

Neurological complications of prolonged hunger strike

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We investigated neurological findings in 41 prisoners (mean age: 28.6) who participated in a hunger strike between 2000 and 2002. All cases were evaluated using neuropsychological, neuroradiological, and electrophysiological methods. The total duration of fasting ranged from 130 to 324 days (mean 199 days). All cases had 200–600 mg/day thiamine orally for 60–294 days (mean 156) during the hunger strike, and had neurological findings consistent with Wernicke–Korsakoff syndrome. All 41 patients exhibited altered consciousness which lasted from 3 to 31 days. All patients also presented gaze-evoked horizontal nystagmus and truncal ataxia. Paralysis of lateral rectus muscles was found in 14. Amnesia was apparent in all cases. Abnormal nerve conduction study parameters were not found in the patient group, but the amplitude of compound muscle action potential of the median and fibular nerves and sensory nerve action potential amplitude of the sural nerve were lower than the control group, and distal motor latency of the posterior tibial nerve was significantly prolonged as compared with the control group. The latency of visual evoked potential was prolonged in 22 cases. Somatosensory evoked potential (P37) was prolonged but not statistically significant. Our most significant finding was that the effect of hunger was more prominent on the central nervous system than on the neuromuscular system, despite the fact that all patients were taking thiamine. In our opinion, partial recovery of neurological, and neurocognitive signs in prolonged hunger could be a result of permanent neurological injury.

Introduction

Nutritional disorders of the nervous system, although changing to some extent in character and distribution over the years, remain remarkably common. Although the most common neurological complications of nutritional deficiency occur in chronic alcoholism, a large number of cases are seen in other conditions such as prolonged fasting [1]. However, results of nutritional disorders on the nervous system because of prolonged hunger strike have not so far been investigated in detail in the literature in a large number of groups or over long time periods. There have been several studies of fasting for a few days, but in the past 15 years only three studies have described voluntary total fasting for prolonged periods [2]. The first was of a monk who tried to fast for 40 days for religious reasons but was forced to stop on day 36 because of unacceptable symptoms [3]. The second was of four adults who were planning to fast indefinitely. One became very unwell on day 38, and the others ceased fasting on day 40 [4]. The third was a retrospective study of 33 South African

political prisoners on hunger strike for up to 28 days [5]. Several recent articles have addressed the ethics of treating hunger strikers [6–8] but there is less information available on the physiological issues [9–11]. This country experienced a prolonged hunger strike between October 2000 and February 2002, which was performed by political prisoners. Forty-one of the prisoners on hunger strike were admitted to our neurology department and were followed up for 2 years. We had the opportunity to observe and examine the participants as far as they allowed us according to the Declaration of Malta [12]. The purpose of this study was to determine the neurological, neurophysiological and neurocognitive consequences in a group of patients who presented with the neurological complications of prolonged hunger strike. We had no chance to compare our results with previous studies because the neurological manifestations of prolonged hunger strike have been very rarely reported and therefore minimal data was available regarding the pathophysiological mechanism of total fasting.

Materials and methods

Twenty-two male and 19 female prisoners aged between 22 and 43 years (mean 28.6) were admitted to our

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hospital. Medical histories included four cases of peptic ulceration, six of migraine and two of hypertension. History of regular alcohol consumption or alcohol abuse was not obtained in any of the cases. However, as the prisoners were in jail when they started to fast, alcohol would have been unavailable to them for several months. The total duration of fasting ranged from 130 to 324 days (mean 199). All cases had a daily oral intake during fasting of 200–600 mg thiamine for 60–294 days (mean 156) in addition to a jug of tap water with a teaspoon of sucrose and a teaspoon of table salt dissolved in it. They started taking thiamine tablets between 9th and 20th day of fasting (mean 10) (Table 1). Thiamine tablets were administered to cases by nursing staff, who kept a record of their ingestion.

