of physical activity results in a decrease of free cholesterol and an only initial increase of LDL cholesterol. After 8 days insulin, TG, and VLDL are still lower than at baseline, however, they have increased compared to the initial phase, probably counterregulatory to a further increase of NEFA.

Schlüsselwörter

Fasten · Gemüsesäfte · Cholesterin · Nicht veresterte Fettsäuren · Lipoproteine · Insulin

Zusammenfassung

Fragestellung: Wir untersuchten die Effekte eines bekannten Saft-Fastenprogrammes auf den Fettstoffwechsel. **Probanden und Methode:** 5 männliche, normalgewichtige Freiwillige fasteten 8 Tage. Die Energiezufuhr war auf 150–300 kcal pro Tag ausschliesslich in Form von Kohlenhydraten (Gemüse- und Obstsaften) beschränkt. Die körperliche Aktivität wurde wie vorher beibehalten. Am Beginn des Fastens, an den Tagen 2, 3 und 8 während des Fastens und an den Tagen 2 und 8 nach dem Fasten wurden Serumlipide, Lipoproteine und Insulin untersucht. **Ergebnisse:** Das Saft-Fasten führte zu biphasischen Veränderungen: Bis Tag 2 und 3 nahmen Triacylglyceride (TG), Apolipoprotein B (Apo B) der VLDL (very low-density lipoproteins) und Insulin um 52, 51 bzw. 65% ab ($p < 0,01$), während unveresterte Fettsäuren (NEFA), Apo B der LDL (low-density lipoproteins) und LDL-Cholesterin um 363, 38 bzw. 35% anstiegen ($p < 0,05$). Zwischen Tag 3 und 8 stiegen die NEFA weiter an, TG und Insulin stiegen ebenfalls an, blieben aber unterhalb des Ausgangswertes, und LDL-Cholesterin normalisierte sich. Nach 8 Tagen Saft-Fasten wurden signifikante ($p < 0,05$) Veränderungen im Vergleich zum Ausgangswert lediglich für freies Cholesterin (–10%), Phospholipide (–14%), Apo AI (–9%), Apo AII (–11%), Insulin (–42%) und C-Peptid (–57%) sowie für NEFA (+535%, $p = 0,0001$) gefunden. Das Gesamtcholesterin war nach 8 Tagen um 9% (n.s.) abgefallen. Eine Woche nach Beendigung des Fastens hatten sich alle Parameter normalisiert. **Schlussfolgerung:** Im Gegensatz zu totalem Fasten und Fasten mit limitierter körperlicher Aktivität führt 8 Tage Saft-Fasten ohne Limitation der körperlichen Aktivität zu einer Abnahme des freien Cholesterins und nur zu einem vorübergehenden Anstieg von LDL-Cholesterin. Nach 8 Tagen liegen Insulin, TG und VLDL unter dem Ausgangswert, sind aber, verglichen mit der initialen Phase, angestiegen, was wahrscheinlich auf eine Gegenregulation gegen den weiteren Anstieg der NEFA zurückgeführt werden kann.

Introduction

Fasting as voluntary abstention from food has a long tradition in different religions and is nowadays popular as part of a healthy lifestyle, for self-awareness, prevention of cardiovascular diseases, and for weight reduction. However, controlled studies which prove beneficial long-term effects on body weight or the cardiovascular risk profile are lacking; even the short-term effects of fasting on important risk factors such as low-density lipoprotein (LDL) cholesterol and total cholesterol (TC) are discussed controversially, although the physiological changes of lipid and protein metabolism are well known in principle.

Fasting results in an increase of nonesterified fatty acids (NEFA) and ketone bodies as source of energy because glycogen stores are limited [1–3]. Due to lipolysis and a decreased LDL cholesterol uptake by the liver, serum LDL cholesterol increases during one week of total fasting by about 66% [4]. Conflicting data have been reported regarding the effects of prolonged fasting on TC [4–8] and triacylglycerols (TG) [8–12]. Sävendahl and Underwood [4] convincingly demonstrated that during total fasting for 8 days in nonobese healthy adults who were limited in physical activity TC increased by about 37%. Other authors [6–8] reported no change or a decrease of TC during subtotal fasting. TG did not change [4, 11] or changed in relation to pre-fasting values [8, 9] during the first week of fasting, but decreased after 2 and 3 weeks [11, 12]. Low caloric intake as carbohydrates combined with prolonged physical exercise, however, resulted in a 30–40% reduction of TG as well as TC [13].

