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The economic impact of chronic fatigue syndrome

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Abstract

Background: Chronic fatigue syndrome (CFS) is a chronic incapacitating illness that affects between 400,000 and 800,000 Americans. Despite the disabling nature of this illness, scant research has addressed the economic impact of CFS either on those affected or on the national economy.

Methods: We used microsimulation methods to analyze data from a surveillance study of CFS in Wichita, Kansas, and derive estimates of productivity losses due to CFS.

Results: We estimated a 37% decline in household productivity and a 54% reduction in labor force productivity among people with CFS. The annual total value of lost productivity in the United States was \$9.1 billion, which represents about \$20,000 per person with CFS or approximately one-half of the household and labor force productivity of the average person with this syndrome.

Conclusion: Lost productivity due to CFS was substantial both on an individual basis and relative to national estimates for other major illnesses. CFS resulted in a national productivity loss comparable to such losses from diseases of the digestive, immune and nervous systems, and from skin disorders. The extent of the burden indicates that continued research to determine the cause and potential therapies for CFS could provide substantial benefit both for individual patients and for the nation.

Background

Chronic fatigue syndrome (CFS) is an illness defined by disabling physical and mental fatigue and physical and mental symptoms that are not explained by conventional medical and psychiatric diagnoses [1]. CFS affects between 400,000 and 800,000 people in the United States [2,3] and has an average duration of 5 years, but symptoms can persist as long as 20 years [4]. The prognosis for recovery of severely ill CFS patients is poor [5,6]. Despite CFS's disabling, enduring, and prevalent nature, scant studies have quantified its impact on the health and well-

being of those affected, on the health care system, or on society as a whole.

The burden of CFS is poorly recognized, and the illness remains an inadequately managed health problem. Two population-based studies of CFS have been conducted in the United States, and both found that CFS is one of the more common chronic illnesses among women across all racial/ethnic groups and that less than 20% of those who suffer from CFS have been diagnosed by a health care provider [2,3]. Only three studies, all of which were clinic

based, have attempted to quantify the impact of CFS, and each showed that people with the syndrome were likely to have lost their job or to be unemployed [6-8]. In addition, it was shown that persons with CFS pose a disproportionate burden on the health care system and their families since they are sick for long periods of time and since there is no known cure for the illness [9].

The study reported herein is the first attempt to develop more generalizable results concerning the impact of CFS. To this end, we derived quantitative measures of lost productivity by interviewing persons identified as having CFS and non-fatigued people who were representative of the general population of Wichita, Kansas. We assessed the economic burden of CFS on afflicted individuals and on society as a whole and found that lost productivity in the United States amounted to an annual loss of \$9.1 billion or about \$20,000 per afflicted person.

Methods

Study Design

This study adhered to human experimentation guidelines of the U.S. Department of Health and Human Services. All participants were volunteers who gave informed consent. The Centers for Disease Control and Prevention (CDC) Human Subjects Committee approved study protocols. Details of the population-based study to estimate the prevalence and incidence of CFS in the adult population of Wichita, Kansas, have been published [2]. In brief, the study used random-digit dialing to screen about 56,000 persons between 18 and 69 years of age. Those reporting fatigue of at least one-month duration and randomly selected non-fatigued respondents were interviewed in detail on the telephone to ascertain demographic characteristics, previous diagnosis of medical or psychiatric conditions that excluded classification as CFS, symptoms, occupation, and household income. People who were suspected to have CFS on the basis of the detailed interview were invited to participate in a clinical evaluation to determine if they did indeed have CFS or some other illness.

For analysis, subjects were classified into the "non-fatigue group" (n = 3,634) if they did not report fatigue during the telephone interview or into the "fatigue group" (n = 3,528) if they reported fatigue lasting ≥ 1 month. The fatigue group was further divided into 3 subgroups: those with "prolonged fatigue" (n = 2973), those with "suspected CFS" (n = 555), and those with "CFS" (n = 43). Fatigue group respondents were classified into the prolonged fatigue subgroup if they reported fatigue lasting ≥ 1 month but did not fulfill criteria for CFS. Fatigue group respondents were classified into the suspected CFS subgroup if they met the CFS case definition based on self-reported telephone interview responses, and they were

classified into the CFS subgroup if clinical evaluation confirmed a diagnosis of CFS.

To estimate lost productivity due to CFS, data were obtained from individual responses to the detailed interview and clinical evaluation. The detailed interview and subsequent analysis provided individual responses and classifications for current employment status, categorical household income, age, sex, ethnicity, level of education, duration and classification of fatigue, and occupation. In addition, responses and analysis detailed household chores prior to and during fatigue and medical and psychiatric conditions. The clinical evaluation and subsequent independent review determined those individuals with CFS and those with exclusionary medical conditions from the suspected CFS group. Table 1 summarizes the descriptive statistics for the study groups.

