Original Articles

Blood Pressure Reference Tables for Children and Adolescents of Karnataka

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Background: *The blood pressure levels may vary in population because of genetic, ethnic and socio economic factors. Local reference values have to be established to understand the blood pressure variable.* ***Methods:*** *Blood pressure data of 2278 boys and 2930 girls in the age group of 3-18 years were analysed to study the distribution pattern of systolic blood pressure and diastolic blood pressure and to develop reference values to define hypertension. Blood pressure was measured using standardised techniques in all. The first and fifth phases of Korotkoff sounds were taken as indicative of systolic blood pressure and diastolic blood pressure respectively. Height percentiles were computed for each one-year age group. According to percentiles of height 50th, 90th, 95th and 99th percentiles of systolic blood pressure and diastolic blood pressure were estimated for every one-year age.* ***Results:*** *The blood pressure (both systolic and diastolic) tends to increase with age. The stepwise regression analysis revealed that the age and height but not gender, are important determinants of blood pressure. Age and height specific, 50th, 90th and 95th and 99th percentiles of systolic and diastolic blood pressure were derived and are presented in tabular form.* ***Conclusion:*** *The blood pressure of children and adolescents can be evaluated using the reference table according to body size. The table provided helps to classify blood pressure as 'normal' or 'pre hypertension' and to define different stages of 'hypertension'.*

Key words: *Blood pressure, Children, Reference.*

ELEVATED blood pressure (BP) in childhood may be early expression of essential hypertension in adulthood(1,2). Regular measurement of blood pressure in young is recommended to detect elevation of blood pressure(3). Prevalence of hypertension differs among the racial and ethnic groups compared to general population(4). The factors that have to be taken into account while predicting hypertension are race, ethnicity and geographic origin to which the people belong(5,6). Reference norms developed for one particular population may not be applicable to other because of racial, ethnical and cultural differences across the world. The local reference data is essential to evaluate any observed blood pressure values. Age and height specific normative data for Indian children has been reported in tabular form previously, based on sample derived from school children of Delhi(7). The study had adopted fourth phase of Korotkoff sound to define diastolic blood pressure (DBP) instead of fifth phase and added height in addition to

age. Currently, the fourth report from the National High Blood Pressure Education Program (NHBPEP) Working Group on Children and Adolescents provide updated recommendations for diagnosis, evaluation, and treatment of hypertension. The new Blood pressure tables based on normative distribution of BP in healthy children includes 50th and 99th percentiles of blood pressure values along with earlier 90th and 95th percentile values(3,8).

The objective of present study was to provide age and height specific reference standards of blood pressure in apparently healthy children and adolescents of Karnataka in the age group of 3-18 years.

Subjects and Methods

The survey was carried out in 20 randomly selected government schools and Anganwadi centers between June 2001 to May 2002, in and around Bangalore and Haveri districts of Karnataka, India. The study sample consisted of 5773 (2500 boys/3273 girls) apparently healthy children in the age group 3-18 years. This age group represents about 35% of population of Karnataka, a south Indian state with total population of 52.7 million(9).

Children with history of or suffering from acute/chronic illness, with signs of anemia, cardiac and renal disorder on medical examination were not included in the study.

A team consisting of four doctors and four volunteers collected the data from the selected schools. Volunteers were trained to record height and weight using standardized methods. A portable weighing scale was used to measure weight of the child and was calibrated before each use. Weight was measured to nearest 1 kg. Height was measured to nearest 1 cm with subject standing without shoes using stadiometer. Age was verified from school records and rounded off to the completed years.

The doctors measured blood pressure on regular schooldays with normal activities. Before recording blood pressure the procedure was explained to children and sufficient time was given to allay anxiety and fear. Blood pressure was recorded in sitting position in right arm by auscultatory method using standard mercury monometer with a set of different sized cuffs. The cuff bladder was wide enough to cover at least 2/3 of arm and long enough to encircle arm completely. The first and fifth phases of Korotkoff sounds were taken as indicative of the systolic and diastolic blood pressures respectively.

