nature metabolism

Letter

https://doi.org/10.1038/s42255-023-00782-2

Total daily energy expenditure has declined over the past three decades due to declining basal expenditure, not reduced activity expenditure

Supplementary materials

Contents

1. Materials and methods : Systematic review of BMR trends

This systematic review was registered at PROSPERO, 2021 (CRD42021270242) and executed per PRISMA guidelines (see Extended data figure 6). The details of search strategy, data extraction and analysis were as follows.

Search Strategy

A literature search was carried out on PubMed using the following keywords: “Basal metabolic rate”, “BMR”, “basal energy expenditure”, “BEE”, “resting metabolic rate”, “RMR”, “resting energy expenditure”, “REE”, “Indirect calorimetry”, “open circuit indirect calorimetry”, “ventilated hood indirect calorimetry”, “healthy”, “apparently healthy”. Papers published in English from 1900 to 2021 were considered. Cross-references from these papers were also evaluated.

Eligibility and study selection

Papers reporting the measurement of BMR (or BEE) or resting metabolic rate (RMR) on healthy male and female adults, aged 18-65 years, across different body mass index (BMI) were included. Additionally, only studies on either the American or European population were considered. Data were abstracted from cross-sectional studies as well as randomized controlled trials (RCTs). For RCTs, the data collected for control group, which met our inclusion criteria, were included. Studies on infants, children, adolescents, elderly, moderate or heavy activity workers, soldiers and athletes were excluded. The study selection was carried out in two levels: first, articles were included based on their title and abstract; second, the included articles were again filtered based on a reading of their full text. Finally, 163 studies were included into the analysis, as listed in the references below.

Data Extraction

From the selected articles, data on age, sex, geography, population/ethnicity, sample size, weight, height, body mass index, physical activity level, fat mass, fat free mass, method of measuring BMR or RMR, measured value for BMR or RMR, and the instrument error or intra-individual variability were extracted where available. When raw data were available in some papers, the individual data was included in the analysis. When BMR or RMR was reported as kcal or KJ per day, it was converted to MJ per day. When the BMR or RMR data was provided as per kg body weight or fat free mass (FFM) or per square meters surface area, then it was converted to MJ per day by multiplying the respective body weight, FFM or surface area. Finally, assuming that RMR is 10% higher than BMR, any reported RMR data were converted to BMR as 0.9 x RMR. Where mean for age and weight was not provided in the paper [11,21,23,75,80,93,146,154], but range or dispersion indicators of age and weight (minimum/maximum or 95% CI or IQR) were provided, the middle values of these were transformed to obtain the mean values. In some papers, rather than body weight, FFM and fat mass (FM) values were reported; here, these were added to obtain the body weight [47,84,93,151,159]. When SD or SE of weight was provided, these were converted to 95% CI. If FFM and body weight were reported, the FM was calculated as a difference between body weight and FFM.

The data were extracted, sorted, coded and entered into an Excel workbook; statistical analyses were carried out on R version 4.1.0 (R Core Team, 2021, Vienna, Austria). A weighted regression analysis of loge BMR (MJ) on time was performed where loge (body weight), age and sex were considered as covariates along with regression weights assigned to studies based on their study size (n).

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2. Supplementary tables

Table S1. Patterns in change of metabolic rate of males over the last 35 to 40 years including or excluding data prior to 1987. Values show the change in MJ/day over 30 years and the associated p value. ns = not significant. None of the patterns or interpretations are changed by the omission of the early data.

		Including		Excluding	
Unadjusted	TEE	+0.55	$p > .05$, ns	+0.60	$p > .05$, ns
	BEE	-1.19	$p < 0.00002$	-1.16	$p < 0.00002$
	AEE	+0.50	$p > .05$, ns	+0.54	$p > .05$, ns
Adjusted	TEE	-0.93	$p < 0.0001$	-0.94	$p < 0.0002$
	BEE	-0.96	$p < 10^{-9}$	-0.91	$p < 10^{-8}$
	AEE	+1.01	$p < 0.0003$	+1.02	$p > 0.0003$

Table S2: Impact of removing individual studies on the relationship between male BEE and date. Individual studies are identified by the code for the study is that in the database. N is the number of samples omitted. Dates covered are the months since jan-82 that were involved in the particular data set. Coefficient is the fitted linear regression coefficient converted to the change in MJ/d over 30 years. R2x100 is the explained variation (%) by time since 1987. And F and p are the regression statistics for the time effect.

