

RESEARCH FINDINGS ON THE  
SOCIAL CONSEQUENCES OF MALNUTRITION

by

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## Research Findings on the Social Consequences of Malnutrition<sup>1/</sup>

The purpose of this section is to present a review of nutrition and related research on the possible social consequences of malnutrition and/or hunger in the United States. Unfortunately very little research has been done in the United States in recent times that is directly applicable to this subject. It is necessary therefore to review nutrition research that has in many cases been conducted in other countries or has been done with other goals in mind. Much of this research is clinically or biochemically oriented and is usually concerned with identification of nutritional disorders and measurement of the possible physiological results. This work is often done in developing countries where the incidence of severe nutritional disorder is relatively high. In attempting to apply the results of this research to the United States situation extreme care is needed to insure against improper application. As has been pointed out earlier there are nutritional problems in the United States. Although the incidence of nutritional deficiencies is relatively high in some low income groups surveyed in the U.S. the problem is of a lower magnitude than that experienced in the low income groups in developing countries.

This section is divided into three parts. The first will deal with the social consequences of malnutrition in children through school age. Second, the question of nutrition and human reproduction will be examined with emphasis on birth weights and neonatal mortality. In the third part nutrition and physical productivity as it relates to working adults will be discussed.

### Growth and Development of Children

#### Mental Development

One of the most discussed topics in recent years has been the relationship between malnutrition and mental development, learning ability and ultimately intellectual performance in children. The general feeling seems to be that malnutrition at an early age may permanently retard the mental development of children. This popular interpretation of research dealing with this topic needs to be examined in some depth. The social consequences of retarded mental development are obvious and prevention would bear high priority.

The evidence supporting the relationship between malnutrition and mental development comes from two general areas. First is the research on brain growth and development, and secondly the field studies with human populations.

#### Brain Growth

In the child the brain achieves 80% of its adult weight in the first three years, but in the same period the child will only reach 20-25% of its adult weight. Scrimshaw (1967) therefore argues that since the human brain is gaining weight at such a rapid rate after birth, severe protein-calorie deficiency serious enough to limit physical development would also limit brain development. Head circumference is often used as an indicator of brain size and differences in head circumference of individuals with comparable genetic but different nutritional backgrounds are reported in the literature. These studies were done in Uganda by Dean and Brown (1960, 1965), in Peru by Graham (1964), and Mexico by Ambrosius (1961). In addition recent work by Winick and Rosso (1969) indicate decreased cellular growth in the brains of severely malnourished infants. Numerous research studies have linked poor nutrition with retarded growth and physical development (Jackson 1966, Woodruff 1966, Guzman 1968). Two other

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<sup>1/</sup> Review paper prepared by Dr. David L. Call for the Bureau of the Budget.  
~~Not for publication or quotation.~~

recent review articles by Eichenwald and Fry (1969) and Winick (1969) adequately describe the effects of protein-calorie malnutrition on the structure, maturation and growth of the brain. These authors imply that slowed brain development creates a strong likelihood that mental development is likewise affected. The numerous research studies done on animals would tend to support these findings in humans.

Pollitt (1969) on the other hand effectively argues that:

"our present information on the biological basis of intelligence is not sufficient to single out the histological, biochemical and physiological changes that must occur in the brain to affect learning. There is no conclusive evidence, for example, that show biochemical rate of maturation or comparatively small brains at maturity like that found in malnourished children are detrimental to intelligence. On this account, although the data on malnutrition and neural growth have suggestive and heuristic value, it does not warrant any specific conclusions on the relationship between malnutrition and behavior."

With reference to the United States there have been practically no attempts to correlate malnutrition with brain size and development. It is not known whether the more mild forms of malnutrition experienced in the United States, while severe enough to possibly effect growth and physical development, have an impact on neural development.

#### Field Studies

A number of field studies have attempted to prove the link between malnutrition at an early age and later intellectual development. It is difficult to interpret most of these studies since nutrition is only one of many factors known to influence performance on various intelligence tests. It has been extremely difficult to control effectively the many cultural factors such as social deprivation, parental education, environment, maturation and external stimuli. Scrimshaw (1967) has stated that:

"For underprivileged children in the United States and other industrialized countries these factors are likely to override any effects of nutritional status and make such effects difficult or impossible to detect."

This does not imply that malnutrition or hunger may not affect school performance but seems to imply that structural damage will be difficult to prove.

In the major field studies that have been concerned with this problem the evidence is impressive that children who have suffered from severe nutritional shortages do less well on various intelligence tests than a more normally nourished control group (Klein and Gilbert 1967, Guatemala; Cravioto and Robles 1965, Mexico; Monckeberg 1968, Chile; Stoch and Smythe 1968, South Africa). Pollitt (1969) has prepared an excellent review of eight studies conducted since 1963. Each of the studies that has been done can usually be criticized on the basis of sample selection, intelligence tests utilized, controls for experimental effect and other problems. From a research standpoint this criticism is often justified but the evidence is still impressive in spite of these difficulties.