In order to verify the accuracy of use of single BP measurement we recorded two BP measurements, with 2 min interval between each measurement on two hundred and seventy five subjects. The data analysis for each one year age group between 7-18 years and by gender indicated mean difference between the two recording ranges from –1.5 to 4.7 mm Hg for boys and –2 to 4.8 mm Hg for girls in systolic blood pressure (SBP) –3.5 to 4.9 mm Hg for boys and –3.3 to 3.33 mm Hg for girls in DBP respectively. The results indicated that the magnitude of difference between the first and second readings for each age years and sex was not statistically significant. Therefore, subsequently, only a single reading of BP was obtained for all the remaining individuals and used to develop normative data.

In order to eliminate inter-rater variability among doctors blood pressure measurement was done by all four doctors for 50 subjects. Whenever the difference in BP was more than 5 mm of Hg between observers was noticed, and then consensus was arrived, so that at later stage between observers variability could be reduced.

In order to have normal reference children population, of the 5773 children we excluded undernourished (BMI <5th percentile, n = 283) and obese (BMI >95th percentile, n = 282) for specific age and sex respectively.

Statistical analysis

Statistical analyses were performed using SPSS version 11.0.

A total data of 5208 children were analysed. Separate analyses were performed for systolic and diastolic blood pressure. A stepwise regression analysis was carried out to find principal determinants of blood pressure with independent variables such as age, sex and height. Age and height were principal determinants of blood pressure. As height entered into the regression model, sex did not remain a significant determinant of blood pressure. We therefore, pooled both sexes to formulate age-and height specific reference values of blood pressure.

We first calculated age specific height percentiles of reference sample then converted height percentiles to Z score scale. Regression of blood pressure on height was done for each one-year age, sex pooled group. The 50th, 90th, 95th and 99th percentiles of systolic blood pressure and diastolic blood pressure at specific height percentiles were estimated using regression equations, Blood pressure (age) = $\alpha + \beta$ (Z height) + X.σ where σ^2 was estimated from the residual mean square from regression model and X = 1.280, 1.645 or 2.326 for the 90th, 95th and 99th percentiles, respectively(8,10).

Results

After excluding undernourished (n = 283) and obese (n = 282), data of 5208 children were considered for analysis. The study sample characteristics are shown in *Table I*. The maximum numbers of children were in the age group of 14 years (n = 834) with minimum number of children in the age group of 4 and 5 years (n = 70). Age and height were principal determinants of blood pressure (*Table II*). The height percentile values of the 5th through 95th percentiles for each one-year age group were calculated and reported in *Table III*. The height was ranging from 81 to 179 centimeters. In the age groups 3 to18 years the values of systolic and diastolic blood pressure ranged from 60-180 mm Hg and 30-110 mm Hg respectively. The mean values of body mass index (BMI) show steady increase with age from 9 year onwards and were ranging from 13.6 to 20.4.

Regression coefficients from age specific blood pressure regression models in reference sample to calculate the 50th, 90th, 95th and 99th percentile values of systolic and diastolic blood pressure by age and height are given in *Table IV*.

The percentile BP levels by age and height percentiles are reported in *Table V*. The mean blood pressure increased with age (exception 9, 13 and 17 years for systolic blood pressure and 13 and 18years for diastolic blood pressure). The rate of increase was gradual with a spurt of 4 to 5 mm Hg in systolic blood pressure at the of age 8 years and 14 years.

Table V shows that the systolic blood pressure of 11th and 17th year and diastolic blood pressure of 8th, 11th and 13th year children with height between 5th through 95th percentiles is lower than those of previous age groups with corresponding height percentiles. We recommend that the higher values be used for all above mentioned age group children to avoid any possibility of mislabeling. To interpret the blood pressure of a child, his/her height percentile has to be determined from *Table III*, and then *Table V* has to be consulted to estimate different percentile values of