Study omitted	n	dates covered	coefficient	r2x100	F	p
None	0		-0.912	5.47	35.3	$< 10^{-8}$
10	12	191	-0.918	5.57	35.2	$< 10^{-8}$
13	4	61	-0.952	5.81	37.3	$< 10^{-8}$
17	4	97	-0.886	4.90	32.7	$< 10^{-8}$
20	10	85	-0.964	5.82	37.0	$< 10^{-8}$
22	8	92	-0.942	5.63	35.9	$< 10^{-8}$
23	21	109	**-0.653**	3.02	18.4	**$< 10^{-5}$**
24	10	96-99	-0.966	5.88	37.4	$< 10^{-8}$
31	38	121	-0.794	3.96	23.6	$< 10^{-6}$
32	26	145	-0.912	5.47	35.3	$< 10^{-8}$
35	12	157	-0.960	6.07	38.6	$< 10^{-8}$
36	10	138-171	-0.886	5.19	32.9	$< 10^{-8}$
37	10	157	-0.892	5.29	33.5	$< 10^{-8}$
40	19	183-185	-0.937	5.82	36.5	$< 10^{-8}$
41	4	184	-0.901	5.38	34.5	$< 10^{-8}$
43	30	193-197	-0.908	5.39	34.6	$< 10^{-8}$
46	7	185-190	-0.875	5.36	34.1	$< 10^{-8}$
49	30	205-214	-0.888	5.54	33.6	$< 10^{-8}$
51	9	199-200	-0.905	5.42	34.4	$< 10^{-8}$
55	10	235-236	-0.902	5.40	34.3	$< 10^{-8}$
57	10	259-269	-0.906	5.40	34.3	$< 10^{-8}$
59	12	241	-0.892	5.34	33.7	$< 10^{-8}$
60	24	290	-0.972	6.03	37.6	$< 10^{-8}$
62	18	191-314	-0.982	6.12	38.6	$< 10^{-8}$
65	22	339-358	-1.140	7.79	49.7	$< 10^{-12}$
69	18	373-380	-1.135	7.32	47.9	$< 10^{-12}$
72	14	322-327	-0.998	6.28	39.9	$< 10^{-10}$
74	190	199-305	-0.577	3.05	13.4	$< 10^{-4}$
79	11	302-321	-0.925	5.52	34.9	$< 10^{-8}$
129	25	266-269	-0.813	4.63	28.4	$< 10^{-7}$

Table S3: Impact of removing individual studies on the relationship between female BEE and date. Individual studies are identified by the code for the study is that in the database. N is the number of samples omitted. Dates covered are the months since jan-82 that were involved in the particular data set. Coefficient is the fitted linear regression coefficient converted to the change in MJ/d over 30 years. r2x100 is the explained variation (%) by time since 1987. F and p are the regression statistics for the time effect. ns is P > 0.1. when P < 0.1 the exact p is quoted.

Study omitted	n	dates covered	coefficient	r2x100	p
None	0		-0.119	0.11	ns
10	16	191	-0.099	0.10	ns
13	2	61	-0.134	0.15	ns
14	3	92	-0.133	0.18	ns
15	3	85	-0.092	0.09	ns
20	11	85	-0.117	0.14	ns
22	5	92	-0.105	0.11	ns
30	20	133	-0.053	0.03	ns
31	21	121	-0.009	0.01	ns
33	11	149-158	-0.141	0.21	ns
34	17	145	-0.065	0.04	ns
37	11	157	-0.107	0.12	ns
42	7	174	-0.103	0.16	ns
46	12	185-191	-0.082	0.11	ns
49	28	205-217	-0.091	0.07	ns
51	4	200-201	-0.115	0.14	ns
55	15	235-236	-0.120	0.15	ns
57	24	254-268	-0.140	0.21	ns
59	6	241	-0.117	0.15	ns
62	12	310-314	-0.166	0.29	ns
65	33	339-358	**-0.393**	1.53	**0.001**
69	18	373-381	-0.248	0.59	0.032
73	6	199-233	-0.108	0.17	ns
74	184	199-233	-0.170	0.40	ns
75	34	314-341	-0.050	0.03	ns
79	45	305-321	-0.083	0.07	ns
85	2	50-52	-0.065	0.04	ns
86	9	97	-0.148	0.22	ns
93	23	93-124	-0.151	0.26	ns
118	147	234-251	-0.047	0.03	ns
129	25	266-269	-0.095	0.10	ns
135	22	312	-0.135	0.18	ns

