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Abstract

A growing literature identifies associations between subjective and biometric indicators of wellbeing. These associations, together with the ability of subjective wellbeing (SWB) metrics to predict health and behavioral outcomes, have spawned increasing interest in SWB as an important concept in its own right. However, some social scientists continue to question the usefulness of SWB metrics. We contribute to this literature in three ways. First, we introduce a biometric measure of wellbeing – pulse – which has been largely overlooked. Using nationally representative data on 165,000 individuals from the Health Survey for England (HSE) and Scottish Health Surveys (SHeS) we show that its correlates are similar in a number of ways to those for SWB, and that it is highly correlated with SWB metrics, as well as self-assessed health. Second, we examine the determinants of pulse rates in mid-life (age 42) among the 9,000 members of the National Child Development Study (NCDS), a birth cohort born in a single week in 1958 in Britain. Third, we track the impact of pulse measured in mid-life (age 42) on health and labor market outcomes at age 50 in 2008 and age 55 in 2013. The probability of working at age 55 is negatively impacted by pulse rate a decade earlier. The pulse rate has an impact over and above chronic pain measured at age 42. General health at 55 is lower the higher the pulse rate at age 42, while those with higher pulse rates at 42 also express lower life satisfaction and more pessimism about the future at age 50. Taken together, these results suggest social scientists can learn a great deal by adding pulse rates to the metrics they use when evaluating people's wellbeing.

Keywords: pulse; wellbeing; mental health; general health; life satisfaction; paid work; life-course; birth cohort; NCDS.
JEL Codes: I10; J1

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1. Introduction

For decades economists eschewed the study of subjective wellbeing (SWB) and were dismissive of endeavors to understand its correlates or use wellbeing metrics in economic analysis. They were content to leave the analysis of individuals' reports of their own subjective well- and ill-being to psychologists. That changed when, in 1978, Richard Freeman showed that job satisfaction was a strong predictor of quits (Freeman, 1978). For the first time economists became interested in the potential that SWB might have in predicting economic behavior. It was apparent from Freeman's work, and indeed subsequent studies on quit behavior (eg. Green, 2010), that SWB scores contained information which could help predict economic behaviors.

Economists' interest grew as it became increasingly apparent that how people felt about themselves and the situations they faced could help explain departures from standard models of rational economic behavior. These insights, captured in the work of psychologist Daniel Kahneman and recognized in his 2002 Nobel Prize in economics, marked the advent of behavioral economics. At the same time economists began to argue that "*for many purposes, happiness or reported subjective wellbeing is a satisfactory empirical approximation to individual utility*" (Frey and Stutzer: 2002: 408). Evidence in support of this proposition came from new research measuring experienced utility, initially captured using day reconstruction methods (DRM) with time use data, and more recently in experience sampling methods (ESM) relying on responses to smartphone prompts. Both types of study have indicated that periods of work are ranked low relative to other activities in daily life, consistent with the standard assumption in neoclassical labor supply theory that, holding income constant, work is a disutility (Kahneman et al., 2004; Bryson and MacKerron, 2017).

The centrality of subjective wellbeing to new economic thinking is perhaps best encapsulated in the work of Richard Layard who argued that the happiness of its citizens should be a key objective for government, and should drive policymaking (Layard, 2005). This challenge has been taken up subsequently by governments and is reflected in the work of the Sarkozy's Commission on the Measurement of Economic Performance and Social Progress in France, prompting the OECD's Better Life Initiative for Measuring Well-being and Progress and annual progress reports from the World Happiness Report (https://worldhappiness.report/).

However, the value of subjective wellbeing data has been questioned recently by economists. Bond and Lang (2019) find that key empirical regularities in the wellbeing literature cannot be replicated using non-parametric identification techniques due to assumptions regarding the underlying functional form of the ordered responses which are usually elicited in survey questions about SWB.

In this paper we argue that SWB indicators remain important for economists, in part because they are correlated with and can predict health and labor market outcomes, but also in their own right. However, we argue that these should be supplemented with a biometric indicator, pulse rate, which has been largely overlooked in the literature. Like SWB, pulse is relatively easy to measure, but it has the advantages of being a cardinal scale and a biomarker which, as the literature in Section Two illustrates, is associated, and predictive of, a range of health conditions.

Our empirical analyses tackle three issues. First, using nationally representative data for the Health Surveys for England and Scotland and the National Child Development Study (NCDS), we show that pulse rate equations look similar to SWB equations. They have similar correlates: pulse rates are higher among women, single people, the widowed, the unemployed and disabled, the least educated, those with higher BMIs, smokers and drinkers, and those with low income. Pulse rates also vary by area being lowest in prosperous areas and higher in deprived areas. A pulse equation looks much like a GHQ equation. This helps validate SWB measures. However, unlike mental and general health, pulse rate falls monotonically with age.

Second, we consider the predictive value of pulse for SWB, general health, employment and optimism about the future in subsequent years. We do so with pulse rate data from 9000 members of the NCDS, a birth cohort who were born in a single week in 1958 in Britain. We track the impact of pulse rate measured in mid-life (age 42) on health and labor market outcomes five to ten years later. We find that pulse measured in mid-life is predictive of SWB, employment and optimism about the future five to ten years later, even when controlling for lagged dependent variables, health-related behaviors and other biomarkers such as BMI.

The remainder of the paper proceeds as follows. Section Two reviews the literatures on SWB metrics and their correlates, the association between pulse and SWB, and the literatures on the role of wellbeing indicators – subjective and biometric – in predicting health, labor market and attitudinal outcomes. Section Three introduces our data and estimation methods. Section Four presents results before we discuss the implications of our findings in Section Five.

2. Literature

We discuss four related literatures. First, we review the debate about the validity of SWB as indicated by its predictive capacity. Second, to establish whether pulse equations look like SWB equations we review the demographic, behavioral and biometric correlates of SWB in the literature.[3] Third, we consider the literature to date on the relationship between pulse, SWB, and other wellbeing metrics. Fourth, we review the small literature on the association between pulse and subsequent labour market and attitudinal outcomes.

2.1: The validity of SWB Metrics

The debate regarding the validity of SWB metrics has been reignited recently by Bond and Lang (2019) who find that key empirical regularities in the wellbeing literature cannot be replicated using non-parametric identification techniques due to assumptions regarding the underlying functional form of the ordered responses which are usually elicited in survey questions about SWB. They argue that trying to compare the relative happiness of two groups with such data relies upon identification assumptions that are strong and unlikely to be satisfied because standard parametric approaches cannot identify rankings unless the variances are exactly equal. They point out that if this is not the case ordered probit findings can be reversed by lognormal transformations. They directly challenge Ferrer-i-Carbonell and Frijters' (2004) claim, based on the fact that the correlates of SWB are similar regardless of functional form assumptions, that these assumptions are innocuous. They go on to show that in the case of nine prominent empirical regularities in happiness research conditions for nonparametric identification are rejected and standard

[3] Since ours are individual-level data we do not discuss the role of job quality or experiences in the workplace which are also known to affect worker wellbeing. For a review of these literatures see Bryson et al. (2014).

parametric results are reversed using plausible transformations. They conclude: "certainly calls to replace GDP with measures of national happiness are premature" (2019: 1639).[4]

However, a broad literature suggests SWB metrics have predictive validity because SWB predicts important outcomes for individuals over time. In addition to the association between job satisfaction and quit behavior (Freeman, 1978; Green, 2010) mentioned above, economic studies also point to the value of SWB in improving workplace performance. Using linked employer-employee panel data for Britain, Bryson et al. (2017) show that increases in mean workplace job satisfaction were positively associated with improvements in managerial assessments of workplace performance. Their differencing estimator overcomes potential confounding from fixed workplace traits since it relies on within-workplace variance over time. They also perform tests to discount the possibility of reverse causality, concluding:

"*The findings suggest that there is a prima facie case for employers to maintain and raise levels of job satisfaction among their employees. They also indicate that initiatives to raise aggregate job satisfaction should feature in policy discussions around how to improve levels of productivity and growth*" (p. 1017)

At the individual level, Oswald et al.'s (2015) laboratory experiment which randomly assigned happiness through a comedy intervention found happiness was causally linked to improved labor productivity in a real effort setting.