All cases were bedridden during the hunger strike because of weakness and unsteadiness. A team of physicians from our hospital including neurologists, psychiatrists, and internists examined the cases in routine visits twice a day. Immediately after the termination of the hunger strike, all patients were referred to our intensive care unit, mostly because of life-threatening medical conditions. As the patients did not allow it earlier, treatment could only be started when the patients were confused. Nutritional rehabilitation started with intravenous (iv) fluids and electrolytes for approximately 48 h. Treatment involved the parenteral administration of 100 mg of thiamine per day for at least 5 days. This regimen was followed by standard peripheral parenteral nutrition (10% or 20% glucose

Case	Age	BMI beginning	BMI end	Duration of hunger	Thiamine dosage/day (mg)	Thiamine duration (days)	Days of thiamine starting
1	28	19.46	11.38	160	600	153	11
2	30	28.70	12.37	324	600	294	11
3	30	16.91	10.85	172	600	153	11
4	30	21.09	10.95	244	600	174	9
5	26	18.61	9.52	177	400	135	10
6	26	25.35	13.58	171	600	128	9
7	25	21.71	13.69	176	400	147	10
8	22	24.54	15.19	130	200	98	20
9	28	22.13	14.87	180	600	137	11
10	29	21.70	11.20	171	600	102	11
11	32	23.63	13.25	190	600	147	10
12	29	20.42	15.02	224	600	184	10
13	21	22.03	15.05	135	600	60	9
14	24	20.33	13.55	176	600	146	9
15	28	23.30	14.34	206	600	193	9
16	26	18.14	10.88	160	600	80	9
17	22	22.38	13.69	290	600	273	9
18	28	20.82	10.78	220	600	160	9
19	26	21.87	11.75	260	600	243	9
20	28	23.88	12.59	253	600	211	9
21	27	21.73	14.59	172	600	157	10
22	27	21.88	12.65	135	600	93	10
23	29	24.56	14.53	148	600	135	11
24	34	23.40	13.73	208	600	165	11
25	30	21.35	14.09	213	600	213	10
26	29	19.38	11.96	240	600	195	16
27	27	19.94	10.16	210	600	150	12
28	29	21.64	11.65	220	600	160	11
29	27	21.63	13.21	200	600	200	9
30	27	23.71	12.42	220	400	160	14
31	26	20.70	12.79	217	600	120	16
32	26	22.70	13.01	220	600	148	9
33	28	23.18	13.04	260	600	220	10
34	28	20.04	12.33	214	600	120	12
35	28	19.46	11.38	160	600	153	10
36	27	18.17	10.02	175	600	152	10
37	24	19.61	10.50	179	600	112	10
38	25	18.19	9.02	152	600	143	9
39	27	21.72	13.59	197	600	145	9
40	27	19.46	11.38	167	600	118	9
41	26	21.02	11.19	220	600	124	11

Table 1 Body mass index (BMI) and thiamine usage during hunger strike

and aminoacids) in combination with modest amounts of a semi-elemental oral diet enriched with glutamine. Three days later 100 % of the planned prescription was well tolerated by mouth in the form of a polymeric diet restricted in fiber and lipids but supplemented with substantial amounts of glutamine. Between the 5th and 9th day after the start of feeding, all patients tolerated an unrestricted general diet. After the acute episode, all patients received a daily oral thiamine dose (100 mg) in conjunction with other B vitamins, including riboflavin, niacin, pyridoxine, and vitamin B12, for 3 months. None of the cases died.

In the 2 weeks after the confusional status disappeared, all cases were assessed by neuropsychological tests like Weschler Memory Scale, verbal memory process test, verbal fluency, alternating verbal category, Stroop neuropsychological screening test, Wisconsin card sorting test, visuospatial tests, Benton facial recognition test, Benton judgment of line orientation test and Weschler Adult Intelligence Scale-Revised.

As nine of 41 cases refused the electrophysiological studies, 32 patients (17 female, 15 male, mean age 28) and 26 healthy controls (16 female and 10 male, mean age 27) were included in the electrophysiological investigations. Nerve conduction study, needle electromyography (EMG), somatosensory evoked potentials (SEP) and visual evoked potentials (VEP) were recorded using a four-channel portable device (Medelec Sapphire 4ME, Surrey, UK) between the 7th and 20th day after the start of the treatment. Motor and sensory studies were performed bilaterally according to the most commonly referenced techniques for the following nerves: median, ulnar, fibular, and tibial motor nerves; and median, ulnar, and sural sensory nerves [13]. The sensory nerve conduction studies were all performed antidromically and the onset of the electrical response as well as the amplitude from the baseline to the negative peak were recorded. In motor conduction studies, velocity, latency to the first negative deflection and peak-to-peak amplitude of the compound muscle action potentials (CMAP) were measured. The needle EMG studies included the biceps, abductor pollicis brevis, tibialis anterior and quadriceps femoris muscles in 32 cases [13]. Median and tibial SEPs were performed with electrical stimulation at wrist and ankle, which was adjusted to produce a minimal twitch of the hand and foot muscles. The locations of scalp electrodes were specified using the international 10–20 system. The latencies of the N20 and P37 potentials were measured [14]. For VEP recordings, the recording electrode was placed at the Oz position of the 10–20 international system and the reference electrode in the Fz point. The latency and peak-to-peak amplitude of the P 100

