Learning disabilities and poor motivation to achieve due to prolonged iodine deficiency\textsuperscript{1–3}

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ABSTRACT The effect of prolonged iodine deficiency on learning and motivation was studied. One hundred male children—matched for age, socioeconomic status, and formal education—were selected from both severely iodine-deficient (SID) and mildly iodine-deficient (MID) villages. Mean urinary iodine excretion was significantly lower in the SID than in the MID group (219.84 ± 57.52 compared with 449.14 ± 32.31 nmol/L, \( P < 0.001 \)). The serum thyroxine concentration was significantly lower (90.36 ± 6.46 compared with 123.70 ± 15.42 nmol/L, \( P < 0.001 \)) and serum thyroid-stimulating hormone (TSH) was significantly higher in the SID group than in the MID group (6.23 ± 3.40 compared with 4.85 ± 0.48 mU/L, \( P < 0.01 \)). The children were administered maze, verbal, and pictorial learning tasks and a test of motivation. The results showed that SID children are slow learners compared with MID children. In both groups the rate of learning over trials was superior in younger (aged 9–12 y) children although the initial performance of older (aged 12–15 y) children was better (\( P < 0.01 \)). SID children scored significantly lower than MID children on the achievement motivation scale (\( P < 0.01 \)). The results are suggestive of neural impairment as well as poor sociopsychologic stimulation, resulting in learning disability and lowered achievement motivation. Unless iodine nutrition is improved in the community as a whole, these abnormalities may prevent millions of children from the SID areas from achieving their full potential even if learning opportunities are made available to them. \textit{Am J Clin Nutr} 1996;63:782–6.

KEY WORDS Iodine deficiency, learning disability, achievement motivation

INTRODUCTION

Certain specific cognitive and intellectual functions, eg, verbal and perceptual performance, memory, and mathematical abstractions, are particularly vulnerable to iodine deficiency as suggested by serious impairment of these capacities in cretins (1, 2). Available information does not indicate any gross specific defects at physiologic or functional levels in severely iodine-deficient (SID) populations other than cretins; however, it is generally recognized that the spectrum of clinical features extend from mild hypothyroidism to frank cretinism in affected populations. The subclinical effects of iodine deficiency on central nervous system (CNS) development and function that are more subtle in nature may be difficult to detect by commonly used intelligence tests (3). Thus, alternate methods to test the effects of iodine deficiency \textit{in utero} on fluid intelligence representing the basic neural apparatus are necessary. More dynamic tests to measure learning ability and the efficiency by which new information can be absorbed and processed have recently been recommended for assessment of the effect of iodine deficiency on learning potential of children in endemic areas (4). Given the numbers of children at risk of iodine deficiency worldwide, there is surprisingly little information on this important aspect (5).

It is now accepted that slight but prolonged lowering of circulating concentrations of thyroxine (although within the normal range for the population) may produce a state of cerebral hypothyroidism in the clinically euthyroid populations in SID areas, which may lead to slow mentation of the whole society (6). Assessing the effect of iodine deficiency on sociocultural stimuli provided by siblings, peers, parents, neighbors, and the community as a whole is important to quantitate variables like motivation to achieve. As such, the requirement for methods to test intelligence that reflect the contribution of sociocultural variables and capacities acquired through learning and particularly through exposure to education also cannot be overlooked (4). Because motivation to achieve and the ability to learn (7) are two important aspects of intelligence, we investigated the effect of iodine deficiency on these variables.

SUBJECTS AND METHODS

Subjects

The present study was carried out by using a simple randomized group design in which the two groups were matched for age, socioeconomic status, and formal education (8). We selected 10 iodine-deficient villages from the Padruana region in eastern Uttar Pradesh, India. The prevalence of goiter was > 60% and the cretinism rate was 3.4%, indicating SID. Four villages of the same region with goiter rates < 10% and without any cases of cretinism were chosen as the controls. How-

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ever, biochemical evaluation of the control group suggested mild iodine deficiency (MID). Both SID and MID villages were situated at an average distance of 6 km from the town of Padrauna. Cultural indexes such as dialects, exposure to cultural events such as weekly markets and rural dance and drama programs, and participation in religious festivals were found to be similar in both SID and MID villages.