Analysis

The economic theory of human capital is the basis of the simulation model we used to estimate the impact of CFS. The human capital approach models an individual's productivity (in terms of employment and earnings) as a function of human capital characteristics such as age, education, occupation, and health status [10-13], and it hypothesizes that specific attributes of workers are valued in the marketplace; thus, it recognizes differences among individuals in terms of their experience, training, education, and other characteristics that are valued in labor markets. Just as machines or other productive capital involve investment that lead to future returns, human capital requires investments in schooling, health, apprenticeships, and other skill-building that may pay off in higher future wages. We treat illnesses, such as CFS, as a negative shock, which may potentially negatively affect an individual's ability to achieve returns on their human capital, given the severity of the illness. Therefore, the human capital framework enables us to examine the impact of CFS on the ability to work and, given work, on pay.

To estimate productivity loss, we employed methods developed as part of the RAND Health Insurance Experiment microsimulation [14-16]. Table 2 explains the two-step microsimulation approach that first used logistical regression to predict employment and then ordinary least squares regression to estimate expected income, conditional on employment, for the fatigue and non-fatigue groups. The expected decline in employment and income, given employment, would most likely stem from the change in health status that resulted from the CFS diagnosis. The two-step model provided consistent and efficient estimates through better exploitation of the sample characteristics of the household income distribution [15,17,18].

Table 1: Demographic Characteristics of the U.S. population and the Wichita Sample by Fatigue and Non-Fatigued Group

Demographic Characteristics	U.S. Population*	Wichita Surveillance Groups†			
		Non-Fatigue Group (n = 3,634)	Prolonged Fatigue‡ (n = 2,973)	Suspect CFS§ (n = 512)	CFS (n = 43)
Age, Mean (years)	41.0	40.5	42.7	44.1	47.8
<35 years (%)	35.6	37.3	29.1	18.9	8.3
35–49 years (%)	35.2	35.5	38.6	50.6	46.8
50–69 years (%)	29.2	27.2	32.3	30.6	45.0
Male (%)	49.1	49.3	34.7	29.1	14.6
Female (%)	50.9	50.7	65.3	70.9	85.4
Black (%)	12.1	8.5	11.2	5.5	2.8
Latino (%)	12.6	4.8	5.0	5.7	1.9
Employed (%)	78.4	76.5	64.1	68.4	52.8
Mean Household Income	NA	\$33,477	\$39,027	\$44,143	\$40,802
<\$20,000 (%)	26.8	17.7	33.6	24.3	16.8
\$20,000–\$49,999 (%)	38.1	40.7	40.0	41.7	46.2
\$50,000–\$74,999 (%)	17.8	18.1	12.6	19.1	23.6
≥\$75,000 (%)	17.4	12.7	6.6	8.2	5.4
Not Reporting (%)	0.0	10.8	7.1	6.6	8.1
Education (%)					
<12 Years	14.9	7.8	14.8	8.5	2.7
High School Graduate	31.5	28.4	32.6	33.2	35.6
Some College	28.2	36.4	35.9	40.0	51.9
College Graduate (4-Year)	17.3	16.7	8.5	11.1	6.0
Post Graduate Education	8.2	8.9	5.8	4.7	3.7
Not Reporting	0.0	1.7	2.4	2.5	0.0
Occupation (%)					
Management or Professional	23.4	27.1	20.3	25.9	16.8
Clerical Worker	10.3	10.2	12.1	12.8	22.8
Service Worker	10.6	6.9	9.4	7.4	10.7
Sales Professional	8.7	6.6	5.2	5.1	7.5
Technician	2.5	6.6	6.3	5.8	17.0
Skilled Craftsman	8.3	4.3	5.0	6.3	4.6
Homemaker	NA	1.9	2.4	2.3	3.5
Other/Not Reporting	36.2	36.2	39.3	34.4	17.2

* Based on analysis of the March Supplement to the Current Population Survey, 2002 conducted by SRA International, Inc. Columns may not add to 100% due to rounding. † Weighted to reflect population of Wichita, Kansas. Columns may not add to 100% due to rounding. ‡ Excludes the 555 CFS-like observations. § Excludes the 43 CFS observations.

The dependent variables for our analysis are an indicator variable for employment and a continuous measure of household income. Individuals were coded as participating in the labor force if they reported that they were currently employed. Household income was collected as a categorical variable. We defined household income at the mid-point for each category to develop a continuous measure, and the top category was coded at the truncation

point of \$100,000. Since we used household income as the dependent variable in the income regression, we ideally would control for marital status and household composition in the regression. Unfortunately, this information was not included in the Wichita survey.

Ideally, personal income per household member is the desired proxy to more accurately estimate individual and

Table 2: Microsimulation steps for estimating the cost of productivity losses due to CFS.

