Diurnal Rhythm Related to Standing Posture of a Man*

Kinsaku INAMURA and Yoshimitsu AMAGISHI

(Received Oct. 1, 1977)

A. Introduction

The purpose of this study is to find out the diurnal rhythm related to man's physical ability to stand. Physiological function groups related to standing posture are subject to exercise, rest and abrupt changes of circumstances.

Some works concerned with standing posture have been reported[1,2,3,4] but they were usually carried out under some external factors or with exercise. In this paper, we discuss the experiment mainly performed under the constant circumstances and with no exercise, i. e., under no-load situations.

On the other hand, diurnal rhythms appearing in the change of some muscle strength have been reported,[8,9] but to our knowledge, this is first to present such rhythms found in muscular activities which are measured by use of the electromyogram and digital Fourier transform techniques.

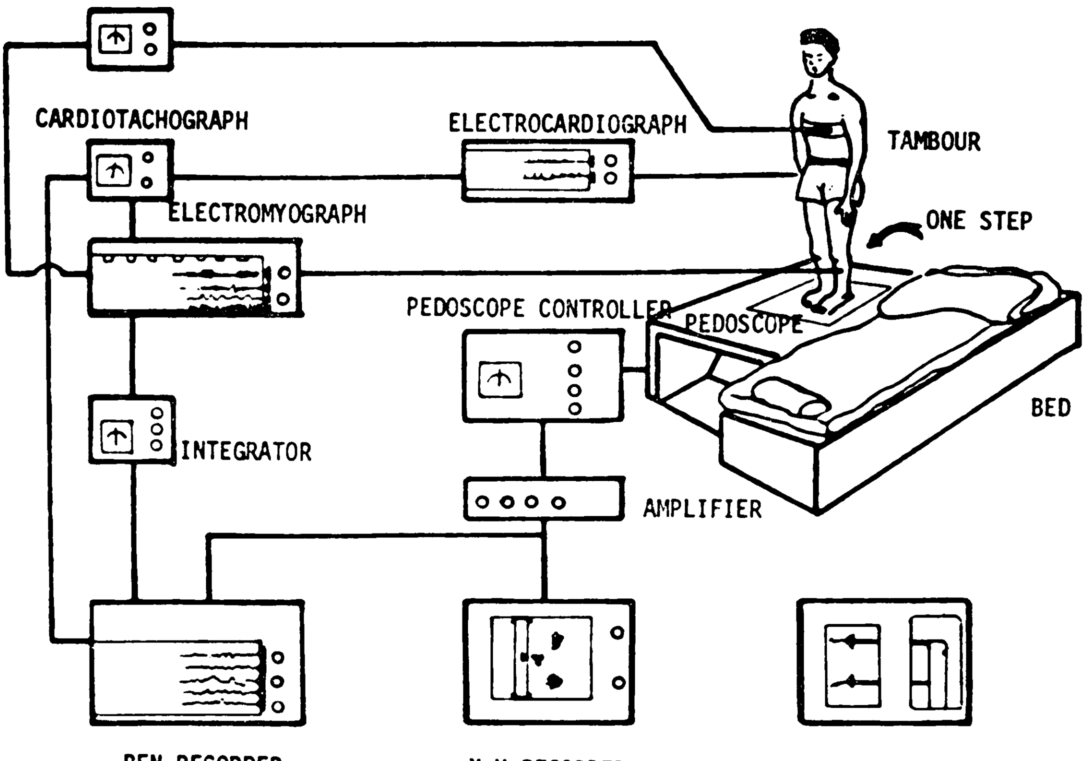

Fig. 1. A block diagram of experiment.

* Presented by K. INAMURA in Fourth International Symposium of Posturography (Sofia, Bulgaria), 19–23, September (1977).