Initially, 340 goitrous male children aged 8–18 yr were selected from the SID villages. Cretins were excluded from the study. Initial selection was based on socioeconomic status (SES) rating scores (which measured nine components of deprivation: housing conditions, home environment, economic sufficiency, nutrition, clothing, formal educational experiences, parental characteristics, travel and recreation, and miscellaneous components) within the range of 80–110 (9). Of these, 160 were selected for this study because of their formal educational experience, which was a prerequisite for assessment of motivation to achieve. Formal education, as defined, included the ability to read, write, and comprehend. Finally, 100 children (50 aged 9–12 yr and 50 aged 12–15 yr) were selected as the SID group. The remaining 60 children were excluded because they did not know their exact age. One hundred age-matched children from MID villages were selected as the control subjects. The SID and MID groups were matched for SES [r (198) = 1.33, P > 0.05, NS] and formal educational experience [r (198) = 1.90, P > 0.05, NS]. In the 9–12-yr-old group from the endemic villages, 10 (20%) subjects had goiter grade Ia, whereas 40 (80%) had goiter grade Ib. In the 12–15-yr-old group, 15 (30%), 31 (62%), and 4 (8%) subjects had goiters of grade Ia, Ib, and II, respectively. Investigators were blinded to the identity of the group to which the subjects belonged. The study protocol was approved by the Ethical Committee of the Indian Council of Medical Research. Informed consent was obtained from the children’s parents before the start of the study.

Biochemical analysis

The magnitude of iodine deficiency in SID and MID groups of subjects was ascertained by biochemical analysis of urine and blood samples collected from one-third of the total subjects, who were randomly selected. The urinary excretion of iodine was determined by the method of dry ashing (10) and serum thyroxine (normal range in our laboratory: 70–170 nmol/L) and thyroid-stimulating hormone (TSH) (normal range: 0.30–5.0 mU/L) by radioimmunoassay using a kit from BARC, Bombay. The urinary excretion of iodine (219.84 ± 57.52 and 449.14 ± 32.31 nmol/L for SID and MID groups, respectively, P < 0.001) and serum thyroxine (90.36 ± 6.46 and 123.70 ± 15.42 nmol/L, respectively, P < 0.001) was significantly less in the SID group than in the MID group. Serum TSH was significantly higher in the SID group than in the MID group (6.23 ± 0.34 and 4.85 ± 0.28 mU/L, respectively, P < 0.01). Urinary iodine excretion and TSH suggested that by international standards our MID subjects were mildly iodine-deficient and may also have had subclinical hypothyroidism.

Learning materials

Human stylus maze

Blindfolded subjects were tested by using a human stylus maze pattern having one through-path and some blind alleys. Subjects were required to learn the correct through-path from starting point to goal with a metal stylus through 10 learning trials. The number of errors and time taken in seconds to reach the goal point were recorded. Learning was reflected by improvement in performance over trials. We used the modified version of the test that has been used extensively (11, 12).

Verbal learning

The verbal learning test was a modified version of one used earlier (11). Two separate lists of vernacular (Hindi) words, each containing 15 items (words), three from each of the five conceptual categories (animal, fruit, vegetable, cereals, and utensils) were prepared. The selection of these words was based on familiarity calibration of a large number of words. Words of a moderate degree of familiarity were used in the present study. The items were printed on 3- by 5-inch (8- by 13-cm) cards. The cards were given a fixed sequence such that no two words of the same category appeared adjacent. The sequences were arranged in two lists: “A” for learning by free-recall method and “B” for learning by serial-recall method.

In the free-recall method of learning, items were presented orally one by one to a subject at a speed of one item per 2 s. When the whole list was presented, the subject was instructed to recall the items in any order he liked. The correct recalls were recorded. This constituted one trial of learning. Ten such trials were given in all. In the serial-recall method of learning, the subject was required to recall the items in the sequence in which they were presented.

Pictorial learning

Twenty black-and-white photographs (55 mm × 45 mm) of boys all approximately the same age with uniform dress and neutral facial expressions with moderate identifiability were prepared. The stimuli were randomly divided into two groups: the old group and the new group, each containing 10 photographs. Five learning trials were given to each subject. In each trial, a subject was shown the old group of 10 photographs one after the other, each for a duration of 3 s. Then these photographs were mixed and shuffled with the 10 photographs of the new group and the subject was asked to identify those photographs that were shown to him previously. Five such learning trials were run. The number of correct recognitions in each trial was recorded. Pictorial learning was reflected in the increasing number of correct recognitions over trials.

