Heart rate variability and baroreflex sensitivity are reduced in chronically undernourished, but otherwise healthy, human subjects

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ABSTRACT
Alterations in autonomic nerve activity in subjects in a chronically undernourished state have been proposed, but have been inadequately documented. The present study evaluated heart rate and systolic blood pressure variability in the frequency domain in two underweight groups, one of which was undernourished and recruited from the lower socio-economic strata [underweight, undernourished (UW/UN); n = 15], while the other was from a high class of socio-economic background [underweight, well nourished (UW/WN); n = 17], as well as in normal-weight controls [normal weight, well nourished (NW/WN); n = 27]. Baroreflex sensitivity, which is a determinant of heart rate variability, was also assessed. The data indicate that total power (0–0.4 Hz), low-frequency power (0.04–0.15 Hz) and high-frequency power (0.15–0.4 Hz) of RR interval variability were significantly lower in the UW/UN subjects (P < 0.05) than in the NW/WN controls when expressed in absolute units, but not when the low- and high-frequency components were normalized for total power. Baroreflex sensitivity was similarly lower in the UW/UN group (P < 0.05). Heart rate variability parameters in the UW/WN group were generally between those of the UW/UN and NW/WN groups, but were not statistically different from either. The mechanisms that contribute to the observed differences between undernourished and normal-weight groups, and the implications of these differences, remain to be elucidated.

INTRODUCTION
The study of autonomic nerve activity in altered nutritional states has focused largely on obesity [1–4]. This has, in part, been fuelled by the putative involvement of enhanced sympathetic nerve activity in obesity-related cardiovascular disease, including hypertension [5], on the one hand, and the possible role of reduced sympathetic nerve activity in the genesis of obesity on the other [6].

In contrast with the wealth of literature on autonomic function and obesity, there is a paucity of data on thin individuals who are below the lower limit of the normal range of body mass index (BMI; kg/m²). In developing countries, these individuals constitute a large proportion of the general adult population [7]. In India, for instance, it has been estimated that close to 50% of the adult population has a BMI of less than 18.5 kg/m² [8].

Data on autonomic nerve activity in chronically undernourished individuals are limited. While the evidence for lowered sympathetic nerve activity in acute under-feeding experiments in animals [9,10] and humans [11] is strong, the data from chronically undernourished

Key words: autonomic nervous system, baroreflex, India, nutritional status.
Abbreviations: BMI, body mass index; PAL, physical activity level; SBP, systolic blood pressure; NW/WN, normal weight, well nourished; UW/UN, underweight, undernourished; UW/WN, underweight, well nourished.
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The advent of high-fidelity beat-to-beat blood pressure measuring devices, the development of mathematical techniques of assessing heart rate and blood pressure variability and the delineation of the physiological correlates of this variability has extended the ability of physiologists to investigate the autonomic control of the heart and blood vessels non-invasively [14,15]. In addition, heart rate variability measures predict morbidity and mortality in population studies in developed countries [16–19]. While there is a lack of heart rate variability studies in developing countries, a ‘J’-shaped relationship between morbidity/mortality and BMI, with an increase in both parameters in individuals of low BMI [7], has been described. Whether individuals from the low BMI category who are known to have increased morbidity and mortality also have reduced heart rate variability is presently unknown. The present study was, therefore, conducted to evaluate heart rate and systolic blood pressure (SBP) variability in undernourished but otherwise healthy subjects recruited from a low socio-economic stratum, and to compare these parameters with those of anthropometrically similar subjects from a higher socio-economic stratum (underweight group), as well as those of well nourished controls. In addition, we evaluated baroreflex sensitivity, since this is, in part, a determinant of heart rate variability [20].

MATERIALS AND METHODS

A total of 59 male subjects were recruited for the study from among the students of the Medical College, healthy subjects undergoing routine refractory examination at the Ophthalmology Department of the Medical College Hospital, and residents in residential areas, slums and villages close to the Medical College. Subjects with a history of recent noticeable weight gain or weight loss, diagnosed asthma, diabetes, hypertension or any other cardiovascular condition, on chronic medication, or with an alcohol consumption of greater than two standard drinks per day were excluded from the study. All subjects received an explanatory statement outlining the purpose of the study and the procedures involved, and gave written consent to the protocol, which was approved by the Ethics Review Committee of the institution.