B. Experimental procedure

The diurnal rhythm related to standing posture of a healthy male (20–year–old) is measured under the constant circumstances and with no exercise. A block diagram for our experiments is shown in Fig. 1. Before measurements the subject stayed 8 hours in a laboratory (room temperature (25 ± 2) °C, humidity (60 ± 15) %, constant light with which a man can read a newspaper). He was required to lay on his back on a bed closed to a Pedoscope. This Pedoscope can project swaying movements of the center of gravity. He was made to stand upon the Pedoscope 29 times at interval of one hour (from 8:00 p. m. to the next day) after a pretest. He was also required to stay in the bed while eating some sandwiches (1500 Cal/day), drinking water and urinating. During this experiment he ate sandwiches of about 890 Cal, drank water of 635 cc, and passed water of 703 cc.

Measurements

1) Barometers of the ability to stand are measured by use of the electrogravitiogram (EGG), which was first used by HIRASAWA.[4] Terms of our experiments are: One Foot Test (Rombelg Standing for 20 sec, One Foot Standing for 10 sec) and Cross Test (leaning forward, backward, leftward and rightward without waist bent for 45 sec). Our analysis method of data of EGG is described in Fig. 2.

2) Room temperature (RT), Room humidity (RH) and the number (N) of his turning in bed were also measured as important parameters responsible for the ability to stand. The number N was determined by measurements with the electromyogram of musculus erector spinae.

3) In order to check the body conditions, the following matters were measured;

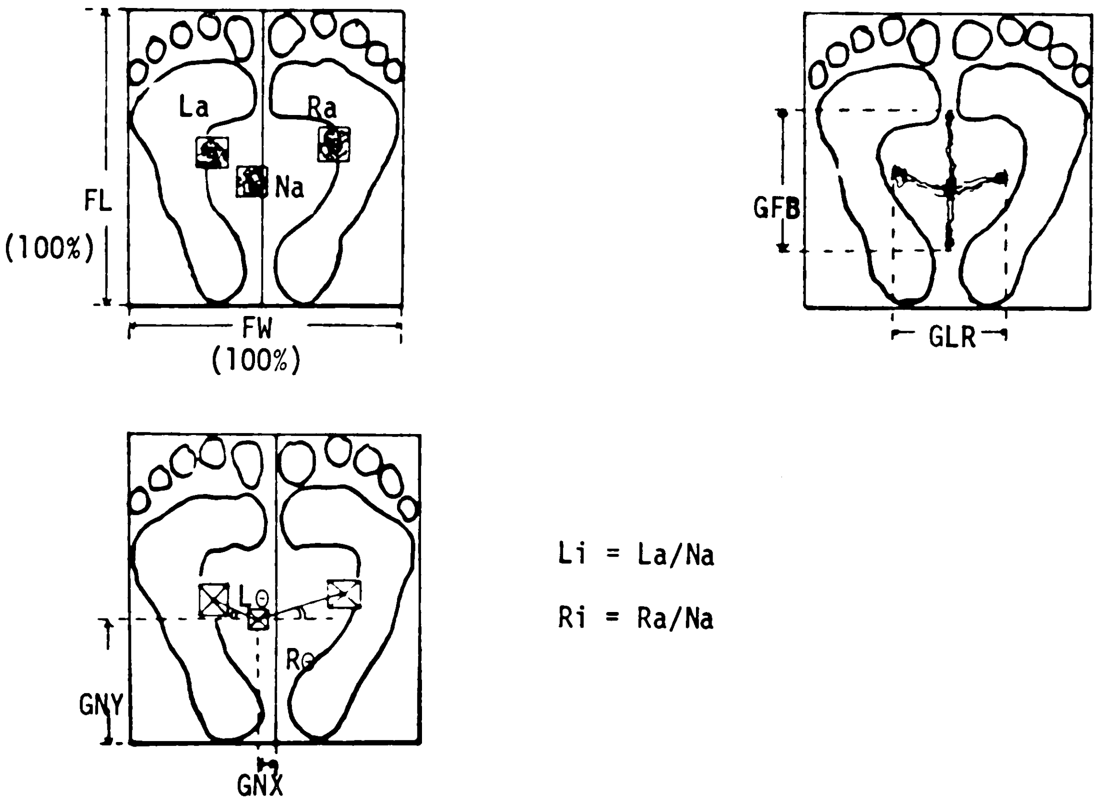

Fig. 2. Analysis terms of EGG and definition of symbols.

oral temperature (OT), heart rate (HR), respiratory rate (RR), breath holding befor these tests (BH1), and breath holding after the tests (BH2). Activities of left musculus tibialis anterior and left musculus soleus were also measured with the electromyogram. Their areas are calculated by integrating records with time. Let us call the areas of the former, EMT1 and EMT2, and the areas of the latter, EMS1 and EMS2, according to one-foot test and cross test.

