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Prevalence of Iron Deficiency in the General Population in Taiwan

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Abstract

Assessment of iron status was carried out on a nationally representative sample collected in the first year of "The Nutrition and Health Survey in Taiwan (NAHSIT) 1993-1996", which used a multi-staged, stratified, clustered design. A total of 935 males and 1,042 non-pregnant females aged 4 year and older were included, for whom indicators of iron status (hemoglobin, transferrin saturation, and serum ferritin) were measured. Iron deficiency was defined as having an abnormal value for any 2 out of 3 laboratory tests, and iron deficiency anemia was defined as having 3 abnormal values. Iron deficiency rate was 2.1% in males and 10.7% in females, and rate of iron deficiency anemia was 0.2% in males and 2.1% in females. Several groups in the population exhibited relatively high prevalence of impaired iron status: males older than 65 year (13%) and aged 13-18 year (5.7%), and females aged 4 year and older (5.7%-14.2%). In conclusion, iron deficiency is relatively common in females and should be considered an important issue in women's health.

Key words: iron status, iron deficiency, iron deficiency anemia, ferritin, transferrin saturation, Taiwan, Chinese

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Introduction

Assessment of iron status in a population can be approached by dietary survey as well as laboratory tests. Previous dietary surveys in Taiwan indicate that iron intake has increased over the past 20 years. The daily intake per capita increased from 12 mg in 1973 and 1976 to 13.9 mg in 1980 (1-3), and increased further to 16.9 mg in 1985 (4). The intake reported in the most recent survey NAHSIT 1993-1996 was 15.6 mg (5). The prevalence of iron deficiency in the population was not estimated by sex or age classifications in the previous surveys because of limitation in methods. It is important to know whether dietary intake can be used to identify subjects with low iron status, since dietary iron intake seems to be an invalid measure of iron status (6).

There is convincing evidence that iron deficiency has many negative effects on health, including changes in immune function, cognitive development, temperature regulation, energy metabolism, and work performance (7). Although it was once thought that abnormalities occurred only with iron deficiency anemia and not with iron deficiency alone, some recent studies have suggested that iron deficiency alone can alter cognition in non-anemic children and adolescents (8, 9). Iron deficiency is known to be the most common nutritional disorder in the world (10), and the leading cause of anemia in Western societies (11, 12). Unfortunately, little information exists on the iron status of large representative samples of the population in Taiwan. In light of concerns for public health, it is necessary to assess the prevalence of iron deficiency in Taiwan.

Traditionally, iron deficiency is equated with anemia. However, because of a marked overlap for hemoglobin values between anemic and normal populations, the arbitrary definition of anemia based on hemoglobin levels results in a large number of false positive and false negative findings (13, 14). Serum ferritin and transferrin saturation are more sensitive and specific indicators, since concentration of serum ferritin is proportional to the body level of iron stores (15, 16), and the level of transferritin saturation provides information on the adequacy of the iron supply to the erythroid marrow (17). However, each indicator may be affected by the coexistence of confounding factors (17-19). It is generally agreed that the use of a combination of several iron indicators leads to improved accuracy in the detection of individuals with iron deficiency (19-22).

The present study was carried out to assess the iron status of a representative sample of the population in Taiwan, using laboratory measurements of multiple iron indicators including hemoglobin, total iron binding capacity, serum iron and serum ferritin.

Subjects and Methods

The "The Nutrition and Health Survey in Taiwan (NAHSIT) 1993-1996" was designed to supply health and nutritional information for the civilian non-institutionalized population aged 4 year and older in Taiwan. Details of the design, contents and operations are described in a separate paper in this issue (23). Briefly, NAHSIT 1993-1996 was carried out from July 1993 to June 1996. The survey adopted a multi-staged, stratified, clustered sampling scheme and seasonal effect was also considered. The analytical sample used in this study was limited to the 935 males and 1042 non-pregnant females aged 4 year and older from the first year of the survey (from July 1993 to June 1994), for whom there were data for the biochemical indicators of iron status. The age and sex distribution is listed in Table 1. The overall response rate was 91% for the subjects receiving health examination, but the age group 4-6 years showed the lowest response rate of 66-68% (Table 1).

Table 1 Response rates classified according to age and sex in the survey of iron status, NAHSIT

Age (yr)	Household interview (n)		Health examination (n)		Iron status investigated (n)		Response Rate[1] (%)	
	Male	Female	Male	Female	Male	Female	Male	Female
4-6	161	159	101	120	67	82	66	68
7-12	328	333	249	243	231	222	93	91
13-18	316	315	176	209	168	203	95	97
19-64	674	693	396	466	376	442	95	95
65+	172	171	103	110	93	93	90	85
Total	1651	1671	1025	1148	935	1042	91	91

[1] Percentage of participants in health examination in whom iron parameters were also collected.

Venous blood samples were collected into vacunm tubes (BECTON DICKSON) from fasting subjects. Heparinized whole blood was used for on-site measurement of hemoglobin and serum samples were frozen and shipped to the laboratory for biochemical assessments after the sample collection was completed. Indicators of iron status measured were hemoglobin, serum iron, transferrin, and serum ferritin. Total iron binding capacity (TIBC) and transferrin saturation were calculated.