Most of the literature on the predictive power of SWB focuses on health-related outcomes. Subjective wellbeing has been causally linked to longevity (Diener and Chan, 2011), wound healing (Christian et al., 2006) and improved cardiovascular health.[5]

There is also evidence that the taking of anti-depressant medications is hump-shaped in age, tracking the hill-shape observed in unhappiness data as reported in Blanchflower and Oswald (2016), Blanchflower and Graham (2021a) and Blanchflower and Bryson (2021b). This is another type of validation of SWB data.

2.2: The correlates of subjective wellbeing

Subjective wellbeing is multi-dimensional. One might therefore expect to see differences in the correlates of, for example, experienced utility in the moment on the one hand, and eudemonic wellbeing on the other, since the latter involves individuals evaluating their experiences over a longer time frame. This is apparent, for example, with respect to paid employment, discussed below. Notwithstanding this, there are a number of empirical regularities that have emerged from the literature.

Perhaps the most striking, and one of the least well-understood, is the mid-life dip in wellbeing. In their review of the literature, Blanchflower and Graham (2021a) identify 375 studies indicating

[4] Recently Chen et al. (2021) have challenged this proposition, arguing the Bond and Lang critique does not hold if one focuses on ranking median happiness as opposed to mean happiness.

[5] For reviews of the literature see De Neve et al. (2013) and Steptoe (2019)'s more circumspect reflections on the state of the literature.

that wellbeing is U-shaped in age, and that the drop is substantial, akin to an event such as losing a spouse or becoming unemployed.[6] Interestingly, the happiness of great apes (assessed by keepers) is similarly U-shaped in age (Weiss et al., 2012).

The literature examining the SWB of men and women is inconsistent, with studies producing conflicting results (see Batz and Tay, 2018 who review individual studies and meta-analyses). There is emerging evidence to suggest that women are more likely to be at the extremes of the SWB spectrum when compared with men such that women are both more likely than men to be happy, but also more likely to be unhappy. For example, the UK Office of National Statistics (ONS) includes four well-being questions in its main labor market survey the Labour Force Survey. It finds that in the raw data females have higher levels of life satisfaction; happiness and worthwhileness as well as higher levels of anxiety.[7]

The more highly educated are healthier than the less educated, even when one nets out the positive effect of income on health. There is some debate as to whether this education effect is causal, with some maintaining that a causal effect is apparent and leads to healthier behaviours (Viinikainen et al., 2021). However, higher education is often correlated with lower life satisfaction and satisfaction with other facets of life, perhaps because the more highly educated have greater expectations of what their lives will be (Kristoffersen, 2018).

Whilst higher education can translate into higher income, income has its own independent association with SWB. The relationship between income and evaluative wellbeing is log-linear whereas early research suggested the relationship between income and experienced wellbeing was inverted-U shaped, rising up to a certain point beyond which the marginal returns to income diminish (Kahneman and Deaton, 2010). However, Killingsworth (2021) has recently revisited the issue and concludes that, based on 1,725,994 experience-sampling reports from 33,391 employed adults in the United States, both experienced and evaluative SWB increase linearly with log(income), directly contradicting the earlier research. Of particular note for our study, which examines SWB and pulse as a potential biometric marker of wellbeing, Johnston et al. (2009) find no evidence of an income/health gradient using self-reported hypertension as a wellbeing metric but a sizeable gradient when using objectively measured hypertension. The authors conclude that self-reported health measures may underestimate the true income-related inequalities in health.

There are a number of states that people enter which event studies indicate raise their SWB, although habituation to the new state can lead to some attenuation in the effect, whereas leaving that state can lead to reduced SWB, although studies indicate some mean reversion after a period. For instance, marriage leads to increased life satisfaction, whilst divorce or widowhood reduces

[6] The number of studies identified has since increased to 578 see https://cpb-us-e1.wpmucdn.com/sites.dartmouth.edu/dist/5/2216/files/2021/11/575-u-shapes.pdfc

[7] For example for the period September 2012-September 2017 the ONS reported the average scores for men and women as follows for the four variables scored on a 10-point scale;
1) Life satisfaction, M=7.40 F=7.49;
2) Happiness M=7.27 F=7.33;
3) Worthwhileness M=7.58 F=7.82
4) Anxiety M=2.94 F=3.16.
https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/datasets/personalwellbeingestimatesbyageandsex

life satisfaction for a while before individuals become habituated to their new state, which leads to mean reversion, though there is some heterogeneity across individuals (Lucas et al., 2003). Similar effects are observed with respect to negative health shocks, such as disabling injuries or accidents, which result in substantial falls in SWB followed by some (albeit incomplete) mean reversion (Oswald and Powdthavee, 2008).

Associations between paid employment and SWB vary according to the wellbeing dimension under consideration. As noted earlier, paid work is negatively correlated with individuals' wellbeing – work comes second bottom only to being sick in bed (Bryson and Mackerron, 2017) – but it is invariably positively and significantly associated with life satisfaction (Bryson et al., 2014). The positive association with paid work persists even controlling for income, suggesting the wellbeing effects of paid work are not confined to the utility derived from income. However, job quality matters for wellbeing: those with poor quality jobs suffer greater anxiety and stress, for example (Bryson et al., 2016).

Conversely, event studies show losing a job and becoming unemployed is particularly problematic for SWB. Indeed, it is one of the few events from which individuals' eudemonic and reflexive wellbeing does not recover, until it is reversed through re-employment (Clark and Georgellis, 2013).[8] There is some evidence that SWB deteriorates with downturns in the business cycle, though the effects tend to be short-lived (Deaton, 2012). Using repeat cross-section data from the Health Survey for England over the period 1991-2010 Katikireddi et al. (2012) show the mental health of men, measured with the GHQ, in Britain deteriorated after the Great Recession of 2008, but women's mental health was unaffected.

Many studies indicate that poor health behaviours such as smoking and drinking are linked to lower SWB. For example, in their study using the Health Surveys for England for 1998-2006, Blanchflower et al. (2011) find happiness is negatively associated with smoking. Conversely, good heath behaviours, such as the consumption of fruit and vegetables, are positively associated with SWB (op. cit.). The same is true of physical exercise, which is associated with positive affect even in healthy people (Buecker et al., 2020).

The literature on links between SWB and biometric wellbeing is still relatively new. It tends to find clear associations between biometric wellbeing measures and contemporaneous SWB. For instance, BMI is associated with lower happiness (Blanchflower et al., 2011). Associations in longitudinal studies are less clear-cut. Using the data we use in this study, Blanchfower and Bryson (2021a) show chronic pain in mid-life is associated with depression, emotional and psychiatric problems a decade later. Yet, using the Young Finns Study (N=1905), Böckerman et al. (2017) found no robust association between eight biomarkers measured in childhood (1980) and happiness in adulthood (2001).[9]

[8] The unemployed are able to find coping strategies, however. They exploit their free time by shifting towards more enjoyable activities, subject to their budget constraints, thus closing the momentary wellbeing gap on those in paid employment who do not have the same free time (Knabe et al., 2010).

[9] Genome-wide studies have recently investigated genetic variants associated with SWB (Okbay et al., 2016) while Weiss et al. (2002) show that SWB is heritable in great apes.

2.3: The Association Between Pulse and Wellbeing

Few studies consider the correlation between pulse and wellbeing. Among those that do are studies seeking to establish whether affect is associated with underlying health. These studies are motivated by the literature showing raised heart rate – and higher blood pressure – are risk factors for coronary heart disease (Kannel et al., 1987). There is also emerging evidence that SWB may be a protective mechanism against cardiovascular disease (Sin, 2016).

In the study for Finland, Böckerman et al. (2017) found a positive correlation between pulse in childhood (1980) and happiness in adulthood (2001) with a one standard deviation increase in pulse associated with a 0.6 point increase in a 5-point happiness scale. Although the correlation remains positive and statistically significant when conditioning on other biomarkers, contemporaneous education and earnings, and family income as a child, it loses statistical significance when conditioning on physical activity and childhood consumption of fruit, vegetables, and carbohydrates.