The subjects were divided into three groups based on BMI cut-off values defined previously [7] for undernutrition as well as socio-economic status. Socio-economic status was defined using the modified Kuppuswamy urban socio-economic scale [21], with income categories updated for the current consumer price index. The Kuppuswamy scale uses weighted values for income, occupation and education to categorize individuals into five socio-economic classes. The control normal-weight, well nourished (NW/WN) subjects had BMIs of between 18.5 and 25 kg/m², and belonged to the upper three socio-economic classes. The underweight, undernourished (UW/UN) subjects had BMIs of less than 18.5 kg/m² and belonged to classes IV and V of the Kuppuswamy scale. A third group of underweight but well nourished (UW/WN) subjects were anthropometrically similar to the undernourished subjects (BMI < 18.5 kg/m²) but belonged to the upper three socio-economic classes. The UW/UN subjects were specifically recruited from the lower socio-economic strata, since earlier work has indicated that, in deprived populations, the use of BMI cut-offs results in only 5% of the population being wrongly classified as being undernourished when they are actually thin but active [22].

The experiments were conducted in the morning, with subjects in the fasted state. Subjects were asked to refrain from caffeinated beverages and cigarettes for at least 12 h prior to the experiment, and to complete their evening meal by 21.00 hours. The subjects spent the night prior to the experiment in the residential ward of the laboratory facility.

All subjects underwent an anthropometric assessment. This included measurement of height recorded to the nearest 0.1 cm using a stadiometer (Nivotise Brivete Depose), weight to the nearest 100 g (Soehnle Digital S, Murrhardt, Germany), mid-upper arm circumference and waist circumference. Skinfold thickness was also measured (Holtain calipers; Holtain, Crymmych, U.K.) as the mean of measurements at three sites (biceps, triceps and subscapular), and used to estimate percentage fat and fat-free mass using the age- and gender-specific equations of Durnin and Womersley [23].

Because physical activity is a confounding variable in measurements of autonomic nerve activity, we assessed levels of physical activity over the preceding 1 month using a physical activity questionnaire [24]. A composite index of the level of activity was computed as the physical activity level (PAL), which is the 24 h energy expenditure divided by the estimated basal metabolic rate. PAL cut-off values for grades of physical activity have been defined previously: < 1.4, sedentary; 1.55–1.6, moderately active; > 1.75, very active [25].

After instrumentation and a mandatory 30 min rest period, a continuous lead II ECG was obtained (Nihon Kohden RM-6000) for a duration of 10 min in a quiet room, during which the subject was awake, lay supine and breathed normally. Subjects were asked to avoid unnecessary movements during this period. In 52 subjects (24 NW/WN, 13 UW/UN and 15 UW/WN), beat-to-beat blood pressure recordings (Portapres) were obtained simultaneously. Four of the seven subjects from whom
recordings were not obtained had low-frequency oscillations, and of these two had thick calloused skin at the site of the pressure cuff. In the remaining three subjects, data were inadequate for analysis due to either movement artefacts or loss of the signal during recording. The data were subjected to the following analyses.

(1) Spectral analysis of heart rate and blood pressure variability. Briefly, as described previously [26], the data were digitized on-line at 1000 Hz using an IBM-compatible PC and a data acquisition package (CVMS; World Precision Instruments Inc., Sarasota, FL, U.S.A.) incorporating a signal manifold and a ClO-AD16Jr A/D card that was installed within the computer. The data acquisition system included a threshold peak detection from which RR intervals and beat-to-beat SBP were determined. Data segments of 128 s duration were sampled at 2 Hz to create 256-point data sets. For each 10 min recording, an average of eight data sets of 256 points overlapping by half were processed. The linear trend was removed from each data set to avoid its contribution to low-frequency power. A Hanning window was used to attenuate ‘spectral leakage’. Spectral analysis was performed using a Fast Fourier Transform. The frequency resolution was 0.0078 and the highest frequency evaluated was 0.4 Hz. The spectra obtained for the different data sets were averaged to reduce variance and to sharpen reproducible central peaks. Power was calculated in two bands. The 0.04–0.15 Hz band of RR power (referred to as the low-frequency band) is believed to reflect, at least in part, sympathetic nerve activity to the heart, while the 0.15–0.4 Hz band (high-frequency band) reflects parasympathetic nerve activity to the heart. The low-frequency component of SBP variability was expressed in absolute units, and is believed to reflect vasomotor sympathetic nerve activity [15]. In addition to the absolute power, data for heart rate variability are also presented as normalized units, as recommended [27], whereby the power in the two bands is expressed as a percentage of the total power minus the power of the very-low-frequency band (0.0–0.04 Hz).

