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Supplementary information

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Implausibility of radical life extension in humans in the twenty-first century

In the format provided by the authors and unedited

Supplementary Note 1

According to Vallin and Meslé,[1] Louis Dublin claimed in 1928 that life expectancy would not rise above 64.75 years. In 1952, Bourgeois-Pichat estimated the maximum life expectancy was 76.3 for males and 78.2 for females.[2] In 1980, Siegel estimated the maximums at 73.8 for males and 79.4 for females.[3] In 2008, Vallin and Meslé estimated the maximum life expectancy under optimum conditions at 84.4 for males and 88.9 for females.[4] In 2019, Canudas-Romo et al. concluded that the maximum life expectancy was 84.4 for males and 90.8 for females, although there are nuanced differences between this latest estimate and others.[5] With some exceptions in the modern era, all such efforts yielded maximums that were eventually exceeded. The reasons they underestimated longevity is two-fold. Initially, they did not anticipate the magnitude of the mortality improvement at younger and middle ages. More recently, old-age mortality has proven to be more modifiable than previously thought.

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[1] Vallin, J., Meslé, F. The segmented trend line of highest life expectancies. *Population and Development Review* 35(1): 159-187 (2009).
[2] Bourgeois-Pichat, J. Essai sur la mortalite biologique de l'homme [Essay on the mortality biology of humans]. *Population* 7(3): 381–94 (1952).
[3] Siegel, J.S. Recent and prospective demographic trends for the elderly population and some implications for health care. In S. G. Haynes & M. Feinlied (Eds.), Second conference on the epidemiology for aging (NIH Publ. No. 80–969) (pp. 17–82). Bethesda: US Department of Health and Human Services (1980).
[4] Vallin, J., Meslé, F. Minimum mortality: A predictor of future progress? *Population* (English Edition) 63(4): 557–90 (2008).
[5] Canudas-Romo, V., Booth, H., Bergeron-Boucher, M.P. Minimum death rates and maximum life expectancy: the role of concordant ages. *North American Actuarial Journal*, *23*(3): 322-334 (2019).

Supplementary Note 2

The dramatic increase in life expectancy in humans occurred mostly during the 20th century. In the ten countries evaluated here, the annual rate of increase in $e_{(0)}$ for males and females combined from 1900-2000 was about 0.33 or 3.3 years per decade. Because there was considerable variation in the timing with which these improvements in life expectancy occurred across these nations in the 20th century (e.g., the Japanese, Hong Kong, and South Korean populations concentrated their large increases in life expectancy only in the last quarter of the 20th century), a 0.3 annual rate of improvement in $e_{(0)}$ was used to simplify and operationally define radical life extension in humans. Data used to generate this estimate was drawn from the Human Mortality Database (mortality.org).

Supplementary Note 3

According to Vaupel and Kistowski,[1] "*if life expectancy were approaching an unavoidable biologically maximum that cannot be surmounted, then the increase in life expectancy should be slowing especially in countries that witness the lowest death rates*" (p.8). The evidence provided

here shows exactly this required deceleration phenomenon occurring in the last three decades for the longest-lived populations across the globe.

[1] Vaupel, J., Kistowski, K.G. Broken Limits to Life Expectancy. *Ageing Horizons* 3:6-13, (2005).

Supplementary Note 4

Vallin and Meslé[1] came to similar conclusions in 2008 (just beyond the halfway point between our 1990 presentation of the limited lifespan hypothesis and today but before the notable deceleration in rising life expectancy observed after 2010) after exploring the maximum life expectancy for humans under ideal conditions: *"After the cardiovascular revolution, there is clearly room to push life expectancy higher, but, unless some new breakthrough occurs to increase the human lifespan, progress will very likely decelerate as mortality reduction affects individuals at older and older ages. Indeed, to go faster, it would be necessary to significantly raise the maximum age at death to a level that is not easily imaginable today."*

[1] Vallin, J., Meslé, F. Minimum mortality: A predictor of future progress? *Population* (English Edition) 63(4): 557–90 (2008).