Hemoglobin was measured colorimetrically using cyano-methemoglobin method (Merckotest, Merck) on a portable filter photometer (Flash) calibrated with hemoglobin cyanide standard solution (Merck). Serum ferritin was measured with a radioimmunoassay kit (Allegro Ferritin Kit, Nichols Institute, USA) and quantified with a gamma counter (Wallac 1282 Compugamma, LKB). Transferrin and serum iron were measured on an automated clinical analyzer (Hitachi 7450) using a turbidimetric immunoassay kit (Tina-quant Transferrin, Boehringer Mannheim) and a colorimetric kit (Iron without deproteinization, Boehringer Mannheim), respectively. TIBC was calculated by multiplying the concentration of transferrin by a factor of 1.27. Transferrin saturation was calculated by expressing the serum iron a per cent of the TIBC. Quality control serum were: Precinorm U and Precipath U (Boehringer Mannheim) for serum iron, Precinorm Protein and Precipath Protein (Boehringer Mannheim) for transferrin, and Lyphocheck Immunoassay Control Serum Levels 1, 2, 3 (BIO-RAD, CA) for serum ferritin.

Cutoff values for the indicators of iron status are: transferritin saturation $< 15\%$ and ferritin < 12 μg/L for all age-sex groups (19), and hemoglobin value < 11 g/dL for age < 7 yr, < 12 g/dL for age 7-14 yr, < 12 g/dL for female > 14 yr, and $<$ 13 g/dL for male > 14 yr (24). Iron deficiency was defined as having 2 or more abnormal values, and 3 abnormal values indicated iron deficiency anemia.

Statistical analysis was performed using SAS software (SAS Institute, Cary, NC). A weighing procedure based on selection probabilities, adjustments for nonresponse, and post-stratification adjustments was applied to each observation (23). In order to demonstrate the extent to which each laboratory value normally differs according to age and sex, normal values of hemoglobin, total iron binding capacity, transferrin saturation and serum ferritin were obtained after values from iron deficient subjects were excluded. Parameters other than serum ferritin are expressed as mean $\pm$ standard deviation. Difference between the two sex groups by age was tested using Student's t test. Both means and median values are listed for serum ferritin because of skewed distribution and difference between sex groups by age was tested using Student's t test after log transformation of the means. The significant level was set at $P < 0.05$.

Results

Age and sex related changes in biochemical indicators of iron status

Normal values of hemoglobin, total iron binding capacity, transferrin saturation and serum ferritin by age and sex are listed in Table 2. In addition, the effect of age on these parameters for each sex is shown in Figure 1. The mean values for hemoglobin were not different between sex for groups aged 4 to 12 yr. The ranges of individual differences, represented by standard deviation, were smaller in females than in males for all age groups. Difference according to sex became apparent in the second decade of life. Hemoglobin values were higher in males than in females and remain so with increasing age (Figure 1A). Differences in TIBC according to sex have no consistent trend. In each sex, values were highest in adolescents and young adults, and decline gradually with increasing age (Figure 1C). Transferrin saturation showed a substantial rise in young adult males, but changed relatively little in females. Beginning from age 13, values were significantly higher in males than in females and remained that way even in the elderly (Figure 1B). Median values for serum ferritin in children showed no difference by sex. For groups aged 13 yr and older, significantly lower values were found in females than in males. In male subjects, serum ferritin steadily increased before age 29. In contrast, serum ferritin values in females remained low until age 50, beyond which time a rapid increase was observed (Figure 1D).

Table 2 Normal values of hemoglobin, total iron binding capacity, transferrin saturation and serum ferritin by age and sex in the surveyed population from NAHSIT[1]

Sex and Age (yr)	n	Hemoglobin[2] (g/dL)	TIBC[2] (μg/dL)	Transferrin[2] Saturation (%)	Serum ferritin[3] (μg/L)	
Males					mean	median
4-6	65	12.6±0.9	386±35*	23±11	44	37
7-12	218	13.2±1.0	394±43	22±10	62	54
13-18	160	14.5±1.4*	390±40*	27±12*	107	72*
19-29	53	15.1±1.6*	370±47*	30±15*	188	174*
30-50	173	14.5±1.6*	380±42*	32±15*	227	173*
51-64	145	14.5±1.3*	358±45*	30±14*	236	165
65+	83	13.9±1.7*	346±45*	27±12*	249	241*
Females						
4-6	78	12.4±0.7	371±32	22±13	49	41
7-12	209	12.8±1.2	397±37	24±11	55	43
13-18	178	13.0±0.9	402±41	23±10	55	42
19-29	59	12.6±1.3	390±39	22±9	54	31
30-50	169	12.6±1.5	372±39	25±9	72	39
51-64	145	13.0±1.1	374±35	24±8	191	157
65+	85	12.6±1.0	370±38	23±8	178	134

[1] Values from iron deficient subjects were not included for the calculation of normal values.

[2] Mean ± SD, and an asterisk indicates significant difference between sex by Student's t test at $P < 0.05$.

[3] Mean and median values are provided and an asterisk indicates significant difference between sex by Student's t test at $P < 0.05$ after log transformation of the values.