TABLE I–*Characteristics of Study Sample*

Age (Years)	Total Number	Number of Male/female	SBP (mmHg)	DBP (mmHg)	Height (cm)	Weight (kg)	BMI (kg/m^2)
3	98	42/56	98(11)	63(11)	95(8)	13.1(2.3)	14.5(1.7)
4	170	97/73	100(10)	64(9)	97((5.7)	13.5(1.8)	14.3(1.5)
5	70	43/27	99(12)	65(10)	103(6)	15.5(1.8)	14.6(1.80
6	165	92/73	102(11)	68(9)	110(6)	16.4(2.4)	13.6(1.4)
7	243	105/138	102(12)	68(10)	114(7)	18.1(2.1)	13.8(1.2)
8	252	118/134	106(10)	70(8)	118(7)	19.7(3.3)	14.1(1.2)
9	256	109/147	105(11)	71(9)	124(6)	21.7(3)	14(1.2)
10	222	103/119	107(10)	72(9)	128(8)	24(3.6)	14.6(1.3)
11	362	183/179	108(9)	73(7)	131(11)	25.3(5)	14.7(1.3)
12	525	253/272	110(11)	73(9)	136(13)	28.3(6.8)	15.5(1.5)
13	787	318/469	109(11)	72(8)	145(10)	34.5(7.4)	16.2(2.2)
14	834	269/565	113(11)	74(8)	150(8)	37.9(6.4)	17.4(2)
15	700	298/402	115(11)	75(8)	145(10)	34.5(7.4)	17.7(2)
16	336	158/178	117(12)	76(8)	156(8)	43.6(6.4)	17.7(2)
17	94	34/60	116(12)	77(8)	156	43.6(5.3)	17.9(2)
18	94	56/38	117(15)	75(11)	164(9)	55(9.2)	20.4(2.3)

Figures in parentheses are standard deviations; SBP–Systolic blood pressure; DBP–Diastolic blood pressure; BMI–Body mass index.

TABLE II–*Results of Stepwise Regression Analysis of SBP and DBP on Independent Variables*

	Dependent variable SBP		Dependent variable DBP	
Variables	Regression coefficient (Standard error)	*P*	Regression coefficient (Standard error)	*P*
Constant	78.16(1.4)	<0.001	53.04 (1.15)	<0.001
Height	0.19(0.02)	<0.001	0.13(0.01)	<0.001
Age	0.45(0.09)	<0.001	0.23(0.03)	<0.005
Sex	0.40(0.30)	0.188	–0.40(0.24)	0.09

SBP-systolic blood pressure DBP-Diastolic blood pressure.

systolic and diastolic blood pressure. The BP level <90th percentile is normal. The BP measurements between the 90th and 95th percentiles indicate prehypertension. The BP level ≥ 120/80 mm Hg in an adolescent is considered prehypertension. The BP level ≥95th percentile is hypertension. Stage 1 hypertension is the designation for BP levels that range from the 95th percentile to 5 mm Hg above the 99th percentile. Stage 2 hyper-

Table III– *Height Percentiles by Age in the Reference Sample*

Age (years)	Height percentile						
	5	10	25	50	75	90	95
3	81	85	88	95	101	107	109
4	87	90	93	97	102	105	106
5	95	95	98	103	107	110	112
6	100	101	105	109	114	117	122
7	104	105	110	114	119	124	127
8	107	110	112	118	122	128	130
9	113	116	120	124	128	131	134
10	116	119	122	129	133	137	141
11	105	119	126	132	138	144	147
12	110	115	130	138	145	151	156
13	125	134	140	145	151	157	160
14	137	140	145	150	155	161	164
15	140	143	149	154	159	165	169
16	144	146	150	155	162	167	170
17	145	147	151	156	162	166	168
18	150	153	158	165	170	176	179

tension is the designation for BP levels that are >5 mm Hg above the 99th percentile.

Discussion

In this study age and height specific, 50th, 90th, 95th and 99th percentile values of systolic and diastolic blood pressure are reported in tabular form in *Table V* based on the first BP measurement taken on 5208 children(3). This table helps clinician to decide, whether observed BP values are normal or abnormal. The child is normotensive if the BP is below 90th percentile. If the BP is ≥90th percentile, the BP measurement should be repeated at that visit to verify an elevated BP. The average BP measurements between the 90th and 95th percentiles are high normal or prehypertension. Adolescents with BP levels ≥120/80 mm Hg should be considered to be prehypertensive even if the

TABLE IV–*Regression Coefficients from Age Specific Blood Pressure Regression Models in Reference Sample*