Step	Equation
1.	<p>Divide the study sample data into two groups: Fatigued (F), N = 3,528, and Non-Fatigued (NF), N = 3,634. Estimate logistic regressions to obtain the probability that an individual is employed for F, $P[W = Y/F]$, and NF, $P[W = Y/NF]$, subsamples, as a function of human capital characteristics, as displayed in equations 1a and 1b.</p> <p>a. $P[W = Y/F] = f(\text{age, sex, ethnicity, education, suspected CFS, CFS, history of diseases that exclude respondent from CFS diagnosis})$ b. $P[W = Y/NF] = f(\text{age, sex, ethnicity, education, history of diseases that exclude respondent from CFS diagnosis})$</p>
2.	<p>Estimate ordinary least squares regressions to predict the natural log of income (I) given employment for the F, $E[I/W = Y,F]$, and NF, $E[I/W = Y,NF]$, subsamples, as a function of human capital characteristics, as displayed in equations 2a and 2b.</p> <p>a. $E[I/W = Y,F] = f(\text{age, sex, ethnicity, education, suspected CFS, CFS, history of diseases that exclude respondent from CFS diagnosis, occupation})$ b. $E[I/W = Y,NF] = f(\text{age, sex, ethnicity, education, history of diseases that exclude respondent from CFS diagnosis, occupation})$</p> <p>Note: Once these regressions are estimated, <i>only</i> the sample of 43 individuals with CFS are used for the remainder of the microsimulation to estimate mean labor force and household productivity by age and sex in the presence and absence of CFS.</p>
3.	<p>Calculate predicted mean F and NF employment rates by age and sex categories, weighting by sampling weights. Multiply the coefficient estimates from the F (Blf) and NF (Blnf) Logit regressions by the human capital characteristics of the 43 individuals with CFS (X) to obtain their F ($P[W = Y/F]$) and NF ($P[W = Y/NF]$) employment rates, respectively, as shown in equations 3a and 3b. Then, calculate the mean employment rate across the 43 individuals with CFS for each age and sex category weighting these means to reflect the survey sampling rates.</p> <p>a. $P[W = Y/F] = \{ \exp(X*Blf) / 1 + \exp(X*Blf) \}$ b. $P[W = Y/NF] = \{ \exp(X*Blnf) / 1 + \exp(X*Blnf) \}$</p>
4.	<p>Calculate predicted mean F and NF income given employment by age and sex categories weighting by sampling weight. Multiply the coefficient estimates from the F (Bolsf) and NF (Bolsnf) OLS income regressions by the human capital characteristics of the 43 individuals with CFS (X) to obtain their F ($E[I/W = Y,F]$) and NF ($E[I/W = Y,NF]$) income given employment, respectively. Then, apply the smearing adjustment to the exponent of these F and NF products, as shown in equations 4a and 4b, to correct for the "retransformation" bias that arises from estimating impacts using loglinear models and to protect against data issues such as heteroskedasticity¹. The smearing factors for the regressions among individuals with F (Sf) and in the absence of F (Snf) are equal to the means of the anti-logs of the residuals of the respective income regressions. Calculate predicted F and NF income given employment for each age and sex category weighting by the survey sampling weights, and adjust these means from 1997 to 2002 dollars to account for inflation using the Department of Labor, Bureau of Labor Statistics Consumer Price Index from 1997 to 2002². Apply an adjustment factor for the difference between mean income in Wichita and the nation based on analysis by the U.S. Department of Commerce³ increasing the estimated losses by 1.3 percent. In addition, to account for fringe benefits, multiply predicted income by a factor of 1.338, which is obtained from the <i>Bureau of Labor Statistics Report on Employer Costs for Employee Compensation – June 2002</i>⁴.</p> <p>a. $E[I/W = Y,F] = \{ \exp(X*Bolsf)*Sf \}^{1.114} * 1.013 * 1.338$ b. $E[I/W = Y,NF] = \{ \exp(X*Bolsnf)*Snf \}^{1.114} * 1.013 * 1.338$</p>
5.	<p>Calculate predicted household productivity given employment and no employment in absence of F. The value of household productivity by sex, age, and employment status absent F is calculated on the basis of data on the number of hours spent on household chores for the NF sample, given employment (HH hours/W = Y,NF) and no employment (hours/W = N, NF). Value these hours at the average hourly wage for a service industry worker as estimated on the basis of the March Supplement of the Current Population Survey 2002 or \$9.20. Similar to employment income, increase the value of the service industry worker wage by a factor of 1.338 to account for the value fringe benefits. This equation is displayed in 5a and 5b.</p> <p>a. $E[HH/W = Y,NF] = E[HH \text{ Hours}/W = Y, NF] * \\$9.20 * 1.338$ b. $E[HH/W = N,NF] = E[HH \text{ Hours}/W = N, NF] * \\$9.20 * 1.338$</p>
6.	<p>Calculate predicted household productivity given F. Assume that the percentage reduction in employment related income, given work, is equal to the percentage reduction in household productivity. Apply a reduction factor representing the estimated reduction in employment-related income, given work, resulting from CFS to the predicted values of household productivity, given employment and no employment, as displayed in 6a and 6b. Calculate reduction factors separately for males and females.</p> <p>a. $E[HH/W = Y,F] = E[HH/W = Y,NF] * E[I/W = Y,F] / E[I/W = Y,NF]$ b. $E[HH/W = N,F] = E[HH/W = N,NF] * E[I/W = Y,F] / E[I/W = Y,NF]$</p>
7.	<p>Calculate predicted mean F and NF total productivity for each CFS individual. Overall, each CFS individual's expected total productivity in the presence or absence of F, $E[Y/F]$ or $E[Y/NF]$ respectively, is equal to the probability that they participate in the labor force, $P[W = Y/F]$ or $P[W = Y/NF]$, times the expected value of their total labor force and household productivity if they participate in the labor force plus the probability they choose not to participate in the labor force, $P[W = N/F]$ or $P[W = N/NF]$, times the expected value of their household productivity when they do not participate in the labor force. Equations 7a and 7b display expected productivity.</p> <p>a. $E[Y/F] = P[W = Y/F] \{ E[I/W = Y,F] + E[HH/W = Y,F] \} + P[W = N/F] \{ E[I/W = N,F] + E[HH/W = N,F] \}$ b. $E[Y/NF] = P[W = Y/NF] \{ E[I/W = Y,NF] + E[HH/W = Y,NF] \} + P[W = N/NF] \{ E[I/W = N,NF] + E[HH/W = N,NF] \}$</p>
8.	<p>Calculate estimated number of individuals with CFS nationally by age and sex. Using the Wichita Prevalence Study data, calculate the prevalence of CFS per 100,000 by age and sex cells and then use national population data from the Current Population Survey to calculate the number of individuals in each age and sex category with CFS.</p>
9.	<p>Calculate individual and societal productivity losses due to CFS. Compute the difference between predicted mean total productivity without and with F, $(E[Y/NF] - E[Y/F])$, by age and sex category to estimate the individual loss for each age and sex cell and then multiply these differences for each sex and age cell by the estimated by number of individuals with CFS nationally in each cell and sum across the cells to estimate the total societal cost of lost productivity due to CFS.</p>