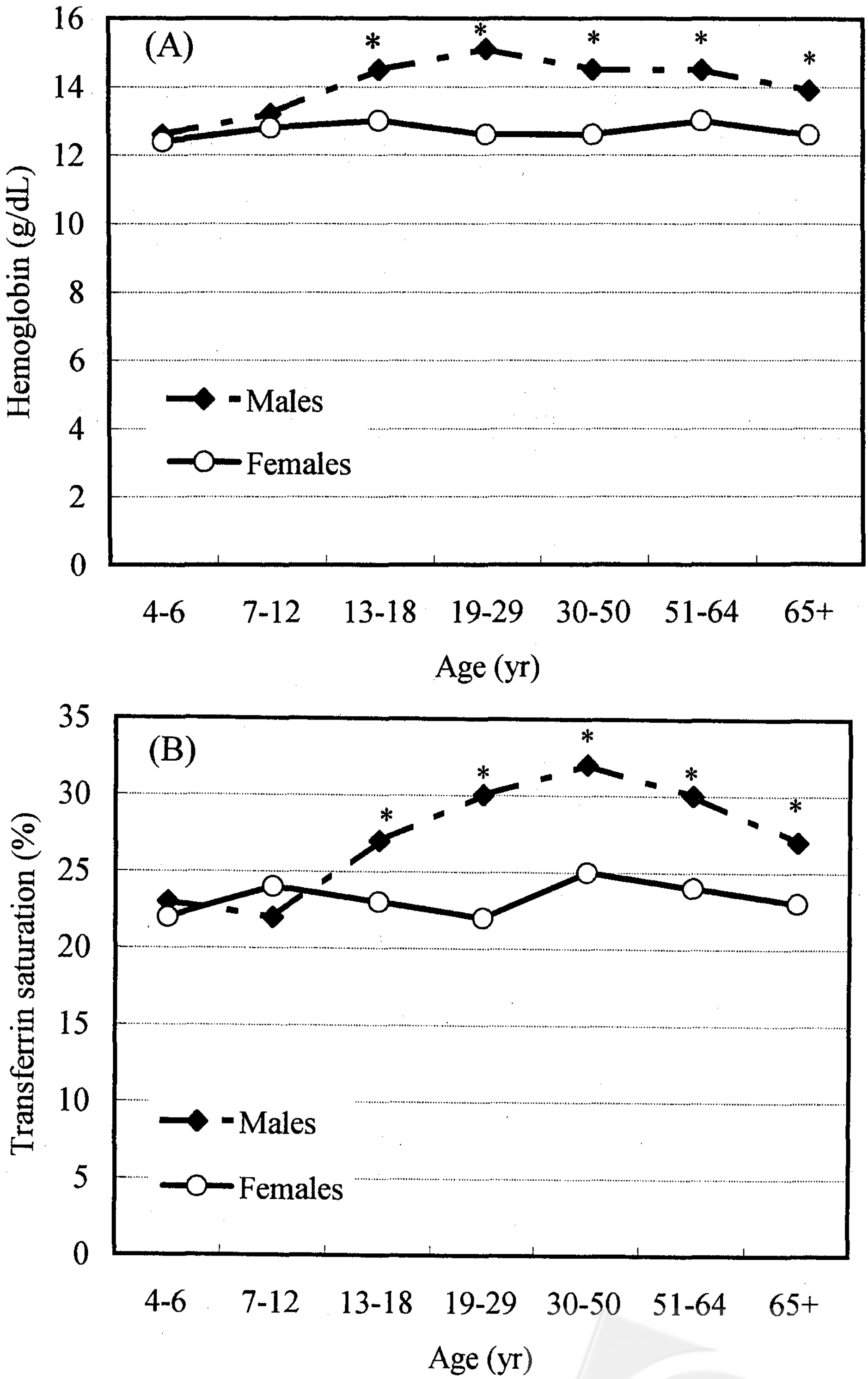

Figure 1 Age-related changes in the mean values of (A) hemoglobin, (B)transferrin saturation, and (C)total iron binding capacity (TIBC), and (D) median values of serum ferritin by sex in the general population in Taiwan. An * indicates significant difference between males and females.