Supplementary Table 1

Table **1**. Composite mortality schedule and complete period life table for males and females representing the lowest age-sex-specific death rates and highest life expectancy observed globally in 2019.

Males

qx	Age	qx	lx	dx	Lx	Tx	ex
0.00184	0	0.00184	100000	184	99908	8308918	83.17
0.00025	1	0.00025	99816	25	99804	8209010	82.25
0.00014	2	0.00014	99791	14	99784	8109206	81.27
0.00013	3	0.00013	99777	13	99771	8009422	80.28
0.00006	4	0.00006	99764	6	99761	7909652	79.29
0.00009	5	0.00009	99758	9	99754	7809890	78.29
0.00008	6	0.00008	99749	8	99745	7710137	77.30
0.00007	7	0.00007	99741	7	99738	7610392	76.30
0.00007	8	0.00007	99734	7	99731	7510654	75.31
0.00006	9	0.00006	99727	6	99724	7410923	74.31
0.00005	10	0.00005	99721	5	99719	7311199	73.32
0.00007	11	0.00007	99716	7	99713	7211480	72.32
0.00008	12	0.00008	99709	8	99705	7111768	71.33

0.00011	13	0.00011	99701	11	99696	7012062	70.33
0.00013	14	0.00013	99690	13	99684	6912367	69.34
0.00017	15	0.00017	99677	17	99669	6812683	68.35
0.00019	16	0.00019	99660	19	99651	6713014	67.37
0.00029	17	0.00029	99641	29	99627	6613363	66.38
0.00030	18	0.00030	99613	30	99598	6513736	65.40
0.00036	19	0.00036	99583	36	99565	6414138	64.42
0.00044	20	0.00044	99547	44	99525	6314574	63.45
0.00044	21	0.00044	99503	44	99481	6215049	62.47
0.00051	22	0.00051	99459	51	99434	6115568	61.50
0.00051	23	0.00051	99409	51	99383	6016134	60.53
0.00049	24	0.00049	99358	49	99333	5916750	59.56
0.00050	25	0.00050	99309	50	99284	5817417	58.59
0.00049	26	0.00049	99259	49	99235	5718133	57.62
0.00047	27	0.00047	99211	47	99188	5618897	56.65
0.00055	28	0.00055	99164	55	99137	5519710	55.68
0.00050	29	0.00050	99110	50	99085	5420573	54.71
0.00055	30	0.00055	99060	54	99033	5321488	53.73
0.00050	31	0.00050	99006	50	98981	5222455	52.76
0.00056	32	0.00056	98956	55	98928	5123474	51.79
0.00062	33	0.00062	98901	61	98870	5024546	50.82
0.00065	34	0.00065	98839	64	98807	4925676	49.85
0.00072	35	0.00072	98775	71	98740	4826869	48.88
0.00065	36	0.00065	98704	64	98672	4728129	47.92
0.00079	37	0.00079	98640	78	98601	4629457	46.95
0.00079	38	0.00079	98562	78	98523	4530856	45.99
0.00087	39	0.00087	98484	86	98441	4432333	45.03
0.00093	40	0.00093	98398	92	98353	4333892	44.06
0.00099	41	0.00099	98307	97	98258	4235539	43.11
0.00105	42	0.00105	98210	103	98158	4137281	42.15
0.00115	43	0.00115	98106	113	98050	4039123	41.19
0.00129	44	0.00129	97994	126	97930	3941073	40.24
0.00137	45	0.00137	97867	134	97800	3843142	39.30
0.00164	46	0.00164	97733	160	97653	3745342	38.35
0.00176	47	0.00176	97573	172	97487	3647689	37.42
0.00195	48	0.00195	97401	190	97306	3550202	36.48