Analysis Method

Raw data are first digited, followed by computing autocorrelation functions, and auto power spectrum density which is estimated from the transient Fourier transform of correlation functions. A block diagram is shown in Fig. 3. Some serious attentions should be paid to such a digital analysis of finite data, but details are described in separate papers.[5,6]

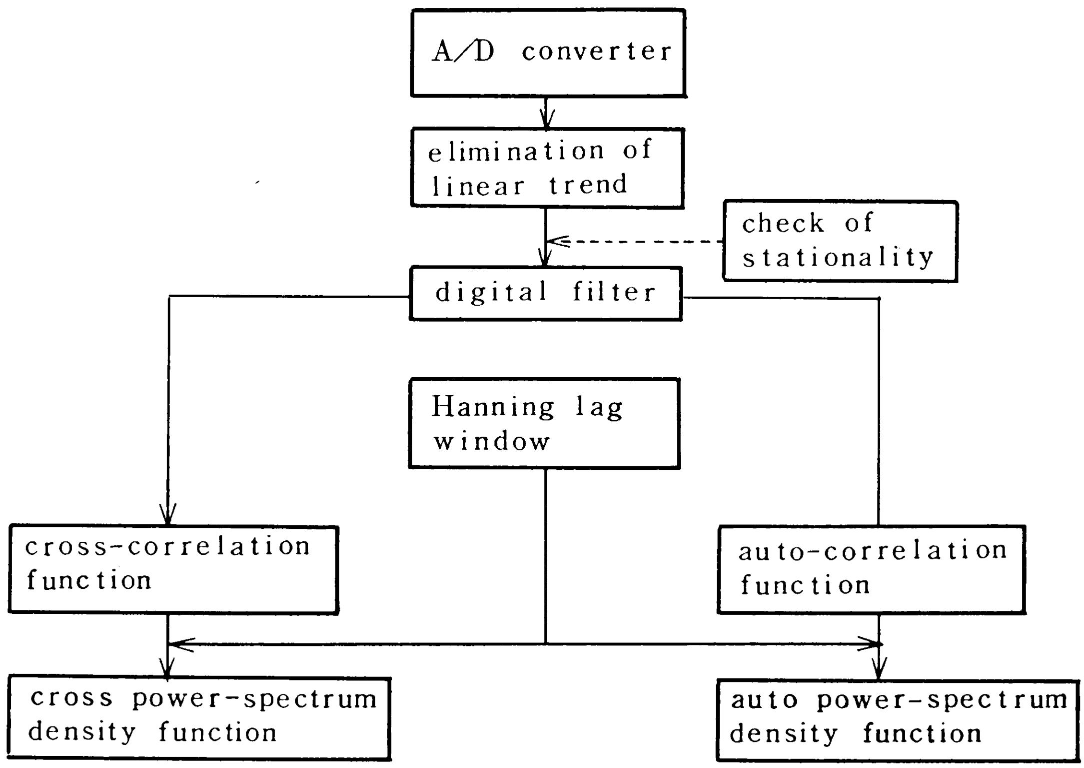

Fig. 3. A block diagram of digital analysis.

C. Results

Trend Components

Accoding to the digital analysis, we obtain the following quantities whose values are tabulated in Table 1: means (M), standard deviation (SD), trend and index of determination (ID) of trend in original data. In our discussions, we may neglect small trend components where ID is less than 0.1. RT shows high ID values, but we regard it almost constant, because it seems to be due to sampling interval time (see Fig. 4).