potential was measured [14]. Electroencephalography (EEG) was performed in the second week, after all of the patients had fully recovered from their confusional state. Scalp EEG recordings were obtained according to the international 10–20 system with a Nihon Kohden (Tokyo, Japan) digital EEG device. Cranial magnetic resonance imaging (MRI) investigation was also performed using a 0.5T scanner 2 weeks after the recovery of consciousness. T1 and T2 weighted images were obtained. The time of all investigations are displayed in Table 4.

Student's *t*-test and Spearman correlation test were used for all statistical analyses (CI % 95, $P < 0.05$).

The study was approved by the ethics committee of our hospital and within 2 weeks after the confusional status disappeared informed written consent was obtained from all subjects for the performance of examinations and investigations.

Results

Physical signs

On admission to our intensive care unit nearly all subjects were found to be lean and all were considered to be mildly or moderately dehydrated. Their average oral temperature was 36.3°C, and ranged from 35 to 37°C. Heart rate was slow in 27 patients, ranging from 49 to 70 beats/min (mean 56.8/min). The mean admission supine blood pressure was $95.3 \pm 12.1/56.4 \pm 14.5$ mmHg and rose significantly after feeding, to $112 \pm 10.8/74 \pm 6.8$ mmHg in all cases. Body weights before and after the hunger strike were 43–93 kg (mean 63.2 kg) and 22–52 kg (mean 36.9 kg), respectively. Mean weight loss was 40.3 kg. In the initial evaluation, the mean body mass index (BMI) of our cases was 21 ± 173 kg/m² (mean 21.98 kg/m²) and heights were between 152 and 187 cm (mean 173 cm) (Table 1).

Neurological and neuropsychological signs

The initial neurological examination of the 41 patients revealed altered consciousness (mild confusion to stupor). The total duration of the confusional state ranged from 3 to 31 days. All patients presented gaze-evoked horizontal nystagmus (vertical nystagmus in nine). Limb ataxia was found in three, whereas truncal ataxia existed in all 41 patients. Nystagmus, ataxia and paralysis of lateral rectus muscles were found in 14. There was manifest muscle atrophy and reduced subcutaneous fat in all patients, and in 11 a generalized muscle weakness was recorded without any considerable difference between the proximal and distal muscles. In 11 patients tendon reflexes were decreased in the lower and

upper extremities. Abnormalities in sensation to touch or pinprick were observed in 17 patients, whilst 15 complained of paresthesia in the legs (Table 2). Loss of vibration and joint position sensations in the distal regions of the extremities with a readily observable Romberg's sign was noted in 10 cases. The findings of motor strength and sensory examinations were considered to be somewhat unreliable in confused patients. Temporal pallor of the optic discs and sensory-neural hearing loss were evident in three cases. All patients had symptoms and signs compatible with the diagnosis of Wernicke's encephalopathy [1,15]. Following treatment with iv high-dose thiamine and then oral thiamine, all

cases recovered from confusion in between 3 and 31 days. An assessment 1 year later showed that nystagmus and ataxia had disappeared in 22 patients. The remaining 19 patients showed no improvement in these symptoms. Paralysis of lateral rectus muscles showed no improvement in 11 patients. Loss of tendon reflexes were permanent in two patients whilst in nine patients they had returned to normal. Examination showed sensory functions to be normal in all patients. Anterograde amnesia and retrograde memory loss in relation to the preceding several years were apparent in all cases (Table 3). Thirty patients' verbal responses included many confabulations.

