Causal effect of health on socio-economic prosperity: Experimental evidence

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There is abundant evidence that health status and socio-economic success are positively correlated. Isolating the component of the correlation that can be attributed to a causal effect of health on socio-economic success has proved to be very difficult in studies that use non-experimental data. Causality almost surely runs in both directions and, in most empirical studies, there are likely to be unobserved factors that affect both health and socio-economic success. Analyses using non-experimental data rely on statistical assumptions that are difficult or, in some cases, impossible to verify.

This paper describes a random-assignment treatment-control experiment which was specifically designed to rigorously test whether an important dimension of health, micronutrient status, has a causal impact on social and economic prosperity. The Work and Iron Status Evaluation (WISE) is an on-going study following over 18,000 people living in 5,000 households in Central Java, Indonesia. Half the study subjects were assigned to a treatment of 100 mg of iron every week for a year; the controls were given an identical placebo. Results are reported for 10,000 older adults (age 30 through 70 years) included in the experiment.

The experiment focuses on iron status for four reasons. First, iron deficiency is widespread throughout the developing world with estimates indicating that over 3 billion people are iron deficient in the world today. Among older adults in Indonesia over 30 per cent of males and 50 per cent of females are iron deficient. Second, the impact of iron on metabolic functioning is extremely well understood right down to the cell level. Iron plays an essential role in oxidative energy production. Low hemoglobin, an indicator current iron levels, reduces the maximum amount of oxygen the body can use. In addition, low iron stores reduces endurance through forcing the heart to work harder for the same activity. Random assignment laboratory experiments have demonstrated with both animal and human subjects that iron deficiency results in reduced work capacity and energy efficiency which provides a potential causal mechanism for health to affect economic and social prosperity. Third, implementing social experiments is extremely difficult because subjects may adjust their behavior in response to their perception of the benefits of the experiment. This may be manifest by failure to comply with the study protocol. By carefully measuring levels of iron in the blood during the study, it is possible to monitor the impact of the iron supplements on the treatments, relative to the controls and, thereby, measure the extent to which the protocols have been successfully implemented. Finally, it is relatively inexpensive and technically straightforward to eradicate iron deficiency through food fortification which means that the study results have the potential to be of practical value.

The first goal of the paper is to describe the design and implementation of the experiment, highlighting some of the ways in which we sought to assure the quality of the study, evaluate the effectiveness of the protocols and maintain the highest ethical standards. The second goal is to present analytic results from the experiment regarding the causal impact of health on social and economic prosperity.

We begin with a careful description of the protocols that were developed to provide iron tablets to the study subjects, the trade-offs that were encountered in designing the field protocols and the results of a series of pilot tests that were conducted to evaluate different protocols. In a study of this nature, it is critically important that study participants comply with the intervention regimen. Procedures for assuring the highest possible compliance was maintained are discussed in detail, including a description of the pilot studies that were conducted to test different protocols, methods that were adopted to maintain subject co-operation through the course of the entire study and strategies used to of subjects. Subjects were given a blister pack of four tablets every four weeks and were visited twice a week at the beginning of the study and less frequently as the study progressed. The number of pills that are removed from the blister packs is recorded at each visit and provides an upper bound estimate of the number of pills consumed by the subject. An advantage of focusing on iron is that we are able to measure the level of iron in the blood throughout the study and, thereby, have a direct indicator of compliance and protocol efficacy. Hemoglobin (Hb) levels were measured for every subject in the home using a Hemocue photometer. Hb was measured three times before the intervention, at four month intervals during the intervention and at four month intervals for a year after the intervention. Transferrin Receptor concentrations, an indicator of iron stores, were also measured using dry blood spots.

The iron supplement was designed to balance the goal of raising iron levels in the blood against possible side effects. Drawing on the nutritional biochemistry literature, we estimated that the average adult male who was iron deplete prior to the intervention and received the treatment would be iron replete after about six months of supplementation. The average female would take longer. In addition, supplementation should have no effect on the iron levels of subjects who were iron replete at baseline. Our results are consistent with these predictions.

After 12 months of supplementation, there is no difference in the iron levels of treatment and control subjects who were not iron deplete at baseline. Among iron deplete subjects, iron levels of treatments were significantly higher than that of controls. Subjects were followed for 12 months after the iron supplements ended in order to measure the longevity of these effects. We find that the benefits of supplementation dissipated relatively quickly for females who were iron deplete at baseline: 12 months after the intervention ended, the gap in iron levels between treated and control females had been reduced by over 50 per cent. For males who were iron deplete at baseline, the benefits of the supplementation are considerably more long-lived: the gap between treatments and subjects declined slightly after supplementation ended but continue to be both large and significant a year after supplementation ended.

A second check on the efficacy of the intervention is provided by replicating results for the impact of iron deficiency on work capacity that have been well-established in the biomedical literature. Work capacity is measured by giving a subject a physically exhausting task such as riding an ergocycle (stationary bicycle) with weights that are increased over time, measuring the work output and thereby calculating $V0_{2max}$. A subsample of subjects completed this test in a physiology laboratory in Yogyakarta and $V0_{2max}$ was significantly higher for treatments, relative to controls, at the end of the iron supplementation.

In order to measure the impact of the intervention on economic and social prosperity, study subjects have been interviewed every four months during the three years of the study. Subjects were interviewed three times prior to the initiation of the iron intervention, three times during the intervention and three times after subjects stopped taking the pills.

Preliminary results indicate that iron supplements given to iron deplete subjects have resulted in greater economic productivity as well as improvements in health and social well-being. For example, after six months of supplementation, average hourly earnings among iron deficient males who received the treatment was about 10 per cent higher than the earnings of comparable controls. Almost all of these gains are concentrated among males who were working in the self-employed sector at baseline. Hourly earnings is likely to be a good indicator of economic productivity among self-employed workers. Moreover, most of the self-employed men work in farming, construction or provide services (such as bicycle rickshaw riders), all of which are physically demanding occupations and, therefore, productivity is likely to be related to work capacity. The earnings of iron-deficient males who were working for wages (such as civil servants or employees in stores) were not affected by the supplements. For them, wages are unlikely to be closely linked to productivity. However, the way men in the wage sector allocated their time was related to whether or not they received the supplement: they tended to sleep less and used up all the additional time in leisure. Self-employed men did not change the way they allocated their time. All iron deficient males who received the treatment reported being able to do more physically arduous tasks, reported having more energy than usual and reported being in better psycho-social health. Results for women are in the same direction but emerge as significant differences between the treatments and controls only after 12 months of supplementation. This is consistent with the slower rate of absorption or iron by women – as indicated in the biomedical literature – and reflected in our results for hemoglobin.

These results provide evidence that rejects the hypothesis health has no causal effect on economic prosperity of adults during middle and older ages. While this causal mechanism explains only a small part of the correlation between health and socio-economic success, the benefits of iron supplementation clearly exceed reasonable estimates of the costs associated with fortification of food.