Before the experiment, he had been catching a cold, and then it is seen that the recovery from his slight fever made the negative trends in OT and HR. Trends of GFB and GLR mean the increase of maximum displacements of the center of gravity at the cross leaning movement. Trends of EMT1 and EMT2 mean the decrease of spike

TABLE 1. Means (M), standard deviation (SD), trend index of determination (ID) of trend obtained from raw data.

			M	S D	Trend	ID
effective factors	RT	(°C)	23.9	0.86	Y = −0.078 t +23.9	0.499
	RH	(%)	58.3	7.41	Y = −0.287 t +58.3	0.091
	N	(times)	16.4	9.13	Y = −0.290 t +16.4	0.061
body conditions	OT	(°C)	36.9	0.20	Y = −0.015 t +36.9	0.314
	HR	(times)	66.3	5.98	Y = −0.303 t +66.3	0.156
	RR	(times)	17.3	2.49	Y = −0.071 t +17.3	0.049
	BH 1	(sec.)	90.8	16.64	Y = −0.397 t +90.8	0.035
	BH 2	(sec.)	69.2	17.92	Y =0.708 t +69.2	0.095
	EMT 1	(arb.)	408.6	165.5	Y = −8.796 t +408.6	0.171
	EMS 1	(arb.)	102.7	85.6	Y =1.115 t +102.7	0.010
	EMT 2	(arb.)	346.7	162.7	Y = −15.597 t +346.7	0.558
	EMS 2	(arb.)	227.9	97.8	Y =8.031 t +227.9	0.409
barometers of the ability to stand	FL	(cm)	25.7	0.21	Y =0.005 t +25.7	0.029
	FW	(cm)	20.7	0.34	Y =20.2+1.05×0.89 t	0.201
	GNY	(%)	57.4	5.14	Y =0.470 t +57.4	0.507
	GNX	(%)	− 3.3	1.95	Y = −0.116 t +3.26	0.216
	Lθ	(degree)	27.4	12.29	Y =0.210 t +27.4	0.018
	Rθ	(degree)	26.2	10.78	Y =0.153 t +26.2	0.012
	Na	(%)	0.9	0.50		
	La	(%)	2.3	0.97	Y = −0.014 t +2.25	0.013
	Ra	(%)	2.0	1.03	Y = −0.037 t +2.00	0.078
	Li	(arb.)	3.3	1.62	Y =0.033 t +3.21	0.025
	Ri	(arb.)	2.6	1.36	Y ≒ −0.002 t +2.60	0.000
	GFB	(%)	59.4	3.97	Y =0.187 t +59.4	0.134
	GLR	(%)	55.7	6.66	Y =0.337 t +55.7	0.155

discharge of muscles at left foot standing and cross leaning. This tendency is explained as the effect of learning.

Periods (*Frequencies*)

Raw data of RT and RH are shown in Fig. 4. They have a period of 1.22–1.32 hours which corresponds to that of an air conditioner. Their fluctuations are so small as mentioned early in this section that they may be regarded as constant. The effective factor for the ability to stand, N, has no components of the diurnal rhythm of about 24 hours.

Figure 5 (a) shows a record of the area of the swaying movement of the center of gravity, (b), one after passing through the low pass digital filter, and (c), power spectrum density function of trace (a). Figure 6 also shows those of maximum displacement of the center of gravity. Obviously, power spectra of both cases have a peak around the mark 24 on the time scale, which indicate there exists diurnal rhythm. Figures 5 (b) and 6 (b) suggest the higher performance of the ability to stand from evening to night, compared with that in the morning. Results of the power spectral analysis for various data are shown in Table 2. From this table we can see that the barometers of the ability to