Case	*Blood pressure	Heart rate/minute	Altered consciousness	Nystagmus	Ataxia	Paralysis of lateral rectus muscles	Decreased tendon reflexes	Abnormalities in sensation
1	100/60	52	+	+	+	+	-	+
2	105/60	52	+	+	+	-	-	-
3	100/55	62	+	+	+	-	-	+
4	95/45	54	+	+	+	-	-	-
5	100/55	70	+	+	+	+	+	+
6	60/40	62	+	+	+	-	+	+
7	90/40	52	+	+	+	+	-	-
8	80/30	57	+	+	+	+	-	-
9	90/30	58	+	+	+	+	-	-
10	105/65	62	+	+	+	-	+	+
11	85/30	52	+	+	+	+	+	+
12	110/60	58	+	+	+	-	-	-
13	100/55	60	+	+	+	-	+	-
14	100/85	62	+	+	+	-	-	+
15	100/70	62	+	+	+	+	-	-
16	85/50	52	+	+	+	+	-	+
17	65/35	57	+	+	+	-	-	-
18	110/75	54	+	+	+	+	+	+
19	100/55	62	+	+	+	-	-	-
20	65/30	56	+	+	+	-	-	-
21	110/65	52	+	+	+	-	-	-
22	100/70	57	+	+	+	+	-	-
23	100/55	61	+	+	+	-	+	+
24	100/65	52	+	+	+	+	-	+
25	115/75	53	+	+	+	-	+	+
26	95/55	50	+	+	+	-	+	+
27	90/60	52	+	+	+	-	-	+
28	80/40	62	+	+	+	+	-	-
29	100/75	55	+	+	+	-	-	-
30	100/70	58	+	+	+	-	-	+
31	95/50	49	+	+	+	-	-	-
32	105/75	62	+	+	+	-	-	-
33	100/70	62	+	+	+	-	-	-
34	90/65	52	+	+	+	+	+	+
35	85/40	59	+	+	+	-	-	-
36	95/55	62	+	+	+	-	-	-
37	100/65	54	+	+	+	-	-	-
38	95/50	61	+	+	+	-	-	-
39	110/75	59	+	+	+	-	-	-
40	100/65	52	+	+	+	-	-	-
41	100/50	52	+	+	+	+	+	+

Table 2 Clinical neurological findings on admission

*Blood pressure: systolic/diastolic (mmHg).

Table 3 Outcome data after 1 year

Case	Amnesia	Nystagmus	Ataxia	Paralysis of lateral rectus muscles	Decreased tendon reflexes	Abnormalities in sensation
1	+	+	+	+	-	-
2	+	+	+	-	-	-
3	+	-	-	-	-	-
4	+	+	+	-	-	-
5	+	-	-	-	-	-
6	+	-	-	-	-	-
7	+	+	+	+	-	-
8	+	+	+	+	-	-
9	+	+	+	+	-	-
10	+	-	-	-	-	-
11	+	-	-	-	-	-
12	+	-	-	-	-	-
13	+	+	+	-	-	-
14	+	+	+	-	-	-
15	+	+	+	+	-	-
16	+	-	-	-	-	-
17	+	+	+	-	-	-
18	+	-	-	-	-	-
19	+	-	-	-	-	-
20	+	+	+	-	-	-
21	+	-	-	-	-	-
22	+	+	+	+	-	-
23	+	+	+	-	-	-
24	+	-	-	-	-	-
25	+	+	+	+	+	-
26	+	+	+	+	-	-
27	+	-	-	-	-	-
28	+	+	+	+	-	-
29	+	-	-	-	-	-
30	+	-	-	-	-	-
31	+	+	+	-	-	-
32	+	-	-	-	-	-
33	+	-	-	-	-	-
34	+	+	+	+	-	-
35	+	-	-	-	-	-
36	+	-	-	-	-	-
37	+	-	-	-	-	-
38	+	-	-	-	-	-
39	+	-	-	-	-	-
40	+	-	-	-	-	-
41	+	+	+	+	+	-

The intellectual functions of all patients were normal (mean verbal IQ of 97 and performance of 108).