Table 2: Microsimulation steps for estimating the cost of productivity losses due to CFS. (Continued)

¹Duan N. Smearing Estimates: **A non-parametric retransformation technique.** *J Am Stat Assoc* 1983,383:605–10. ²Consumer Price Index from 1997 to 2002. Department of Labor, Bureau of Labor Statistics. (<http://data.bls.gov/cgi-bin/surveymost?cu>, then select U.S. All items, 1982-84=100 CUUR0000SA0) ³Per capita net earnings (\$) Metro Comparisons. Department of Economics, Iowa State University, Midwest Profiles, Public Resources Online. (<http://www.bea.doc.gov/bea/regional/reis/>, then select Personal income and population summary estimates (CAI-3) plus per capita personal income plus Metropolitan Statistical Areas*) ⁴Employer Costs for Employee Compensation – June 2002. Bureau of Labor Statistics, September 2002. (<http://data.bls.gov/cgi-bin/surveymost?cc>, then click on Civilian, All workers, Total compensation - CCUI10000100000D)

national productivity loss. Personal income per household individual allows one to distinguish between productivity losses resulting from CFS affliction versus productivity losses stemming from household members assuming caregiver roles at the expense of their employment productivity. Ideally, when estimating individual productivity loss from CFS, one should distinguish between the productivity loss associated with CFS affliction and that associated with the assumption of caregiver roles at the expense of employment productivity.

The national productivity loss estimate should include both to reflect accurately the total national reduction in employment productivity stemming from CFS. However, given the structure of the Wichita Study questionnaire, a recorded change in household income stems from an individual within that household acquiring CFS; thus it captures productivity losses that result directly from CFS affliction and indirectly from the assumption of caregiver roles by non-afflicted household members. To date, CFS research reports a clear reduction in hours worked by those afflicted directly with CFS; thus, we believe that the annual productivity loss due to assuming caregiver roles is small. Therefore, using household income from the Wichita Study to estimate annual, national productivity loss should realize an accurate estimate, but the reported average individual productivity loss may be somewhat biased because of the inability to distinguish productivity losses associated with individuals afflicted with CFS versus productivity losses associated with household members assuming a caregiver role.

The independent variables include an indicator variable for female and continuous variables for age and age-squared to capture any non-linear effect of age on income. This effort used indicator variables for black and Latino on the basis of self-reported race and ethnicity, for education on the basis of self-reports of the highest level of education completed, for occupation on the basis of self-reports of current or most recent occupation, and for the presence of select health conditions and illnesses on the basis of self-reports of whether the individual had ever been diagnosed or treated by a physician for the conditions or illnesses.

Bootstrap standard errors were calculated for the estimated declines in employment, income given employment, and total productivity derived from the microsimulation model by age and sex cell. Bootstrap errors were calculated to test the sensitivity of the microsimulation to sampling error. Employment declines were all significant at the 95 percent confidence level. For female age cells, income declines were significant at the 95 percent level for the 18 to 34 and 50 to 69 age cells and at the 90 percent level for the 35 to 49 year age cell. Income declines estimated for males were not significant. This may result because low earning males exit the labor force and higher earning males retain employment, causing the mean earnings of those with employment to rise. Overall, the total declines in productivity estimated under the model were significant at the 99 percent confidence level with the exception of males 18 to 34 and 35 to 49 years of age, which were significant at the 90 percent level.

