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RESEARCH ARTICLE

Weight gain is associated with shorter lifespan: a longitudinal study of New Zealand soldiers serving in both world wars

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Abstract

Obesity is an increasing public health concern with important mortality consequences. Weight gain or maximum adult BMI, not BMI at one point in time, has been shown to be an important risk factor in cohorts studied recently during an era of rapid increase in population levels of overweight and obesity. However, there is limited evidence on individual weight trajectories from cohorts born before the mid-twentieth century. Archival world war military personnel files from New Zealand are freely available online, and identify service in both wars. A pilot study of 316 soldiers confirmed the files contain sufficient information to examine health trajectories and lifespan. Because this cohort are now entirely deceased, nearly the entire sample can be found in death records to estimate the impact of weight increases on lifespan. Weight change over 20–30 years and its relationship with lifespan is examined using ordinary least squares regression. The study demonstrates that military records are a feasible source for collecting data on adult weight and health trajectories in the first half of the twentieth century. Although this sample is likely to be composed of men fitter than average, there is a clear pattern of increasing weight from early to mid-adulthood. Weight gain from early adulthood to middle-age was found to be more strongly associated with mortality than weight in early adulthood. A one unit increase in BMI over the inter-war period was found to be associated with an 8 month decline in lifespan. These results confirm that weight gain in adulthood has an important impact on mortality in an earlier birth cohort than previously studied, and that data exist to measure any changes more precisely over time.

Keywords: Obesity; Demography; Longevity and ageing

Introduction

Since 1980 obesity (BMI>30) has increased significantly around the world (Finucane *et al.*, 2011). The mortality consequences are serious: the World Health Organization estimated that in 2009 4.8% of worldwide deaths, and 8.4% of deaths in high-income countries, were related to overweight and obesity (World Health Organization, 2009; GBD 2015 Obesity Collaborators, 2017). However, many studies of the relationship between overweight and mortality are limited by observing weight at one point in time, and only following cohorts for a short period (Stokes & Preston, 2016a; Zheng *et al.*, 2021). As more research has measured weight at multiple points, and followed cohorts for longer, it is clear that maximum lifetime weight (Stokes & Preston, 2016b) or weight change have a stronger relationship with mortality.

Weight change and maximum lifetime weight both proxy for the duration of exposure at higher BMI. With three or more observations of weight, the trajectory of weight over a long period can be characterized categorically. Alternatively, multiple observations allow the time path of BMI to be modelled by assuming a functional form for change between observations (Preston *et al.*, 2013). Approaches using multiple measurements of weight more precisely assess individual risk than a single observation at the beginning of a study. However, most of the research on weight fluctuations and mortality has been conducted on cohorts born after the 1930s, and with weight measured after 1980. Cohorts born in the late nineteenth and early twentieth centuries had significantly different duration of exposure to highly processed food, motor cars and powered equipment for performing work tasks. The weight trajectories of cohorts born earlier than those studied in the extant literature are likely to have been different, with lower exposure to obesogenic environments.

This paper examines how military records for men who served in both world wars could be used to measure weight trajectories, and their impact on lifespan for men born in the late nineteenth century. Military records for the world wars have been well preserved in Australia, Canada, Great Britain and New Zealand, and there are extensive digitization efforts underway in all four countries making access and sampling easier (Inwood & Ross, 2016). Men who served in both world wars from these countries are a selected group. Depending on their country of origin, they may have been conscripted in World War I and thus more representative of a cohort of young men than volunteers. But in World War II none of these countries conscripted men older than 45 for foreign service. Men who served in both world wars were volunteers the second time around, and form a highly selected population. It is likely that middle-aged men volunteering to serve again were fitter than their birth cohort, and fitter than peers they served with in World War I. These biases are likely to bias estimates of weight gain downwards, and provide a useful lower bound for understanding broader trends in their cohort.

Analysis of a pilot data set from New Zealand shows that most men who volunteered to serve again in World War II were physically examined when they volunteered in the 1940s. Accurate linkages could be made to mortality records. Weight gain from young adulthood in 1914/18 to middle-age was modest in comparison to general population samples over a similar interval in the late twentieth century. However, even these modest increases in weight were associated with lower life expectancy in line with the direction of findings from contemporary populations. Military records are a viable source for further investigation of weight trajectories at the beginning of the twentieth century rise in overweight and obesity (Komlos & Brabec, 2011).