There were negative correlations between the duration of prolonged hunger and working memory ($P = 0.03$, $r = -0.3$), long-term memory ($P = 0.03$, $r = -0.3$), and orientation of person ($P = 0.02$, $r = -0.3$). Negative correlations were found between the duration of taking vitamin B1 and working memory ($P = 0.009$, $r = -0.4$), long-term memory ($P = 0.004$, $r = -0.4$), sentence recall ($P = 0.002$, $r = -0.4$), story recall ($P = 0.001$, $r = -0.5$), orientation of person ($P = 0.004$, $r = -0.4$), orientation in time ($P = 0.01$, $r = -0.4$), verbal fluency ($P = 0.002$, $r = -0.4$), categorization ($P = 0.002$, $r = -0.4$), recognition ($P = 0.04$, $r = -0.3$), and visual memory ($P = 0.01$, $r = -0.4$).

There was no correlation between percentage of loss of BMI and neuropsychological tests.

Laboratory findings

On admission to the intensive care unit all patients had ketonuria, which persisted until refeeding started. Urine was microscopically normal and cultures were sterile in the eight patients with dysuria. Thirty-one patients had electrolyte imbalance. Serum urea concentrations were normal (7–25 mg/dl) in all but six subjects; however, serum creatinine levels were raised (1.3 mg/dl) in 12. A mild reduction in total erythrocyte count and leukocytosis were recorded in 12 and three patients, respectively. Blood glucose levels were normal or at the

Table 4 Time of all investigations

	Time of investigation
Neuropsychological tests	in 2 weeks
MRI	in 2 weeks
EEG	in 2 weeks
NCS and EMG	7th–20th day
SEP	7th–20th day
VEP	7th–20th day

MRI, magnetic resonance imaging; EEG, electroencephalography; NCS, nerve conduction study; EMG, electromyography; SEP, sensory evoked potential; VEP, visual evoked potential.

lower end of the normal range in all patients (70–109 mg/dl). Other abnormal findings in serum chemistry were as follows: hypoproteinemia in 14 patients (4.2–5.8 g/dl), increased creatine kinase in six (696–872 U/l), Fe deficiency anemia in 17, increased liver transaminase in 10 (serum glutamic oxaloacetic transaminase (AST/SGOT): 64–593, serum glutamic pyruvic transaminase (ALT/SGPT): 44–884), hypercholesterolemia in six (198–220 mg/dl), and hypocholesterolemia in nine (100–140 mg/dl). Two weeks after completion of the hunger strike, cranial MRI investigations were normal in 32 cases. Cortical atrophy was seen in the form of enlarged lateral ventricles and widening of the interhemispheric fissures, Sylvian fissures and frontal sulci in nine patients.

Electrophysiological tests

Electroencephalography was found to be normal in 35 of 41 cases. Diffuse theta activities were seen in three patients. Three other patients had non-specific focal or generalized paroxysmal sharp-wave discharges. The most frequent abnormalities were low amplitude CMAPs elicited with stimulation at wrists or ankles in motor nerve conduction velocity (NCV) studies. Although the amplitude of CMAPs and NCVs of the median motor nerve of the patients group was significantly lower than the values of the control group ($P < 0.05$), pathological results were observed only in two patients. The amplitude of the fibular nerve CMAP was significantly lower than that of the control group, and distal motor latency of the posterior tibial nerve was significantly prolonged as compared with the control group ($P < 0.05$), although a pathological result was not observed. The sensory nerve action potential amplitude of the sural nerve was significantly lower in patients compared with controls ($P < 0.05$) but no abnormal values were obtained in any case. Electrophysiological results are presented in Table 5. In all patients, needle EMG findings were found to be normal except in one patient, who showed mild denervation potentials and some neurogenic changes in

motor unit action potentials in proximal and distal muscles of the upper and lower extremities. The latency of P100 wave of pattern reversal VEP was found to be prolonged in 22 cases ($P = 0.000$), whilst the peak-to-peak amplitudes were in the normal range in both groups. The latency of the cortical P37 potential was the commonest abnormal finding in the SEP studies but did not present a statistically significant difference as compared with the control group (Table 6).