Although faults may be found in the research design, often these studies still provide valuable evidence of possible benefits from intervention programs.

One study done in the United States that is frequently quoted illustrates some of the problems. Kugelmass, Poull and Samuel (1944) reported on a study of New York school children where nutritional intervention improved test scores on two standard I.Q. tests. In this research 182 children were divided into two groups. Each group had 41 retarded and 50 normal children. The first group was labelled "malnourished" and the second well nourished. Unfortunately the criteria for the groupings was not given. The groups were equated for age and I.Q. scores. Two batteries of tests were given although the time period between tests was not stated. Although not specifically stated it is assumed that Group I was fed in some manner during the test period. By the time of the second test the average scores of the normal Group I children had increased 18 points and the scores of the retarded children in the same group had increased 10 points. The children in Group II showed no significant change in scores. Since a correlation between age and improvement in scores was found the authors concluded that the younger the child is when intervention takes place the greater the chance for mental improvement. This research has been criticized on the basis that it was not proven that nutrition alone was the reason for the improvement in test scores. The increased attention could have had a major effect since rejected or neglected children have been shown to benefit just from attention (Scrimshaw 1967). This criterium may be valid from the standpoint of determining cause and effect but the results of the intervention are dramatic and do show that intervention can be successful. In other words food may be a vehicle which combined with attention or other stimulus can result in significant changes.

Another study recently reported on the development of 35 infants hospitalized with severe malnutrition during the first year of life in Denver, Colorado (Chase 1969). Nineteen of these children were studied three and a half years later and matched with a control group of similar ethnic and socio-economic status and age. A significant correlation was reported between duration of malnutrition and mental development. The average I.Q. score of 82 for the malnourished group compared with 100 for the control group. Although attempts were made to match the two groups, the malnourished group had more children per family, and a higher incidence of alcoholism, parental separation, and maternal psychological problems. Obviously these factors, as well as the period of hospitalization, could have affected the mental development. Despite its faults the evidence is suggestive that even in the United States severe malnutrition in conjunction with the undesirable cultural characteristics may affect mental development.

As reported earlier the incidence of severe protein-calorie malnutrition found in recent U.S. surveys is very low. The social consequences of reduced mental capacity due to severe malnutrition at early age in the U.S. would seem to be rather low. Other childhood diseases and even inborn errors of metabolism may be more important in actually causing mental retardation. Possibly the more important conclusion that can be drawn from these studies is that in a food short, culturally deprived environment children are not developing to their maximum potential. Education specialists and other social scientists have ample proof to verify this condition. Food intervention programs may be an important contributor to a broader attack on this problem.

#### Nutrition and Infant Morbidity and Mortality

The synergism between malnutrition and other illnesses particularly diarrheal and respiratory infection in the developing countries has been well

documented (Scrimshaw, Taylor and Gordon 1968). Generally it has been found that the malnourished infant is much more susceptible to these types of infection and the severity of what are normally considered mild infections is greatly increased. Measles and whooping cough have a much higher fatality rate in malnourished populations than in the United States for example. Unfortunately research on this synergism in the developed countries has been almost nonexistent. Since the reported death rates for measles and other childhood diseases in the United States is very low, some might assume that poor nutrition was not playing a role. Unfortunately it is not possible to examine these mortality or morbidity figures with respect to economic or social class. Since infant mortality rates are higher in low income countries, in the United States it is possible that chronic undernutrition is a contributing factor in some undefined manner (Lowe 1968). It is not possible to make a research based judgment on the possible impact of better nutrition on infant mortality in poverty areas. The problem of prematurity and immaturity which is directly related to 20% of the infant mortality will be covered in the next section.

Better nutrition, i.e. relief from chronic undernutrition, could be one factor in breaking the cycle of poor health in poverty populations. Many important social variables could be affected if a broad program including food were instituted. Research would suggest that child morbidity would be lowered, for example, which could affect school attendance and performance. In the developing countries it has been shown that in addition to poor nutrition, inadequate sanitation, poor medical facilities and care, and other cultural and environmental factors play a role in high mortality and morbidity rates. Improved nutrition may help but not solve all these problems.

#### Nutrition and School Performance

The possible impact of malnutrition and hunger on school performance is related to the earlier discussion of mental development. It is useful to separate this phase from the discussion of the impact of malnutrition on the pre-school child although it is an artificial separation. The question is after the child has reached school does malnutrition at that time affect his performance. Equally or more important is the effect of the child's environment and the family situation, and it has been almost impossible to separate out the effect of nutrition.

