

Calculations of 24-Hour Respiratory Quotient and Energy Expenditure from Gas Exchanges Measurements in a Whole-Room Indirect Calorimeter

The ratio between the average CO₂ production (VCO₂) and the average O₂ consumption (VO₂) calculated over 24 hours is defined as the respiratory quotient (RQ):

$$RQ = VCO_2/VO_2.$$

The energy production rate (energy expenditure or EE) is calculated based on VO₂ and RQ values using Lusk's equation as follows:

$$EE = VO_2 \times [4.686 + (RQ - 0.707) \times 0.361/0.293],$$

where 4.686 is the caloric equivalent of 1 L of O₂ when the RQ is 0.707; 0.707 is the RQ when fat is oxidized; 0.293 is the difference between the RQ for carbohydrate oxidation and fat oxidation; 0.361 is the difference in the caloric equivalent of 1 L O₂ between an RQ=1.000 and an RQ=0.707 (=5.047-4.686 kcal/L O₂).

Examples of Food Items During Each Dietary Intervention

ENERGY BALANCE Diet (2000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
Breakfast			390.4	21.35	39.54	16.25	259
Borden's Lite-Line cheese	15	Gram	27.32	3.11	0.8	1.55	15
Egg, egg, large, raw	100	Gram	158	12.2	1.2	11.2	100
Tortilla, flour, soft taco, mission foods	50	Gram	157.78	5.28	26.28	3.5	50
Orange juice, 3/1 concentration	85	Gram	38.3	0.56	9.15	0	85
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Lunch			605.69	29.65	79.12	18.46	348
Beef	95	Gram	132.05	20.9	0	4.66	95
Rice, white, long-grain, parboiled, dry	50	Gram	185.5	3.4	40.85	0.3	50
Butter, butter, salted, solid	11	Gram	78.87	0.1	0.01	8.92	11
Bread, white, soft, enrich, slice	25	Gram	67	2.1	12.6	0.8	25
Ban, banana, peeled, fresh	40	Gram	37.27	0.45	9.36	0.18	40
Orange juice, 3/1 concentration	0	Gram	0	0	0	0	0
ld cook, Lorna Doone, cookie	14	Gram	70	1	8.8	3.4	14
Green beans	104	Gram	26	1.5	5.4	0.2	104
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Dinner			605.69	29.65	79.12	18.46	348
Beef	95	Gram	132.05	20.9	0	4.66	95
Rice, white, long-grain, parboiled	50	Gram	185.5	3.4	40.85	0.3	50
Butter, butter, salted	11	Gram	78.87	0.1	0.01	8.92	11
Bread, white, soft, enrich, slice	25	Gram	67	2.1	12.6	0.8	25
Ban, banana, peeled	40	Gram	37.27	0.45	9.36	0.18	40
Orange juice, 3/1 concentration	0	Gram	0	0	0	0	0
ld cook, Lorna Doone, cookie	14	Gram	70	1	8.8	3.4	14
Green beans	104	Gram	26	1.5	5.4	0.2	104
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Evening snack			407.33	19.63	53.31	13.28	375
Turkey, breast meat, white	60	Gram	66	13.44	0	0.84	60
Bread, white, soft, enrich, slice	50	Gram	134	4.2	25.2	1.6	50
Butter, butter, salted, solid	13	Gram	93.21	0.12	0.01	10.54	13
Peach, peaches	150	Gram	66.32	0.95	17.37	—	150
Orange juice	95	Gram	42.8	0.63	10.23	0	95
Mustard, packet	1	Each	5	0.3	0.5	0.3	7

ld cook, cook.