Five members of our team at the Freiburg University Hospital wanted to experience a juice fasting program modified according to Buchinger, which is popular in Germany [14–16]. This program allows the intake of carbohydrates as vegetable and fruit drinks. On the background of the controversial reports we wanted to sophisticatedly investigate the changes of lipids and lipoproteins and classify the effects of this fasting program. In order to reflect the conditions of ambulatory fasting we performed fasting during daily life.

Volunteers and Methods

Five healthy, male volunteers participated in the study. Their age and body mass index are given in table 1. Fasting for 8 days (180 h) was standardized with a daily intake of 150–300 kcal as carbohydrates (solely vegetable or fruit drinks). The intake of water was unlimited. Normal daily activity was maintained as before fasting, but extreme physical exercise was avoided. Before and after fasting a normal mixed diet (>1,800 kcal) was taken. Blood tests were performed at baseline (following night fasting), on days 2 (36 h), 3 (60 h), and 8 (180 h) after start of fasting and on days 2 and 8 (over night fasting) after fasting was finished. All blood samples were obtained between 8.00 and 8.30 in the morning with the volunteers at rest for about 10 min.

Table 1. Characteristics of the 5 volunteers

	Age, years	Body mass index	Weight, kg	Weight loss, kg
Mean	38.2	23.1	73.4	4.3
Maximum	41	23.7	84.7	5.7
Minimum	29	22.2	70.5	2.8

Laboratory Methods

TC, free cholesterol (FC), TG, phospholipids (PL), and high-density lipoprotein (HDL) cholesterol were measured using enzymatic methods and reagents from Wako (Neuss, Germany). The measurements were performed on a Wako 30R automatic analyzer and were calibrated using secondary standards from Roche Diagnostics (Mannheim, Germany). Esterified cholesterol was calculated as the difference between TC and FC. Apolipoproteins were measured by turbidimetry using reagents and standards from Greiner Biochemica (Flacht, Germany).

The determination of the LDL cholesterol fractions was performed by a combined ultracentrifugation precipitation method (β -quantification) [17, 18]. Very low-density lipoproteins (VLDL) were removed quantitatively by ultracentrifugation using a TFT 56.6 rotor (Kontron, Germany) with adapters for 0.8 ml polycarbonate tubes. 500 μ l plasma was pipetted into the tubes and 0.1 ml of 0.9% NaCl solution was layered on top of the plasma. After centrifugation (18 h, 30,000 rpm, 10 °C) the floated VLDL fraction was aspirated until the supernatant was completely clear. The volume was reconstituted to the original weight with 0.9% saline. LDL were precipitated in the infranant using phosphotungstic acid/MgCl₂ (PTA, Roche, Mannheim, Germany). HDL lipids were measured in the supernatant after precipitation. Lipids in the LDL fraction were calculated as the difference between the concentrations in the density fraction $d > 1.006$ kg/l and the HDL fraction.

Statistical Analysis

For each parameter a univariate repeated measurements ANOVA was fitted to the data. Dunnett tests were used to test the hypothesis of mean changes from baseline [19]. Thus, all tests are multiply adjusted for an overall significance level of 5%.

Results

All subjects completed the whole fasting and follow-up period. The mean weight loss was 4.3 kg. Ketone bodies in urine were present in 4 subjects during days 2 to 8 and in one subject during days 5 and 8 only. The effects on lipids, lipoproteins and insulin are shown in tables 2 and 3. After 180 h TC decreased by 9% (n.s.), FC by 10% ($p < 0.05$), VLDL FC by 41% ($p < 0.01$), TG by 27% (n.s.), VLDL TG by 36% ($p = 0.05$), PL by 14% ($p < 0.01$), apo AI by 9% ($p < 0.05$), apo AII by 11% ($p < 0.05$), insulin by 42% ($p < 0.05$) and C-peptide by 57% ($p < 0.0001$), while NEFA increased by 535% ($p = 0.0001$). After 60 h the decrease of TG (52%, $p < 0.01$) was more pronounced than after 180 h. TG fell in all subjects and decreased more in subjects with higher pre-fasting values. After 36 and 60 h the increase of LDL cholesterol was 35% ($p < 0.05$), of LDL apo B 38% ($p < 0.05$), while VLDL apo B decreased by 51% ($p < 0.01$) and insulin by 65% ($p < 0.01$).