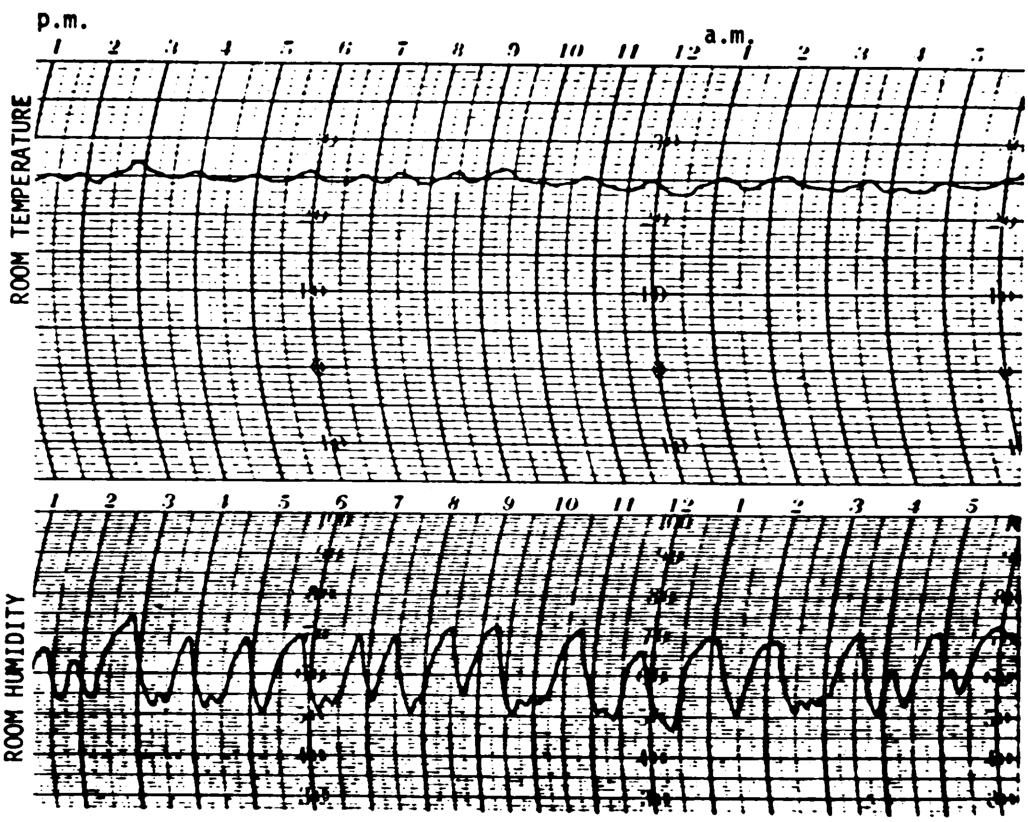

Fig. 4. Raw data of RT and RH.

TABLE 2. Comparison of peak values of the power spectrum density functions.

	Period (hours)	diurnal rhythm 24	9.6	5.3
effective factors	RT			0.198
	RH			0.159
	N			0.091
body conditions	OT	0.181	0.090	
	HR	0.077	0.117	
	RR		0.034	
	BH 1	0.229		
	BH 2	0.263	0.055	
	EMT 1	0.191		
	EMS 1			
	EMT 2			
	EMS 2	0.085		0.033

	Period (hours)	diurnal rhythm 24	9.6	5.3
barometers of the ability to stand	FL			
	FW	0.117		0.063
	GNY	0.070		
	GNX		0.062	
	Lθ	0.157	0.072	
	Rθ	0.085		
	Na	0.105		
	La	0.221		
	Ra	0.099		
	Li	0.126	0.061	0.075
	Ri	0.127	0.059	
	GFB	0.164		
	GLR	0.084		

stand have period components of not only the diurnal rhythm, but also two other kinds.

It should be noted that FL has no diurnal rhythm but FW does. HIRASAWA[7] reported that his subjects showed in daily life the diurnal rhythm in the change of foot length and foot width; he explained it as resulting from weighting of their body. These two different kinds of experimental results suggest that the diurnal rhythm of FW is caused by not only weight but tonus of ligaments group concerning to arcus pedis transverail, while FL is almost independent of such tonus of ligaments group.