(2) Baroreflex sensitivity (x coefficient) was determined from the spectral analysis of SBP and RR interval variability, as the squared ratio of RR and SBP power in the 0.07–0.14 Hz range [28]. Following the 10 min resting period measurements, subjects underwent standard autonomic function tests. The subjects did not receive prior training in the conduct of these tests. The tests included ‘timed deep breathing’, during which subjects were instructed to breathe maximally in (5 s) and out (5 s) for a total of six cycles. The maximal difference in heart rate during inspiration and expiration was computed for each cycle, and the average of these differences was used in the analysis. The immediate heart rate response to standing was computed as the 30:15 ratio, calculated as the ratio of longest RR interval around the 30th beat following standing to the shortest RR interval around the 15th beat. The Valsalva manoeuvre required the individual, after application of a noseclip, to blow into a mouthpiece attached to a sphygmomanometer, via a 1 litre glass bottle, so as to raise the pressure by 40 mmHg for 10 s. A large-bore needle was inserted into the tubing to ensure that pressure was not maintained merely through the use of cheek muscles. The Valsalva manoeuvre was performed twice for each subject. The Valsalva ratio was calculated as the ratio of the longest RR interval within 20 beats of the manoeuvre to the shortest RR interval during the manoeuvre. Manoeuvres that were performed inadequately were discarded; thus data were obtained for 14 UW/UN, 23 NW/WN and 16 UW/WN subjects. The highest Valsalva ratio was used in the analysis [29].

Statistical analysis was performed using SPSS for Windows (Version 10.1). Data are presented either as means ± S.D. when normally distributed, or as median (interquartile range) [30]. Comparisons between the three groups were carried out using the Kruskal-Wallis test for non-normally distributed data, followed by an independent Student’s t test (with the P value calculated for unequal variances, confirmed using Levene’s test) with a Bonferroni correction as the post hoc test. When the data were normally distributed, a one-way ANOVA with Scheffé as the post hoc test was used when variances between the groups were similar, while the Games-Howell test was used for unequal variances. Spectral data for heart rate and SBP variability are presented both before and after logarithmic transformation. The null hypothesis was rejected at P < 0.05.

RESULTS

Table 1 summarizes the characteristics of the study subjects. The mean height of the three study groups was comparable. All other anthropometric parameters, both primary as well as derived, including weight, BMI, mid-arm circumference, percentage fat, fat mass and fat-free mass, were significantly higher in the NW/WN group compared with both the UW/UN (low BMI; low socio-economic status) and the UW/WN (low BMI; high socio-economic status) groups (all P < 0.01). The two underweight groups were anthropometrically similar. The overall physical activity patterns in the three groups, as indicated by PAL, were comparable. Standard tests of autonomic nervous function, including the 30:15 ratio on standing, the change in heart rate with timed deep breathing and the Valsalva ratio, were similar across the study groups (all differences not significant).

Resting heart rate was similar across the groups (Table 2). The Kruskal-Wallis test indicated that the total power and absolute low- and high-frequency power of RR interval variability differed significantly between the
Table 1  Characteristics of the three study groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UW/UN</th>
<th>NW/WN</th>
<th>UW/WN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>15</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22 ± 3</td>
<td>22 ± 4</td>
<td>22 ± 3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.0 ± 7.0</td>
<td>169.7 ± 6.7</td>
<td>168.4 ± 7.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>45.9 ± 4.2</td>
<td>61.7 ± 6.8↑↑</td>
<td>49.4 ± 4.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.6 ± 0.9</td>
<td>21.4 ± 1.6↑↑</td>
<td>17.4 ± 0.8</td>
</tr>
<tr>
<td>Mid-upper-arm circumference (cm)</td>
<td>22.1 ± 1.9</td>
<td>26.1 ± 2.0↑↑</td>
<td>23.2 ± 1.7</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>11.1 ± 2.4</td>
<td>18.6 ± 4.6↑↑</td>
<td>13.5 ± 3.5</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>40.8 ± 3.3</td>
<td>50.0 ± 5.3↑↑</td>
<td>42.8 ± 4.7</td>
</tr>
<tr>
<td>PAL</td>
<td>5.1 ± 1.5</td>
<td>11.5 ± 3.4↑↑</td>
<td>6.7 ± 1.7</td>
</tr>
<tr>
<td>Immediate heart rate response to standing (30:15 ratio)</td>
<td>1.70 ± 0.30</td>
<td>1.70 ± 0.20</td>
<td>1.64 ± 0.2</td>
</tr>
<tr>
<td>Change in heart rate on timed deep breathing (beats/min)</td>
<td>34.3 ± 8.9</td>
<td>33.8 ± 8.0</td>
<td>35.3 ± 6.4</td>
</tr>
<tr>
<td>Valsalva ratio</td>
<td>1.69 ± 0.30 (n = 14)</td>
<td>1.78 ± 0.24 (n = 23)</td>
<td>1.68 ± 0.30 (n = 16)</td>
</tr>
</tbody>
</table>