Discussion

Nutritional deficiencies can damage both the central and peripheral nervous systems [1,16,17]. Chronic hunger is a fact of life in overpopulated, agriculturally challenged, and poor countries and can degenerate to true famine as a result of droughts, floods, and military conflicts [17]. The most devastating and widespread occurrence of food deprivation in modern times was precipitated by World War II, which affected millions of people in industrialized and developing countries alike. Hunger strike is a popular means of protest amongst prisoners all around the world. The natural result of prolonged hunger is Wernicke's encephalopathy and Wernicke–Korsakoff syndrome [1,15,16,18,19]. Although the strikers were informed about the consequences of prolonged hunger, they chose to continue their action. They signed a declaration refusing medical intervention as long as they were conscious. In accordance with the guidelines of the Declaration of Malta [12], we started treatment immediately patients lost consciousness. Wernicke's encephalopathy is a medical emergency and requires the immediate administration of thiamine in a dose of 50–100 mg, either intravenously or intramuscularly. Doses should be given daily, to build up the body's reserves until the patient is able to resume a normal diet. Thiamine has been established as the treatment of choice for over 50 years, but there is uncertainty about appropriate dosage, route and duration [20,21]. Thiamine is the only treatment known to alter the outcome of this disorder. If left untreated, Wernicke's encephalopathy is progressive; the mortality, even with thiamine treatment, is 10–20% [15]. In our study we did not have any chance to assess serum thiamine levels. Signs of Wernicke encephalopathy were observed in all our cases during fasting and in the early period of refeeding treatment. According to the correlation test results, the longer the duration of hunger the worse were the memory functions. However, memory functions did not improve in line with the duration of thiamine intake. Within a few months of treatment with a daily oral dose of thiamine 100 mg supplemented by multivitamins, the patients showed subjective evidence of improvement in

Table 5 Results of electroneurography of patient group and control group

	Group		<i>P</i> (independent samples <i>t</i> -test)
	Patients <i>n</i> = 32 (mean ± SD)	Controls <i>n</i> = 26 (mean ± SD)	
Median sensory velocity	51.75 ± 4.91	52.17 ± 6.22	0.780
Median sensory amplitude	30.72 ± 14.11	31.50 ± 10.49	0.821
Ulnar sensory velocity	49.56 ± 4.89	52.13 ± 4.88	0.057
Ulnar sensory amplitude	29.84 ± 12.65	30.88 ± 11.59	0.756
Median motor latency	2.99 ± 0.39	3.19 ± 0.39	0.068
Median motor velocity	56.09 ± 4.24	58.96 ± 4.19	0.015*
Median motor amplitude	9.75 ± 3.32	12.13 ± 2.86	0.007*
Ulnar motor latency	2.48 ± 0.31	2.65 ± 0.24	0.147
Ulnar motor velocity	56.81 ± 5.37	59.75 ± 5.75	0.056
Ulnar motor amplitude	9.06 ± 3.04	10.08 ± 3.45	0.251
Fibular motor latency	4.15 ± 0.88	4.18 ± 0.88	0.899
Fibular motor velocity	47.13 ± 5.65	48.79 ± 3.82	0.218
Fibular motor amplitude	4.06 ± 1.93	5.38 ± 2.22	0.022*
Tibial motor latency	4.93 ± 0.92	4.32 ± 0.93	0.019*
Tibial motor velocity	47.45 ± 3.74	46.00 ± 3.38	0.142
Tibial motor amplitude	9.77 ± 3.49	9.67 ± 4.10	0.917
Sural sensory velocity	41.88 ± 9.11	45.63 ± 3.55	0.062
Sural sensory amplitude	11.76 ± 5.76	16.63 ± 10.17	0.043*

* = *P* < 0.05 statistically significant.

Table 6 Sensory evoked potential (SEP) and visual evoked potential (VEP) values in patient group and control group

	Group		<i>P</i> (independent samples <i>t</i> -test)
	Patients <i>n</i> = 32 (Mean ± SD)	Controls <i>n</i> = 26 (Mean ± SD)	
Median SEP N20 latency	19.06 ± 1.22	18.74 ± 1.02	0.151
Tibial SEP P 37 latency	39.69 ± 3.69	38.96 ± 1.95	0.199
VEP P100 latency	107.48 ± 6.92	101.99 ± 4.94	0.000*
VEP Amplitude	6.38 ± 3.01	5.93 ± 2.31	0.384

* = *P* < 0.05 statistically significant.