Table S4 Mouse diet details. A; Ingredients of 45% kcal high-fat diets. All diets were modeled after Research Diets D12451. B: Dietary fat composition of 45% kcal high-fat diets. Amounts are listed as percentages of weight and kilocalories. Note that each diet contains 5.5 kcal% soybean oil (providing essential fatty acids).

A:	**Mouse high-fat diets**		
		grams	**kcal (%)**
	Protein	24	20
	Carbohydrate	41	35
	Fat	24	45
	Total		100
	Caloric density (kcal/g)	4.7	
Macronutrient	Ingredient	**grams**	**kcal**
Protein	Casein, 80 Mesh	200	800
	L-Cystine	3	12
Carbohydrate	Corn Starch	72.8	291
	Maltodextrin 10	100	400
	Sucrose	172.8	691
Filler	Cellulose BW200	50	0
Vitamins and Minerals	Mineral Mix S10026	10	0
	DiCalcium Phosphate	13	0
	Calcium Carbonate	5.5	0
	Potassium Citrate, 1 H_2O	16.5	0
	Vitamin Mix V10001	10	40
	Choline Bitartrate	2	0
Fat	Soybean oil	25	225
	Dietary Fat Source	177.5	1598

B: Diet	Catalog #	Amount	Butter	Cocoa butter	Coconut oil	Fish oil	High oleic Safflower oil	High oleic Sunflower oil	Lard	Olive oil	Palm oil	Peanut oil	Safflower oil	Soybean oil
Butter	D06022405	gram	20.7	0	0	0	0	0	0	0	0	0	0	2.9
		kcal	39.4	0	0	0	0	0	0	0	0	0	0	5.5
Cocoa butter	D11112703	gram	0	20.7	0	0	0	0	0	0	0	0	0	2.9
		kcal	0	39.4	0	0	0	0	0	0	0	0	0	5.5
Coconut oil	D05122301	gram	0	0	20.7	0	0	0	0	0	0	0	0	2.9
		kcal	0	0	39.4	0	0	0	0	0	0	0	0	5.5
Fish oil	D03022403	gram	0	0	0	20.7	0	0	0	0	0	0	0	2.9
		kcal	0	0	0	39.4	0	0	0	0	0	0	0	5.5
High oleic Safflower oil	D05122103	gram	0	0	0	0	20.7	0	0	0	0	0	0	2.9
		kcal	0	0	0	0	39.4	0	0	0	0	0	0	5.5
High oleic Sunflower oil	D07062503	gram	0	0	0	0	0	20.7	0	0	0	0	0	2.9
		kcal	0	0	0	0	0	39.4	0	0	0	0	0	5.5
Lard	D12451	gram	0	0	0	0	0	0	20.7	0	0	0	0	2.9
		kcal	0	0	0	0	0	0	39.4	0	0	0	0	5.5
Olive oil	D06022403	gram	0	0	0	0	0	0	0	20.7	0	0	0	2.9
		kcal	0	0	0	0	0	0	0	39.4	0	0	0	5.5
Palm oil	D07081501	gram	0	0	0	0	0	0	0	0	20.7	0	0	2.9
		kcal	0	0	0	0	0	0	0	0	39.4	0	0	5.5
Peanut oil	D16010705	gram	0	0	0	0	0	0	0	0	0	20.7	0	2.9
		kcal	0	0	0	0	0	0	0	0	0	39.4	0	5.5
Safflower oil	D02062102	gram	0	0	0	0	0	0	0	0	0	0	20.7	2.9
		kcal	0	0	0	0	0	0	0	0	0	0	39.4	5.5
Soybean oil	D05042003	gram	0	0	0	0	0	0	0	0	0	0	0	23.6
		kcal	0	0	0	0	0	0	0	0	0	0	0	44.9

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