Table 2  Comparison of resting heart rate variability, SBP variability and baroreflex sensitivity in the three study groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UW/UN</th>
<th>NW/WN</th>
<th>UW/WN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>15</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td>Resting heart rate (beats/min)</td>
<td>63 ± 7</td>
<td>64 ± 8</td>
<td>64 ± 8</td>
</tr>
<tr>
<td>LF power (0.04–0.15 Hz) (ms²)</td>
<td>666 (514–882)</td>
<td>1410 (650–1793)↑</td>
<td>856 (568–1352)</td>
</tr>
<tr>
<td>log(LF power)</td>
<td>2.82 ± 0.25</td>
<td>3.10 ± 0.37↑</td>
<td>2.91 ± 0.35</td>
</tr>
<tr>
<td>HF power (0.15–0.4 Hz) (ms²)</td>
<td>604 (351–1337)</td>
<td>1345 (834–3842)↑</td>
<td>869 (563–1495)</td>
</tr>
<tr>
<td>log(HF power)</td>
<td>2.81 ± 0.34</td>
<td>3.20 ± 0.47↑</td>
<td>2.97 ± 0.39</td>
</tr>
<tr>
<td>Total power (0–0.4 Hz) (ms²)</td>
<td>2218 (1839–2697)</td>
<td>4322 (2151–7072)↑</td>
<td>2906 (1635–3840)</td>
</tr>
<tr>
<td>log(total power)</td>
<td>3.30 ± 0.24</td>
<td>3.60 ± 0.37↑</td>
<td>3.41 ± 0.33</td>
</tr>
<tr>
<td>Normalized LF</td>
<td>54.9 ± 17.7</td>
<td>49.3 ± 21.4</td>
<td>50.1 ± 18.5</td>
</tr>
<tr>
<td>Normalized HF</td>
<td>52.7 ± 15.8</td>
<td>59.7 ± 17.7</td>
<td>55.9 ± 16.5</td>
</tr>
<tr>
<td>LF/HF ratio</td>
<td>1.27 ± 0.88</td>
<td>1.03 ± 0.95</td>
<td>1.11 ± 0.85</td>
</tr>
</tbody>
</table>

three groups (P = 0.013, 0.027 and 0.016 respectively). An independent Student's t test with the Bonferroni correction indicated that these three parameters were significantly lower in the UW/UN group than in the NW/WN group. On log-transforming the data, a one-way ANOVA indicated that there were significant differences across the groups in total power (P = 0.018), low-frequency power (P = 0.015), and high-frequency power (P = 0.015). The Games–Howell post hoc test indicated that specific differences existed between the NW/WN and UW/UN groups (total power, P = 0.004; low-frequency power, P = 0.015; high-frequency power, P = 0.009), but that there were no significant differences between the UW/WN group and the other two study groups. A ‘box and whiskers’ plot revealed that there were several ‘outliers’ in relation to heart rate variability...
parameters (Figure 1). While there was no reason to omit these data from the analyses, we performed secondary analyses without these subjects in order to determine whether these ‘outliers’ had skewed our interpretation of the data. The Kruskal-Wallis test continued to show significant differences across the groups (total power, $P = 0.02$; low-frequency power, $P = 0.036$; high-frequency power, $P = 0.037$), with significant differences between the UW/UN and NW/WN groups ($P < 0.05$). A one-way ANOVA with the log-transformed data without the outliers indicated that the between-group differences in total power were significant ($P = 0.04$; Games–Howell between UW/UN and NW/WN groups: $P = 0.032$), while the differences in low-frequency and high-frequency power were just short of statistical significance ($P = 0.054$ and $P = 0.053$ respectively). The heart rate variability parameters in the UW/WN group were intermediate between those of the NW/WN and UW/UN subjects, but were not statistically different from either.