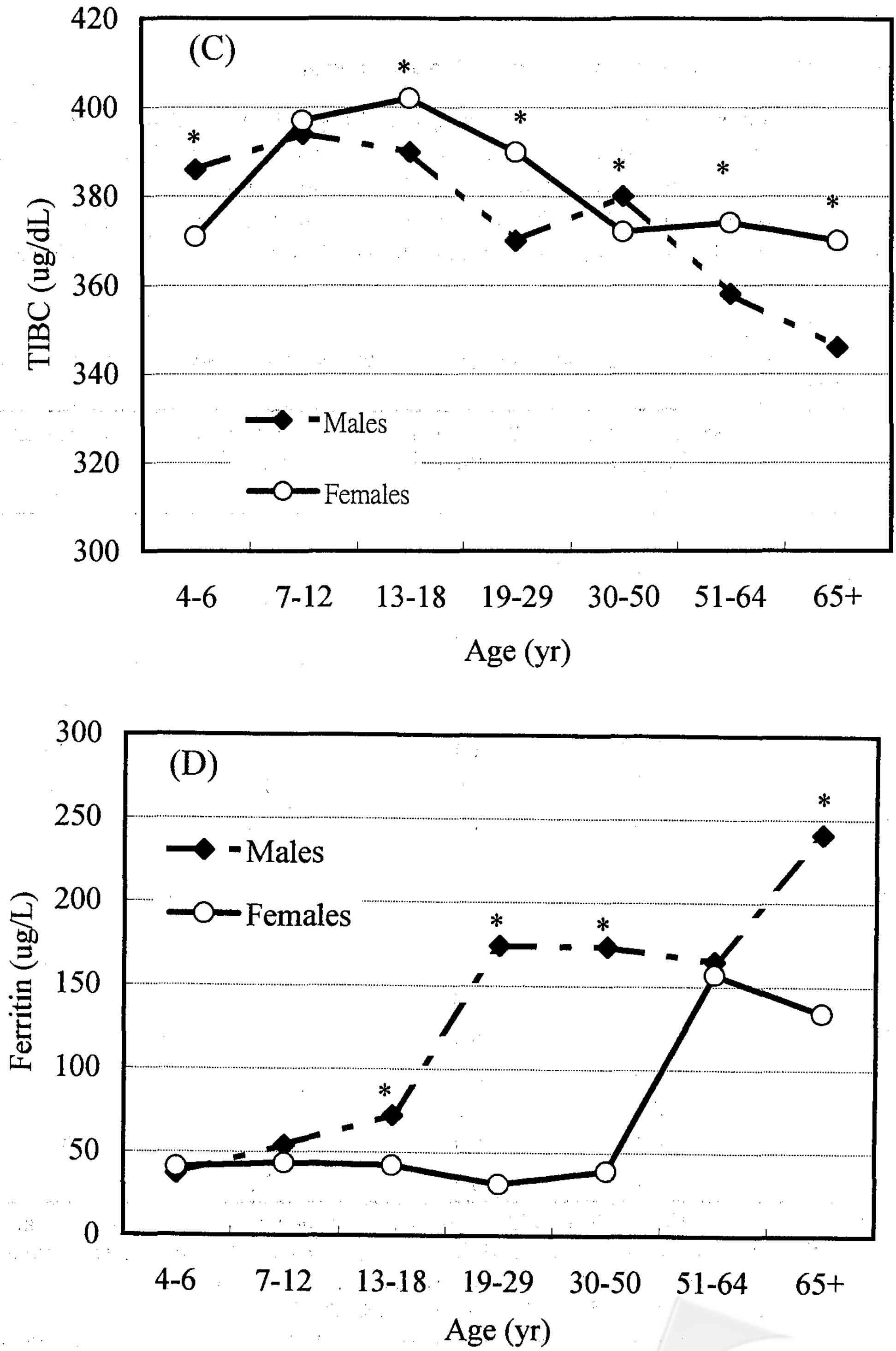

Figure 1 Age-related changes in the mean values of (A) hemoglobin, (B)transferrin saturation, and (C)total iron binding capacity (TIBC), and (D) median values of serum ferritin by sex in the general population in Taiwan. An * indicates significant difference between males and females. (Cont.)

Prevalence of iron deficiency and iron deficiency anemia

Prevalence by sex and age For the general population aged 4 yr and older, prevalence of both iron deficiency and iron deficiency anemia were higher in females than in males. Iron deficiency was found in 2.1% males and in 10.7% females, and iron deficiency anemia was found in 0.2% males and 2.1% females. The prevalence of iron deficiency and iron deficiency anemia according to sex and age are shown in Table 3.

Table 3 Prevalence of iron deficiency by age and sex in the surveyed population from NAHSIT

Sex and Age (yr)	Serum ferritin < 12 (μg/L) (%)	2 Abnormal values[1,2] (%)	Fe deficiency anemia[3] (%)	Fe deficiency, total[4] (%)
Males				
4-6	0.1	0.2	0	0.2
7-12	0.2	1.7	0	1.7
13-18	3.6	5.6	0.1	5.7
19-29	1.9	0	0	0
30-50	0	0	0	0
51-64	1.3	1.4	1.3	2.7
65+	4.9	13.0	0	13.0
Total	1.3	1.9	0.2	2.1
Females				
4-6	0	6.2	0	6.2
7-12	1.7	5.7	0	5.7
13-18	10.7	5.5	3.6	9.1
19-29	13.0	8.4	0.6	9.0
30-50	7.8	10.6	3.6	14.2
51-64	5.1	9.2	2.7	11.9
65+	0.2	9.8	0.1	9.9
Total	7.7	8.6	2.1	10.7

1 Parameters are ferritin, transferritin saturation and hemoglobin. Abnormal values are: transferritin saturation < 15% and ferritin < 12 μg/L for all age-sex groups, and hemoglobin value < 11 g/dL for age < 7yr, < 12 g/dL for age 7-14 yr, < 12 g/dL for female > 14 yr, and < 13 g/dL for male > 14 yr.