Background: population-level changes in diet and physical activity

Cohorts born since the 1930s in high-income countries have lived much of their lives in an obesogenic environment. A similar nutrition transition has now spread to low- and middle-income countries (Popkin, 2001). The experience of cohorts born before 1900 was different in important ways around both diet and physical activity. People born in the late nineteenth century had less exposure to highly processed foods until the 1950s (Baker *et al.*, 2020). These cohorts also entered adulthood and careers before car ownership was widespread. Men working in construction, trades and utilities also had considerably higher energy expenditures for routine work activities, with fewer tasks assisted by powered equipment (Gray, 2013). In high-income countries, such as Australia, New Zealand, Canada and the United States, significant changes in diet and physical activity were evident by the 1950s. Car ownership was widespread by the mid-1950s (Dravitzki & Lester, 2006), and construction and manufacturing workers had greater access to powered equipment, reducing the physical demands of manual work. Taken together, these trends imply that people born in the late nineteenth century formed habits around physical activity and diet in significantly different circumstances. Later in adulthood, even as early as the 1920s and 1930s, physical activity may have declined, and consumption of processed foods increased. However, because childhood and adolescence are important in forming eating and physical activity habits (Riet *et al.*, 2011; Olsen *et al.*, 2013) people who reached adulthood before processed food and personal vehicles were common probably formed different habits than subsequent birth cohorts.

While the onset of the obesity epidemic in high-income countries is conventionally dated to the 1980s (Robinson *et al.*, 2013), there is increasing evidence that body mass has risen throughout the twentieth century. For example, Komlos and Brabec (2010, 2011) and Reither *et al.* (2009) showed rising BMI in the United States earlier than the 1980s 'obesity epidemic'. Using a variety of sources to examine the early twentieth century before the earliest national health surveys, Cranfield *et al.* (2017) found growing BMI in Australia, Canada and New Zealand (Wilson & Abbott, 2018). Declining levels of physical activity and increased consumption of processed foods were regarded as plausible contributors to these trends. Doctors and epidemiologists in the mid-twentieth century viewed rising BMI as a growing health issue, particularly in middle-aged people (Armstrong *et al.*, 1951), suggesting a life course paradigm is helpful.

But there are limited sources for studying longitudinal change in individual adult weight before the 1950s (Inwood & Roberts, 2010). Pioneering early longitudinal studies of growth and development such as the Fels, Berkeley and Harvard growth studies, did not recruit children until the 1920s, making their cohort too young. Large pre-World War II (WWII) studies of adults based on life insurance policy holders who were weighed to assist in the somewhat crude determination of premiums were typically weighed just once (Dublin & Marks, 1930). Only a few highly selected clinical studies of overweight patients examined the connection between weight change and health (Dunlop & Lyon, 1931; Fellows, 1931).

Because of the timing of the world wars, a large number of men served in both world wars. A man born in 1897, for example, could enter WWI at age 18–21, and be in his early 40s in World War II. These men are a promising source of systematic data on health and weight change in the early twentieth century. Some of the most accessible data are from Australia, Britain, Canada and New Zealand, where most World War I (WWI) records have been digitized (Inwood & Ross, 2016), and medical files from both wars contain weight information. Unfortunately, most United States soldiers' files from WWI were destroyed in a 1973 fire (Stender & Walker, 1974). Men who served in both world wars will be a selected sample. While many were conscripted into WWI, most were volunteers for WWII. The small number who did not volunteer for WWII were generally officers, and thus selective in other ways. While a sample of dual-world war service men is selective, the bias is likely to *understate* the relationship between changing weight and mortality. Given their age at the start of WWII, men volunteering to serve again were likely to be fitter than the average man from their cohort. Personnel files also include occupation – an important measure of socioeconomic status to include so as not to overstate the weight–mortality connection (Stokes & Preston, 2016a).