We conducted sensitivity tests on key assumptions of the simulation model. We examined how the decision to model male and female productivity separately impacted estimated productivity losses, and we examined the sensitivity of the model to the demographic characteristics of the sample of individuals with CFS. Aggregate productivity loss varied by less than 17 percent.

Results

CFS Prevalence

Based on the prevalence of CFS in Wichita, Kansas, we estimated that 454,439 individuals nationwide suffered from CFS. Women aged 18 to 69 represented 82% (373,891) of those afflicted with CFS and men aged 18 to 69 represented the remaining 18% (80,548).

Productivity Loss

We hypothesized that persons with CFS have lower employment rates and income relative to those with similar characteristics without CFS. The microsimulation first applied logistic and ordinary least squares regressions to estimate expected employment and income, respectively, for individuals in the fatigue and non-fatigue groups (Table 3). The sign and magnitude of the coefficient estimates for the independent variables in the regressions are

Table 3: Employment and Income Regression Results

	Employment Regression		Income Regression	
	NF* Coefficient Estimate (95% CI [†])	Fatigue Coefficient Estimate (95% CI [†])	NF Coefficient Estimate (95% CI [†])	Fatigue Coefficient Estimate (95% CI [†])
Intercept	-1.744 (-2.471, -1.017)	-0.628 (-1.446, 0.190)	8.853 (8.598, 9.108)	8.580 (8.237, 8.923)
CFS	NA	-0.699 (-1.345, -0.052)	NA	-0.081 (-0.382, 0.219)
Suspected CFS	NA	-0.006 (-0.234, 0.223)	NA	-0.03 (-0.118, 0.049)
Education				
≤12 Years	-0.7 (-1.021, -0.387)	-0.583 (-0.828, -0.338)	-0.308 (-0.430, -0.185)	-0.218 (-0.328, -0.109)
Some College	0.228 (0.019, 0.438)	0.099 (-0.083, 0.281)	0.080 (0.013, 0.146)	0.074 (0.001, 0.146)
College Graduate (4-Year)	0.347 (0.066, 0.628)	0.410 (0.106, 0.714)	0.279 (0.197, 0.360)	0.263 (0.156, 0.370)
Post Graduate Education	0.615 (0.266, 0.963)	0.768 (0.384, 1.153)	0.250 (0.151, 0.350)	0.328 (0.197, 0.459)
Not Reporting	0.490 (-0.210, 1.189)	0.550 (0.020, 1.079)	0.155 (-0.041, 0.351)	0.022 (-0.162, 0.206)
Age	0.235 (0.198, 0.272)	0.144 (0.105, 0.184)	0.074 (0.061, 0.087)	0.084 (0.067, 0.101)
Age Squared	-0.003 (-0.004, -0.003)	-0.002 (-0.003, -0.002)	-0.001 (-0.001, -0.001)	-0.001 (-0.001, -0.001)
Race/ethnicity Black	-0.265 (-0.619, 0.089)	-0.233 (-0.528, 0.063)	-0.342 (-0.460, -0.225)	-0.288 (-0.407, -0.168)
Race/ethnicity Latino	-0.135 (-0.554, 0.284)	0.089 (-0.279, 0.457)	-0.309 (-0.437, -0.181)	-0.108 (-0.244, 0.028)
Female	-0.953 (-1.143, -0.762)	-0.380 (-0.568, -0.191)	-0.065 (-0.122, -0.008)	-0.092 (-0.163, -0.020)
Ever Diagnosed or Treated For				
Alcohol and Drug Dependency	-0.210 (-0.747, 0.327)	-0.203 (-0.494, 0.088)	-0.315 (-0.475, -0.155)	-0.180 (-0.296, -0.063)
Anemia with Blood Transfusion	0.325 (-0.303, 0.954)	-0.278 (-0.593, 0.038)	-0.112 (-0.314, 0.089)	-0.191 (-0.334, -0.047)
Anorexia Nervosa or Bulimia	-0.859 (-1.814, 0.096)	-0.031 (-0.601, 0.539)	-0.123 (-0.493, 0.247)	0.102 (-0.117, 0.321)
Cancer	-0.411 (-0.811, -0.011)	-0.151 (-0.423, 0.122)	0.129 (-0.024, 0.282)	-0.040 (-0.162, 0.082)
Chronic Bronchitis or Emphysema	0.230 (-0.266, 0.727)	-0.188 (-0.420, 0.045)	-0.057 (-0.215, 0.102)	-0.148 (-0.249, -0.047)
Chronic Hepatitis or Cirrhosis	0.536 (-0.514, 1.586)	-0.416 (-0.875, 0.043)	-0.074 (-0.372, 0.224)	-0.166 (-0.362, 0.030)
Depression	-0.192 (-0.511, 0.128)	-0.385 (-0.556, -0.213)	-0.038 (-0.143, 0.066)	-0.030 (-0.099, 0.038)
Diabetes	-0.318 (-0.720, 0.085)	-0.319 (-0.568, -0.070)	-0.020 (-0.174, 0.133)	-0.030 (-0.143, 0.084)