A series of studies by Andrew Steptoe and colleagues using samples from the Whitehall II studies of British civil servants suggest positive SWB is associated with health-relevant biological processes. These studies include investigations of links between heart rate and SWB both contemporaneously and in a three year follow-up.

In their study of 216 middle-aged men and women from the Whitehall II study Steptoe and Wardle (2005) and Steptoe et al., (2005) found greater happiness – assessed through repeated measurements over the course of the working day – was associated with a lower heart rate among men, but not women. The association was apparent controlling for age, grade of employment, smoking, BMI, physical activity levels and GHQ scores. Happiness was not associated with ambulatory systolic blood pressure. A follow up on a non-random subset of cases (N=162) found happiness at baseline predicted lower heart rate 3 years later among men. The follow up also found a significant inverse association between happiness and systolic blood pressure. Commenting on the gender differences in results they say: "*the explanation of the gender difference in heart rate is not clear, but observational epidemiological studies have shown consistent associations between mortality and heart rate more in men than women*".

In a large study of Whitehall II participants (n=4,754) in their sixties tracked 5 years later, Ikeda et al. (2020) examine links between aortic stiffness –an aspect of cardiovascular disease – and two types of SWB, namely affective wellbeing and eudaimonia. Aortic stiffness is measured by aortic pulse wave velocity (PWV). They find eudaimonic wellbeing (CASP-19 items relating to control, autonomy, personal growth and self-realization) was correlated with lower PWV at baseline and PWV 5 years later (captured with the interaction of wellbeing and time lapsed before next measurement), but only in men, while affective wellbeing (the pleasure in life sub-scale of CASP-19) is not associated with PWV. There was no association between changes in PWV and changes in SWB among men or women.

This study, like others, suggests a negative correlation between SWB and cardiac function in men but not women. They say: "In the present study, eudaimonic wellbeing in men, but not in women, was associated with a favorable atherosclerosis risk profile, characterized by lower BMI and HR and lower hypertension medication use. However, our present findings were maintained after adjusting for an array of social, behavioral, and biologic factors, suggesting that other mechanisms linking wellbeing with these biological alterations may explain the observed sex differences". One of the controls in their models is resting heart rate, but little attention is paid to the link between pulse rate and aortic stiffness. However, in their supplementary material, it seems heart rate falls as eudaemonia rises in both men and women (Ikeda et al., 2020: Table S3).

Wells and Townsend (2020) note that there are three aspects of pulse that are potentially related to cardiovascular function. These are rate, regularity and quality.[10] In our empirical estimates we focus on pulse rate. Sloan et al. (2017) examine correlations between SWB and heart rate variability or regularity: they find no association between heart rate variability and SWB (positive affect and eudaimonia). However, Bhattacharyya et al. (2008) find positive affect is associated with healthier levels of heart rate variability.

One hundred years ago Addis (1922) showed pulse rose with work load. Some studies examine the heart rates when subjects are under strain. For instance, Troubat et al. (2009) record changes in heart rate and metabolism among chess players and show heart rate rises during mental stress.

In their work Shedler et al. (1993) examined the response of the heart to distinguish between people who were genuinely distressed (according to a clinician) yet appeared 'healthy' based on their responses to a battery of mental health questions (a state they term "illusory mental health"), and those who reported distress and were judged distressed by a clinician (the "manifestly distressed"). They measured pulse responses to stress using heart rate and a slightly different metric (rate pressure product, which combines heart rate and blood pressure).

In laboratory experiments the authors show that those with illusory mental health showed greater coronary reactivity, that is, greater heart response under stress as compared to baseline non-stress spells, than those who were manifestly distressed subjects. The authors suggest "this is consistent with the hypothesis that the mental health scales were not assessing mental health in these subjects, but instead were assessing defensive denial" (p. 1127). The study is important in the context of our study because it warns of the dangers in over-reliance on self-reports of mental wellbeing, and the value of heart rate measures in checking for underlying mental health.

In their single-site study of employees in a mid-size firm in California Wright et al. (2009) examine the role of psychological wellbeing[11] in predicting cardiovascular health, which they measure in terms of employees' diastolic blood pressure (DBP), systolic blood pressure (SBP) and pulse rate. They combine these three measures into a pulse product measure which is defined as the difference between SBP and DBP multiplied by the puse rate and divided by 100. They find pulse product was negatively related to wellbeing, even after controlling for other cardiovascular health risk factors whereas SBP and DBP were not significantly related to psychological wellbeing.

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[10] Pulse pressure – which is the difference between disastolic and systolic blood pressure – is a different measure again.

[11] Measured with the 8-item Index of Psychological Well-Being developed by Berkman (1971).

2.4: The Association Between Pulse and Subsequent Labour Market and Attitudinal Outcomes

With the exception of some of the studies above which look at the relationship between pulse and health or SWB outcomes over short time-frames, there are very few studies that consider the role of pulse in predicting longer-run outcomes.

Chandola and Zhang (2018) followed 1116 individuals aged 35-75 over three years to examine the value of re-employment in a poor quality job versus remaining unemployed. They found those who transitioned into poor quality jobs had greater adverse levels of biomarkers than those remaining unemployed, but there were no significant differences in pulse.[12]

3. Data and Estimation

In the first part of our analyses we use pooled cross-sectional time series data from the Health Survey for England (HSE) and the Scottish Health Survey (SHeS) to examine the correlates of pulse rates. The HSE monitors trends in the nation's health and care. It provides information about adults aged 16 and over, and children aged 0 to 15, living in private households in England. The survey consists of an interview, followed by a visit from a nurse who takes some measurements and blood and saliva samples. Each survey in the series includes core questions, and measurements such as blood pressure, height and weight measurements and analysis of blood and saliva samples. In addition there are modules of questions on specific topics that vary from year to year. The SHeS series was established in 1995 to provide data about the health of the population living in private households in Scotland. It was repeated in 1998 and 2003 and has been carried out annually since 2008.

We begin with models containing demographic traits only, then extend them to include health behaviours and biomarkers. We compare these models with SWB models containing identical co-variates. Our SWB outcomes are the GHQ36, self-assessed general health, life satisfaction and the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS).[13]

With the exception of Table 1, which includes individuals of all ages, we confine our analyses to those aged under 70 given our interest in the importance of pulse rates for those of working age. We then turn to the NCDS Biomedical Survey, conducted when cohort members were between the ages of 42 and 44 years, to establish the correlates of pulse rates and other health-related outcomes (self-assessed general health, anxiety and sleep problems).

In the final part of the paper we use the longitudinal data in the NCDS to establish the long-run consequences of pulse rates measured at age 42-44 in the Biomedical Survey on the probabilility of working, health status, optimism and life satisfaction roughly 5-10 years later.

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[12] The adverse effects were apparent with regards to allostatic load, triglycerides, C-reactive protein, fibrinogen and cholesterol.

[13] *WEMWBS was developed to enable the measuring of mental wellbeing in the general population and the evaluation of projects, programmes and policies which aim to improve mental wellbeing. The 14-item scale has 5 response categories, summed to provide a single score. The items are all worded positively and cover both feeling and functioning aspects of mental wellbeing, thereby making the concept more accessible.*

Throughout the pulse rate is the number of times the heart beats per minute and is measured by a nurse. In both the HSE and the SHeS the pulse variable we use is taken as the average of three readings and if three are not all available, the average of two or just a single reading if that is all that is present. In the HSE we have pulse data available every year from 1998-2018 with a mean of 70.22 and SD=10.68 and a sample size of 142,310. In the SHeS we have data available for 1998; 2003 and 2008-2019; pulse has a mean of 69.94 and an SD of 11.32 with a sample size of 25,278.

The pulse variable in the NCDS is also taken by a nurse, as part of a biomedical survey conducted when cohort members were aged between 42 and 44. Once again our pulse rate measure is the average of three readings. The variable has a mean of 71.7 with an SD of 10.6 and there are 9,299 observations.