Methods

A pilot study of men serving in both world wars in the New Zealand armed forces was conducted to assess the potential for using military records to create longitudinal data on individual health and mortality. In both wars, personnel files recorded standardized demographic and health information when men were conscripted or volunteered for service. Key demographic information include birthplace, occupation, place of residence at enlistment and birth dates. Death dates are typically recorded within the file, because accurate accounting of vital status for veterans was necessary for post-war administration of service pensions. When death dates were not in the file, the year of death was identified in public death indices (available at https://www.bdmhistoricalrecords.dia.govt.nz/).

To impute a day within the year, the sequentially assigned death registration number was used to make a linear estimate of a death date within the year. In both wars medical data includes measured height and weight, and in World War II blood pressure and pulse rates. Since 2006, records

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Table 1. Sample construction from personnel files and death records

Sample construction stage	*n*	Proportion of previous group
All sampled records	316	
Lifespan data available	314	0.99
BMI data also available in both wars	200	0.63

of men serving in World War I have been digitized and are publicly available online from Archives NZ. The master list of individuals who served in World War I identified a total of 12,924 men with an additional service number from World War II, from which a simple random sample was drawn.

A pilot sample of 316 subjects who had service records from both wars was collected. Of these, 201 men had height and weight data from both wars, and complete lifespan data (Table 1). This extent of missing data is partly an administrative artefact. Service records were created for men who attempted to serve in either war. Thus, the sampling process revealed men who tried and failed to enter the forces when too young (WWI) or too old (WWII). Men who were serving in non-combatant roles, such as clerical and transport duties, were less likely to be measured.

Studies of BMI and mortality based on single observations of anthropometric characteristics are constrained to choosing different forms of regression models relating weight at one point in time to mortality. When follow-up is censored, duration models are appropriate for estimating hazards of mortality. Analysis of complete lifespans can be undertaken with OLS regression, as censoring is no longer an issue. With multiple observations – even just two – there are more analytical choices for characterizing the BMI trajectory over the lifetime. Two approaches used previously (Xu *et al.*, 2018; Zheng *et al.*, 2021) are using maximum weight, or the change in weight.

The analyses in this paper focus on estimating OLS models of age at death, controlling for age, occupational status at enlistment and either maximum weight or weight change. In this cohort the average age for the first BMI observation was 23, with a second at age 47, making the preferred estimate weight change. With just two observations on BMI, maximum observed BMI can only occur in the early 20s or late 40s. In this sample, where men have survived two decades since the previous observation, *and* are volunteering for military service, losing weight is less likely to be a sign of illness. For these men, being heavy in early adulthood (WWI) may not be relevant to health in their 40s and beyond if they were sufficiently fit in WWII to be accepted into military service in some form. A BMI change, even between two observations, is informative about changes in diet and physical activity over more than 20 years.

Arithmetically regressing lifespan on the change in BMI is identical to including terms for weight at both observations. Coefficients on other variables have been estimated identically. But in this sample the change in BMI occurs over an important period for adult health. Modern research has shown the importance of increases in BMI over precisely this period of life for increasing mortality risk (Song *et al.*, 2016; Zheng *et al.*, 2021). Thus, despite the arithmetic equivalence of entering BMI at both observations into a regression, the single coefficient for change in weight has a clearer interpretation and relevance for health.

Results

At enlistment in WWI, the characteristics of the group of men who would later volunteer for WWII were similar to those observed in general samples of New Zealand soldiers from both WWI (Inwood *et al.*, 2010) and WWII (Cranfield *et al.*, 2017) (Table 2). By WWII, men were likely to be performing more sedentary jobs or report no occupation (Figure 1). Notably, while BMI had increased by an average of 2 kg/m^2, this was in line with the age-specific profile observed

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Table 2. Summary statistics of sample soldiers