2 Including all the subjects with only 2 abnormal values but not with 3 abnormal values.

3 Including all the subjects with 3 abnormal values.

4 Including all the subjects with 2 or more abnormal values

In males, the highest prevalence of iron deficiency occurred in the age group 13-18 yr (5.7%) and the elderly (13%), and the highest prevalence of iron deficiency anemia occurred in the age group 50-64 yr (1.3%). Iron deficiency was found in 1% or fewer males aged 4-6 yr and 19-50 yr. On the contrary, iron deficiency and iron deficiency anemia were relatively common in the females, ranging 5.7% to 14.2% and 2.7 % to 3.6%, respectively. In females aged 13 yr and older, 9% to 14% had iron deficiency and 2.7% to 3.6% had iron deficiency anemia. The highest prevalence of iron deficiency anemia occurred in age groups 13-18 (3.6%) and 30-64 (2.7% to 3.6%). In females aged 4-12 yr, the prevalence of iron deficiency was slightly lower (5.7% to 6.2%) and iron deficiency anemia was rare. Impaired iron status was more prevalent in females than in males for all age groups.

Prevalence by strata Prevalence of iron deficiency and iron deficiency anemia was shown in Table 4 for subjects aged 19 yr and older according to sex and strata. For males, the highest prevalence of iron deficiency was found in metropolitan cities (3.6%) and mountainous area (3.1%). The prevalence was slightly lower in the east coast area and Penghu Islands (1.8% to 2.6%), and was less than 1% in Hakka area, provincial cities and urbanization class I townships.

In contrast, iron deficiency and iron deficiency anemia were both common and were more prevalent in females than in males for all strata. For females, the prevalence of iron deficiency anemia was highest in Hakka area and mountainous area (8.1 % to 9.8%), slightly lower in the east coast area, Penghu islands, metropolitan cities and urbanization class II townships (2.6% to 5.9%), and rare in provincial cities and urbanization class I townships. The prevalence of iron deficiency was more than 10% in all strata except in urbanization class II townships (8.4%). The prevalence was highest in Hakka area, mountainous area, east coast area and Penghu Islands (17.3% to 20.3%), and slightly lower in metropolitan cities and urbanization class I townships (12.4% to 13.4%). For the females, iron deficiency was less prevalent in cities and urbanized strata than in other strata. It is interesting to point out that among all the strata, while Hakka area had the highest prevalence of iron deficiency in females, it also had the lowest prevalence in males.

Prevalence according to dietary iron intake For both males and females aged 13 to 18 yr, the prevalence of iron deficiency declined noticeably when daily iron intake increased to more than 14 mg (Table 5). For those aged 19 to 50 yr, prevalence of iron deficiency was rare for the whole range of iron intake in males, while in females, it was 14.7% when daily iron intake was below 6 mg, and it remained at a level of 8.9% to 11.7% as iron intake increased (Table 6). For women aged 19 to 50 yr, both iron deficiency and iron deficiency anemia were most prevalent when daily iron intake was less than 7 mg, and declined rapidly when intake increased to more than 7 mg (Figure 2). When iron intake was more than 10 mg, iron deficiency anemia decreased steadily to less than 3%, while iron deficiency rate was about 10% and remained at that level even when iron intake increased to more than 14 mg (Figure 2).

Table 4 Prevalence of iron deficiency in subjects aged 19 and older from NAHSIT classified according to strata and sex

Sex and Strata	Serum ferritin < 12 (μg/L) (%)	2 Abnormal values[1,2] (%)	Fe deficiency anemia[3] (%)	Fe deficiency, total[4] (%)
Males				
Hakka area	0	0	0	0
Mountainous area	0.6	3.1	0	3.1
East coast area	1.2	1.8	0	1.8
Penghu islands	0	2.6	0	2.6
Metropolitan cities	3.5	3.6	0	3.6
Provincial cities and urbanization class I townships	0	0.7	0	0.7
Urbanization class II Townships	1.4	1.1	0.6	1.7
Females				
Hakka area	17.8	9.4	9.8	19.2
Mountainous area	16.7	12.2	8.1	20.3
East coast area	16.4	14.7	2.6	17.3
Penghu islands	6.7	12.0	5.9	17.9
Metropolitan cities	6.7	9.4	3.0	12.4
Provincial cities and urbanization class I townships	10.0	13.4	0	13.4
Urbanization class II Townships	6.4	4.8	3.6	8.4

[1] Parameters are ferritin, transferritin saturation and hemoglobin. Abnormal values are: transferritin saturation < 15% and ferritin < 12 μg/L for all age-sex groups, and hemoglobin value < 11 g/dL for age < 7yr, < 12 g/dL for age 7-14 yr, < 12 g/dL for female > 14 yr, and < 13 g/dL for male > 14 yr.

[2] Including all the subjects with only 2 abnormal values but not with 3 abnormal values.

[3] Including all the subjects with 3 abnormal values

[4] Including all the subjects with 2 or more abnormal values.

Table 5 Prevalence of iron deficiency in adolescents aged 13-18 year classified according to daily iron intake

Daily Fe intake (mg/day)	Percent of RDNA[1] (%)	Males (13-18 yr)		Females (13-18 yr)	
		Fe deficiency (%)	Normal Fe status (%)	Fe deficiency (%)	Normal Fe status (%)
<6	<40	13.9	86.1	4.0	96.0
6-10	40-66.7	3.3	96.7	12.2	87.8
10-14	66.7-93.3	6.1	93.9	14.6	85.4
>14	>93.3	3.2	96.8	3.3	96.7

[1] RDNA, Recommended Daily Nutrient Allowances, for iron is 15 mg per day for both males and females aged 13-18 years.