The School Lunch Program was designed to improve the nutritional status of school children and it is assumed with the understanding that hungry children make poor students. The recent experimental efforts with School Breakfast Programs are aimed at the same problem. A number of studies have evaluated the nutritional effectiveness of school lunch programs. In general they show that properly designed programs can improve the nutritional status of students who exhibit signs of mild malnutrition. In Florida a five year study showed a shift of the normal distribution of values from one of pronounced clinical deficiency to a condition of sufficiency. The height and weight for age more closely followed the norm or advanced slightly. Prevalence of anemia for example dropped from 71% to 24%. The special feeding program was comparable in all essential food factors to the Type A lunch. Unlike a normal lunch program severely malnourished children were given supplements of iron and vitamin A and C until they reached the median nutritional level of their group. No effort was made to measure the impact of this program on school performance or absenteeism (Abboto et al. 1946).

A three year study in Ohio was designed to investigate the effectiveness of a supplementary feeding program on the health of children in an elementary school for farm and industrial families (Patton et al. 1961). After a one year observation period nutrients determined to be low were added to the diet. Foods rich in vitamin A and C, calcium and protein were used. (It is assumed they were used in quantities greater than normal.) A larger proportion of the children participating in this program had good diets relative to the RDAs than in a control group.

On the other hand in a short study (six weeks) conducted near Washington, D.C. children in relatively good nutritional status did not benefit from a lunch program (Butler 1950). Clinical examinations, biochemical tests and diet histories showed no significant changes between a group with a lunch program and another group without a program. It appears that school lunch programs can improve the nutritional status of children if there are deficiencies and the programs are well managed. Mack (1947) cautions that poorly planned meals may be detrimental in that meals planned and/or prepared by untrained people may be less nutritious than the child would receive at home.

The question of the impact of the school lunch on school performance has been inadequately researched. Most evaluations are based on subjective assessments and are seldom well controlled. Hampton et al. (1967) for example found no correlation between school performance as measured by a Grade Point Average and diet as measured by the number of nutrients below two-thirds of the RDA. The students from the lower socio-economic groups did have poorer dietary histories. It is probable that in studies like this both measures are too gross to pick up small differences. Also this type of study does not measure what an improved diet might accomplish.

Several studies have shown rather conclusively that school performance can be expected to deteriorate when no breakfast is eaten by the student (Tuttle and Herbert 1960, Tuttle et al. 1954). The consensus of the school authorities in the latter study was that the omission of breakfast exerted a significant detrimental effect on the attitudes and scholastic attainments of the boys involved in the test.

Tuttle et al. also did a series of studies on the effects of various breakfast types on physiologic responses of several age groups. With school boys aged 12 to 14, they found maximum work rate, maximum work output, neuromuscular tremor and choice reaction time were not affected by a basic breakfast built around bacon, eggs and milk, or cereal and milk. A comparison of the responses after a basic breakfast (750 calories) and a heavy breakfast (1200 calories including 60% more protein) also showed no difference in response (Daum, K. et al. 1955).

University women 18 to 25 years old were used to study the effect of a light breakfast (300 calories) versus a heavy (1000 calories) breakfast, and no breakfast versus a basic breakfast (600 calories). No difference in physiologic response was established between a light and a heavy breakfast. When compared with no breakfast, a basic breakfast significantly reduced tremor magnitude, increased choice reaction time in 60% of the cases, and increased the maximum work output in 80% of the cases (Daum, K. et al. 1950).

The effects of a light, heavy or coffee only breakfast were determined in six women 22 to 27 years of age. The omission of breakfast caused a decrease in the maximum work output, an increase in simple and choice reaction time, and

an increase in tremor magnitude. When coffee alone was substituted for a heavy breakfast there was a decrease in the level of performance in maximum work output and choice reaction time, and a decrease in tremor magnitude. Substitution of a light breakfast for coffee alone significantly improved the maximum work output and choice reaction time, and decreased the tremor magnitude (Tuttle et al. 1949).

In men aged 21 to 28 years the omission of breakfast increased their tremor magnitude, decreased the maximum work output in 80% of them, and decreased the choice reaction time in 60% (Tuttle et al. 1950).

Physiologic responses did not differ in men receiving a basic breakfast of 750 calories planned around cereal or bacon and egg. A heavy breakfast (1200 calories), when compared to a basic breakfast, significantly reduced the work output in 75% of the cases (Tuttle et al. 1950).

The effect of a pineapple versus water mid-morning break was studied in nursery school children. Juice seemed to reduce fatigue, irritability, and tension in the children; however, age and outdoor activity also affected this negative behavior (Keister, M. E. 1950).

Although the skipping of breakfast seems to be a growing trend of all ages of people in the United States, it would seem particularly detrimental to children from lower income groups whose diet might be marginal to begin with.

The National Institute for Dairying in England did one of the most complete investigations of the effect of a milk supplement on school children. The 8,435 children aged 5-14 years were divided into four groups receiving the following supplements: 1/3 pint pasteurized milk, 2/3 pint pasteurized milk, 2/3 pint raw milk or biscuits of low nutritive value. Objective measurements including height, weight, chest circumference and pull and subjective measurements such as clinical assessment of nutrition, posture, and scholastic ability were taken.