	WWI Mean (SD)	WWII Mean (SD)
Year of birth	1892.4 (5.1)	
Year of death	1967.1 (11.5)	
Number missing	2	
Age at death (years)	74.7 (11.1)	
Number missing	2	
Age at enlistment (years)	22.8 (8.4)	47.83 (4.72)
Number missing	5	78
Height, WWI (m)	1.73 (0.06)	1.73 (0.07)
Number missing	20	69
BMI (kg/m^2)	22.1 (2.0)	24.1 (3.4)
Number missing	62	75
Change in BMI (kg/m^2)		2.0 (3.3)
Number missing		115
Systolic blood pressure (mmHg)	Not recorded	137.4 (16.8)
Number missing		68
Diastolic blood pressure (mmHg)	Not recorded	83.7 (9.9)
Number missing		71
Hypertension at exam (mmHg)		
Normal: $<$140 mmHg		126 (50.8%)
Hypertensive: 140–149 mmHg		56 (22.6%)
Hypertensive: 150–159 mmHg		44 (17.7%)
Hypertensive: 160+ mmHg		22 (8.9%)
Number missing		68
Residence in WWI		
Rural, $<$1000 population	71 (22.5%)	38 (12.0%)
Town of $\geq$1000; not 'main centre'	120 (38.0%)	100 (31.6%)
Main centre[a]	108 (34.2%)	109 (34.5%)
Number missing	17 (5.4%)	69 (21.8%)

[a]The four largest cities of Auckland, Wellington, Christchurch and Dunedin are referred to in New Zealand as the 'main centres'.

more broadly in NZ soldiers. Elevated blood pressure was evident in a significant minority of soldiers, consistent with other evidence that hypertension was an important health issue at the time (Roberts & Wood, 2014).

Weight was observed in both wars for 201 of 316 men who were sampled (200 of these men had lifespan data). This reflected incomplete measurements in both wars, with 53 men measured in WWI only, 40 in WWII only and 22 in neither war. No statistically or substantively important associations were measured between the presence of a measurement in either war, and other observable characteristics. For example, there was no association with age or BMI in the war in which they were measured.

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Figure 1. Occupational distribution of sample serving in both world wars.

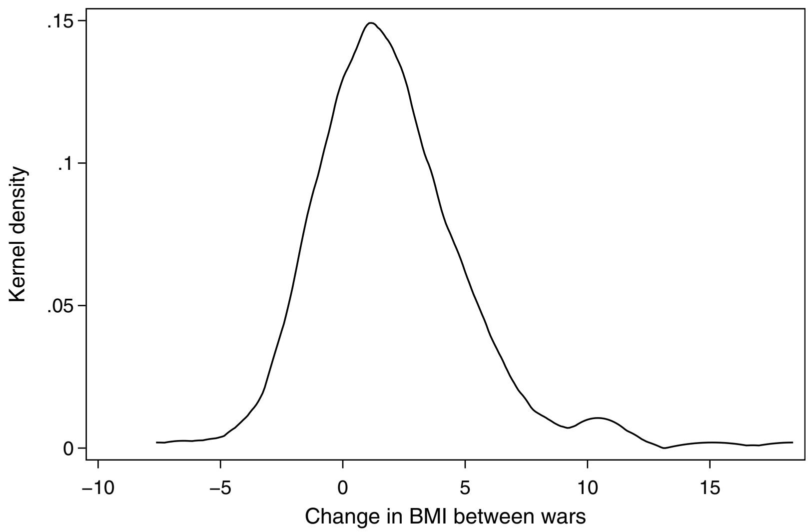

Figure 2. Distribution of BMI changes between the two world wars.

Despite a mean increase of 2.0 kg/m^2 in BMI, 56 of 201 men with two measurements lost weight, and the median change in BMI was 1.5 kg/m^2. For men of average height (1.73 m) this corresponds to an increase of 5 kg over 24 years. Among men whose weight increased, the median (mean) increase in BMI was 2.4 (3.3) kg/m^2. Skewness in the distribution arises from a small number of men who put on significant weight, with BMI increases of 7 kg/m^2 or more for the 5% of the sample gaining the most (Figure 2). To put this concretely, a man of average height (1.73 m) who gained 7 kg/m^2 was putting on 20 kg between the wars. The increase in BMI in this sample is most comparable to modern studies of adolescent to mid-adulthood weight trajectories with objective measurements at multiple times (McTigue *et al.*, 2002; Engeland *et al.*, 2004; Gordon-Larsen *et al.*,