STANDARD OVERFEEDING Diet (4000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
			4001.22	221.37	463.97	138.27	2811
Breakfast			990.67	51.44	112.07	37.56	638
1c ch, Borden's Lite-Line cheese	45	Gram	81.96	9.32	2.41	4.66	45
Egg, egg, large, raw	200	Gram	316	24.4	2.4	22.4	200
Tortilla, flour, soft taco, mission foods	150	Gram	473.33	15.83	78.83	10.5	150
Orange juice, 3/1 concentration	225	Gram	101.37	1.48	24.23	0	225
Hot sauce, jalapeno, packet	2	Each	18	0.4	4.2	0	18
Lunch			1098.82	56.96	132.33	37.33	752
Beef	190	Gram	264.1	41.8	0	9.31	190
Rice, white, long-grain, parboiled, dry	65	Gram	241.15	4.42	53.11	0.39	65
Butter, butter, salted, solid	25	Gram	179.25	0.23	0.03	20.27	25
Bread, white, soft, enrich, slice	50	Gram	134	4.2	25.2	1.6	50
Ban, banana, peeled, fresh	55	Gram	51.25	0.63	12.88	0.25	55
Orange juice, 3/1 concentration	120	Gram	54.07	0.79	12.92	0	120
ld cook, Lorna Doone, cookie	21	Gram	105	1.5	13.2	5.1	21
Green beans	208	Gram	52	3	10.8	0.4	208
Hot sauce, jalapeno, packet	2	Each	18	0.4	4.2	0	18
Dinner			1089.82	56.76	130.23	37.33	743
Beef	190	Gram	264.1	41.8	0	9.31	190
Rice, white, long-grain, parboiled, dry	65	Gram	241.15	4.42	53.11	0.39	65
Butter, butter, salted, solid	25	Gram	179.25	0.23	0.03	20.27	25
Bread, white, soft, enrich, slice	50	Gram	134	4.2	25.2	1.6	50
Ban, banana, peeled, fresh	55	Gram	51.25	0.63	12.88	0.25	55
Orange juice, 3/1 concentration	120	Gram	54.07	0.79	12.92	0	120
Cook, Lorna Doone, cookie	21	Gram	105	1.5	13.2	5.1	21
Green beans	208	Gram	52	3	10.8	0.4	208
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Evening snack			821.92	56.21	89.33	26.06	678
Turkey, breast meat, white	200	Gram	220	44.8	0	2.8	200
Bread, white, soft, enrich, slice	100	Gram	268	8.4	50.4	3.2	100
Butter, butter, salted, solid	24	Gram	172.08	0.22	0.02	19.46	24
Peach, peaches	160	Gram	70.74	1.01	18.53	—	160
Orange juice, 3/1 concentration	180	Gram	81.1	1.19	19.38	0	180
Mustard	2	Each	10	0.6	1	0.6	14
% recommendation			1152.49	3328.93	971.92	1280.19	

1c ch, cheese.

HIGH-CARBOHYDRATE NORMAL-PROTEIN Overfeeding Diet (4000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
			4001.84	193.16	748.89	33.31	4658
Breakfast			1093.42	73.7	169.52	11.13	1214
Ham, honey, 97% fat free, Hillshire Deli Select	210	Gram	262.5	33.75	11.25	5.63	210
Egg substitute	300	Gram	147.54	29.51	4.92	0	300
Pancakes original	4	Serving	306.34	8.34	58.03	4.61	132
Syrup, pancake, packet	2	Each	131.04	0	34.42	0	56
Pineapple juice		Serving	123	0.6	29.7	0.3	216
Fruit	3	Serving	123	1.5	31.2	0.6	300
Lunch			881.63	34.45	184.76	5.01	1038
Cottage cheese, nonfat	200	Gram	131.15	21.31	11.48	0	200
Bagel, plain, Sara Lee	95	Gram	250	9	51	1	95
Jelly, 0.5 oz packet	28	Gram	74.48	0.04	19.59	0.01	28
"a" salad, garden salad and drsp pkg	1	Serving	30	0.8	6.1	0.4	100
Fruit roll ups, variety, betty cracker	3	Each	150	0	36	3	42
Fruit	3	Serving	123	1.5	31.2	0.6	300

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
Orange juice, 3/1 concentration	3	Serving	123	1.8	29.4	0	273
Dinner			1205.91	32.81	249.76	12.72	1479
b&b stew	1	Serving	240	18.5	36.1	2.7	100
Tortilla, flour, soft taco, mission foods	82	Gram	235.34	7.13	40.67	4.92	82
Green beans with pimento	2	Serving	60	3.2	12.4	0.6	228
Fruit	3	Serving	123	1.5	31.2	0.6	300
Apple juice	3	Serving	120	0.3	29.7	0.3	255
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Sherbet, orange	180	Gram	259.2	1.98	54.72	3.6	180
Soda, root beer	325	Gram	159.37	0	42.86	0	325
Evening snack			820.88	52.19	144.85	4.45	927
Bagel, plain	95	Gram	250	9	51	1	95
Turkey, breast meat, white	120	Gram	132	26.88	0	1.68	120
Cheese product, American, pasteurized processed, sliced, nonfat	56	Gram	82.88	12.71	6.55	0.56	56
Fruit	3	Serving	123	1.5	31.2	0.6	300
Grapefruit juice	3	Serving	123	1.8	29.4	0.3	321
Mustard, packet	1	Each	5	0.3	0.5	0.3	7
Jellybeans	28	Gram	105	0	26.19	0.01	28
% recommendation			119.2	6403.72	162.23	31.89	

drsp pkg, dressing package; b&b stew, beef and bean stew.