Table 2. Mean \pm standard deviation of different parameters of the lipid metabolism

Parameter	Baseline	Fasting			Follow-up	
		36 h	60 h	180 h	48 h	168 h
Cholesterol, mg/dl	199 \pm 35	202 \pm 35	190 \pm 34	183 \pm 44	181 \pm 31	209 \pm 45
Triacylglycerols, mg/dl	110 \pm 42	62 \pm 28	49 \pm 16	76 \pm 37	93 \pm 31	110 \pm 34
Phospholipids, mg/dl	254 \pm 45	228 \pm 32	215 \pm 28	220 \pm 48	243 \pm 31	270 \pm 49
NEFA, mmol/l	0.4 \pm 0.4	0.9 \pm 0.4	0.9 \pm 0.2	1.2 \pm 0.2	0.3 \pm 0.1	0.3 \pm 0.1
Glycerin, mg/dl	1.5 \pm 0.6	1.7 \pm 0.5	1.7 \pm 0.4	1.8 \pm 0.2	1.1 \pm 0.2	1.4 \pm 0.3
Apo AI, mg/dl	168 \pm 18	166 \pm 16	156 \pm 13	153 \pm 17	160 \pm 13	178 \pm 23
Apo AII, mg/dl	58 \pm 10	58 \pm 8	55 \pm 8	52 \pm 10	54 \pm 7	60 \pm 11
Apo B, mg/dl	88 \pm 26	89 \pm 25	83 \pm 26	80 \pm 26	79 \pm 21	93 \pm 31
Insulin, mU/ml	6.2 \pm 1.7	3.8 \pm 0.8	1.8 \pm 0.6	3.3 \pm 1.6	4.5 \pm 1.2	6.4 \pm 1.4
C-peptide, ng/ml	1.4 \pm 0.2	0.9 \pm 0.2	0.5 \pm 0.1	0.6 \pm 0.2	1.1 \pm 0.4	1.3 \pm 0.2
Glucose, mmol/l	4.8 \pm 0.7	5.0 \pm 0.4	4.7 \pm 0.3	4.7 \pm 0.9	5.0 \pm 0.5	5.2 \pm 0.5
Insulin sensitivity ¹	1.3 \pm 0.4	0.8 \pm 0.2	0.3 \pm 0.1	0.7 \pm 0.4	1.0 \pm 0.3	1.2 \pm 0.6

¹Obtained by the formula: $20 \times \text{insulin (mU/ml)} / \text{glucose (mmol/l)} - 3.5$.

Table 3. Mean \pm standard deviation of lipoproteins

Parameter, mg/dl	Baseline	Fasting			Follow-up	
		36 h	60 h	180 h	48 h	168 h
VLDL cholesterol	60 \pm 27	26 \pm 8	25 \pm 9	41 \pm 11	45 \pm 13	58 \pm 12
VLDL triacylglycerols	75 \pm 34	30 \pm 18	22 \pm 9	44 \pm 30	56 \pm 23	72 \pm 22
VLDL apo B	32 \pm 17	13 \pm 6	15 \pm 4	23 \pm 5	23 \pm 6	30 \pm 9
LDL cholesterol	84 \pm 16	112 \pm 25	104 \pm 33	83 \pm 34	78 \pm 31	88 \pm 34
LDL apo B	56 \pm 14	76 \pm 19	68 \pm 24	57 \pm 24	55 \pm 22	63 \pm 27
HDL cholesterol	56 \pm 7	64 \pm 10	61 \pm 11	60 \pm 9	58 \pm 6	63 \pm 12
HDL triacylglycerols	20 \pm 5	16 \pm 4	14 \pm 3	17 \pm 5	20 \pm 4	23 \pm 6

The composition of VLDL changed during fasting. After 60 as well as after 180 h they had reduced amounts of TG, compared to other components. The composition of LDL did not change.

One week after the ending of fasting all parameters were at baseline levels or slightly higher.

Discussion

We investigated the impact of a modified juice fasting program, which is popular in Germany, on lipid metabolism. The subjects fasted at work, during their normal daily life and were not limited in physical activity except for extreme exercises. 8 days of modified Buchinger fasting resulted in a mean weight loss of 4.3 kg, decrease of insulin and C-peptide, and a strong increase of NEFA. As expected, the mean weight loss during Buchinger fasting was lower than during 8 days of total fasting in nonobese healthy subjects (5.5 kg), as reported by Säven-dahl and Underwood [4].