The supplements of 1/3 pint pasteurized and 2/3 pint pasteurized or raw milk resulted in a greater increase in height, weight and chest circumference than occurred in the biscuit-control group. Both sexes, irrespective of age, showed these increases and they were greater in the groups receiving 2/3 pint raw or pasteurized milk than in those receiving 1/3 pint milk. Clinical assessment of the children's nutrition state was determined throughout the study. By the end of the study 6% of the boys and 9% of the girls receiving 2/3 pint milk had improved to an above-average nutrition status. Also the children's scholastic ability was assessed by their teachers throughout the experiment. In the group receiving 2/3 pint milk, 10% more boys and 6% more girls moved into the average or above-average scholastic categories (National Institute for Dairying, 1939).

There seems to be a strong possibility that provision of food to poverty groups in such a way as to insure a proper breakfast and lunch for school children could have an important impact on scholastic performance. Social benefits could include lower dropout rates, improved scholastic performance, and better training for vocational opportunities.

### Summary

Malnutrition and hunger in the United States is probably having its major impact on the school performance of children. The problem appears to be more

closely connected to motivation and mental attitude than pure physical condition. It does not appear that this is due to any permanent reduction in mental capacity due to serious protein-calorie malnutrition in early life for the evidence would indicate that this is a minor problem in the U.S. Hunger, that is attending school without a breakfast and/or an inadequate lunch, appears to be more important than malnutrition per se. Improved school performance would seem to be one of the major benefits to be expected from a comprehensive intervention program. For pre-school children from poverty areas malnutrition is probably contributing to a higher morbidity rate. Also the ability of poorly fed children to compete when they reach school may be reduced.

A comprehensive food intervention program should produce significant social benefits if school performance can be improved. Unfortunately there is no evidence upon which to base estimates of the magnitude of these benefits.

### Nutrition and Human Reproduction

In the United States the neonatal and infant mortality rates have persisted at levels well above those of several other developed countries. Attempts to provide solutions to this problem have indicated that nutrition may play an important role in what is often referred to as reproductive efficiency. It has been felt for some time that the best indirect evidence of nutritional adequacy of the mother can be found by examining birth weights of infants and neonatal mortality rates. Lowe (1968) states that almost 20% of infant mortality is directly related to prematurity or immaturity at birth. If improved maternal nutrition could affect birth weights or in other words reduce the incidence of prematurity and immaturity, then the social benefits could be quite high. The association of low birth weight with cerebral palsy, impaired mental development, behavioral disorder and other neurologic disease has been well documented and is subject to little debate (Harper and Wiener 1965, Wiener 1962, Drillien 1964). A study done in 1950 reported a much higher death rate for infants with birth weights of less than 2500 grams, 173.7 per 1000 live births as contrasted with 7.8 per 1000 live births with weights greater than 2500 grams. Obviously birth weights below 2500 grams present a double barreled threat and are of important social significance.

A relatively recent Government report presents statistics on the variation in birth weights among legitimate births in the U.S. in 1963 (National Center for Health Statistics, 1968). The statistics are based on data collected in a mail survey of mothers, physicians, and medical facilities connected in a birth.

Approximately 7.2% of the legitimate babies born in the U.S. in 1963 weighed less than 2500 grams. The percentage of babies weighing less than 2500 grams was almost twice as high in families with an income of under \$3,000 as in families with an income of \$7,000 or more. Within each income class babies born to nonwhite mothers had a lower average birth weight and were more likely to weigh 2500 grams or less than babies born to white mothers. For example in families with a 1962 income of under \$3,000, 8.8% of babies born to white mothers and 14.0% of the babies born to nonwhite mothers were below the generally accepted 2500 gram figure. This study also reports on the relationship between birth weight and amount of medical care. Although the relationships are not entirely clear there appears to be a relationship between amount of medical care and low birth weights. For example, when the mother made fewer than 10 visits for medical care 10.5% of the babies were of low birth weight compared with 5.2% for those mothers who had 10 or more visits. These data offer strong support to



directing intervention programs at low income groups, particularly nonwhites in the child bearing age groups. The following paragraph from a draft of a report of Maternal Nutrition Committee of the Food and Nutrition Board summarizes the situation with respect to factors causing low birth weights.

"The incidence of low birth weight infants, and closely related high neonatal mortality, show differentials by socioeconomic status and color of mother. The maternal factors that are implicated include; biological immaturity (under 17 years of age), high parity, short stature, low pre-pregnancy weight for height, low gain in weight during pregnancy, poor nutritional status, smoking, certain infectious agents, chronic disease, complications of pregnancy and a history of prior reproductive loss."