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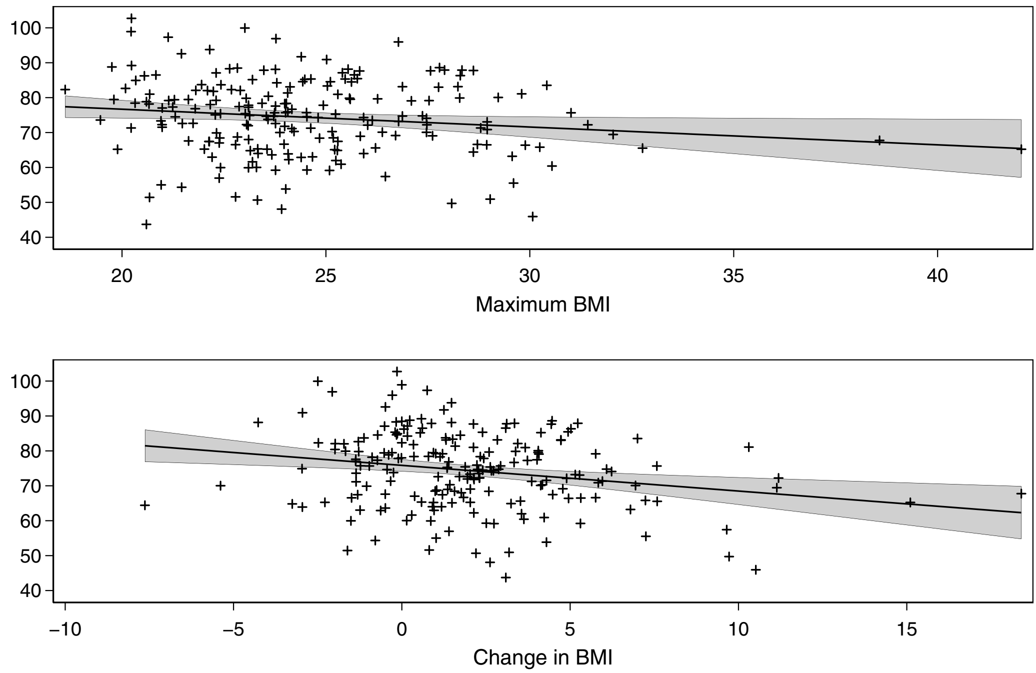

Figure 3. BMI change and lifespan in a cohort of New Zealand soldiers serving in both world wars.

2010). The increase in BMI in this sample is significantly less than seen in modern cohorts, where mean increases of more than 4.0 kg/m^2 are commonly reported.

Some men who served in both wars were relatively young at enlistment in World War I, either enlisting before they were of legal service age (18 years) or obtaining permission from their parents to enlist at age 18 or 19. Birth dates were verified in online birth registers to confirm accurate ages. The presence of teenagers in the sample at the first observation raises the possibility that some men were still growing at enlistment, and therefore likely to weigh less for their height than men who had completed growing. However, there was no clear relationship between age at enlistment, and either height or BMI. Men who enlisted at a young age were likely to be taller for their age, and though they did not know it, near their terminal height. For men aged 15–20, the average change in height between the world wars was 0.8 cm.

A trajectory of increased BMI from early adulthood into middle-age is common in recent cohorts, and has been associated with increased mortality (Engeland *et al.*, 2003; Østbye *et al.*, 2011; Hirko *et al.*, 2015; Johnson *et al.*, 2015; Song *et al.*, 2016). In the study cohort, the average increase in weight was 9%: lower than observed over similarly long follow-up periods in recent cohorts (Rosengren *et al.*, 1999; Kvaavik *et al.*, 2003). There was a correlation of 0.37 (95% CI: 0.25–0.48) between BMI in WWI and WWII – slightly lower than values observed over 30 years in modern studies (Bayer *et al.*, 2011; Aarestrup *et al.*, 2016). The average interval between medical examinations was 24.5 years (range: 20–30 years). Although the average change in BMI in 25 years was modest, there was a clear relationship between greater weight gain and shorter lifespan, as shown in Figure 3.

The correlation between inter-war growth in BMI and lifespan was –0.21 (95% CI: –0.09 to –0.35). Because the cohort is now deceased, ordinary least squares (OLS) models can be used instead of hazard models to examine the relationship between weight gain and lifespan. In both bivariate and multivariate models each additional unit of BMI increase was associated with a decline in lifespan of around 8 months (Table 3).