HIGH-FAT NORMAL-PROTEIN Overfeeding Diet (4000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
Breakfast			4003.16	205.3	203.97	274.6	2174
Milk, whole, 3.25%, with vitamin D	224	Gram	828.52	39.06	42.47	56.47	589
Eggs, hard boiled, lrg, ea	4	Each	316	24.4	2.4	22.4	200
Bac, bacon, cooked, crisp	4	Serving	116	6	0.04	10	20
Ban, banana, peeled, fresh	125	Gram	116.48	1.42	29.26	0.57	125
Butter, butter, salted, solid	20	Gram	143.4	0.18	0.02	16.22	20
Lunch			871.3	46.21	71.8	57.21	611
Lunchmeat, ham, honey	235	Gram	330.99	39.72	16.55	23.17	235
Bread, white, soft, enrich, slice	2	Each	140	4	28	2	56
Mayonnaise, regular, Kraft	40	Gram	285.71	0	0	31.43	40
"a" salad, garden salad and drsp pkg	1	Serving	30	0.8	6.1	0.4	100
Oranges, fresh, medium, 2 5/8" diameter	180	Gram	84.6	1.69	21.15	0.22	180
Dinner			1391.78	67.34	62.77	95.49	564
Beef patty, broiled, 20% fat	228	Gram	615.6	58.71	0	40.54	228
Bun, hamburger bun, 1/2 serving	2	Serving	166	4.6	29.6	3.2	56
Carrot, carrots, frozen, vegetable	110	Gram	42.17	1.28	9.9	0.18	110
Potato, baked, medium	110	Gram	102.3	2.75	23.27	0.14	110
Mayonnaise, regular, Kraft	40	Gram	285.71	0	0	31.43	40
Oil, olive, extra virgin	20	Gram	180	0	0	20	20
Evening snack			911.56	52.69	26.93	65.42	410
Turkey, breast meat	175	Gram	192.5	39.2	0	2.45	175
Cheese, cheddar	56	Gram	220	12	1	18	56
Crackers, fresh stacks	14	Gram	72.92	0.88	8.46	4.08	14
Apples, fresh, medium	115	Gram	67.65	0.17	17.42	0.34	115
Butter, butter, salted	50	Gram	358.5	0.45	0.05	40.55	50
% recommendation			149.51	404.12	55.4	329.65	

lrg, large; ea, each.

HIGH-PROTEIN HIGH-FAT Overfeeding Diet (4000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
			4020.67	301.61	256.15	194.48	2698.89
Breakfast			782.36	70.59	49.94	32.25	884
Bac, bacon, cooked, crisp	6	Serving	174	9	0.06	15	30
Egg substitute, scramblers, MorningStar Farms	250	Gram	171.5	28.73	9.88	1.9	250
Cottage cheese, large curd, 4%	220	Gram	223.73	20.51	11.19	9.32	220
Fruit	1	Serving	41	0.5	10.4	0.2	100
Milk, 2%	275	Gram	163.14	11.65	16.31	5.83	275
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Lunch			1016	45.1	46.1	71.5	397
Beef	2	Serving	350	12.4	0	32.8	112
Cheese Enchilada	1	Serving	590	30.8	28.7	38.4	100
Green beans	1	Serving	26	1.5	5.4	0.2	104
Pineapple juice	1	Serving	41	0.2	9.9	0.1	72
Hot sauce, jalapeno, packet	1	Each	9	0.2	2.1	0	9
Dinner			1067.6	110.02	102.45	23.33	630.89
Chili con carne	1	Serving	466	51.9	40.3	10.4	100
Beef	140	Gram	194.6	30.8	0	6.86	140
Pinto beans	75	Gram	95	5.63	17.75	0.38	75
“a” salad, garden salad and drsp	1	Serving	30	0.8	6.1	0.4	100
Pure protein bar, chewy chocolate chip	1	Each	200	20	18	5	49.89
Fruit	1	Serving	41	0.5	10.4	0.2	100
Grape juice	1	Serving	41	0.4	9.9	0.1	66
Evening snack			1154.71	75.9	57.66	67.39	787
Ham, turkey ham	140	Gram	179.2	26.32	0.56	7.14	140
Cheese, cheddar	60	Gram	235.71	12.86	1.07	19.29	60
Bread, white, soft, enrich, slice	2	Each	140	4	28	2	56
Cottage cheese, large curd, 4%	220	Gram	223.73	20.51	11.19	9.32	220
Milk, 2%	275	Gram	163.14	11.65	16.31	5.83	275
Mustard, packet	1	Serving	5	0.3	0.5	0.3	7
Butter, butter, salted	29	Gram	207.93	0.26	0.03	23.52	29
% recommendation			119.76	9999.04	55.49	186.2	

LOW-PROTEIN HIGH-FAT Overfeeding Diet (4000 kcal)