This clearly shows that the link between maternal nutrition and birth weights is not a simple one of cause and effect. Few well developed and controlled studies of the impact of maternal malnutrition on birth weights and behavioral development have been reported. Read (1969) summarizes the research findings as follows:

"Investigations of children born to mothers during the 'hungry winter' of starvation in the 'Low Countries' during World War II have shown few permanent sequellae although the babies were smaller than normal at birth. Data to the contrary have been obtained in studies of North African children where the children of chronically malnourished mothers were larger than European babies at birth but later showed retarded development. Studies of twins also suggest that the smaller sibling may develop less satisfactorily, presumably due to intrauterine malnutrition. Full-term babies that are smaller than normal at birth, and premature babies (regardless of social class) may also demonstrate an impairment of behavioral development. On the other hand, recent studies have shown that the isolated conditions which surround the premature infant during his first few weeks or months of life may also influence behavioral development, suggesting that caution be used in interpreting prematurity and small-baby data in terms of intellectual development.

None of the studies mentioned above have been directed specifically at the effects of nutritional improvement programs on fetal development. All studies reported to date are confounded by the presence of many other medical, social, and ecological factors which accompany malnutrition. Nevertheless, it remains possible that nutritional status of the mother, perhaps even over the years preceding pregnancy, has some effect on fetal and infant development."

The problems associated with attempting to provide more evidence of the relationship between nutrition and birth weight are highlighted in this paragraph from the Maternal Nutrition Committee draft report:

"It is obvious that reproductive performance has multiple determinants. Research to assess the relative importance of individual factors, including poor nutrition, has

been handicapped because many of the factors tend to be associated with one another in the same women, or groups of women. The most vulnerable women are likely to have been born and brought up in poor homes, and in large families having inadequate means to obtain good medical care, food and education for their children. Poor crowded housing tends to favor the spread of infectious diseases that are not properly cared for. Immunizations and other preventive health services are not available, or are not sought. Children grow up with poor health habits and poor food habits. Girls brought up under such circumstances tend to bear their children early and to rear them under similar unfavorable circumstances. Such women often do not grow and develop to their full genetic potential and they enter pregnancy with sub-optimal health and nutritional status. While poverty appears to be central to the chain of circumstances described, there are women who for other reasons, including the current fad for slimness, arrive at child-bearing age with poor health and nutritional status and poor health habits."

Although research has not provided a definite link between nutrition and reproductive efficiency several reports have discussed the positive benefits of intensive maternal nutrition programs. In Britain during World War II pregnant women were given special priority for food. The quality of the diets of pregnant women particularly those in low income groups was significantly improved. Between 1939 and 1945 the still birth rate fell from 38/1000 to 28 or a drop of 25%. Obviously other factors may have influenced the drop but nutrition appears to have played an important role.

Another report that is often mentioned is the work of Toverud (1950) reporting on experiences in Oslo from 1939 to 1944. In brief a health station was established that provided intensive health care and a dietary regimen for pregnant mothers in addition to other health services such as post-partum care. The study was conducted under unusual conditions, i.e. wartime and food rationing, and is not well reported. In spite of these problems the results of this program were impressive. The still birth rate dropped by about 50% compared with the city of Oslo. Although the number of births at the station was relatively small, 728, the death rate during the first year and first month were lower (1.4 versus 3.0 and 1.1 versus 2.0) than for the city of Oslo. Although there were few premature births (less than 2500 g) there were only half as many (2.2%) among supervised mothers as among mothers without prenatal supervision. These paragraphs from the summary are interesting:

"From this brief review of the activities of the Sagene Health Station in Oslo it has been shown that the regimen was of great value in improving the general health of the pregnant and lactating women and of the children and infants.... The great improvement in health of mother and child was accomplished by a regimen comprising medical supervision and dietary management including provisions of supplements. To evaluate the importance of each of these factors separately is not possible. However, together they raised the nutritional status of the subjects."

This study would indicate that better nutrition alone may not guarantee higher birth weights or better reproductive efficiency.

Some other studies on the relationship between diet and birth weight present conflicting evidence. Burke et al. (1943) have reported consistent associations between good maternal diet and birth weight. Since there was no control for social class the effect of diet alone cannot be positively identified. McGanity et al. (1954) after studying a population of low to middle income white women found no relationship between a good dietary intake and birth weight. Of those women who delivered low birth weight infants there was a twofold increase in the rating of poor nutrition based on physical examination. Unfortunately the study design (requiring payment of fees) may have excluded some women of low nutritional status. Thomson (1959) in Great Britain found an association between dietary intake, social class and birth weight. But the mothers in higher social classes were larger in stature and he concluded that diet itself was of little importance.

One other problem of increasing concern to medical authorities and nutritionists is the increasing number of births to girls under 17 years of age. The added stress of pregnancy in an immature girl can increase nutritional requirements significantly. This situation seems to demand special counseling and action programs.

### Summary

There is little doubt that poor nutrition before and during pregnancy is one of many factors affecting birth weights. Short of actual starvation of pregnant women the relationship is complex and difficult to pinpoint. The risks associated with low birth weights of greatly increased mortality and a probability of mental damage indicate that preventive programs are needed. The relationship between the higher incidence of low birth weights in poverty areas implies deficiencies in nutrition, education and medical care and facilities.

Based on the research evidence it would appear that a nutrition intervention program would be more efficient if it was combined with a broader maternal health program. This would be more costly but nutritional intervention alone may not produce any measurable effect.