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Table 3. OLS models of age at death of sample soldiers

	Change models		Maximum models	
	B/(*t*)	*B*/(*t*)	*B*/(*t*)	*B*/(*t*)
Change in BMI	−0.73	−0.63		
	(−3.15)	(−2.65)		
Maximum BMI			−0.49	−0.46
			(−2.07)	(−1.89)
WWI occupation				
Professional (Ref.)				
Clerical		2.84		2.71
		(0.81)		(0.77)
Sales		−2.84		−2.43
		(−0.69)		(−0.59)
Service work		0.71		0.90
		(0.21)		(0.27)
Manufacturing/utilities		2.05		2.32
		(0.60)		(0.67)
Labourer		−2.72		−2.31
		(−0.76)		(−0.64)
Farmer		0.23		0.79
		(0.07)		(0.23)
Farm labourer		2.85		3.22
		(0.67)		(0.75)
No occupation		7.69		8.26
		(1.64)		(1.74)
Age at WWI enlistment				
15–20 (Ref.)				
20–24		2.00		2.57
		(0.90)		(1.15)
25–29		0.58		1.09
		(0.22)		(0.40)
30–34		8.56		9.88
		(2.18)		(2.53)
35–39		11.58		13.62
		(1.45)		(1.70)
40–44		6.00		10.85
		(0.53)		(0.96)
Constant	75.79	72.87	86.42	82.00
	(85.26)	(19.96)	(14.65)	(11.63)

(*Continued*)

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Table 3. (*Continued*)

	Change models		Maximum models	
	B/(*t*)	*B*/(*t*)	*B*/(*t*)	*B*/(*t*)
N	200	200	200	200
R^2	0.05	0.12	0.02	0.11

An increase in BMI was also associated with a higher likelihood of reporting high blood pressure. In bivariate and multivariate models, the odds of reporting a systolic blood pressure of 140 mmHg or greater were 7–8% higher for each 1 kg/m^2 increase in BMI (p=0.10 in both models). This result is consistent with increasing BMI being associated with slightly worse cardiovascular health in mid-adulthood.

The impact of increased BMI over 25 years was only modestly attenuated from the bivariate estimate (–0.73) to the multivariate estimate (–0.63) when controlling for socioeconomic variables from both wars including occupation, place of residence and education. In supplementary analyses the change in BMI was interacted with height tertiles to examine if shorter men were at greater risk, but there was no difference between tertiles. As expected, maximum BMI had a smaller impact on age at death than change in BMI, with each additional 1 kg/m^2 associated with a 6 month shorter life. When both the change in BMI and maximum BMI are included, the coefficient on maximum BMI is precisely 0, while the coefficient on change remains 0.63 (approximately 8 months). In line with expert recommendations, controls for cardiovascular health indicators such as hypertension and cardiovascular fitness were not included (Stokes & Preston, 2016a).

Discussion and Conclusion

While this cohort has definite biases from selecting men who volunteered and were accepted to serve in WWII, and likely to be fitter than average for their age, this bias towards a healthy group is likely to understate the degree of increasing BMI in the general population of New Zealand. In WWI, when the men in this sample were largely conscripted into the army, they were, as a group, similar to the average man of their age. Military records proved a feasible source for gathering information on weight trajectories. In this pilot study, socioeconomic differences in BMI levels and trajectories were not evident at statistically significant levels. It is likely that a larger sample would shed light on how occupational shifts affected weight trajectories.

Thus, with socioeconomic variables not being statistically significant, it is notable that the pilot study shows such a clear trend of increasing BMI though smaller than modern cohorts at similar intervals. Obesity was rare (5% of men measured in WWII) in this cohort and the average man at WWII enlistment had a BMI of 24. Nevertheless, even in men whose weight trajectories were moving upwards in the normal and overweight categories, there was a clear and strong relationship between increased weight gain and shorter lifespan. These results suggest the tendency towards increasing BMI from young adulthood into middle-age dates to an earlier period than generally recognized. Even in the normal and mildly overweight range, a trajectory of increasing BMI was associated with earlier mortality. The median change in BMI of 1.5 kg/m^2 over approximately 25 years was associated with a reduced lifespan of one year, compared with remaining at the same BMI. These results suggest that the impact of increasing average BMI on life expectancy began in an earlier era than previously realized, and at BMI values that were largely in the normal and moderately overweight range.