Age	Systolic BP			Diastolic BP		
	Alpha (α)	Beta (β)	Sigma (σ)	Alpha (α)	Beta (β)	Sigma (σ)
3	97.82	5.08	9.76	63.41	3.48	10.43
4	99.78	2.25	9.78	64.24	1.42	8.82
5	99.13	3.48	7.47	64.69	2.24	9.77
6	101.67	2.26	10.93	68.17	1.72	9.02
7	102.00	2.77	11.76	68.04	1.82	9.78
8	106.47	2.58	9.69	69.82	2.26	8.19
9	105.42	2.28	10.77	70.51	1.42	8.49
10	107.43	1.17	10.42	71.98	1.88	8.90
11	108.19	1.83	8.56	72.93	1.64	6.95
12	109.82	1.99	10.52	73.44	1.25	8.62
13	109.42	1.71	10.59	72.31	0.77	8.08
14	112.53	1.93	10.85	73.66	1.33	8.19
15	114.99	0.98	11.08	75.46	1.33	7.70
16	116.58	0.83	11.66	76.00	.34	8.08
17	116.17	1.30	11.64	77.00	1.26	8.72
18	117.24	3.71	14.87	74.99	.30	11.14

Blood pressure (age)=$_{\alpha 1+}\beta$ (Z height)+ X.σ, where σ^2 was estimated from the residual mean square from regression model and X=2.326, 1.64 or 1.280 for the 99th, 95th and 90th percentiles, respectively.

TABLE V– *Blood Pressure Levels for the 50th, 90th, 95th and 99th Percentiles of Systolic and Diastolic Blood Pressure by Percentiles of Height in Boys and Girls of Age 3 to 18 years*

Age (Yrs)	BP percentile	Systolic BP (mm Hg) By percentiles of height							Diastolic BP (mm Hg) By percentiles of height						
		5	10	25	50	75	90	95	5	10	25	50	75	90	95
3	50	90	91	94	98	101	104	106	58	59	61	63	66	68	69
	90	99	101	104	107	111	114	116	70	71	73	76	78	80	81
	95	102	104	107	111	114	117	119	74	75	77	80	82	84	85
	99	109	111	114	117	120	124	126	81	82	84	87	89	90	92
4	50	96	97	98	100	101	103	103	62	62	63	64	65	66	67
	90	106	106	108	109	111	112	113	72	73	74	75	75	76	77
	95	109	110	111	113	114	116	117	75	76	77	79	79	80	80
	99	116	117	118	119	121	122	123	81	82	83	84	85	86	86
5	50	93	95	97	99	101	104	105	61	62	63	65	66	68	68
	90	100	101	103	106	108	110	114	73	73	75	76	78	79	80
	95	103	104	106	108	111	113	117	76	77	78	79	81	83	83
	99	114	116	119	123	126	129	131	83	83	85	86	88	89	90
6	50	98	99	100	102	103	105	105	65	66	67	68	69	70	71
	90	109	110	111	113	114	116	116	76	77	78	79	80	81	82
	95	113	114	115	117	118	120	120	79	80	81	82	83	84	85
	99	114	115	117	119	120	122	123	85	86	87	88	89	90	91
7	50	97	98	100	102	104	106	107	65	66	67	68	69	70	71
	90	109	111	112	114	116	118	119	77	77	78	80	81	82	83
	95	114	115	116	118	120	122	123	80	81	82	83	84	85	86
	99	120	121	123	125	127	128	119	87	87	88	90	91	92	93
8	50	102	103	105	106	108	110	111	66	67	68	70	71	73	74
	90	112	113	114	116	118	119	120	76	76	78	79	81	82	83
	95	115	116	118	119	121	123	124	79	79	81	82	84	85	86
	99	120	120	122	124	125	127	128	84	85	86	88	89	91	92
9	50	102	103	104	105	107	108	109	68	69	70	71	71	72	73
	90	112	113	115	116	118	119	120	78	79	79	80	81	82	83
	95	116	117	119	120	122	123	124	79	82	83	83	84	85	86
	99	125	125	126	127	128	129	130	87	87	88	89	90	91	91
10	50	106	106	107	107	108	109	109	69	70	71	72	73	74	75
	90	116	116	117	118	119	119	120	79	80	81	82	84	85	85
	95	120	120	121	122	122	123	123	83	83	84	86	87	88	89
	99	125	126	127	128	129	130	131	89	89	90	92	93	94	94

Contd...