It would appear that in selected areas of extreme poverty with high incidences of low birth weights and high infant mortality rates improved nutrition alone should produce some modest reduction in these rates. The broader the intervention program beyond just nutrition the greater the chances for significant results.

### Nutrition and Physical Productivity

The relationship between food intake and physical productivity output appears on the surface to be quite direct. Since physical activity requires an increased rate of energy expenditure it would appear that direct correlation between food intake and work output or some other measure of productivity would be possible. If this were true, then it should be possible to estimate potential gains in productivity given improvements in food intake and nutritional status in employed adults whose nutrition is sub-optimal. Unfortunately the situation is not this simple and research does not provide us with simple guidelines for such a calculation. This discussion will explore the relationships between nutrition and productivity by first examining energy requirements and then discussing proteins and vitamins.

## Energy Requirements

It is generally accepted that individual variations in energy requirements are a function of age, size, environment and muscular activity, and to some extent, of efficiency and training (Booyens and McCance, 1957).

The total energy output is generally assumed to be the sum of the energy needs for basal metabolism, specific dynamic action, physical activity and the maintenance of a constant body temperature (Konishi and McCay, 1960). In recent years research has shown that this assumption is too simple and additional factors may play a role in determining the specific energy output of an individual.

The Food and Nutrition Board (NAS-NRC 1968) states that "The body requires food energy for resting metabolism, synthesis of body tissues (growth maintenance, pregnancy and lactation), physical activities, excretory processes, and to maintain thermal balance (also for physiological and psychological stress)."

That the basal metabolic rate is constant for an individual is a classical and generally accepted assumption. Calculation of basal metabolic rates are usually made from standard tables or formulas after determination of oxygen usage. Keys (1949-50) estimates individual variations to be within  $\pm 10$  per cent. It should also be noted that Keys considers the standard values to be about 10 per cent too high based on his own research.

The energy needed by an individual beyond his basic metabolic needs is difficult to measure since the energy needed for physical or muscular activity varies with the extent of the activity and to a lesser extent between individuals for the same activities. Tables showing the specific energy costs for different kinds of activity are available. Again considerable error is possible in estimating the energy costs since these tables may contain an inter-individual error of  $\pm 10$  per cent (Spitzer and Hettinger, 1958). Edholm et al. (1955) found these differences to be substantially greater than  $\pm 10$  per cent.

It should be obvious that even with careful measures of physical activity the possible variation of  $\pm 10$  per cent in the BMR plus an even greater possible variation in the energy costs of physical activity commonly lead to broad range of estimates of individual energy requirements. As with any nutrient requirement, this problem is overcome to a certain extent by using energy allowances for large population groups.

For the United States the Recommended Dietary Allowances of the Food and Nutrition Board are generally accepted for guidance in determining energy requirements. It should be clear that these should not be interpreted or used for comparisons with levels of intake for individuals or small groups of individuals.

## Energy and Work Performance

The concept that work performance declines with a reduction of the caloric intake is theoretically correct. The key question that has not been adequately answered is the specific relationship between work output and alternative levels of caloric insufficiency.

The research evidence supporting the direct relationship between calories and work output come from two separate series of studies. The Minnesota Starvation experiments of Keys, Brozek, Henschel, Mickelson and Taylor (1950) examined

in great detail the physical performance of young males with standardized tests during periods of semi-starvation. The general finding was that performance seriously declined during the 24 week starvation period and returned to normal (control) levels after 20 weeks of rehabilitation. Since the caloric reduction was so severe and of relatively short duration these findings have limited applicability to the general U.S. situation today. In addition a subsequent study by Brozek and Taylor (1958) failed to identify meaningful changes in work performance in volunteers maintained on about 1000 calories for 24 days. Two studies have observed that caloric restriction for a short period of time actually led to an improved score on the Harvard Fitness Test (Consolazio and Forbes, 1946; Rodahl, 1961). Consolazio (1965) indicated later that an important factor in both cases may have been overweight and poor physical condition of the test subjects before the calorie restriction.

The other research activity that is frequently discussed relative to this subject is the work of Kraut and Mueller (1946). Their investigation conducted in Germany during and right after the Second World War dealt with calorie supply and work output in three experiments.

In one study the authors observed that while miners were on a diet consisting of 2800 calories output was 7.0 tons of coal per man. During a second period caloric intake was increased to 3200 calories and output increased to 9.6 tons, but the body weight of the workers declined an average of 1.2 kilograms. In a third period 3800 calories were provided and the average work output increased to 10.0 tons per man and body weights returned to normal. In a similar study the authors reported a 22% increase in work output of steam hammer operators provided an extra 400 calories per day. Other workers in the same camp whose output was restricted due to machine capacity but who received the same extra 400 calories experienced a weight increase in three months of 5.5 kilograms. In a third study 20 workmen were building an embankment and with 820 work calories (method of determination of BMR not given) they handled 1.5 tons per hour. Work calories were soon increased to 1300 and after one year the rate of output had risen to 2.2 tons per hour and weight increased slightly. At this stage cigarettes were offered as a premium and output increased sharply to 3.4 tons. During this premium period the workers lost an average of 3.5 kilograms.