Heart Attack	-0.233 (-0.795, 0.330)	-0.288 (-0.668, 0.092)	0.024 (-0.226, 0.274)	-0.059 (-0.242, 0.124)
Heart Condition Limiting Ability to Walk	-0.578 (-1.402, 0.247)	-0.498 (-0.876, -0.120)	0.251 (-0.094, 0.597)	0.052 (-0.139, 0.242)
Heart Failure or Fluid in Lungs	-0.513 (-1.271, 0.245)	-0.312 (-0.636, 0.012)	0.003 (-0.291, 0.298)	-0.038 (-0.192, 0.117)
High Blood Pressure	-0.243 (-0.485, -0.001)	-0.013 (-0.201, 0.176)	0.022 (-0.063, 0.106)	-0.090 (-0.168, -0.011)
Hypothyroidism	0.298 (-0.056, 0.652)	-0.103 (-0.324, 0.118)	0.070 (-0.049, 0.189)	0.072 (-0.022, 0.166)
AIDS	0.227 (-1.816, 2.270)	-1.520 (-2.266, -0.773)	0.471 (-0.299, 1.242)	0.142 (-0.257, 0.540)
Lupus or Sjogren's Syndrome	0.498 (-0.963, 1.959)	-0.449 (-0.931, 0.033)	-0.041 (-0.633, 0.551)	0.043 (-0.187, 0.273)
Manic Depressive or Bipolar Disorder	-0.611 (-1.501, 0.279)	-0.618 (-1.001, -0.236)	-0.025 (-0.319, 0.269)	-0.127 (-0.304, 0.050)
Multiple Sclerosis	-0.797 (-2.615, 1.020)	-1.259 (-1.773, -0.745)	-0.096 (-0.776, 0.584)	-0.245 (-0.505, 0.014)
Organ Transplant	-1.133 (-2.628, 0.363)	-1.043 (-1.996, -0.090)	-0.029 (-0.667, 0.609)	-0.134 (-0.616, 0.347)
Rheumatoid Arthritis	-0.586 (-1.050, -0.121)	-0.495 (-0.738, -0.251)	-0.169 (-0.353, 0.015)	-0.057 (-0.172, 0.058)
Schizophrenia	-3.095 (-5.463, -0.727)	-0.924 (-1.976, 0.128)	-2.247 (-3.521, -0.973)	-0.269 (-0.832, 0.294)
Stroke	-0.096 (-1.057, 0.865)	-0.732 (-1.232, -0.232)	-0.315 (-0.725, 0.095)	0.091 (-0.182, 0.364)
Occupation				
Management or Professional	NA	NA	0.188 (0.116, 0.260)	0.158 (0.071, 0.244)
Self-employed	NA	NA	0.006 (-0.124, 0.137)	0.062 (-0.067, 0.190)
Technician	NA	NA	0.093 (-0.020, 0.207)	0.082 (-0.056, 0.220)
Clerical Worker	NA	NA	0.022 (-0.076, 0.119)	-0.040 (-0.143, 0.063)
Sales Professional	NA	NA	0.082 (-0.031, 0.195)	-0.081 (-0.223, 0.062)
Skilled Craftsman	NA	NA	0.009 (-0.130, 0.147)	0.041 (-0.106, 0.188)
Machine Operator	NA	NA	0.130 (-0.041, 0.302)	-0.098 (-0.263, 0.067)
Transportation Operator	NA	NA	-0.114 (-0.355, 0.126)	-0.212 (-0.485, 0.062)
Private Household Workers	NA	NA	-0.133 (-0.562, 0.296)	-0.672 (-1.054, -0.290)
Protection Services	NA	NA	-0.195 (-0.517, 0.128)	-0.155 (-0.522, 0.212)
Service Worker	NA	NA	-0.154 (-0.281, -0.026)	-0.399 (-0.537, -0.261)
Farmer, Farm Worker	NA	NA	0.233 (-0.340, 0.807)	0.017 (-0.770, 0.804)
Unskilled Laborer	NA	NA	-0.168 (-0.337, 0.000)	-0.252 (-0.427, -0.077)
Military Service	NA	NA	0.020 (-0.238, 0.278)	0.103 (-0.452, 0.657)
Not Reported	NA	NA	-0.651 (-1.287, -0.014)	-0.503 (-1.300, 0.295)
Number of Observations	3,634 (NA)	3,528 (NA)	2,493 (NA)	2,129 (NA)

in-line with human capital theory and with the results of similar models in the employment literature. For example, coefficient estimates show that relative to high school graduates, individuals with less than 12 years of education have lower employment rates and income and those with education beyond high school have greater employment rates and income in both the fatigue and non-fatigue regressions. In addition, in fatigue and non-fatigue regressions, employment rates and income increase with age, but at a declining rate, and being female has a negative effect on both employment and income. The regression results indicate that individuals who are black have lower employment rates and income. The results for Latinos are not significant except for a negative impact on income in the non-fatigue regression. Having been diagnosed or treated for a medical condition included in the regressions generally resulted in lower employment rates and income. When the opposite signs were observed, the results were not significant and thus may have been the result of small sample size.