Achievement motivation scale

This scale purports to measure the feeling of competence and worth, tendency to achieve success, and sense of striving for superior performance in school and other phases of life. It also measures perseverance, risk-taking ability, task-orienting approach, and belief in hard work. This scale (11, 14) consists of 16 yes-or-no items with a high degree of test-retest reliability (0.79) and internal consistency (0.81). It is suitable for assessing motivation to achieve only for those children who are going to school and can read and understand the items.

Statistics

The effects of iodine deficiency, age, and practice trials and their interaction were ascertained by 2 (iodine deficiency) × 2 (age) × 10 (trials) trend analysis of variance with repeated
measures. The data for pictorial learning were analyzed similarly with five levels of trial variable. The data for achievement motivation were analyzed by 2 (iodine deficiency) x 2 (age) analysis of variance.

RESULTS

Maze learning

SID children committed significantly more errors in maze learning than did their MID counterparts \( (F_{[1,196]} = 170.36, P < 0.01) \). The initial performance of the older group was better than that of the younger group \( (F_{[1,196]} = 200.15, P < 0.01) \), but the rate of reduction in errors was significantly greater in the younger children \( (F_{[9,1764]} = 88.81, P < 0.01) \) (Figure 1).

SID children took significantly more time to learn the maze than did the MID children \( (F_{[1,196]} = 64.61, P < 0.01) \). Here also, older children took less time to learn \( (F_{[1,196]} = 310.83, P < 0.01) \), but the rate of improvement in the speed of learning was greater in younger children \( (F_{[9,1764]} = 65.45, P < 0.01) \) (Figure 2).

Verbal learning

The effect of iodine deficiency on verbal learning by the free-recall method was not significant. Free recall, being a less demanding task, did not discriminate between SID and MID children of any age. The results of serial learning again showed that SID children are slower learners \( (F_{[1,196]} = 64.45, P < 0.01) \). The older children performed better initially \( (F_{[1,196]} = 32.32, P < 0.01) \) but the rate of improvement in learning over trials was significantly better in the younger children \( (F_{[9,1764]} = 54.31, P < 0.01) \) (Figure 3).

Pictorial learning

The results showed that the MID group performed better at pictorial learning than the SID children \( (F_{[1,196]} = 173.04, P < 0.01) \). Although the older children performed better on the first trial of learning \( (F_{[1,196]} = 54.73, P < 0.01) \), the rate of improvement in correct recognition of pictures was better in younger children \( (F_{[4,784]} = 11.29, P < 0.01) \) (Figure 4).

Achievement motivation

The analysis of variance revealed significant main effects of iodine deficiency \( (F_{[1,196]} = 12.56, P < 0.01) \) and age \( (F_{[1,196]} = 9.76, P < 0.01) \) on motivation to achieve. The iodine deficiency x age interaction effect was also significant \( (F_{[1,196]} = 27.64, P < 0.01) \). Results indicate that MID children, particularly older ones, were significantly more motivated to achieve than were SID children (Figure 5).

Correlations between test scores and severity of iodine deficiency

In maze learning, a decline in error and time scores indicates progress in learning. Significant negative correlations of urinary iodine excretion with errors \( (r = -0.58) \) and time \( (r = -0.40) \) were observed. Thyroxine also showed a significant negative correlation with errors \( (r = -0.53) \) and time \( (r = -0.32) \). TSH showed a significant positive correlation with errors \( (r = 0.18) \) and time \( (r = 0.38) \). The negative correlation of these indexes with urinary iodine excretion and thyroxine and their positive correlation with TSH indicate a significantly poorer rate of learning in the SID group.

A significant positive correlation for urinary iodine excretion was observed with pictorial learning \( (r = 0.25) \) and achievement motivation \( (r = 0.39) \). Correlation of urinary iodine excretion and verbal learning was not significant. A significant positive correlation was observed between thyroxine and motivation to achieve \( (r = 0.39) \). Correlation of thyroxine concentration with verbal and pictorial learning was not found to be significant. Although TSH showed a significant negative correlation with verbal learning \( (r = -0.17) \) it did not show a correlation with pictorial learning.
MOTIVATION AND LEARNING IN IODINE-DEFICIENT CHILDREN

FIGURE 4. Mean pictorial learning scores of severely iodine-deficient (SID) and mildly iodine-deficient (MID) subjects in five trials averaged over age and in different age groups. The pooled SEM lies between 4.7% and 7.3%. SID (----), MID (--), younger group (■), older group (x).