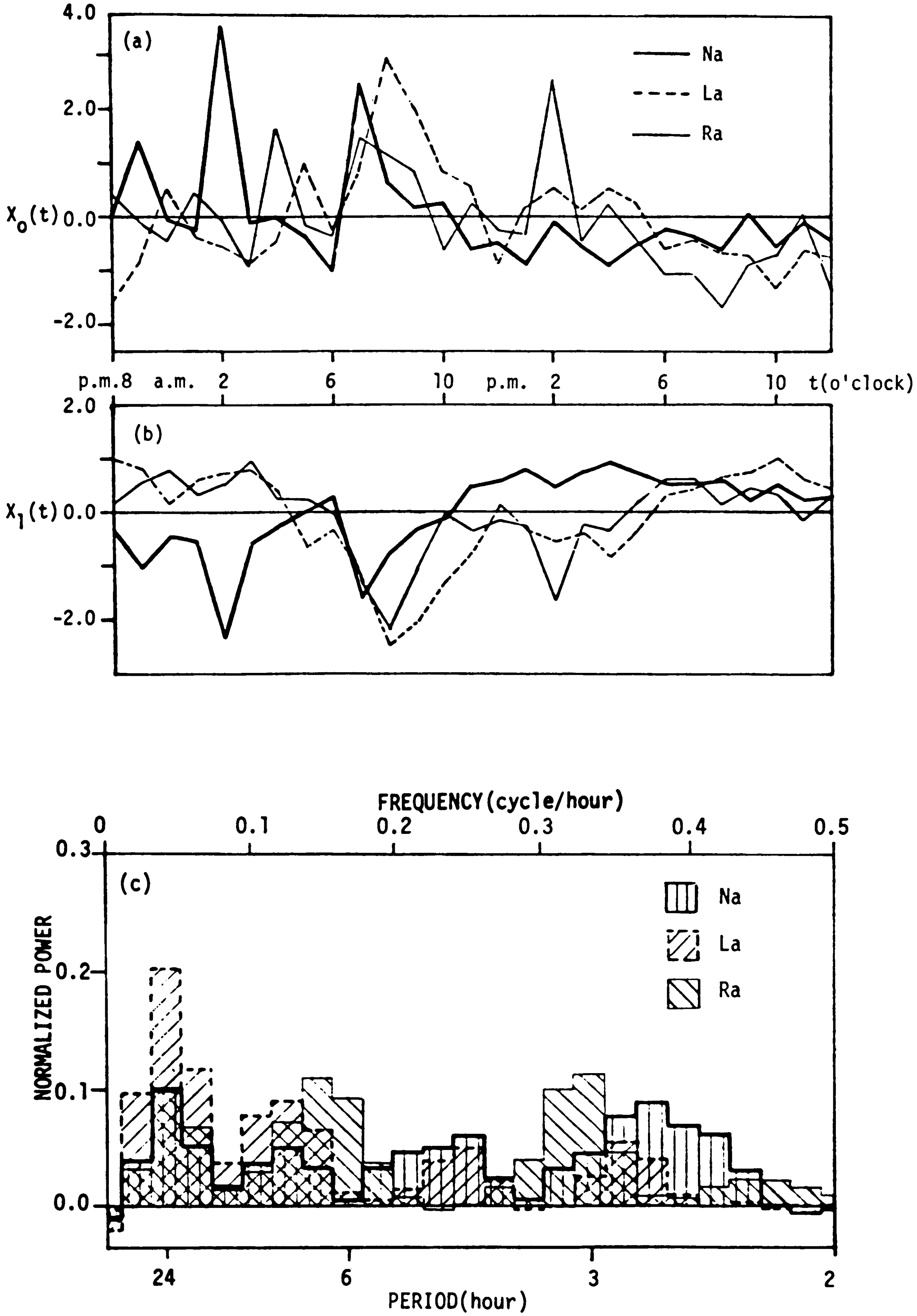

Fig. 5. Areas of the swaying movement of the center of gravity as a function of time. (a) normalized raw data, X_0 (t); (b) data after passing through low pass digital filter, X_1 (t); (c) power spectrum density function of the traces in (a).