Although the regression results for the fatigue and non-fatigue groups are both consistent with the human capital approach, there are some differences. First, the intercept in the fatigue regression is lower than that in the non-fatigue regression for the employment and income model, generally indicating fatigued individuals are less likely to work and have lower income when working than non-fatigue individuals. Also, the CFS coefficient in the fatigue regression is negative in the employment and income model. The income effect is small and not significant; however, the employment impact is substantial and significant. Given the confidence intervals, the other coefficient estimates are generally similar in the fatigue and non-fatigue regressions. One exception is the female coefficient in the employment model. Being female has less of a reduction on employment for individuals who are in the fatigue group than for the non-fatigue group. Another exception is the age coefficient in the employment model, which indicates that employment does not increase as quickly with age for individuals who are in the fatigue group compared with the non-fatigue group.

The differences in the coefficients in the fatigue and non-fatigue regressions translate into substantial declines in employment resulting from CFS for individuals of all age and sex groups (Table 4). For women and men, we estimated about a 27% reduction in employment attributable to CFS. Overall, employment declined from 72.5 to 54.8% for women and from 86.1 to 63.3% for men. These reductions in employment combined with reductions in hours worked and in productivity per hour resulted in reductions in household and labor force productivity of 37% and 54%, respectively. Women suffered substantially greater household and labor force productivity losses (42

and 63%, respectively) than men (4 and 32%, respectively). Table 3 also displays the estimated annual dollar loss per individual and the annual productivity loss for the nation due to CFS. The microsimulation estimated that individuals with CFS lost approximately \$20,000 annually, which implies a total societal loss in 2002 of \$9.1 billion. Twenty-five percent (\$2.3 billion) resulted from lost household productivity, and the remaining 75% (\$6.8 billion) from lost labor force productivity. Women represented 82% of those with CFS and 87% of the productivity losses. The total loss per woman was slightly higher than the loss per man, about \$21,000 compared with about \$15,000.

The individual and national annual estimated loss of \$20,000 and \$9.1 billion respectively stems from a point prevalence of 235 per 100,000 for the Wichita Study. The confidence interval surrounding the point prevalence estimate is 142 to 327 per 100,000, which yields an individual and national estimate range of \$12,000 to \$28,000 and \$5.5 billion to \$12.7 billion, respectively.

Additionally, this research valued household productivity at the average hourly wage for a service industry worker as estimated on the basis of the March Supplement of the Current Population Survey 2002, which is \$9.20. This was because CFS mostly affects females. Using average service industry worker wage rates by age and sex is plausible if incidence amongst males and females was similar. Because the incidence of CFS amongst males was much lower than females, the additional burden of obtaining and using average service industry worker wage rates by age and sex to estimate annual household productivity loss from CFS did not justify their use.

Discussion

The magnitude of the economic impact imposed on the individual and on society by CFS is substantial. Approximately one-quarter of persons with CFS, who would otherwise have participated in the labor force, ceased working. For those who continued to work, average income declined by one-third. This represents an estimated annual loss of almost \$20,000 for the individual suffering from CFS. This magnitude of loss approximates half of their labor force and household productivity in a given year. The \$9.1 billion national loss is comparable to that estimated for other illnesses, such as digestive system illnesses (\$8.4 B) and infectious and parasitic diseases (\$10.0 B) [19] and is greater than the estimated productivity losses from immunity disorders (\$5.5 B), nervous system disorders (\$6.4 B), or skin disorders (\$1.3) [23]. This estimate does not include health care costs, which are likely to be substantial and does not address reductions in quality of life, which are likely to be large due to the debilitating fatigue.

Table 4: Individual and Societal Productivity Losses*

	Women (years)				Men (years)				Total
	18-34	35-49	50-69	Total	18-34	35-49	50-69	Total	
Predicted Employment Rate (%)†									
CFS	69.8	56.5	43.1	54.8	63.6	74.0	49.6	63.3	56.3
Non-fatigue	83.9	79.1	60.5	72.5	85.9	94.2	76.2	86.1	74.9
U.S. Employment Rate‡ (%)	76.9	79.5	59.1	72.5	87.6	91.8	72.0	84.6	78.4
Household Productivity§									
CFS	\$8,502	\$9,703	\$7,764	\$8,495	\$8,536	\$9,629	\$7,100	\$8,513	\$8,498
Non-fatigue	\$14,403	\$15,986	\$13,852	\$14,577	\$9,208	\$9,853	\$7,285	\$8,907	\$13,572
Labor Force Productivity**									
CFS	\$3,891	\$13,999	\$9,442	\$8,932	\$19,179	\$45,016	\$30,862	\$30,828	\$12,813
Non-fatigue	\$20,140	\$31,664	\$22,121	\$24,001	\$26,973	\$64,440	\$50,429	\$45,607	\$27,831
Overall Productivity									
CFS	\$12,394	\$23,702	\$17,207	\$17,427	\$27,715	\$54,645	\$37,962	\$39,341	\$21,311
Non-fatigue	\$34,543	\$47,649	\$35,974	\$38,578	\$36,181	\$74,292	\$57,714	\$54,513	\$41,403
Individual Loss††									
Household Productivity	\$5,901	\$6,283	\$6,088	\$6,081	\$672	\$224	\$185	\$394	\$5,073
Labor Force Productivity	\$16,249	\$17,664	\$12,679	\$15,070	\$7,794	\$19,424	\$19,566	\$14,779	\$15,018
Total Loss	\$22,149	\$23,947	\$18,767	\$21,151	\$8,466	\$19,648	\$19,752	\$15,173	\$20,092
Number of Individuals with CFS	114,373	97,416	162,101	373,891	32,436	26,579	21,533	80,548	454,439
Total Societal Loss (Millions)	\$2,533	\$2,333	\$3,042	\$7,908	\$275	\$522	\$425	\$1,222	\$9,130