0.00220	49	0.00220	97211	214	97104	3452896	35.56
0.00239	50	0.00239	96997	232	96881	3355792	34.64
0.00135	51	0.00135	96766	131	96700	3258910	33.70
0.00224	52	0.00224	96635	216	96527	3162210	32.76
0.00220	53	0.00220	96418	212	96312	3065683	31.83
0.00283	54	0.00283	96206	272	96070	2969371	30.91
0.00341	55	0.00341	95934	327	95770	2873301	30.00
0.00313	56	0.00313	95607	299	95457	2777530	29.10
0.00417	57	0.00417	95308	397	95109	2682073	28.20
0.00319	58	0.00319	94910	303	94759	2586964	27.30
0.00493	59	0.00493	94607	466	94374	2492205	26.41
0.00567	60	0.00567	94141	534	93874	2397831	25.54
0.00616	61	0.00616	93607	577	93319	2303957	24.69
0.00672	62	0.00672	93031	625	92718	2210638	23.84
0.00738	63	0.00738	92405	682	92064	2117920	23.00
0.00817	64	0.00817	91724	749	91349	2025855	22.18
0.00819	65	0.00819	90974	745	90602	1934507	21.35
0.01008	66	0.01008	90229	910	89774	1843905	20.54
0.01041	67	0.01041	89320	930	88855	1754131	19.74
0.01026	68	0.01026	88390	907	87936	1665276	18.94
0.01273	69	0.01273	87483	1114	86926	1577340	18.15
0.01348	70	0.01348	86369	1164	85787	1490414	17.37
0.01400	71	0.01400	85205	1193	84609	1404627	16.60
0.01196	72	0.01196	84012	1005	83510	1320018	15.81
0.01677	73	0.01677	83007	1392	82311	1236508	15.02
0.02148	74	0.02148	81615	1753	80739	1154197	14.30
0.02232	75	0.02232	79862	1783	78971	1073458	13.59
0.02491	76	0.02491	78080	1945	77107	994488	12.90
0.02759	77	0.02759	76135	2101	75084	917380	12.22
0.03145	78	0.03145	74034	2328	72870	842296	11.56
0.03575	79	0.03575	71706	2563	70424	769426	10.93
0.04185	80	0.04185	69142	2894	67695	699002	10.33
0.04636	81	0.04636	66249	3071	64713	631307	9.76
0.05325	82	0.05325	63177	3364	61495	566594	9.21
0.05807	83	0.05807	59813	3473	58077	505098	8.70
0.06474	84	0.06474	56340	3647	54516	447022	8.20

0.06938	85	0.06938	52692	3656	50864	392506	7.72
0.08408	86	0.08408	49037	4123	46975	341641	7.27
0.09226	87	0.09226	44914	4144	42842	294666	6.88
0.10045	88	0.10045	40770	4095	38722	251824	6.50
0.10501	89	0.10501	36675	3851	34749	213102	6.13
0.10095	90	0.10095	32823	3314	31167	178353	5.72
0.12496	91	0.12496	29510	3688	27666	147187	5.32
0.13903	92	0.13903	25822	3590	24027	119521	4.97
0.16327	93	0.16327	22232	3630	20417	95493	4.68
0.17899	94	0.17899	18602	3330	16938	75076	4.43
0.18498	95	0.18498	15273	2825	13860	58139	4.19
0.20088	96	0.20088	12448	2500	11197	44278	3.95
0.21752	97	0.21752	9947	2164	8865	33081	3.73
0.23485	98	0.23485	7783	1828	6869	24216	3.53
0.25278	99	0.25278	5955	1505	5203	17346	3.33
0.27122	100	0.27122	4450	1207	3847	12144	3.16
0.29006	101	0.29006	3243	941	2773	8297	2.99
0.30919	102	0.30919	2302	712	1946	5524	2.84
0.32848	103	0.32848	1591	522	1329	3578	2.69
0.34780	104	0.34780	1068	371	882	2248	2.55
0.36703	105	0.36703	697	256	569	1366	2.40
0.38603	106	0.38603	441	170	356	797	2.24
0.40468	107	0.40468	271	110	216	442	2.04
0.42288	108	0.42288	161	68	127	226	1.78
0.44052	109	0.44052	93	41	73	99	1.36
1.00000	110	1.00000	52	52	26	26	1.00