Table 6 Prevalence of iron deficiency in subjects aged 19-50 year classified according to daily iron intake

Daily Fe intake (mg/day)	Males (19-50 yr)			Females (19-50 yr)		
	Percent of RDNA[1] (%)	Fe deficiency (%)	Normal Fe status (%)	Percent of RDNA[1] (%)	Fe deficiency (%)	Normal Fe status (%)
<6	<60	0	100	<40	14.7	85.3
6-10	60-100	0	100	40-66.7	11.2	88.8
10-14	100-140	0	100	66.7-93.3	8.9	91.1
>14	>140	0	100	>93.3	11.7	88.3

[1] RDNA, Recommended daily nutrient allowances, for iron is 15 mg per day for females and 10 mg per day for males aged 19-50 years.

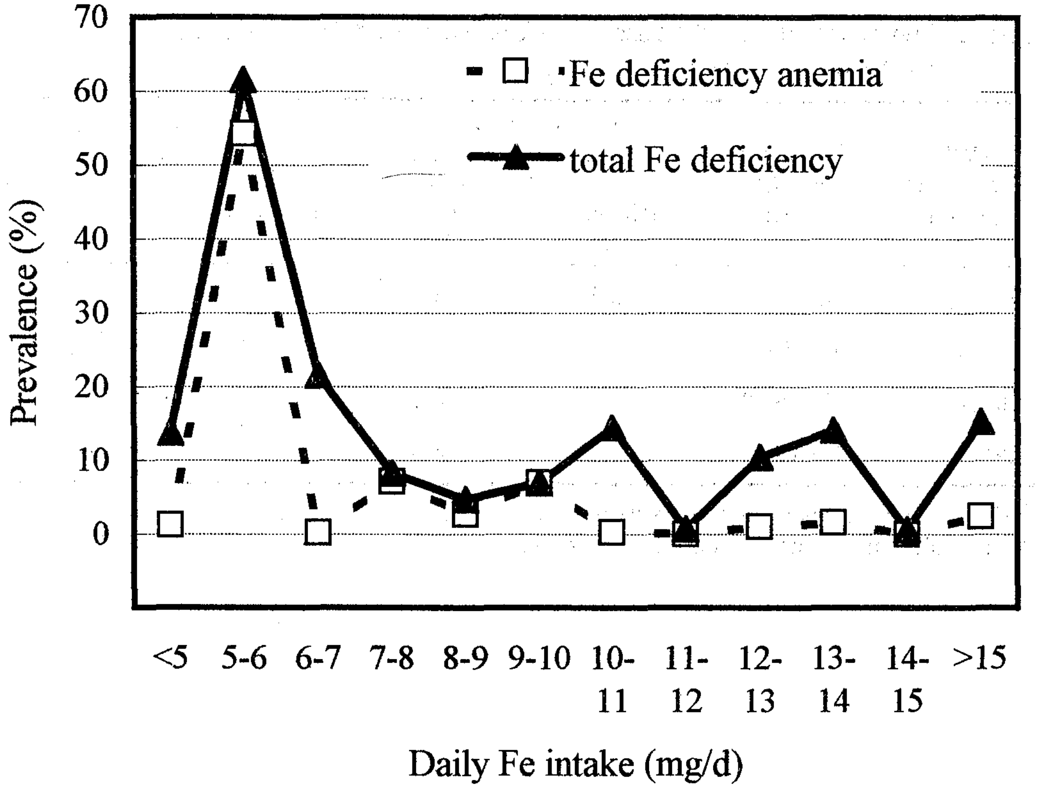

Figure 2　Prevalence of iron deficiency and iron deficiency anemia according to daily iron intake in women aged 19-50 year in Taiwan.

Discussions

Many studies have been undertaken to assess the iron status of different populations in the world. Bearing in mind the differences in methods, dietary patterns, contraceptive choice, and epidemiological factors that might lead to confounding factors, data from available studies are compared with the present study. The age- and sex-related changes in hemoglobin, TIBC, transferrin saturation and serum ferritin in this study demonstrate similar patterns as those in NHANES II (16, 25). In normal subjects, higher values of hemoglobin, transferrin saturation, and serum ferritin in combination with a lower value of TIBC indicate a better iron status. The age-related differences are to a large extent attributable to physiological characteristics such as rapid growth, hormonal changes and appearance of degenerative conditions with increasing age. A comparison of median values of serum ferritin of young and adult males from different countries is shown in Figure 3. Iron store in Chinese men in Taiwan is comparable to those populations with high meat consumption (26) or living in societies practicing iron fortification in staples (16, 19, 27). In general, iron status in males is satisfactory although the elderly had elevated iron deficiency rate.