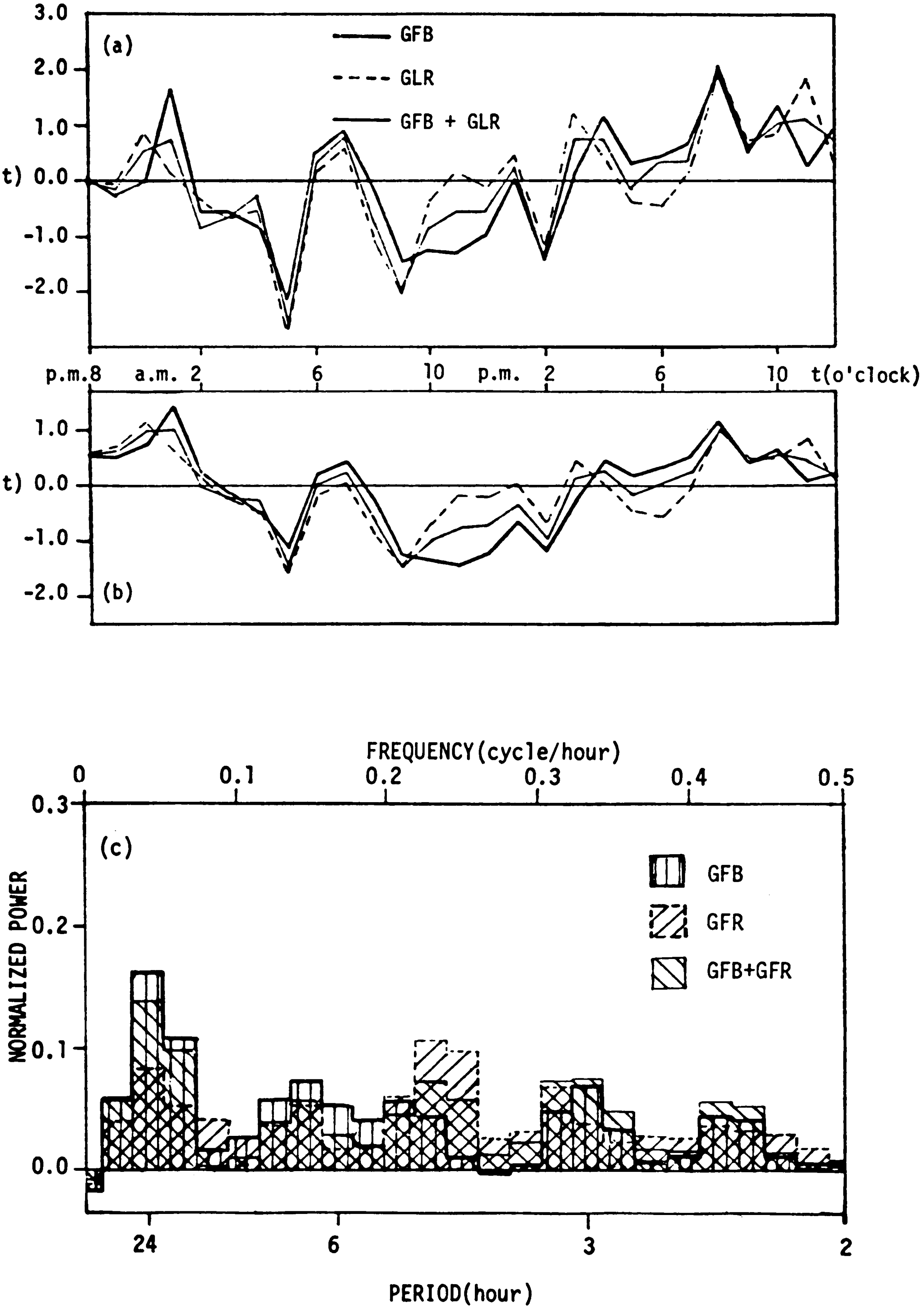

Fig. 6. Maximum displacement of the center of gravity as a function of time.
(a) normalized raw data, Y_0 (t); (b) data after passing through low pass digital filter, Y_1 (t); (c) power spectrum density function of the traces in (a).