DISCUSSION

Our results indicate that SID children are slower learners than MID children. This was true for all learning tasks administered except verbal learning by free recall. This method, which is cognitively less demanding than the other learning tests, proved to be a poor discriminator. Another important finding was that the rate of improvement in performance by practice was significantly greater in MID than in SID children. We also found an age-dependent retarding effect of iodine deficiency on learning ability. Within the SID group, younger children learned the tasks that involved only cognitive functions faster, despite the fact that older children had an advantage in the initial stage. Learning involves formation of new stimulus-response associations. These associations (engrams) are generally formed in the CNS and specifically in the cerebral cortex. Whatever the location and nature (structural or functional) of engrams, the improvement in performance of any task due to practice depends on the formation and consolidation of engrams. It seems that iodine deficiency leads to significant retardation of the formation and consolidation of these engrams.

The inferior performance of SID subjects may not be due entirely to neurologic impairment; it may also be an outcome of the paucity of psychologic stimulation in endemic areas, which is necessary for normal psychologic development (13, 14). Prolonged deprivation of stimuli has been found to affect the motivation to achieve of socioeconomically backward communities (9, 12). The results of this study have shown for the first time that SID children are poorly motivated to achieve. It appears that besides retarding neurologic development in the fetal stage, iodine deficiency also gives rise to a significant scarcity in the psychologic stimulation essential for normal cognitive development. In iodine-deficient villages, psychologic stimulation is further weakened by the fact that the social groups surrounding these children are dull, apathetic, and unmotivated. As a consequence, iodine-deficient children do not find a congenial sociopsychologic environment for learning new skills and various cognitive abilities (14). Note that one type of learning facilitates another type of learning, and so on sequentially. When the combination of the above-mentioned factors retards cognitive development in the initial stages of life of a child, the basic potential in later stages may not improve even if opportunities for learning are available. Motivation to achieve is an acquired motivation that involves performance in the context of standards of excellence and is a desire to have the performance stand well on evaluation against such standards (15). All psychologic motives, including motivation to achieve, are learned (16). Psychogenic motivation such as motivation to achieve is an acquired behavioral manifestation that satisfies one’s need for excellence, social power, feeling of competence, and reduction of anxiety. These motives are not innate like physiologic drives, although the possibility of the contribution of some important innate determinants of such behavior cannot be ruled out.

Note that because the choice of the study subjects required formal educational experience, including the ability to read and write, the study was biased toward higher-functioning children. This bias in fact tends to work against the likelihood of finding learning disabilities and further strengthens the argument that iodine deficiency leads to a general learning disability and supports the thesis that consequences of iodine deficiency are not all or none in character. Iodine deficiency seems to lead to a range of deficits and developmental disadvantages of whole communities residing in iodine-deficient endemic areas. It is possible to reverse this process with proper iodine supplementation and thus improve the psychomotor and cognitive performance of the whole population (17).

The fact that children in iodine-deficient areas are poorly motivated to achieve, a hitherto unknown aspect of the serious consequences of the iodine-deficiency disorders, deserves special attention and adds a further sense of urgency to the programs for their eradication. The significant correlation of biochemical measures of iodine nutrition such as urinary iodine excretion and thyroxine concentrations, with test scores for various indexes of learning and motivation to achieve, suggest that poor iodine nutrition results in increased proneness to errors, and slow mental processes and responses. For learning tasks, a decline in the error rate and time taken to perform the task indicates progress in learning. The negative correlations of errors and time taken in maze learning with urinary iodine excretion and thyroxine concentrations, and their positive correlation with TSH indicate a significantly poor rate of learning in the SID group. This effect seems to be a selective one and the test functions that the child performs more frequently in his day-to-day life, such as verbal learning, are not affected by iodine nutritional status. Whether this effect is due to iodine deficiency alone or to iodine deficiency–induced hypothyroidism and whether the effect is due to thyroid deficiency during juvenile or adult stages or is a residual effect of a hypothyroid state in utero still remains unanswered. To answer some of these questions, evaluation of cognitive functions with more

FIGURE 5. Mean achievement motivation scores of severely iodine-deficient (SID, ----) and mildly iodine-deficient (MID, ---) subjects of different age groups. The pooled SEM lies between 3.7% and 8.4%.
sensitive neuropsychologic instruments after iodine supple-
mentation of iodine-deficient children is required.

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