4. Results

The demographic correlates of pulse rates in the Health Survey for England are presented in column 1 of Table 1. The model, which is run on over 140,000 individuals from the pooled cross-sectional data for HSE from 1998-2018, accounts for roughly 4 percent of the variance in pulse rates across the data.

Pulse rates decline through age until people reach their eighties. Pulse rates are lower among men, in London and the South East. They are higher among the temporarily sick, the permanently disabled and the unemployed. Pulse rates are lower among the more highly educated. Married respondents have lower pulse rates than the never married.

In the rest of Table 1 we examine three other dependent variables:

a) The General Health Questionnaire (GHQ36) score, which is a measure of current mental health, ranges from 0 through 36 and is available for 1998-2010. 2012; 2014; 2016 and 2018. It has a mean of 10.69 and an SD of 4.94: a higher score means less happy with a sample size of 147,568 in column 1.
b) The WEMWBS score ranges between 14 and 70 and has a mean of 51.2 and an SD of 8.9, and a sample size of 47,529 in column 3 and is available for 2010-2016.
c) The general health variable in column 4 has five options – very bad (1.9%); bad (5.6%); fair (18.8%); good (41.7%) and very good (32.1%) and has a mean of 3.96, and SD of .95 and a sample size of 194,155. It is available every year from 1998-2018 except 2015.

The performance of the variables in the pulse rate equation is mirrored closely in columns 2 and 3 for GHQ score and general health both in terms of the signs and significance of the control variables. So, being unemployed is associated with a higher pulse rate and a higher GHQ score and lower WEMWBS and general health. The main difference is that the GHQ score peaks in the age range 45-49 and 55-59 for general health, as is normally the case in SWB equations (Blanchflower and Graham 2021a, 2021b). But, broadly speaking, the pulse rate equations look remarkably like happiness and unhappiness equations.

Table 2 estimates additional pulse rate and GHQ models for HSE which extend the models in Table 1 to include additional covariates relating to BMI, medication, health behaviours and, in columns 2 and 4, income. The adjusted-R^2 doubles relative to Table 1, rising to around 0.10. Unsurprisingly, taking beta blockers is associated with lower pulse rates and GHQ scores. However taking blood pressure medication is associated with higher pulse rates and GHQ scores. Smokers have higher pulse rates, with pulse rates rising with the recency and intensity of smoking. Those who drink alcohol every day also have higher pulse rates but, perhaps surprisingly, those who drink alcohol less frequently have lower pulse rates than non-drinkers. Pulse rates fall as income rises. These results are largely replicated in the GHQ scores in columns 3 and 4, except with respect to drinking alcohol where the highest GHQ scores are recorded by non-drinkers.

Table 3 is an attempt to replicate the Table 1 results using data from the Scottish Health Surveys (SHS) of 1998-2003 and 2008-2019, but for those of working age only (as in Table 2). Sample sizes are smaller than using HSE but include the same four dependent variables as used in Table 1. As with the HSE pulse rates are lower for men, the more educated and the married and decline with age (the non-significant quadratic age term is omitted from the pulse equation). The disabled and the unemployed once again have higher pulse rates. Similarly general health, and WEMWBS are positively correlated with education, work, and marriage.

We now move on to look at longitudinal data on pulse rate taken from the British National Child Development Study (NCDS), a birth cohort of everyone born in a week in March 1958. Cohort members have been followed into their early sixties. We use follow up data through to age fifty-five. We have pulse rates available just once at age 42 in the Biomedical Survey (BIOS) taken in 2000. We look at its determinants and then show it has predictive power years later.

Table 4 uses data that are all provided in the BIOS. The pulse equation in column 1 looks much like those reported in Tables 1-3. Pulse rates are higher among those with a higher BMI, smokers and frequent alcohol drinkers. Pulse is lower for those who drink 2-3 times a week compared to thos who never drink. In keeping with the results on income discussed above, we find pulse rates are higher if individuals have difficulty paying their bills. Consistent with the finding above that those who are sick or disabled have higher pulse, we find pulse rises with the intensity of pain cohort members suffer.[14]

Table 4 presents models containing identical controls for three other outcomes capturing wellbeing, namely self-reported general health (where higher scores mean higher wellbeing), sleep problems and anxiety. General health is coded 1-4 (mean=3.0); sleep problems is a 1,0 dummy if the respondent had problem sleeping last month (mean=.37) and anxious is a 1,0 dummy if the respondent is anxious, nervous and tense (mean=.22). These equations are similar in most respects to the pulse equation.

Table 5 builds on the pulse rate equations in Table 4 with the addition of controls for education, region, and labor force status. Although they are jointly statistically significant, they do not add greatly to the explained variance in the model. Column 2 drops the chronic pain variable which increases the sample size and then in column 3 we add controls for the respondent's father's occupation at the time of their birth in 1958 and reported then. Estimates seem very stable and

[14] For more evidence on the correlates and impact of chronic pain see Blanchflower and Bryson (2021).

look much like happiness equations. It is nevertheless striking to see that one's father's occupation when you were born over four decades earlier can still impact one's pulse rate.

The question then is whether pulse rates have predictive power and it turns out they do. But first, in Table 6 we use the HSE (panel a)) and SHeS (panel b) to assess the correlation between pulse rates and contemporaneous measures of work (1 if working, zero otherwise), GHQ36 and general health, having controlled for age, gender, region, education, marital status and year. In all of them pulse rates are significant and have similar signs – negative in work and health status equations and positive in GHQ scores.

Part c) adds two further variable – WEMWBS and life satisfaction, scored from 1-10 - and as with the general health scores the pulse rate enters negatively and significantly.

Table 7 estimates the probability of paid work at age 55. At that point in their life cycle 81.2% NCDS respondents were employed. In column 1 we see work probabilities are higher in the South East and the West Midlands, and as expected among men, and the more educated. Column 2 then adds the pulse rate at age 42 which is significant and negative and, notably with the same coefficient of -.0022 as found in Table 6 for both the HSE and the SHeS. Several other variables at age 42 are also added including two pain variables and difficulty paying bills which all have significant impacts. The impact of these variables which were recorded thirteen years earlier, including the pulse rate, continues even when we include controls for labor market status from NCDS7 taken at age 40 in 1998 (columns 3 and 4) – noting that labor market status is not available in the BIOS survey.

The pulse rate variable is also significant and negative in column 4 as we add controls for fibrinogen and C-reactive protein (Blanchflower et al., 2011). In column 5 we add the occupation of the respondent's mother's husband (not necessarily their father) and there is little impact on the pulse coefficient which is almost identical to that in column 4 at -.0025. We further experimented in Table 7 including systolic and diastolic blood pressure from the BIOS and BMI in NCDS9 as controls in these work equations and none were significant. This was true for both men and women.

Finally, in Table 8 we estimate the association between pulse rate at age 42 and SWB some years later. Column 1 models self-assessed general health in NCDS9 at age 55. Pulse some 13 years earlier is negative and significant. We then move to using data from NCDS8 at age 50 in 2005 to capture the association between pulse at age 42 and life satisfaction at 50 as well as views on their life ten years ahead. Both are scored from 0 to 11 (mean=7.29 and 7.68 respectively). There are no life satisfaction scores available in NCDS9. A higher the pulse rate 8 years earlier lowers life satisfaction and also makes respondents more pessimistic about their futures.

5. Conclusions

A small number of papers point to the value of using biometric markers of wellbeing in addition to SWB measures because self-reports of wellbeing can be unreliable (Schedler et al., 1993; Johnston et al., 2009). In this paper we have emphasized the potential value of pulse rate as an objective metric of wellbeing. We have shown that it is highly correlated with various subjective wellbeing (SWB) metrics, and that it shares many of the same determinants. We show that it is predictive of subsequent wellbeing – self-assessed health, satisfaction with the way life has turned out and expected life satisfaction in 10 years time – and that it is also predictive of subsequent labour market status, which itself has important implications for individuals' wellbeing.

The value of pulse rate as a wellbeing metric is that, unlike SWB metrics, it is recorded on an objective cardinal scale, which means it can be used as a wellbeing metric without being subject to the Bond and Lang (2019) critique of ordinal SWB scales which points to their fragility to assumptions regarding their underlying functional form.