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Conflicts of Interest. The authors have no conflicts of interests to declare.

Ethical Approval. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

References

Aarestrup J, Bjerregaard L, Gamborg M, Ängquist L, Tjønneland A, Overvad K *et al.* (2016) Tracking of body mass index from 7 to 69 years of age. *International Journal of Obesity* **40**(9), 1376–1383.

Armstrong DB, Dublin LI, Wheatley GM and Marks HH (1951) Obesity and its relation to health and disease. *Journal of the American Medical Association* **147**(11), 1007–1014.

Baker P, Machado P, Santos T, Sievert K, Backholer K, Hadjikakou M *et al.* (2020) Ultra-processed foods and the nutrition transition: global, regional and national trends, food systems transformations and political economy drivers. *Obesity Reviews* **21**(12), e13126.

Bayer O, Krüger H, Von Kries R and Toschke AM (2011) Factors associated with tracking of BMI: a meta-regression analysis on BMI tracking. *Obesity* **19**(5), 1069–1076.

Cranfield J, Inwood K, Oxley L and Roberts E (2017) Long-run changes in the Body Mass Index of adults in three food-abundant settler societies: Australia, Canada and New Zealand. *University of Waikato Working Papers in Economics*, Hamilton.

Dravitzki V and Lester T (2006) The rise and decline of public transport in New Zealand and some lessons for its recovery. *29th Australasian Transport Research Forum. Gold Coast, Queensland, Australia*, pp. 27–29.

Dublin LI and Marks HH (1930) The influence of weight on certain causes of death. *Human Biology* **2**(2), 159–184.

Dunlop DM and Lyon RMM (1931) A study of 523 cases of obesity. *Edinburgh Medical Journal* **38**(10), 561.

Engeland A, Bjorge T, Sogaard AJ, Tverdal A, Engeland A, Bjorge T *et al.* (2003) Body mass index in adolescence in relation to total mortality: 32-year follow-up of 227,000 Norwegian boys and girls. *American Journal of Epidemiology* **157**(6), 517–523.

Engeland A, Bjorge T, Tverdal A, Sogaard AJ, Engeland A, Bjorge T *et al.* (2004) Obesity in adolescence and adulthood and the risk of adult mortality. *Epidemiology* **15**(1), 79–85.

Fellows HH (1931) Studies of relatively normal obese individuals during and after dietary restrictions. *American Journal of Medical Sciences* **181**, 301–312.

Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ *et al.* (2011) National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *The Lancet* **377**(9765), 557–567.

GBD 2015 Obesity Collaborators (2017) Health effects of overweight and obesity in 195 countries over 25 years. *New England Journal of Medicine* **377**(1), 13–27.

Gordon-Larsen P, The NS and Adair LS (2010) Longitudinal trends in obesity in the United States from adolescence to the third decade of life. *Obesity* **18**(9), 1801–1804.

Gray R (2013) Taking technology to task: the skill content of technological change in early twentieth century United States. *Explorations in Economic History* **50**(3), 351–367.

Hirko KA, Kantor ED, Cohen SS, Blot WJ, Stampfer MJ and Signorello LB (2015) Body Mass Index in young adulthood, obesity trajectory, and premature mortality. *American Journal of Epidemiology* **182**(5), 441–450. DOI: 10.1093/aje/kwv084.

Inwood K, Oxley L and Roberts E (2010) Physical stature in nineteenth century New Zealand—a preliminary interpretation. *Australian Economic History Review* **50**(3), 262–283.

Inwood K and Roberts E (2010) Longitudinal studies of human growth and health: a review of recent historical research. *Journal of Economic Surveys* **24**(5), 801–840.

Inwood K and Ross JA (2016) Big data and the military: first world war personnel records in Australia, Britain, Canada, New Zealand and British Africa. *Australian Historical Studies* **47**(3), 430–442.