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
			4005.08	31.6	510.32	208.19	2551
Breakfast			696.4	3.67	157.2	6.12	766
Flakes (low-protein flake cereal)	52	Gram	192.4	0.16	46.8	0.43	52
Rice milk, original	200	Gram	100	0.83	20	2.08	200
Cinnamon raisin swirl bread (low protein)	2	Slice	240	0.48	50	3	100
Grapefruit juice	2	Serving	82	1.2	19.6	0.2	214
Fruit	2	Serving	82	1	20.8	0.4	200
Lunch			455	4	96	7.8	600
CBF pizza primavera, low protein	152	Gram	265	1.1	50	7	152
Green beans	1	Serving	26	1.5	5.4	0.2	104
Fruit	2	Serving	82	1	20.8	0.4	200
Pineapple juice	2	Serving	82	0.4	19.8	0.2	144
Dinner			1423.49	16.03	142.89	88.9	681
Go pockets, cheesy broccoli (low protein)	1	Piece	300	2	53	8	130
“a” salad, garden salad and drsp pkg	1	Serving	30	0.8	6.1	0.4	100
Nuts, peanuts	28	Gram	163.8	6.63	6.02	13.9	28
Fruit	1	Serving	41	0.5	10.4	0.2	100
Grape juice	2	Serving	82	0.8	19.8	0.2	132

<i>Item name</i>	<i>Quantity</i>	<i>Measure</i>	<i>Calories (kcal)</i>	<i>Protein (g)</i>	<i>Carbohydrate (g)</i>	<i>Fat (g)</i>	<i>Weight (g)</i>
Cookie, sandwich, chocolate, Oreo	34	Gram	160	1	25	7	34
Ice cream, vanilla	115	Gram	268.69	4.3	22.57	17.2	115
Oil, olive, extra virgin	42	Gram	378	0	0	42	42
Evening snack			1430.18	7.9	114.23	105.38	504
Homestyle sliced white bread, low protein	100	Gram	220	0.48	48	3	100
Lunchmeat, ham	18	Gram	29.34	3.33	0.2	1.67	18
American cheese singles, low protein	38	Gram	120	1.32	4	10	38
Mayonnaise, regular, Kraft	42	Gram	300	0	0	33	42
Cookie, creme sugar wafers	60	Gram	310.34	0.52	41.38	16.55	60
Orange juice	2	Serving	82	1.2	19.6	0	182
Mustard, packet	2	Serving	10	0.6	1	0.6	14
Butter, salted	50	Gram	358.5	0.45	0.05	40.55	50
% recommendation			119.3	1047.48	110.55	199.33	

The tables show examples of 24-hour meals of one of the volunteers during energy balance and for each overfeeding diet. The four meals consist breakfast (7:00 am), lunch (11:00 am), dinner (16:00 pm), and snack (19:00 pm).

Changes in Free Thyroxine and Free Triiodothyronine Concentrations During Fasting and Overfeeding Diets via Mixed-Model Analysis

DEPENDENT VARIABLE: Change in Free Thyroxine (ng/dL)

<i>Diet</i>	<i>Average difference</i>	<i>Standard error</i>	<i>95% confidence interval</i>	
			<i>Lower bound</i>	<i>Upper bound</i>
SOF	0.005	0.016	-0.027	0.037
CNP	0.024	0.017	-0.009	0.058
EBL	-0.002	0.016	-0.034	0.029
FNP	-0.025	0.016	-0.057	0.007
FST	0.096*	0.016	0.064	0.128
HPF	-0.075*	0.018	-0.110	-0.040
LPF	-0.004	0.016	-0.036	0.028

Bold values indicate $p < 0.05$.

* $p < 0.05$ versus 0 (no change).

DEPENDENT VARIABLE: Change in Free Triiodothyronine (pg/dL)

<i>Diet</i>	<i>Average difference</i>	<i>Standard error</i>	<i>95% confidence interval</i>	
			<i>Lower bound</i>	<i>Upper bound</i>
SOF	-0.074	0.048	-0.169	0.020
CNP	-0.023	0.048	-0.117	0.071
EBL	-0.074	0.047	-0.166	0.018
FNP	0.021	0.048	-0.072	0.115
FST	-0.171*	0.048	-0.265	-0.077
HPF	-0.125*	0.052	-0.227	-0.024
LPF	0.136*	0.048	0.043	0.230

Bold values indicate $p < 0.05$.

* $p < 0.05$ versus 0 (no change).

CNP, high-carbohydrate normal-protein with 75% carbohydrate, 5% fat, and 20% protein; EBL, energy balance diet with 50% carbohydrate, 30% fat, and 20% protein; FNP, high-fat normal-protein with 60% fat, 20% carbohydrate, and 20% protein; FST, 24-hour fasting; HPF, high-protein high-fat overfeeding with 26% carbohydrate, 44% fat, and 30% protein; LPF, low-protein high-fat overfeeding with 51% carbohydrate, 46% fat, and 3% protein; SOF, standard overfeeding with 50% carbohydrate, 30% fat, and 20% protein.