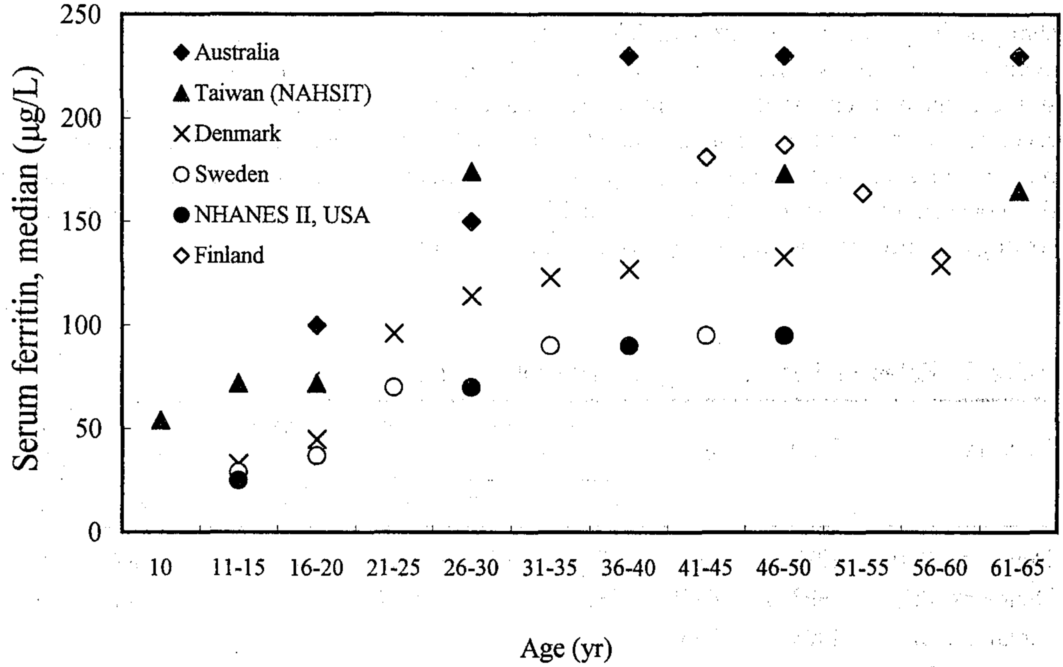

Figure 3 Median values of serum ferritin in adolescents and adult males from different countries including Australia, Denmark, Finland, Sweden, Taiwan, and USA.

The inferior iron status observed in females can be explained by menstrual blood loss and dietary intake. Pre-menopausal women consistently had lower serum ferritin values than postmenopausal women and men, indicating less body iron store. In a subsample of NHANES II, the median ferritin was 27 ug/L in pre-menopausal women, and increased sharply to 63 ug/L in women over 45 years of age, but remained lower than that in men (16). A recent survey in Singapore, 1993 to 1995, showed that mean serum ferritin concentrations in Chinese was 61 ug/L in women aged 30 to 49 years, 144 ug/L in women aged 50 to 69 years, and 236 μg/L in men aged 30-69 years (28). These values are slightly lower than or equivalent to those reported in this study for the same age and sex groups. The dietary iron intake presented in a separate report in this issue (5) is consistent with the sex-related difference in iron status. In men, most age groups had mean intakes greater than RDNA (29), with the exception of age 13-15 (87% RDNA); while in women, mean intakes were at 65% to 75% RDNA for groups aged 13 to 34, and increased to 84% and more in age groups older than 34.

Data in this study indicate that iron deficiency and iron deficiency anemia are relatively common among females aged 4 and above in Taiwan. A compilation of studies reported in 1990s is listed in Table 7. Although the criteria for iron deficiency vary among studies, the results demonstrated a similar trend in different countries: that iron deficiency rate is higher in females than in males. It is also noted that rates of iron deficiency in pre-menopausal women from these counties are comparable. In a report of iron status in NHANES III, Looker et al. have commented that no major changes in prevalence of iron deficiency among adolescent and young adult women is evident between NHANES II and III (22). Efforts, including iron fortification of staples, have been used to combat iron deficiency in the United States, and have successfully reduced anemia in infants and toddlers. However, iron deficiency still remains in some vulnerable subgroups such as women of childbearing age. This raises the concern that the effect of iron fortification has reached a plateau and alternative strategy is needed for improving iron status in women.

Table 7 Rates of iron deficiency in different countries

Country	Year	Age (yr)	Subject number (n)		Iron deficiency (%)		Fe deficiency anemia (%)	
			F	M	F	M	F	M
Denmark (30)	1992	14-23	322	312	6.6-12.5	0-3.5	1.3-4.7	0
Denmark (31)	1992-3	16-31	284	214	8.6-14.7	0.8	3.4-14.7	0
Finland (12)	1993	17-50	446	-	11	-	-	-
France (32)		35-60	6648	-	22.7/5.3[1]	-	4.4/<1[1]	-
		45-60	-	3283	-	Rare	-	rare
Italy (33)	1991	20-60	200	200	13-18/6[2]	<2/>2[2]	-	-
Netherlands (34)	1997	20-49	75	75	16	0	0-5	
		50-79	75	75	5	11		
New Zealand (35)	1993-4	21	371	413	6.7	0.24	5.8	0.97
Singapore (28)	1993-5	30-69	957		7.8/2.6[1]	1.9	-	-
Spain (36)	1997	19-35	130	-	10.7	-	3.9	-
Sweden (37)	1990	15-16	220	207	40	15	0.17	-
Sweden (38)	1993-4	15	214	184	13.9	3.7	0	0
Sweden (27)	1995	18	-	3975	-	0.4	-	0.17
UK (12)	1990	18-49	520	-	17	-	17	-
USA (22)	1988-94	3-11	5147		2-3		<1	
		12-49	5981	5397	9-10	<1	2-5	<1
		50+	3664	3366	5-7	2-4	2	1-2
Taiwan	1993-4	4-12	304	298	5.7-6.2	<1.7	0	0
(this study)		13+	738	637	9.0-14.2	0-1.3	0.1-3.6	<1.3

[1] premenopausal women/postmenopausal women.
[2] aged 20-49 yr/aged 50 yr and above.