Females

qx	Age	qx	lx	dx	Lx	Tx	ex
0.00161	0	0.00161	100000	161	99920	8860981	88.68
0.00025	1	0.00025	99839	25	99827	8761062	87.76
0.00011	2	0.00011	99814	11	99809	8661235	86.78
0.00009	3	0.00009	99803	9	99799	8561427	85.79
0.00009	4	0.00009	99794	9	99790	8461628	84.79
0.00006	5	0.00006	99785	6	99782	8361839	83.80
0.00005	6	0.00005	99779	5	99777	8262057	82.81

0.00006	7	0.00006	99774	6	99771	8162280	81.81
0.00005	8	0.00005	99768	5	99766	8062509	80.81
0.00005	9	0.00005	99763	5	99761	7962743	79.82
0.00005	10	0.00005	99758	5	99756	7862982	78.82
0.00005	11	0.00005	99753	5	99751	7763227	77.83
0.00007	12	0.00007	99748	7	99745	7663476	76.83
0.00010	13	0.00010	99741	10	99736	7563731	75.84
0.00011	14	0.00011	99731	11	99726	7463995	74.85
0.00013	15	0.00013	99720	13	99714	7364269	73.85
0.00013	16	0.00013	99707	13	99701	7264556	72.86
0.00020	17	0.00020	99694	20	99684	7164855	71.88
0.00017	18	0.00017	99674	17	99666	7065171	70.89
0.00019	19	0.00019	99657	19	99648	6965505	69.90
0.00023	20	0.00023	99639	23	99627	6865857	68.92
0.00028	21	0.00028	99616	28	99602	6766230	67.93
0.00028	22	0.00028	99588	28	99574	6666628	66.95
0.00023	23	0.00023	99560	23	99548	6567054	65.97
0.00026	24	0.00026	99537	26	99524	6467506	64.98
0.00025	25	0.00025	99511	25	99499	6367982	64.00
0.00028	26	0.00028	99486	28	99472	6268483	63.02
0.00025	27	0.00025	99458	25	99446	6169011	62.03
0.00030	28	0.00030	99433	30	99419	6069565	61.05
0.00029	29	0.00029	99404	29	99389	5970147	60.07
0.00030	30	0.00030	99375	30	99360	5870757	59.09
0.00029	31	0.00029	99345	29	99331	5771398	58.10
0.00032	32	0.00032	99316	32	99300	5672067	57.12
0.00036	33	0.00036	99284	36	99267	5572767	56.14
0.00040	34	0.00040	99249	40	99229	5473500	55.16
0.00039	35	0.00039	99209	39	99190	5374271	54.18
0.00039	36	0.00039	99170	39	99151	5275082	53.20
0.00041	37	0.00041	99132	41	99111	5175931	52.22
0.00048	38	0.00048	99091	48	99067	5076820	51.25
0.00050	39	0.00050	99043	50	99019	4977752	50.27
0.00057	40	0.00057	98994	56	98966	4878734	49.30
0.00062	41	0.00062	98937	61	98907	4779768	48.33
0.00065	42	0.00065	98876	64	98844	4680862	47.36