* Numbers may not sum exactly due to rounding. † The microsimulation estimated Employment rates by age and sex based on data from Wichita, Kansas. These means were then weighted to reflect the age and sex distribution of the U.S. population using population estimates from the March Supplement to the Current Population Survey, 2002. ‡ Based on the March Supplement to the Current Population Survey, 2002. § Hours of household productivity valued at the mean hourly earnings of service industry worker, and estimate based in 2002 dollars and increased by 33.8 percent to reflect the value of fringe benefits. ** Estimated personal earnings in 2002 dollars increased by 33.8 percent to reflect the value of fringe benefits. †† The individual losses represent the difference between mean productivity with CFS and in absence of CFS.

We estimated annual lost productivity. However, CFS is a chronic illness. The average duration of CFS identified in population studies is 5 years and most patients with CFS seen by health care providers have been ill for more than 6 years [20]. Thus, productivity losses, health care expenses, and reductions in quality of life continue for many years for most affected individuals and thus would have a substantial long-term impact on the standard of living of individuals with CFS and their family members.

Some limitations should be considered when interpreting our results and considering future studies. The prevalence estimates we used are likely to understate the number of individuals affected by CFS since the Wichita study was designed to estimate point prevalence. Forty-three participants were classified as having CFS at baseline because they fulfilled all criteria of the case definition at the time of clinical evaluation. The study continued an additional 3 years, during which the cohort was interviewed annually, and over the entire study, 90 persons were identified as having CFS. Incident CFS was extremely rare, most of the 47 cases identified during subsequent years reported they had been ill with CFS for many years but were in partial remission during previous interviews and so had not acknowledged symptoms at that instant in time. Prevalence estimates from the CDC Wichita Study are about

half those estimated for a study of CFS in a Chicago population [3]. To the extent that the Wichita Study underestimated prevalence, the productivity loss estimates derived in this study are likely to be proportionally understated. Thus, we believe that the productivity loss estimates presented here are a lower bound on the losses related to CFS. In addition, as patients with CFS recover they may no longer fulfill all case-defining criteria but may still have reductions in income because they lost job tenure and experience at the time of their illness. Thus, these individuals should be included in productivity loss estimates.

We used the human capital approach to estimate lost productivity rather than the friction cost method. Several studies that have compared indirect costs of illness by both methods show that the human capital approach potentially overestimates indirect costs related to illness because it does not account for labor scarcity. We take the view that labor markets clear relatively quickly, and that the hypothetical unemployed worker who takes the job vacated by the CFS victim would have soon found employment at about the same wage anyway. For individuals with CFS, we reduced the value of household productivity by the same percentage as the reduction in their labor force income due to the presence of CFS. This con-

servative approach also based its estimate on reductions in labor productivity among those individuals with CFS who remained in the labor force after the onset of their illness. The severity of the illness for these individuals was likely to be much less than that of individuals with the illness who exited the labor force. While there are many difficulties in precisely estimating the costs of illnesses such as CFS because of human factors that are difficult or impossible to quantify, this estimate documents the dimension and magnitude of the stark economic impact that CFS has on individuals, households and on the nation.

Conclusions

Lost productivity due to CFS was substantial both on an individual basis and relative to national estimates for other major illnesses. CFS resulted in a national productivity loss comparable to such losses from diseases of the digestive, immune and nervous systems, and from skin disorders. The extent of the burden indicates that continued research to determine the cause and potential therapies for CFS could provide substantial benefit both for individual patients and for the nation.

Competing interests

None declared.

Authors' contributions

KJR had primary responsibility for data analysis strategies and interpretation of economic data, and drafted the manuscript. SDV conceived the idea to assess the economic impact of CFS presented in this manuscript, participated in analysis strategies, collaborated in interpretation of the data and drafting the manuscript. EB was responsible for data analysis and collaborated in interpretation and drafting the manuscript. WCR conceived of the study from which the data was derived, led its design implementation and conduct, collaborated in conception of this analysis, collaborated in interpretation of the results and drafting the manuscript. All authors read and approved the final manuscript.

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