Many factors contribute to the variations in iron status. Factors positively affecting iron indicators in both males and females include alcohol consumption (26, 39, 45) and meat consumption (26, 32, 34); factors negatively affect iron status include growth spurt at puberty (40-43), blood donation (26, 34, 39, 44, 46), vegetable fraction of diet (32), calcium and fiber (32). Recently, it is reported that serum ferritin levels are reduced in people with increased IgG antibodies to ***Helicobacter pylori***, adding *H. pylori* infection an additional stressor on iron status (47, 48).

Factors that specifically play an important role in female iron status include menarche (43), duration and intensity of menstruation (33, 46, 47), method of contraception (32, 34, 49, 50), and parity (33, 50). Increased duration of menstruation is associated with lower iron store (33, 46, 49), and women of lower iron stores are more susceptible to its negative effects (46). On the other hand, the duration of menstruation is related to the method of contraception. Women using hormonal contraceptives had shorter menstrual bleeding than those using intrauterine devices, with those not using either type of contraceptives stayed in between (32, 34, 49, 50). Inverse correlation has also been found between serum ferritin levels and number of births (33) and multipara had lower serum ferritin than nulli- and uni-para (50).

Since data of iron intake were available for the subjects (5), the rates of iron deficiency associated with each interval of iron intake have been estimated, this provides an opportunity to test the validity of the recommended allowances for iron (51). Based on the definition of RDA (52) or RDNA (29), the recommended intake is set at a level sufficiently high to meet the requirements of almost all individuals (at about 95th percentile), or it is at the level to convey very low risk (such as 3%) of deficiency or inadequacy. For subjects aged 13 to 18 year in both sexes, and males aged 19 to 50 year, the observed risk of iron deficiency agrees reasonably well with the risk of inadequacy predicted with RDNA; while for women aged 19 to 50 years, inconsistency exists between the two. Therefore, we conclude that RDNA of 15 mg iron per day for young adults or 10 mg per day for adult males is reasonable. On the contrary, elevated risk of iron deficiency was found in women of child-bearing age at low iron intake, but it was not reduced to the expected low risk as intake increased. The underlying reason needs to be explored in order to develop public health strategy for improving iron status.

There remain some limitations in this biochemical assessment of iron status. The association of anemia with chronic inflammation or infection is well established, and serum ferritin is useful in distinguishing anemia between iron deficiency and chronic inflammation because it is depressed in iron deficiency but elevated in chronic inflammation. In contrast to the high prevalence (7.8%-13%) of abnormal serum ferritin values in women of childbearing ages, the elderly groups had relatively low prevalence (0.2% for females and 4.9% for males) of abnormal ferritin values, suggesting that elderly individuals with anemia rarely had a low serum ferritin level. It is speculated that inflammatory disease or infection might be a confounding factor and lead to an overestimation of the prevalence of iron deficiency in the elderly groups (18). Because laboratory test in this study did not include parameters of inflammation, the speculation cannot be verified.

In conclusion, iron deficiency remains a relatively prevalent nutritional condition in Taiwan. High prevalence is found in the females, adolescent males and the elderly males.

Acknowledgement

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國人鐵營養狀況與缺鐵盛行率

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摘要

國人鐵營養狀況之評估乃是以「國民營養健康狀況變遷調查，NAHSIT 1993-1996」第一年接受體檢之樣本為對象，總共分析樣本含男性 935 人，女性 1,042 人，分析率達 91%。分析項目有血紅素、血清鐵蛋白、血清運鐵蛋白和血清鐵等之濃度，並據以計算血清運鐵容量與運鐵蛋白飽和度。缺鐵的評定採用鐵蛋白模式，即血紅素、運鐵蛋白飽和度與血清鐵蛋白值，三個指標中必須且僅有兩個指標不正常時表示缺鐵，以三個指標皆不正常表示缺鐵性貧血，兩者合計為總缺鐵率。整體而言，四歲以上國人總缺鐵率為男性 2.1%，女性 10.7%；缺鐵貧血率為男性 0.2%，女性 2.1%；國人缺鐵以無貧血症狀之潛伏性缺鐵為主。國人鐵營養狀況有明顯的性別差異，鐵營養不良的問題以女性較男性為嚴重；男性之中，以成長中的青少年的 5.7% 和 65 歲以上老年人的 13% 缺鐵率較高；女性則四歲以上各年齡層均有缺鐵問題，13 歲以上缺鐵率均達 9% 以上。比對鐵攝取量與缺鐵率的關聯可見，現行之 13-18 歲男女與 19 歲以上男性的鐵建議量足以滿足 96% 以上族群之生理需要，但是 19-50 歲女性在鐵攝取量達建議量 93.3% 時，仍有約 10% 的缺鐵率。如何有效改善女性鐵營養狀況應是重要的公共衛生議題。

關鍵詞：鐵營養、缺鐵率、缺鐵貧血率、鐵蛋白、鐵建議攝取量