For some time individuals have been encouraged to take their pulse rates in stressful situations such as students in classroom settings as a way of assessing their health (Romano, 1992). Even golfers are wearing devices to measure their pulse rate, which appear to get very high at crucial moments.[15] It is now much easier to do so through smart devices (Gyrard and Sheth, 2020). It seems sensible, therefore, for health professionals and academic alike to pay more attention to these data, and perhaps for individuals to have greater regard to their pulse rates, alongside other biomarkers such as blood pressure and BMI.

[15] The PGA Tour has partnered with Whoop, a fitness and recovery tracker, to show live heart rates. It is reported that Rory McIlroy's heart rate on the 72nd hole of the 2021 Wells Fargo Championship at Quail Hollow, that he won, spiked at 140bpm following the tee shot. It settled back to 115 as he addressed his approach to the green but following his putt to win, it reached 151.
https://www.golfwrx.com/654185/rory-mcilroys-heart-rate-hit-stunning-high-on-72nd-hole-at-wells-fargo/

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Table 1. Demographic Correlates of pulse rates, GHQ score and General Health

	Pulse rates	GHQ36	WEMWBS	General health
18-19	.1815 (0.68)	.3916 (3.63)	.7880 (1.76)	-.0536 (3.11)
20-24	-.3512 (1.48)	1.0177 (10.47)	.1188 (0.30)	-.1054 (6.78)
25-29	-.4131 (1.64)	1.4597 (14.06)	-.6458 (1.56)	-.0963 (5.83)
30-34	-.7175 (2.88)	1.5959 (15.40)	-1.1987 (2.92)	-.1050 (6.38)
35-39	-.7905 (3.18)	1.9127 (18.45)	-1.6329 (3.99)	-.1622 (9.84)
40-44	-.7561 (3.03)	2.0239 (19.40)	-1.6438 (4.05)	-.2106 (12.72)
45-49	-.7022 (2.79)	2.0701 (19.60)	-1.8927 (4.67)	-.2633 (15.74)
50-54	-1.0591 (4.19)	2.0558 (19.34)	-1.6241 (3.98)	-.3325 (19.75)
55-59	-1.2998 (5.10)	1.6569 (15.39)	-.8609 (2.09)	-.3354 (19.69)
60-64	-1.6195 (6.19)	1.1844 (10.67)	.4251 (1.02)	-.3326 (19.01)
65-69	-2.3174 (8.48)	.7051 (6.05)	1.6470 (3.85)	-.3117 (16.99)
70-74	-2.9644 (10.48)	.6859 (5.66)	.9812 (2.22)	-.3660 (19.28)
75-79	-3.4994 (11.91)	.7887 (6.23)	1.1023 (2.40)	-.4196 (21.28)
80-84	-3.4826 (11.05)	1.0627 (7.80)	-.0460 (0.09)	-.4889 (23.20)
85-89	-3.1166 (8.51)	1.6611 (10.47)	-.7753 (1.37)	-.5665 (23.44)
90+	-1.9112 (7.64)	1.1841 (10.92)	-.0546 (0.14)	-.0909 (5.46)
Year	-.0084 (1.36)	.0023 (0.83)	-.1517 (5.50)	.0002 (0.57
Male	-2.6211 (44.73)	-.8070 (30.69)	.2141 (2.62)	.0055 (1.35)
NW & Merseyside	-.1998 (1.55)	-.1248 (2.10)	.1556 (0.91)	.0786 (8.68)
Yorks & Humber	.2066 (1.51)	-.1776 (2.83)	.0986 (0.53)	.0482 (5.01)
West Midlands	-.4478 (3.27)	-.1285 (2.04)	.2575 (1.38)	.0731 (7.56)
East Midlands	-.7708 (5.62)	-.1079 (1.72)	-.0204 (0.11)	.0616 (6.43)
Eastern	-.9614 (7.17)	-.3365 (5.48)	.5298 (2.97)	.1188 (12.60)
London	-1.0173 (7.40)	-.1396 (2.26)	.5843 (3.14)	.0826 (8.76)
South East	-1.0044 (7.88)	-.3839 (6.51)	.9630 (5.76)	.1459 (16.15)
South West	-1.1264 (8.40)	-.3274 (5.25)	.3128 (1.72)	.1582 (16.54)
Black	1.2494 (7.34)	-.6765 (9.51)	2.0891 (8.14)	-.1564 (14.56)
Asian	3.3051 (27.19)	.0818 (1.59	.0682 (0.36)	-.2735 (35.34)
Mixed	.6026 (2.62)	-.0204 (0.18)	.8844 (3.70)	-.0840 (5.60)
Other	1.3908 (4.83)	-.0615 (0.50)	.6194 (1.66)	-.1713 (9.55)
Work	.0359 (0.18)	-.6501 (7.79)	-.0895 (0.27)	-.0188 (1.42)
Unpaid work	.1106 (0.18)	.2091 (0.79)	-.8265 (0.93)	-.1530 (3.66)
Waiting take up job	2.3087 (4.94)	.8191 (3.92)	-1.7914 (3.16)	-.2757 (8.70)
Unemployed	1.7519 (6.26)	1.4524 (12.41)	-3.0633 (7.17)	-.2639 (14.42)
Unemployed temp sick	3.9211 (10.87)	6.7138 (39.70)	-10.7012 (22.88)	-1.6197 (65.26)
Permanently disabled	1.2877 (5.71)	3.1169 (31.62)	-2.7311 (7.74)	-1.104 (72.30)
Retired	.6717 (2.95)	.1380 (1.42)	-1.4244 (3.98)	-.3604 (23.51)
Home worker	1.4261 (6.41)	.0528 (0.57)	-1.4334 (3.88)	-.2574 (17.39)
Never went to school	.4951 (1.14)	.9417 (4.67)	-3.5332 (3.66)	-.4779 (17.42)
ALS <=14	.7507 (3.42)	.4295 (4.61)	-2.4840 (6.02)	-.4000 (26.93)
ALS 15	.4818 (2.38)	.0036 (0.04)	-1.9473 (5.21)	-.2321 (16.93)
ALS 16	.5036 (2.57)	-.0757 (0.93)	-1.7629 (4.85)	-.1111 (8.41)
ALS 17	.2524 (1.20)	-.1407 (1.59)	-1.0791 (2.86)	-.0380 (2.67)
ALS 18	-.1722 (0.83)	-.1698 (1.95)	-.4409 (1.19)	.0009 (0.07)

ALS>=19	-.6903 (-3.50)	-.2136 (2.60)	.2773 (0.77)	.0880 (6.63)
Married	-1.3307 (14.06)	-.7623 (18.37)	3.3031 (26.12)	.1261 (19.84)
Separated	.0969 (0.49)	.9862 (11.08)	.8141 (2.92)	-.0292 (2.13)
Divorced	.1155 (0.83)	.2943 (4.68)	1.0723 (5.70)	-.0283 (2.92)
Widowed	-.4315 (2.97)	-.6591 (10.05)	2.4489 (11.78)	.1111 (11.16)
Cohabitee	-.5466 (4.54)	-.2532 (4.80)	2.0155 (13.02)	.0114 (1.41)
Constant	73.0758	5.7088	356.18	4.8309
Adjusted R^2	.0411	.0709	.0756	.2380
N	141,440	147,568	47529	194,155

T-statistics in parentheses: excluded: 16-17; North East; single; going to school college; not yet finished school; white

WEMWBS is available for 2010-2016; pulse and general health for 1998-2018; GHQ36 for 1998-2006; 2008-10; 2012; 2014; 2016 and 2018.