These studies are interesting and seem to prove that caloric intake and work output are directly correlated. Their usefulness as a guide to assessing expected gains in output in other more generalized population groups is severely limited. Several factors limit the usefulness of this research.

(a) In no case was there a proper control group that would show conclusively that nutrition alone was the causal factor. Motivation was obviously important as demonstrated by the cigarette example.

(b) No mention is made of the training effect. In the first study mentioned the men were in a training period. It would be expected that output would increase as they became more experienced. The same question can be raised with respect to the third study where the base period coincided with the beginning of the job.

(c) It would appear that in all three studies the men were required to perform heavy physical labor. This would seem to limit its applicability to less strenuous occupations.

(d) Since these studies were conducted during wartime it would seem logical to assume that working conditions, and many other factors that might effect work output, would more likely be abnormal rather than representing a normal work environment.

In a more recent review (Keller and Kraut, 1961) the authors extended their discussion to include gross output of steel and coal as related to work calories of steel and coal workers. Although steel and coal production dropped as work calories decreased, the review does not discuss any of the possible effects of a wartime economy on industrial output. In discussing the German studies and the Minnesota Starvation studies these authors stated that the gradual reduction of calorie supplies must have made possible a certain adaptability to the lower food intake. If the human body can adapt to lower intakes of nutrients such as nitrogen and energy (Allison, 1958) then the direct relationship between work calories and work output becomes much more indirect.

Except for these studies there is practically no research evidence for the United States which would allow one to project or estimate effects of calorie supplies on productivity. With industrialization and mechanization the actual energy requirements for different types of work have probably been gradually decreasing. It would appear though that under conditions of heavy physical labor an obviously low level of caloric intake might be restricting physical output. Whether increases in calories will automatically increase work output is not at all certain.

The impact of nutrition on motivation as it affects work output has not been adequately researched. Intuitively it would appear reasonable to assume that a well fed worker may be more highly motivated. If this could be verified through properly designed research it could have importance in attempting to assess social benefits.

#### Protein Intake and Work Performance

Protein must be provided to the body in sufficient quantities to provide nitrogen and amino acids for the synthesis of body proteins and other nitrogen containing substances. If protein in the diet is provided in excess of these metabolic needs, it is utilized as a source of energy. In general, research has shown that physical activity does not increase the demand for nitrogen or amino acid above that of basic metabolic needs (Keller and Kraut, 1961). If the protein requirements are not being met then "performance capacity" seems to be affected. In the United States a very high proportion of working adults are receiving protein of sufficient quality and quantity to meet requirements. There is no research evidence to indicate that increased protein consumption would have a beneficial effect on work output or physical productivity.

#### Vitamins and Physical Productivity

The nutritional significance of vitamins in connection with energy yielding reactions has led to a fair amount of research relative to the restriction of vitamins and its effect on work performance. Most of the work has concentrated on vitamins of the B complex and the results have been somewhat contradictory. Shills (1964) pointed out that the differences in subjects, experimental conditions, physical condition of subjects, composition of diets, duration of experimental deficiency and other factors complicate the analysis. Since most of these studies were done with special diets under experimental conditions, they do not

even give clues with respect to possible effects in a more general population group or poverty group. As Leverton (1964) has pointed out it is not now possible to pinpoint behavioral effects with varying levels of vitamin intake ranging downward from the recommended allowances. She has also pointed out that nutrition research has not demonstrated a linear relationship between nutrient intake and metabolic response. In line with this Scrimshaw (1964) has stated that with moderate levels of vitamin deficiency other host factors (for example, age and sex) might become important variables.

In brief it can be said that the body requires vitamins and experimentally certain deficiencies do seem to impair productivity. Obviously when clinical signs of vitamin deficiency are found (pellagra, beri-beri, scurvy) the effect is more direct but these diseases are extremely rare in the U.S. Unfortunately research has not provided guidelines that would be helpful in evaluating more moderate deficiencies.

In spite of these problems there were early claims that vitamin supplementation could improve physical productivity. It was felt that absenteeism due to infectious disease would be reduced and other beneficial effects would be found. More recent reviews express the general conclusion that broad scale vitamin supplementation does not significantly effect productivity (Mitchell, 1964; Glatzel, 1964).

The problems involved with evaluating this type of research are illustrated by the following two studies. Probably the most extensive study involved aircraft workers in Southern California during the war (Borsook, 1945). In this study an experimental group of workers (volunteers) was given a daily vitamin supplement and a comparable control group was given a placebo. A third group (non-volunteers) that was not administered to was also available for comparison. It was felt this third group would provide for a control on the psychotherapeutic effect and the effect of participation.