In our study maximum increase of LDL cholesterol and LDL apo B occurred after 36 and 60 h fasting and was parallel to

the maximum decrease of TG and absolute number of VLDL, represented by VLDL apo B. Insulin and C-peptide fell parallel to the TG and VLDL apo B. These changes during the initial fasting period can be explained by the processing of TG to NEFA, an insulin-dependent up-regulation of the lipoprotein lipase (LPL) activity which stimulates the transformation of VLDL to LDL [20, 21] and, also due to decreased insulin, a down-regulation of the hepatic LDL receptor which reduces the uptake of LDL in the liver [22–24].

During prolonged fasting, between 36/60 and 180 h, TG and VLDL apo B increased and LDL cholesterol and LDL apo B, representing the absolute number of LDL, returned to baseline levels. In contrast, NEFA continued to rise. Insulin secretion and insulin sensitivity increased parallel. These changes during prolonged fasting can be explained by re-esterification of NEFA to TG [25], a supposed stimulation of insulin secretion by increasing NEFA [2, 25–27], a down-regulated activity of the LPL and an up-regulation of the hepatic LDL receptor due to increasing insulin levels.

The hypothesis that increasing NEFA caused an increase in insulin secretion is supported by an analysis of individual courses (fig. 1): The subject with the lowest increase in NEFA

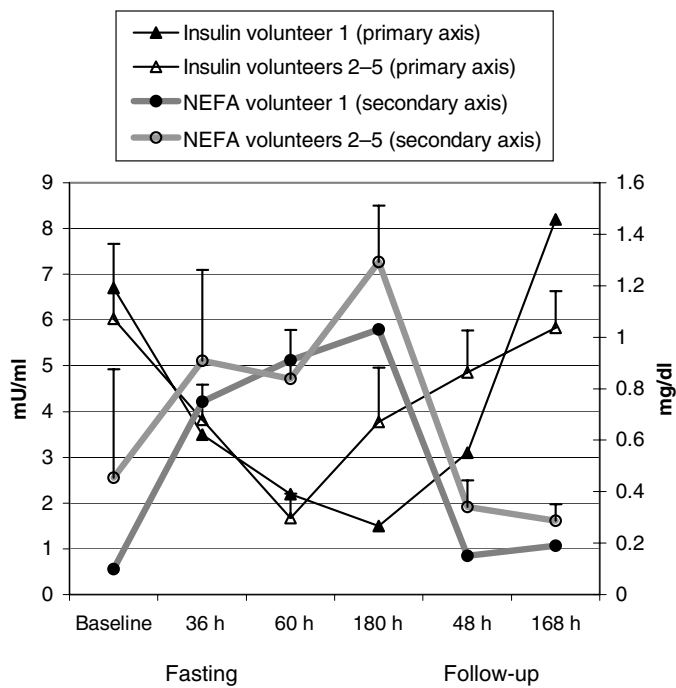


Fig. 1. Courses of insulin and NEFA of the volunteer with the lowest increase of NEFA during fasting compared to the mean \pm standard deviation of the 4 other volunteers before, during and after 180 h juice fasting.

(1.0 mg/dl at 180 h, range of the other 4 volunteers from 1.1–1.7 mg/dl at 180 h) is the only one with a further decrease of the insulin level between 60 and 180 h. The 4 other volunteers with higher NEFA levels had increasing insulin levels between 60 and 180 h. In addition this subject had the lowest increase of TG (10%) between 60 and 180 h (range of the 4 other volunteers from 38 to 114%).

Healthy subjects who underwent total fasting and were limited in physical activity [4] showed, in contrast to our results, a continued rise of TC, LDL cholesterol, and apo B until day 8. The course of NEFA, TG, and insulin in this investigation is not reported. It might be possible that our volunteers, who had an energy intake of 150–300 kcal/d and were not limited in physical activity, had a minor decrease of insulin levels during fasting and reacted more sensitively to an increase in NEFA with a counterregulatory increase in insulin. It can be concluded that the amount of calorie intake and the physical activity during fasting are crucial for the effects on the lipid metabolism, because total fasting or total fasting with limitation of physical activity has different and in part even opposite effects than a modified Buchinger fasting.

Our results are in agreement with other studies [6, 8, 28] that report no change or a moderate decrease of total cholesterol during subtotal fasting without limitation of physical activity.

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