Table 2. Pulse rates, Health Survey for England, 1998-2018 – all ages

	Pulse rates		GHQ36	
BMI	.2277 (39.8)	.2303 (36.29)	.0265 (9.96)	.0287 (9.68)
Taking beta blocker	-9.0107 (76.3)	-8.9770 (67.92)	-.3227 (5.07)	-.3164 (4.49)
N/a beta blocker	-.4097 (5.9)	-.3449 (4.49)	-.7510 (26.17)	-.7420 (23.17)
Taking BP medications	.7767 (10.3)	.7568 (9.08)	.3987 (10.55)	.3539 (8.32)
Used to smoke occasionally	-.3844 (3.0)	-.3606 (2.60)	.2573 (4.37)	.2346 (3.61)
Used to smoke regularly	.0625 (0.8)	.0754 (0.96)	.2530 (7.43)	.2330 (6.20)
Current smoker	3.2150 (41.2)	3.1645 (36.23)	.8954 (25.19)	.8243 (20.58)
Drink 5 or 6 days a week	-1.2891 (8.4)	-1.2516 (7.55)	.0038 (0.05)	-.0147 (0.19)
3 or 4 days a week	-1.6776 (15.2)	-1.6792 (13.96)	-.0756 (1.48)	-.0968 (1.73)
Once or twice a week	-1.2992 (13.1)	-1.3740 (12.66)	-.0650 (1.43)	-.1273 (2.53)
Once or twice a month	-.9453 (8.2)	-1.0330 (8.17)	.2091 (3.92)	.1313 (2.22)
Once every couple months	-.7412 (5.5)	-.9402 (6.32)	.1937 (3.07)	.1377 (1.97)
Once or twice a year	-.6698 (5.0)	-.7851 (5.30)	.2110 (3.43)	.1618 (2.34)
Not at all in last 12 months	-.0018 (0.0)	.2002 (0.55)	.5577 (3.70)	.6753 (3.91)
Male	-2.5503 (42.0)	-2.5402 (37.75)	-.7350 (25.97)	-.7396 (23.41)
2nd income quintile		-.0107 (0.10)		-.3713 (7.45)
3rd income quintile		-.3262 (3.02)		-.6220 (12.30)
4th income quintile		-.6233 (5.53)		-.7132 (13.53)
Top income quintile		-1.1133 (9.40)		-.8054 (14.53)
Constant	109.49	123.19	19.43	21.47
Adjusted R^2	.1068	.1063	.0837	.0896
N	129,448	104,190	129,628	101,024

Notes: all equations also include year dummies, education, 11 age dummies, region, race, labor force and marital status. Excluded – drink almost every day; never smoked at all; doesn't take beta blockers. T-statistics in parentheses

Table 3. Scottish Health Survey, 1998, 2003, 2008-2019

	Pulse rates	Pulse rates.	GHQ36	WEMWBS	General health
Male	-2.7669 (19.13)	-2.6513 (14.74)	-.8453 (20.50)	.1320 (1.80)	.0188 (2.72)
Borders	-.9830 (2.34)	-1.0285 (1.97)	-.1150 (0.94)	.5697 (2.51)	-.1136 (5.49)
Dumfries & Galloway	-.0088 (0.02)	.3053 (0.53)	-.2755 (2.11)	.1773 (0.76)	-.0271 (1.24)
Fife	-.4827 (1.29)	-.2810 (0.59)	-.0570 (0.61)	.2147 (1.32)	-.0198 (1.26)
Forth Valley	-.3173 (0.90)	-.2794 (0.58)	-.0645 (0.57)	-.0231 (0.11)	-.0151 (0.79)
Grampian	-.6074 (1.71)	-.9400 (2.09)	-.3480 (3.77)	.3832 (2.39)	-.0579 (3.71)
Glasgow and Clyde	-.1980 (0.62)	-.3769 (0.95)	.1038 (1.21)	-.1377 (0.93)	.0151 (1.05)
Highland	-1.1107 (3.11)	-1.0125 (2.25)	-.0774 (0.72)	.9110 (4.47)	-.0197 (1.09)
Lanarkshire	.1082 (0.28)	.1144 (0.26)	.0146 (0.15)	-.0951 (0.55)	.0187 (1.13)
Lothian	-.8081 (2.47)	-.4843 (1.17)	-.0908 (1.01)	.3417 (2.17)	-.0550 (3.64)
Orkney	-1.2457 (3.26)	-1.1878 (2.39)	-.2001 (1.66)	.5824 (2.45)	-.1076 (5.25)
Shetland	-1.2123 (2.50)	-.6924 (0.97)	-.2958 (2.07)	.7301 (2.98)	-.0982 (4.11)
Tayside	-.7679 (1.87)	-.9617 (2.03)	-.0832 (0.77)	.1455 (0.79)	-.0852 (4.69)
Western Isles	-.7503 (1.65)	.0991 (0.16)	-.5290 (4.09)	1.1921 (5.03)	-.0776 (3.58)
Never went to school	.1906 (0.12)	-1.8110 (0.92)	1.7595 (2.99)	-3.7679 (2.89)	.2948 (3.21)
ALS <=14	.4550 (0.81)	.2137 (0.28)	.3644 (1.83)	-2.9535 (7.42)	.3550 (0.68)
ALS 15	-.2470 (0.50)	-.3265 (0.49)	-.0539 (0.31)	-2.2026 (6.28)	.2159 (7.38)
ALS 16	-.0459 (0.09)	.0411 (0.06)	-.2455 (1.45)	-1.7789 (5.19)	.0974 (3.40)
ALS 17	-.8928 (1.76)	-.8523 (1.26)	-.3286 (1.89)	-1.0356 (2.98)	.0091 (0.31)
ALS 18	-.9174 (1.70)	-.8977 (1.27)	-.3690 (2.06)	-.5096 (1.43)	-.0059 (0.20)
ALS>=19	-1.8459 (3.76)	-1.6991 (2.58)	-.3020 (1.77)	-.4608 (1.35)	-.0687 (2.39)
Work	.5461 (1.15)	.8538 (1.42)	-.4537 (3.36)	.0666 (0.27)	-.0256 (1.13)
Permanently disabled	4.8296 (8.09)	4.5493 (6.32)	6.0181 (37.07)	-9.4496 (32.10)	1.5665 (57.70)
Unemployed	2.4228 (4.04)	1.7756 (2.33)	1.8155 (10.49)	-2.7220 (8.66)	.2445 (8.39)
Retired	.7025 (1.25)	.7537 (1.07)	.0344 (0.22)	-.6014 (2.09)	.2303 (8.60)
Looking after home	2.7718 (5.06)	2.2685 (3.22)	.2741 (1.73)	-1.3733 (4.70)	.1546 (5.78)
Something else	.7154 (1.20)	2.1945 (2.15)	1.1705 (5.49)	-1.7446 (4.72)	.2853 (7.97)
Married	-.7356 (3.64)	-.4046 (1.63)	-.3724 (6.65)	1.4525 (14.75)	-.0679 (7.22)
Separated	.7939 (1.97)	1.2248 (2.24)	1.3010 (10.27)	-1.3865 (6.05)	.0502 (2.36)
Divorced	.6840 (2.20)	1.3324 (3.41)	.4422 (4.88)	-.5705 (3.52)	.0656 (4.30)
Widowed	.0519 (0.16)	.0803 (0.19)	.1728 (1.77)	-.1107 (0.63)	-.0655 (4.02)

2nd income quintile		.4676 (1.77)	.0422 (0.69)	-.6996 (6.44)	.0603 (5.83)
3rd income quintile		.7284 (2.63)	.2688 (4.19)	-1.0882 (9.56)	.1604 (14.83)
4th income quintile		.6166 (2.09)	.5207 (7.67)	-1.9405 (16.05)	.2817 (24.67)
Top income quintile		1.5263 (4.62)	.9875 (13.22)	-2.8456 (21.48)	.3140 (25.15)
Constant	431.64	562.58	33.30	65.12	8.51
Adjusted R^2	.0537	.0602	.1285	.1379	.2638
N	25,146	15,585	58,129	51,277	62,637

Notes: missing categories; in education; single; not yet finished school; Ayrshire and Arran. Includes 16 age dummies and year. T-statistics in parentheses.