During the first six months the absence rate for the third (C) group was slightly higher but not significantly different than for the other two. In the second six months the absence rate in the C group was 1.4 and 1.7 days/100 days higher than the placebo and vitamin groups respectively. The vitamin group for the second six months had an absence rate 19% lower than the placebo. This accounted for 0.89 days/100 days worked which was statistically significant. When this reduction in absence was examined by type of absenteeism the reduction was greatest in unauthorized absences and least in illness absences. The author clearly felt the main benefit was motivational and that supplementation produced a better mental attitude. The same effect was felt to be responsible for a lower termination rate for the vitamin group.

The company had an internal Merit Review mechanism which also was evaluated. The vitamin group showed significantly improved Merit Review scores compared to those of the placebo and C group which remained quite similar. The conclusion was that the supplementation increased output by 10.5 man days or 4.1% per year. Of the 10.5 days 6.6 was deemed to be the result of improved work performance as measured by improved merit scores, 2.3 days from reduced absenteeism, and 1.6 days from reduced turnover. No information is given on the cost of providing the supplement or the value productivity.

Although there is little reason to question the accuracy of the research, these results have not been duplicated in similar work. Furthermore there is

need to question the applicability to the situation in the U.S. in 1969. In the years since this study was conducted it is possible that the average dietary situation has improved which might remove a beneficial effect. Much more pertinent would be an evaluation of supplementation of workers whose level of earnings or other factors would seem to place them in a risk situation with respect to diet.

Another study in an industrial setting was concerned with two groups of female workers in a food processing plant (Peel and Dodds, 1957). One group of 41 workers had reported no absences the previous year and the second group of 31 had a record of regular attendance at the clinic and at least 9 absences the previous year. Their dietary intakes were evaluated on a recall basis and the group with no absences had a significantly higher level of nutrient intake. Although the conclusions appear clear it is obvious some non-nutritional factors may have affected the absenteeism rate. For example, the high absence group was responsible for twice as many people at home (36 versus 18) and were responsible for three times as many children under 16 years of age. Clearly family responsibilities may have necessitated increased absenteeism.

It is clear that many factors affect absenteeism. To the extent that vitamin or calorie deficiencies may contribute to a reduced disease resistance this could affect the rate. Past research has provided some limited evidence that nutrition may play such a role. The research has been so sparse that one cannot begin to measure possible quantitative gains in productivity that might result from improved nutrition.

Further evidence of the small role that nutrition may play in physical productivity is the lack of research for the United States that relates nutritional status to morbidity data for adults. It can be assumed that adult morbidity is somewhat correlated to absenteeism and work output, but this link is seldom discussed relative to the U.S. Iron deficiency anemia is often classed as one of the more serious nutritional problems of adults, particularly women. A review of the research finds practically no mention of the possible social effects of this problem.

A preliminary report from Great Britain (Elwood and Waters, 1969) may partially explain why less evidence is available. In an intensive and continuing study they found that about 10% of 15,000 women examined had less hemoglobin than the 12 g which WHO accepts as being indicative of anemia. Using supplements they found a rise in hemoglobin levels in a majority of those below the 12 g level. But they were not willing to accept this as evidence of anemia and tested the association between hemoglobin and symptoms of anemia in 920 women in a village in Wales. "The results of this survey gave no evidence whatever that the severity of symptoms of women said to have anemia depended on circulating hemoglobin level." (p. 15) To further test this lack of correlation they carefully selected 100 women with hemoglobins between 8 and 12 g and divided them at random into two groups. One group was given a common iron supplement for eight weeks and the other group a placebo. "Despite a very marked effect of the iron-containing tablets on circulating hemoglobin level, there was no evidence of a beneficial effect on symptoms by either the genuine tablet or placebo." A doctor's examination with a conventional clinical interview was also used with the physician not knowing the nature of the test. He declared that 53% of those given iron had shown improvement during the test as compared with 58% of those receiving the placebo.



One of their conclusions was that symptoms suggestive of anemia may occur with blood hemoglobins around 7 or 8 g and below which is vastly different than 12 g. Obviously this would indicate that anemia as presently defined may not be as serious a health problem as has been commonly believed. If substantiated, this research could have wide ramifications for it would indicate that many of the classical concepts with respect to iron supplementation and the RDA may be outmoded.

#### Summary

In summary it is clear that past research does not provide many guidelines that would be useful in attempting to assess the social benefits in terms of physical productivity of improved nutrition of poverty or other groups.

It seems clear that improved nutritional status would in no way impair physical productivity so the situation becomes one of anticipating gains based on principles of public health and circumstantial nutritional evidence. The research needs are clear. Particularly important would seem to be efforts to examine the relationship between nutritional status of poverty groups and work performance. Work performance in terms of physical productivity is extremely difficult to measure and past attempts have limited applicability. The indirect effects of nutrition on job turnover, absenteeism, performance in training programs and job advancement may be more susceptible to isolation. These are problems of disadvantaged groups and research would indicate that nutrition may contribute to the problems and theoretically partially to its solution.

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