confabulation and anterograde amnesia, although objective tests showed residual deficits in many areas of cognitive and executive functioning, including immediate and delayed recall of verbal and non-verbal materials, visuo-spatial processing, planning, and switching of attention. Frontal lobe functions such as planning, abstract thinking, and verbal fluency were affected as well. The marked disparity between the memory quotients and general IQs of our patients also indicated the Korsakoff amnesic disorder. In the study by Victor *et al.*, complete recovery was noted in patients with sixth nerve palsy, vertical and horizontal gaze palsy, and vertical nystagmus. Ataxia was observed to resolve completely in response to therapy in one-third of patients and to improve to some degree in another third. No response was noted in the remainder despite thiamine supplementation of several months' duration. Only 21% had complete resolution of their neurocognitive deficits. In our opinion, partial recovery of neurological and neurocognitive signs in prolonged hunger could be a result of permanent neurological injury. The relatively short duration of thiamine ingestion com-

pared with the longer duration of hunger could be the reason for permanent injury in our patients.

The acute lesions of Wernicke–Korsakoff syndrome, both the medial thalamic and periaqueductal ones, can be demonstrated by MRI [22]. Shrinkage of the mammillary bodies and additional volume decrease in the anterior diencephalon can be visible on MRI [22,23]. Diffusion-weighted imaging can show the symmetrical pathological thalamic and midbrain signal hyperintensities more distinctly than conventional T2-weighted or fluid-attenuated inversion recovery sequences in patients with Wernicke–Korsakoff syndrome [24]. Cranial MRI scans were normal in most of our cases; a few cases demonstrated mild brain atrophy, but there was no focal abnormality. The reason for the absence of the aforementioned lesions in our patients could be the conventional MRI technique used in our hospital.

Electroencephalography is not used routinely in the diagnosis of Wernicke–Korsakoff syndrome as it is normal in approximately half of cases. Only about half of patients with Wernicke–Korsakoff syndrome show

EEG abnormalities, consisting of diffuse mild to moderate slow activity [1]. EEG findings of our cases gave no results other than those compatible with Wernicke–Korsakoff syndrome.

Signs of peripheral neuropathy, usually mild in degree, are known to be found in the majority of patients with Wernicke–Korsakoff syndrome [9]. However, the neuromuscular effects of a long-lasting and intense lack of nutrition have been reported very rarely. [9,11,18,19]. The muscle atrophy, weakness, and sensory abnormalities which we observed in a great part of the patients were suggestive of neuromuscular system damage. In an earlier study, Öge *et al.* reported the electrophysiological consequences of neuromuscular and central nervous system involvement in a group of patients presenting with the neurological complications of a long-term hunger strike [11]. In their cases neuromuscular signs were mild, as we observed in our patients. It is known that nerve conduction study results vary both with intrinsic factors such as age, height, and sex, as well as with extrinsic factors such as body temperature and study technique. One potential factor that has not been studied adequately to date is weight. As the adipose tissue in the epineurium may be related to some extent to the amount of body fat, it is conceivable that the amount of such fat may affect the conduction of the nerves [25]. Because of the obvious vulnerability of this very special group of patients, more invasive techniques such as muscle and nerve biopsies were avoided although they are highly diagnostic methods. In these patients visual pathways were found to be impaired significantly as were neurocognitive functions. The most prominent findings in most of our patients were the persistence of ataxia, weakness of lateral rectus muscles and nystagmus, whilst an impairment in memory was observed in all cases. Like other studies, we observed that the effect of vitamin B1 is prominent in neurological findings during prolonged hunger [26–29].

In conclusion, we found that the effects of hunger on the neuromuscular system were mild, but involvement of the central nervous system was evident. All previously published studies on the effects of prolonged hunger are limited, with short duration of starvation or with small numbers of cases. In this study we had the exceptional opportunity of observing hunger using clinical, neuropsychological, neuroradiological, and neurophysiological methods during and after a prolonged period of starvation in a relatively large group. In this large group of patients we concluded that the administration of thiamine and other vital approaches were important, and essential to prevent the devastating consequences of prolonged hunger. The essential duty of doctors who are to deal with hunger strikers is not to feed them against their will, but to enlighten them about

its probable consequences and try to persuade them to use vitamins.

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