TABLE 3. Means (M), and standard deviation (SD) obtained from the additional experiment; (*) denotes a significant difference at the 5% level by T-test.

		MORNING		NIGHT		
		M	SD	M	SD	t
barometers of ability to stand	FL	25.3	1.04	25.3	1.01	0.170
	FW	20.7	1.44	21.0	1.50	2.279*
	GNY	43.7	4.73	42.3	6.46	1.339
	GNX	0.47	2.65	0.77	2.58	0.310
	Lθ	21.4	9.63	18.8	12.7	0.249
	Rθ	25.4	19.2	28.5	14.0	1.027
	Na	0.79	0.30	0.76	0.33	0.510
	La	1.42	0.77	1.47	0.57	0.343
	Ra	1.72	1.22	1.71	0.89	0.044
	Li	2.10	1.83	2.27	1.05	0.979
	Ri	2.02	1.09	2.51	1.54	0.775
	GFB	54.2	10.5	59.3	7.1	2.394*
	GLR	55.0	9.58	59.5	7.2	1.882

Miscellany

An additional experiment was performed without any conditions on twelve healthy males in the morning (from 9:30 a. m.) and at night (from 9:30 p. m.) of the same day. Results are shown in Table 3, indicating FL, FW, Rθ, Na, Ra, GFB and GLR have ups and downs of the performance similar to those obtained in our main experiment. This agreement may support strongly our experimental results, i. e., the existence of the diurnal rhythm in man's standing posture.

D. Conclusion

In summary, by virture of the digital analysis method, we quantitatively find the so called diurnal rhythm which is related to the standing posture of a healthy male. This rhythm is caused by postural reflexes as well as other physiological functions. Especially, tonus of ligaments group seems to be one of the important factors which cause the rhythm of foot width. Moreover, the rhythm shows higher performance from evening to night than in the morning.

E. Acknowlegement

The authors wish to express their appreciation to Professor Y. HIRASAWA of Tokyo Institute of Technology for his continuous encouragement. Thanks are also tendered to Mr. Y. YOKOYAMA for his cooperation, and to Messrs. M. OUSHIO, M. NAKAMURA, S. ISHIZUKA, N. MATSUO, N. EGAWA and others for their aid of performing these experiments, and to Misses E. ISHIZAKA and S. TSUNOGAI for their aid in final preparation of this paper.

References

1 ISHIKAWA S., Dizziness in Ophthalmopathy, Chiryou, **57** No. 6 (1975) 1236:24–1244:32.

2 KAWANO R., Analysis of Swaying Movement of the Center of Gravity, Equilibrium Res., **36** (1977) 58–59.

3 INAMURA K., Long Term Rhythms Related to Standing Posture of Humans, Proc. Fifth Extraordinary Meetings of the BÁRÁNY SOCIETY, (1976) 330–333.

4 HIRASAWA Y., Stasiology (1)–(8), Report of the Department for Liberal Arts, Shizuoka Univ., **No. 5–12** (1969–1976).

5 AMAGISHI Y., Notes on Digital Analysis of Random Signals, Report of Institute of Plasma Physics, Nagoya Univ. Japan, IPPJ-T-26 (1976).

6 AMAGISHI Y., & INAMURA K., Analysis of Random Data (1), Report of the Department for Liberal Arts, Shizuoka Univ., **No. 11** (1976) 59–80.

7 HIRASAWA Y., A Study on the Stability of Human Standing Posture Relation to the Contact Surface of a Foot Sole, Mie Igaku, **4** No. 6 (1960) 2241–2259.

8 WRIGHT V., Factors Influencing Diurnal Variation of Strength of Grip, Res. Quarterly, **30** No. (1959) 110–116.

9 ONO M., Study of Diurnal Change of Physical Fitness in Summer, The Japanese J. of Physical Fitness, **12** No. 4 (1963) 137–140.