Table 4. Determinants of Pulse Rates at age 42, only using data from NCDS, Biomedical Survey

	Pulse rates	General health	Sleep problems	Anxious
Male	-2.8247 (11.49)	.0626 (4.47)	-.0802 (7.16)	-.0800 (8.29)
BMI	.3262 (11.57)	-.0281 (17.63)	.0009 (0.67)	.0020 (1.84)
Short pain	.0610 (0.17)	-.1216 (5.91)	.0640 (3.88)	.0331 (2.33)
Chronic pain	.6418 (2.57)	-.2727 (19.19)	.1472 (12.95)	.0482 (4.92)
Ex-smoker	-.1183 (0.44)	-.0544 (3.53)	.0138 (1.12)	.0091 (0.86)
Current smoker	4.0654 (13.81)	-.2584 (15.38)	.0244 (1.82)	.0307 (2.66)
Drink frequency				
Drink <=1 a month	-.7530 (1.40)	.1385 (4.54)	-.0187 (0.76)	-.0641 (3.05)
2-4 times a month	-1.0639 (2.08)	.2177 (7.49)	-.0142 (0.61)	-.0718 (3.58)
2-3 times a week	-1.5075 (3.06)	.2419 (8.62)	-.0172 (0.77)	-.0701 (3.62)
>=4 times a week	-.6901 (1.37)	.2362 (8.23)	.0077 (0.34)	-.0538 (2.72)
Drink missing	-1.2859 (0.64)	-.0573 (0.52)	-.1161 (1.03)	-.1469 (1.51)
Difficulty paying bills				
Great difficulty	-3.0332 (2.20)	.3066 (3.88)	-.1463 (2.32)	-.1055 (1.94)
Some difficulty	-2.9506 (2.50)	.3971 (5.87)	-.1634 (3.04)	-.1011 (2.18)
Slight difficulty	-2.8568 (2.46)	.4904 (7.34)	-.2171 (4.09)	-.1550 (3.39)
Very little difficulty	-2.6925 (2.35	.6270 (9.55)	-.2632 (5.05)	-.1714 (3.81)
Missing	-3.9289 (1.43)	.4872 (3.19)	-.4832 (3.76*)	-.1313 (1.18)
Constant	1.1067	3.0287	.5518	.3914
Adjusted R^2	.0543	.1721	.0389	.0206
N	8,161	8,092	8,165	8,164

Excluded: very great difficulty paying bills; drink not in the last 12 months; never smoked

Table 5. Determinants of Pulse Rates at age 42, NCDS, Biomedical Survey

Male	-2.7876 (9.61)	-2.7249 (9.79)	-2.8625 (10.04)
BMI	.3103 (10.50)	.2946 (0.45)	.2963 (10.24)
Chronic pain	.4145 (1.68)		
Ex-smoker	-.1006 (0.36)	.0025 (0.01)	-.0465 (0.17)
Current smoker	3.9020 (2.26)	3.8561 (2.68)	3.7388 (1.92)
Drink frequency			
Drink <=1 a month	-.6151 (1.09)	-.3652 (0.68)	-.6459 (1.14)
2-4 times a month	-.9916 (1.83)	-.8814 (1.71)	-1.1126 (2.04)
2-3 times a week	-1.3093 (2.50)	-1.0741 (2.15)	-1.3265 (2.51)
>=4 times a week	-.4059 (0.75)	-.1947 (0.38)	-.3996 (0.74)
Difficulty paying bills			
Great difficulty	-3.0019 (2.00)	-2.8707 (1.92)	-3.1706 (2.05)
Some difficulty	-2.9033 (2.25)	-2.9283 (2.28)	-3.5170 (2.64)
Slight difficulty	-2.6147 (2.05)	-2.6173 (2.06)	-3.1242 (2.37)
Very little difficulty	-2.2162 (1.76)	-2.2745 (1.81)	-2.6109 (2.01)
Yorks & Humber	-.6827 (1.10)	-.5261 (0.88)	-.7229 (1.17)
East Midlands	-.5610 (0.88)	-.8461 (1.37)	-1.1257 (1.79)
East Anglia	-1.0647 (1.42)	-.9372 (1.31)	-1.0394 (1.41)
South East	-.4965 (0.94)	-.5434 (1.06)	-.7514 (1.43)
South West	-.8461 (1.38)	-.8651 (1.46)	-.8979 (1.47)
West Midlands	-.1315 (0.21)	-.2544 (0.42)	-.2475 (0.40)
North West	.4108 (0.68)	.3715 (0.64)	.1232 (0.21)
Wales	.2658 (0.37)	.0822 (0.12)	-.0771 (0.11)
Scotland	-.0685 (0.11)	-.0618 (0.10)	-.2882 (0.47)
CSEs 2-5	-.3846 (0.88)	-.3233 (0.78)	-.3724 (0.87)
GCSE A-C	-.4013 (1.09)	-.2278 (0.65)	-.3631 (1.00)
AS levels or 1 A level	-.8609 (0.54)	-1.0096 (0.66)	-.3268 (0.21)
2+ A levels	.2713 (0.53)	.3980 (0.81)	.2311 (0.45)
Diploma	-.4053 (0.63)	-.0723 (0.12)	-.0151 (0.02)
Degree	-1.6470 (3.70)	-1.6004 (3.77)	-1.5969 (3.55)
Higher degree	-.8682 (1.19)	-.9853 (1.39)	-1.1127 (1.50)
PT paid employee	.2710 (0.74)	.3621 (1.02)	.3221 (0.88)
FT self-employed	-.3001 (0.75)	-.2589 (0.68)	-.3443 (0.88)
PT self-employed	-.6863 (0.81)	-.8343 (1.05)	-.5950 (0.73)
Unemployed seeking work	1.3396 (1.33)	1.1484 (1.19)	1.2255 (1.23)
FT education	.4665 (0.22)	.1250 (0.06)	-.5202 (0.24)
Government scheme	-5.9443 (1.15)	-5.9616 (1.16)	-6.0810 (1.18)
Temporarily sick/disabled	5.5549 (2.08)	4.3629 (1.79)	4.1647 (1.71)
Permanently sick/disabled	2.4520 (3.52)	2.6290 (4.04)	2.4225 (3.66)
Looking after home/family	-.0229 (0.04)	.48634 0.89()	.4971 (0.88)
Wholly retired	.9665 (0.76)	2.4510 (0.98)	2.5213 (1.01)
Other	1.7727 (1.44)	2.0806 (1.80)	1.8303 (1.56)
1st marriage	-.3800 (0.95)	-.4087 (1.07)	-.4859 (1.24)
Remarried >=2nd	-.4469 (0.91)	-.5004 (1.07)	-.5773 (1.21)
Legally separated	-.7784 (0.87)	-.3688 (0.44)	.0414 (0.05)

Divorced	-.4621 (0.94)	-.3012 (0.64)	-.2356 (0.49)
Widowed	.8790 (0.73)	.3461 (0.30)	.4912 (0.41)
Father's occupation at birth 1958			
Semi-skilled			.1564 (0.36)
Unskilled worker			-.4003 (0.86)
Armed forces			-.4262 (0.63)
Admin, prof, manager			-.7102 (1.68)
Shopkeepers			-3.2169 (3.88)
Clerical workers			-1.6784 (2.84)
Shop assistants			-.0847 (0.14)
Personal service			-.6037 (0.57)
Foremen			-.5478 (0.66)
Farmers			-.4075 (0.47)
Farm workers			-.4212 (0.63)
Higher admin etc.			.0306 (0.05)
Single no husband			-.2689 (0.32)
Constant	68.8184	69.0664	70.3368
Adjusted R^2	.0612	.0591	.0627
N	7533	8139	7721

Notes: type of worker refers to mother's husband in 1958 (n490); drink frequency, region, height and weight are from biomedical survey at age 42 (2002-2004). Labor force and marital status and education are from NCDS7 in 2000 at age 42.