TABLE V (contd..)– *Blood Pressure Levels for the 50th, 90th, 95th and 99th Percentiles of Systolic and Diastolic Blood Pressure by Percentiles of Height in Boys and Girls of Age 3 to 18 years*

Age (Yrs)	BP percentile	Systolic BP (mm Hg) By percentiles of height							Diastolic BP (mm Hg) By percentiles of height						
		5	10	25	50	75	90	95	5	10	25	50	75	90	95
11	50	105	106	107	108	109	111	111	70	71	72	73	74	75	76
	90	113	114	115	116	117	118	119	78	79	80	81	82	83	84
	95	116	117	118	119	120	122	122	81	81	82	83	84	85	86
	99	121	122	124	125	127	128	129	86	86	87	88	89	90	91
12	50	107	107	108	110	111	112	113	71	72	73	73	74	75	75
	90	117	118	119	120	122	123	124	81	82	83	83	84	85	86
	95	121	122	123	124	125	127	127	85	85	86	87	87	88	89
	99	127	128	130	131	133	135	136	90	91	91	92	93	94	94
13	50	107	107	108	109	111	112	112	71	71	72	72	73	73	74
	90	117	118	119	120	121	122	123	80	81	81	82	82	83	83
	95	121	122	123	124	125	126	127	83	84	84	85	85	86	86
	99	129	130	131	133	134	135	136	90	90	91	91	92	92	92
14	50	109	110	111	113	114	115	116	71	72	73	74	75	75	76
	90	120	121	122	123	125	126	127	81	81	82	83	84	85	85
	95	124	125	126	127	129	130	131	84	84	85	86	87	88	88
	99	133	134	135	136	138	139	140	90	90	91	92	93	93	94
15	50	113	114	114	115	116	116	117	73	74	75	75	76	77	78
	90	125	125	126	126	127	127	128	82	83	83	84	85	86	87
	95	129	129	130	130	131	131	132	85	85	86	87	88	89	89
	99	137	138	138	139	140	140	141	90	91	91	92	93	94	94
16	50	115	116	116	117	117	118	118	75	76	76	76	76	76	77
	90	127	127	128	129	129	130	130	85	85	85	85	86	86	86
	95	131	132	132	133	133	134	134	88	88	88	88	89	89	89
	99	140	140	141	142	142	143	144	93	93	93	94	94	94	94
17	50	114	115	115	116	117	118	118	75	75	76	77	78	79	79
	90	126	126	127	128	129	130	130	85	86	86	87	88	89	89
	95	130	131	131	132	133	134	134	88	89	90	90	91	92	92
	99	141	141	142	143	144	145	146	93	94	95	96	97	98	98
18	50	111	112	115	117	120	122	123	74	75	75	75	75	75	75
	90	127	128	131	133	136	138	139	88	88	88	88	88	89	89
	95	133	134	136	139	141	143	145	92	92	92	92	93	93	93
	99	148	149	150	151	152	153	154	99	100	100	100	100	100	100

level is <90th percentile as with adults according to Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure(11). If the child's BP is ≥95th percentile, the child may be hypertensive and repeated measurements are indicated. Though the precise characterization of a person's BP level is an average of multiple BP measurements taken over weeks to months, it is recommended to take BP measurement on at least 2 additional separate occasions to confirm hypertension. Hypertension is defined as average SBP or DBP that is ≥95th percentile for age and height on at least 3 separate occasions. The 50th percentile values provide the clinician with the BP level at the midpoint of the normal range. The 99th percentile helps to determine the degree or severity of hypertension by staging of BP into stages 1 and 2(8).

Categorisation and staging of BP, is helpful in planning a specific treatment that is most appropriate for an individual. Prehypertension warrants reassessment and consideration of risk factors and for this, treatment is by lifestyle modification. Stage 1 hypertension needs limited evaluation where as in stage 2 hypertension immediate evaluation and therapeutic intervention is indicated.

In order to prepare a normative data, the significant factors influencing systolic and diastolic blood pressure were analyzed. The *Table II* shows that there is a significant effect of age and height ($p < 0.001$, $p < 0.001$) for systolic and ($p < 0.005$, $p < 0.001$) for diastolic blood pressure respectively. The age year groups shows the increasing trend from 3 years through 18 years with the spurt of 4-5 mm of Hg in systolic blood pressure at the age of 10 year and 15 year. Diastolic blood pressure also shows similar increasing trend. Similar observations have been made by other workers and have found a spurt in systolic blood pressure at different age group(12-15). The spurt may be possibly due to age related hormonal and physical changes occurring in the body during puberty.