0.00075	43	0.00075	98812	74	98775	4582018	46.39
0.00082	44	0.00082	98738	81	98697	4483243	45.42
0.00086	45	0.00086	98657	85	98614	4384546	44.46
0.00091	46	0.00091	98572	90	98527	4285931	43.50
0.00105	47	0.00105	98482	103	98430	4187404	42.54
0.00118	48	0.00118	98379	116	98321	4088974	41.59
0.00125	49	0.00125	98263	123	98201	3990653	40.64
0.00143	50	0.00143	98140	140	98070	3892452	39.69
0.00132	51	0.00132	98000	129	97935	3794382	38.74
0.00134	52	0.00134	97870	131	97805	3696447	37.79
0.00152	53	0.00152	97739	149	97665	3598643	36.85
0.00157	54	0.00157	97590	153	97514	3500978	35.90
0.00161	55	0.00161	97437	157	97359	3403464	34.96
0.00179	56	0.00179	97280	174	97193	3306105	34.02
0.00192	57	0.00192	97106	186	97013	3208912	33.08
0.00217	58	0.00217	96920	210	96815	3111899	32.14
0.00230	59	0.00230	96709	222	96598	3015084	31.21
0.00236	60	0.00236	96487	228	96373	2918486	30.28
0.00246	61	0.00246	96259	237	96141	2822113	29.35
0.00272	62	0.00272	96023	261	95892	2725972	28.43
0.00275	63	0.00275	95761	263	95630	2630080	27.50
0.00338	64	0.00338	95498	323	95337	2534450	26.58
0.00374	65	0.00374	95175	356	94997	2439114	25.68
0.00399	66	0.00399	94819	378	94630	2344116	24.77
0.00459	67	0.00459	94441	433	94224	2249486	23.87
0.00506	68	0.00506	94007	476	93770	2155262	22.98
0.00567	69	0.00567	93532	530	93267	2061493	22.10
0.00632	70	0.00632	93001	588	92708	1968226	21.23
0.00715	71	0.00715	92414	661	92083	1875518	20.37
0.00831	72	0.00831	91753	762	91372	1783435	19.52
0.00897	73	0.00897	90990	816	90582	1692063	18.68
0.01033	74	0.01033	90174	932	89709	1601481	17.85
0.01175	75	0.01175	89243	1049	88718	1511772	17.04
0.01292	76	0.01292	88194	1139	87624	1423054	16.24
0.01453	77	0.01453	87055	1265	86422	1335430	15.45
0.01545	78	0.01545	85790	1325	85127	1249007	14.67

0.01880	79	0.01880	84464	1588	83670	1163880	13.91
0.02145	80	0.02145	82876	1778	81988	1080210	13.18
0.02517	81	0.02517	81099	2041	80078	998222	12.47
0.02921	82	0.02921	79057	2309	77903	918144	11.79
0.03340	83	0.03340	76748	2563	75466	840241	11.13
0.03714	84	0.03714	74185	2755	72807	764775	10.50
0.04196	85	0.04196	71430	2997	69931	691968	9.90
0.04968	86	0.04968	68432	3400	66733	622037	9.32
0.05758	87	0.05758	65033	3745	63160	555304	8.79
0.06430	88	0.06430	61288	3941	59318	492144	8.30
0.06868	89	0.06868	57347	3939	55378	432826	7.82
0.06679	90	0.06679	53409	3567	51625	377448	7.31
0.08081	91	0.08081	49841	4028	47828	325823	6.81
0.09265	92	0.09265	45814	4245	43691	277995	6.36
0.10185	93	0.10185	41569	4234	39452	234304	5.94
0.11841	94	0.11841	37335	4421	35125	194852	5.55
0.13071	95	0.13071	32914	4302	30763	159727	5.19
0.14461	96	0.14461	28612	4138	26543	128963	4.86
0.15954	97	0.15954	24475	3905	22522	102420	4.55
0.17549	98	0.17549	20570	3610	18765	79898	4.26
0.19243	99	0.19243	16960	3264	15328	61133	3.99
0.21031	100	0.21031	13696	2881	12256	45804	3.74
0.22905	101	0.22905	10816	2477	9577	33548	3.50
0.24855	102	0.24855	8339	2073	7302	23971	3.28
0.26869	103	0.26869	6266	1684	5424	16669	3.07
0.28933	104	0.28933	4582	1326	3919	11245	2.87
0.31032	105	0.31032	3257	1011	2751	7325	2.66
0.33149	106	0.33149	2246	745	1874	4574	2.44
0.35268	107	0.35268	1501	530	1237	2700	2.18
0.37371	108	0.37371	972	363	790	1463	1.85
0.39443	109	0.39443	609	240	489	673	1.38
1.00000	110	1.00000	369	369	184	184	1.00