Johnson W, Li L, Kuh D and Hardy R (2015) How has the age-related process of overweight or obesity development changed over time? co-ordinated analyses of individual participant data from five United Kingdom birth cohorts. *PLoS Medicine* **12**(5), e1001828.

Komlos J and Brabec M (2010) The trend of mean BMI values of US adults, birth cohorts 1882–1986 indicates that the obesity epidemic began earlier than hitherto thought. *American Journal of Human Biology* **22**(5), 631–638.

Komlos J and Brabec M (2011) The trend of BMI values of US adults by deciles, birth cohorts 1882–1986 stratified by gender and ethnicity. *Economics and Human Biology* **9**(3), 234–250.

Kvaavik E, Tell GS and Klepp K-I (2003) Predictors and tracking of body mass index from adolescence into adulthood: follow-up of 18 to 20 years in the Oslo Youth Study. *Archives of Pediatrics and Adolescent Medicine* **157**(12), 1212–1218.

McTigue KM, Garrett JM and Popkin BM (2002) The natural history of the development of obesity in a cohort of young US adults between 1981 and 1998. *Annals of Internal Medicine* **136**(12), 857–864.

Olsen A, Møller P and Hausner H (2013) Early origins of overeating: early habit formation and implications for obesity in later life. *Current Obesity Reports* **2**(2), 157–164.

Østbye T, Malhotra R and Landerman LR (2011) Body mass trajectories through adulthood: results from the National Longitudinal Survey of Youth 1979 Cohort (1981–2006). *International Journal of Epidemiology* **40**(1), 240–250.

Popkin BM (2001) The nutrition transition and obesity in the developing world. *Journal of Nutrition* **131**(3), 871S–873S.

Preston SH, Mehta NK and Stokes A (2013) Modeling obesity histories in cohort analyses of health and mortality. *Epidemiology* **24**(1), 158–166.

Reither EN, Hauser RM and Yang Y (2009) Do birth cohorts matter? *Age-period-cohort analyses of the obesity epidemic in the United States. Social Science & Medicine* **69**(10), 1439–1448.

Riet JVT, Sijtsema SJ, Dagevos H and De Bruijn G-J (2011) The importance of habits in eating behaviour. an overview and recommendations for future research. *Appetite* **57**(3), 585–596.

Roberts E and Wood P (2014) Birth weight and adult health in historical perspective: evidence from a New Zealand cohort, 1907–1922. *Social Science & Medicine* **107**(4), 154–161.

Robinson WR, Keyes KM, Utz RL, Martin CL and Yang Y (2013) Birth cohort effects among US-born adults born in the 1980s: foreshadowing future trends in US obesity prevalence. *International Journal of Obesity* **37**(3), 448–454.

Rosengren A, Wedel H and Wilhelmsen L (1999) Body weight and weight gain during adult life in men in relation to coronary heart disease and mortality: a prospective population study. *European Heart Journal* **20**(4), 269–277.

Song M, Hu FB, Wu K, Must A, Chan AT, Willett WC and Giovannucci EL (2016) Trajectory of body shape in early and middle life and all cause and cause specific mortality: results from two prospective US cohort studies. *BMJ* **353**, i2195.

Stender WW and Walker E (1974) The national personnel records center fire: a study in disaster. *The American Archivist* **37**(4), 521–549.

Stokes A and Preston SH (2016a) How dangerous is obesity? Issues in measurement and interpretation. *Population and Development Review* **42**(4), 595–614.

Stokes A and Preston SH (2016b) Revealing the burden of obesity using weight histories. *Proceedings of the National Academy of Sciences of the USA* **113**, 572–577.

Wilson R and Abbott JH (2018) Age, period and cohort effects on body mass index in New Zealand, 1997–2038. *Australian and New Zealand Journal of Public Health* **42**(4), 396–402.

World Health Organization (2009) *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. World Health Organization, Geneva.

Xu H, Cupples LA, Stokes A and Liu C-T (2018) Association of obesity with mortality over 24 years of weight history: findings from the Framingham Heart Study. *JAMA Network Open* **1**(7), e184587–e184587.

Zheng H, Echave P, Mehta N and Myrskylä M (2021) Life-long body mass index trajectories and mortality in two generations. *Annals of Epidemiology* **56**, 18–25.

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