The reference table reveals that the 90th percentile of systolic and diastolic blood pressure for 5th through 95th percentiles of height from age group 12 and 10 years onwards respectively exceeds 120/80 mm of Hg. It is now recommended that, as with adults, adolescents with BP levels ≥120/80 mm Hg but <90th percentile should be considered prehypertensive according to the new reports from US(8). Similar trends have been observed in US normative tables. This sudden increase in BP level may be attributed to the rapid growth associated with rapid weight gain from late childhood into adolescence (16).

In the present study, the reference table (*Table V*) shows that, for children of particular age, the 95th percentile values of blood pressure varied from 3 to 12 mm of Hg (for systolic blood pressure) and 1 to11 mm of Hg (for diastolic blood pressure) between 5th and 95th percentiles of height. The difference in the blood pressure values for different height percentiles indicates that the height plays substantial role in determining blood pressure value of an individual. Hence height has to be considered as a factor before classifying a child as hypertensive. This approach of developing BP standards that are based on height provide a more precise classification of BP according to body size and avoids misclassifying children who are very tall or very short.

It is difficult to compare the present study with others because of difference in methodologies such as age group studied, phase of Korotkoff sound used to determine DBP, pooling of sex group *etc*. One major

Key Message

- This study gives the insight into the blood pressure ranges in the healthy children of state of Karnataka. The authors believe that the table could be useful to decipher a particular child's blood pressure as normal or outside the normal range.

observation made in this study is that, in Karnataka, a southern Indian state, the mean value of blood pressure is found to be higher in sample for given age and also for a given height compared to previous Indian reference values in which sample derived is mainly from northern states of India(5) and also to that of US young population(8). This may possibly indicate an increase in the risk of this young individuals becoming hypertensive when they become adults. The high prevalence of hypertension has been related to rising mean systolic blood pressure in adults(17). The higher blood pressure level in this population may be because of many other factors that determine blood pressure level in an individual such as genetic inheritance, low level of physical activity, mental stress and dietary habits and environment which the authors have not studied. The difference in the ethnicity also may be one of the factors. The increased level of normative values of blood pressure may be because of factors such as body size, plasma high-density lipoprotein cholesterol, plasma triglyceride and abnormal glucose tolerance, dietary habits, life style and many other factors stated above that determine BP, which have to be ascertained by further studies.

In our study sample the undernourished children have shown significantly reduced ($P<0.05$) levels of systolic and diastolic blood pressure. This might be one of the reasons for increased level of normative values as compared to previous Indian standards in which children with <5th percentile of BMI (Undernourished) are not excluded(5). Further more, blood pressure is found to be associated with BMI both in normal and obese children(18-21). The higher level of BMI observed in our sample (except for 6 year) might be a contributing factor for our study population having higher values of blood pressure because body size appears to be a major determinant of BP and study by Ramachandran *et al.*, reports that there is a high prevalence of overweight in adolescent children in India(22,23).

The socioeconomic status of the subjects in this study was not considered as the reference values are developed on the basis of BMI of the individuals, which was between 5th-95th percentiles of reference sample.

Limitations of the study

Though the sample was collected from various schools, sample sizes were very low for extreme ages 3, 5 and 17, 18 years to derive the normative values and making it applicable to general population. The sample size for age year 5 was 70 and for age years 3,17, and 18 the sample size was about 100 only, hence care should be taken in interpreting results of these age years.

While it is recommended to use average of multiple blood pressure measurements taken for weeks to months to characterize individual's blood pressure level, high cost, limited resources and time restricted the authors from doing so. However studies on effect of sequential blood pressure reading in normal and hypertensive adults have indicated that the difference between the subsequent BP

measurements depends on age, BMI and initial BP level(24,25). This may be the one of the reasons why no significant difference was observed between the first and second reading of BP in 275 young subjects of our study. But efficacy of single measurement protocol in young individuals needs to be established.

Even though the blood pressure measurements were measured as exact as possible there may be some digit preference in our data. This effect is unlikely to be large as reported in the previous studies(7,26). Blood pressure is also influenced by various other factors such as time of the day, ambience, fasting vs. non-fasting state of the subject etc., which could not be controlled in the study.

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