Table 6. Association between pulse rates and work, health and GHQ score in English and Scottish Health Surveys if age<70

a) English Health Survey, 1998-2018

	Work	GHQ36	General health
Pulse rate	-.0023 (18.50)	.0174 (10.95)	-.0088 (34.36)
Personal controls	Yes	Yes	Yes
Adjusted R^2	.2975	.0329	.1071
N	103,533	85,748	103,554

Personal controls are age bands, gender, year, region, race, education and marital status.
GHQ score available in 1998-2006, 2008-2010, 2012, 2014, 2016, 2018

b) Scottish Health Survey, 2002-2019

	Work	GHQ36	General health
Pulse rate	-.0022 (8.46)	.0217 (6.75)	-.0101 (18.51)
Personal controls	Yes	Yes	Yes
Adjusted R^2	.2836	.0476	.1071
N	21,427	20,765	21,440

Personal; controls are age bands, gender, region, education, marital status and year

c) Scottish Health Survey, 2009-2019

	WEMWBS	Life satisfaction
Pulse rate	-.0369 (4.71)	-.0098 (6.17)
Personal controls	Yes	Yes
Adjusted R^2	.0700	.0997
N	9,839	10,263

Personal; controls are age, gender, region, education, marital status and year

Table 7. Probability of working in NCDS9, age 55, in 2013

Pulse rate at 42		-.0022 (5.33)	-.0016 (4.23)	-.0017 (4.20)	-.0025 (5.74)
Chronic pain at 42		-.0740 (7.67)	-.0257 (2.94)	-.0273 (2.85)	-.0715 (7.20)
Short pain at 42		-.0236 (1.69)	-.0121 (0.97)	-.0213 (1.57)	-.0228 (1.59)
Great difficulty paying bills at 42		.1516 (2.60)	.0220 (0.41)	.0291 (0.48)	.1387 (2.33)
Some difficulty paying bills at 42		.2476 (5.08)	.0608 (1.33)	.0682 (1.37)	.2321 (4.67)
Slight difficulty paying bills at 42		.3130 (6.52)	.0794 (1.76)	.0874 (1.78)	.2969 (6.06)
Very little difficulty paying bills at 42		.2868 (6.07)	.0490 (1.10)	.0538 (1.11)	.2714 (5.63)
Male	.0962 (11.82)	.0788 (8.77)	.0166 (1.78)	.0155 (1.50)	.0778 (8.41)
Yorks & Humber	.0532 (2.44)	.0405 (1.71)	.0277 (1.30)	.0160 (0.71)	.0351 (1.45)
East Midlands	.0540 (2.41)	.0411 (1.71)	.0146 (0.67)	.0068 (0.29)	.0347 (1.41)
East Anglia	.0465 (1.80)	.0198 (0.71)	.0035 (0.14)	-.0077 (0.27)	.0184 (0.64)
South East	.0743 (4.01)	.0540 (2.70)	.0271 (1.50)	.0172 (0.90)	.0498 (2.43)
South West	.0694 (3.27)	.0512 (2.24)	.0196 (0.95)	.0012 (0.06)	.0464 (1.98)
West Midlands	.0764 (3.54)	.0602 (2.59)	.0384 (1.83)	.0209 (0.93)	.0550 (2.31)
North West	.0556 (2.62)	.0411 (1.79)	.0225 (1.09)	.0091 (0.41)	.0351 (1.50)
Wales	.0426 (1.75)	.0305 (1.14)	.0091 (0.38)	.0087 (0.33)	.0251 (0.92)
Scotland	.0635 (2.93)	.0504 (2.15)	.0219 (1.04)	.0118 (0.53)	.0446 (1.87)
CSE D-E	.1077 (0.63)	.2640 (1.23)	.1510 (0.46)	.1631 (0.50)	.2586 (1.20)
CSE, 2-5, Other Scottish	.1106 (7.42)	.0861 (5.12)	.0263 (1.72)	.0311 (1.87)	.0889 (5.12)
GCSE, A-C, good O levels	.1342 (10.88)	.1099 (7.77)	.0429 (3.32)	.0369 (2.61)	.1114 (7.61)
AS levels or 1 A level	.1720 (3.05)	.1312 (2.16)	.0722 (1.32)	.0309 (0.51)	.1519 (2.40)
2+ A levels, Scot higher/6th	.1275 (7.30)	.0927 (4.80)	.0305 (1.74)	.0284 (1.47)	.0958 (4.73)
Diploma	.1225 (5.88)	.0963 (4.20)	.0250 (1.22)	.0201 (0.90)	.1004 (4.23)
Degree level	.1519 (10.71)	.1117 (6.94)	.0394 (2.68)	.0285 (1.77)	.1143 (6.69)
Higher degree	.1896 (8.49)	.1386 (5.66)	.0621 (2.85)	.0620 (2.57)	.1404 (5.38)
Fibrinogen at age 42				-.0155 (1.88)	
C Reactive Protein at age 42				.0005 (0.46)	
Labor force status in NCDS7	No	No	Yes	Yes	No
Father's occupation PMS 1958	No	No	Yes	No	Yes
Constant	.5929	.5647	.9001	.9684	.5922
Adjusted R^2	.0322	.0491	.2599	.2427	.0492
N	9,000	6,913	6,654	5,577	6,650

T-statistics in parentheses.

Table 8. Self-reported health status in NCDS9, age 55 and life satisfaction in NCDS8 at 50

	Health status	Life turned out	Life in 10 years
Pulse rate at 42	-.0101 (9.54)	-.0060 (3.22)	-.0089 (4.86)
Chronic pain at 42	-.3525 (14.51)	-.2698 (6.22)	-.2377 (5.65)
Short pain at 42	-.1322 (3.81)	-.0954 (1.54)	-.0507 (0.84)
Male	-.0316 (1.28)	-.0489 (1.07)	-.2114 (4.78)
Great difficulty paying bills at 42	.0268 (0.19)	1.2508 (5.07)	.9744 (4.08)
Some difficulty paying bills at 42	.2154 (1.77)	1.4885 (7.11)	1.1578 (5.71)
Slight difficulty paying bills at 42	.3320 (2.77)	1.9405 (9.37)	1.3454 (6.71)
Very little difficulty paying bills at 42	.5486 (4.64)	2.4560 (12.05)	1.7970 (9.11)
Yorks & Humber	.0348 (0.59)	-.0706 (0.68)	-.0750 (0.74)
East Midlands	.0368 (0.61)	-.0672 (0.63)	-.1125 (1.10)
East Anglia	.1078 (1.55)	-.1649 (1.32)	-.2059 (1.70)
South East	.1013 (2.02)	-.0459 (0.52)	-.0789 (0.93)
South West	.0759 (1.33)	-.0233 (0.23)	-.0216 (0.22)
West Midlands	.0710 (1.22)	.0663 (0.65)	.0679 (0.68)
North West	.0589 (1.03)	-.0344 (0.34)	.0090 (0.09)
Wales	.1644 (2.46)	-.0873 (0.74)	-.1064 (0.93)
Scotland	.1168 (1.99)	.1929 (1.87)	.0665 (0.67)
Part-time paid employee	-.0478 (1.43)	-.0645 (1.04)	-.0623 (1.04)
Full-time self-employed	.0829 (2.28)	-.0584 (0.86)	-.0390 (0.59)
Part-time self-employed	-.0041 (0.07)	.0025 (0.02)	-.0870 (0.64)
Unemployed seeking work	-.2136 (2.97)	-.3337 (1.89)	-.2700 (1.56)
Full-time education	.0935 (0.25)	-.6593 (1.80)	-.8412 (2.37)
Government scheme	-1.3760 (1.49)	-.1313 (0.19)	-.1586 (0.23)
Temporarily sick/disabled	-1.2319 (6.65)	-.9639 (3.55)	-.9048 (3.44)
Long-term sick/disabled	-1.5614 (27.97)	-1.4788 (12.20)	-1.5598 (13.28)
Looking after home/family	-.2971 (6.00)	-.2437 (2.55)	-.0789 (0.85)
Wholly retired	-.2542 (3.98)	-.8493 (1.72)	-1.7488 (3.66)
Other	.0130 (0.11)	-.1523 (0.52)	-.0621 (0.21)
Constant	3.6432	5.8598	7.0111
Adjusted R^2	.2334	.1053	.0883
N	6,955	7,436	7,412

Notes: all equations include educational controls - missing categories North T-statistics in parentheses.

Life turned out = How satisfied CM is in the way life has turned out so far

Life in 10 years= How satisfied CM expects to be with life in 10 years' time