In contrast with the changes in heart rate variability, low-frequency SBP variability was comparable across the three groups. The Kruskal-Wallis test indicated that baroreflex sensitivity, expressed as the $\rho$ coefficient, was significantly different across the groups ($P = 0.047$). An independent $t$ test with the Bonferroni correction showed a significant difference between the UW/UN and NW/WN groups ($P = 0.006$). The $\rho$ coefficient for the UW/WN group was, however, not different from that of either of the other groups.

## DISCUSSION

The data from the present study demonstrate that, in the main, total power and low- and high-frequency power of RR interval variability in absolute terms, as well as baroreflex sensitivity, are reduced in young undernourished subjects as compared with normal-weight controls. These differences were not related to differences in physical activity profiles, since levels of physical activity were similar in these two groups. The differences between the groups disappeared when the low- and high-frequency power spectra were normalized for total power. The interpretation of heart rate variability measures in the frequency domain, when expressed in absolute units as well as when normalized for total power, continues to be debated [31–33]. Normalization essentially controls for changes in total power, as occur during physiological manoeuvres such as postural changes [34]. In the light of continuing debate about the interpretation of heart rate variability measures in the frequency domain, the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology recommended that both absolute and normalized power be presented [27], which we have done. It has been suggested that normalized power describes a balance, rather than a modulation from individual limbs of the autonomic nervous system [35]. Our own data show no evidence of changes in sympathetic-vagal balance in chronically undernourished subjects using heart rate variability indices. Nor did the low-frequency power of SBP variability indicate any alteration in sympathetic vasomotor activity in the chronically undernourished group. We are unable, therefore, based on these data, to comment on changes in either arm of the autonomic nervous system in our chronically undernourished subjects. These data do not, however, discount the possibility of alterations in sympathetic nerve activity in regions other than the heart and blood vessels, which would need to be evaluated by other techniques, such as the regional noradrenaline spillover technique [36]. The UW/WN subjects, who were anthropometrically similar to the UW/UN group, but belonged to a higher socio-economic status, had heart rate variability parameters that were intermediate between those of the UW/UN and NW/WN groups, but were statistically not different from either.

The lack of differences in standard autonomic tests between the UW/UN and NW/WN subjects was surprising, given the significant differences in baroreflex sensitivity and the relationship between baroreflex sensitivity and cardiac vagal tone [37]. Part of the problem may be methodological; the Valsalva ratio in our study, for instance, was based on two rather than the recommended three measurements, and we utilized the maximum rather than the mean of the measurements [38], since our undernourished subjects, for whom the laboratory experience was unique, were unable to perform three adequate measurements. This would have increased the variance in our measures, making it more difficult to demonstrate subtle differences. The relatively small sample size in each group may also have
contributed. Finally, previous data, at least in subjects with diabetes, suggest that standard autonomic tests may be less sensitive to subtle changes in vagal tone than are measures of baroreflex sensitivity and heart rate variability [39].

In addition to providing information about autonomic function, heart rate variability measures in the frequency domain are also important because reduced total, low-frequency and high-frequency power are associated with cardiac and all-cause mortality in populations [16–19]. Since these values are lower in undernourished subjects, it would be interesting in prospective studies to establish the relationship between heart rate variability measures and mortality in developing countries, in which undernourished subjects constitute a significant proportion of the population. This is especially pertinent because causes of death in developing countries are likely to be very different from those in developed countries, from which the relationships between heart rate variability and mortality have been derived.

The observed decreases in the indices of non-normalized heart rate variability in the UW/UN group may be linked to many factors. Given that a large percentage of individuals with low BMIs in developing countries are undernourished, rather than constitutionally thin or just more physically active, there is a possibility that nutrient deficiencies may have contributed to the decrease in heart rate variability. In this context, frank vitamin B12 deficiency associated with pernicious anaemia has been linked to lowered heart rate variability (both sympathetic and parasympathetic nerve components) [40,41], which is reversed by vitamin B12 supplementation [41]. The effects of more subtle changes in vitamin B12 status, as well as those of other micro-nutrients, on heart rate variability has been largely unexplored, as has the prevalence of various micro-nutrient deficiencies in developing countries. The state of function of adult undernourished subjects may also reflect changes that have occurred due to nutritional deficiencies in utero. In this context, there is evidence from animal models that prenatal undernutrition decreases sympathetic innervation in the long term, at least in the gut [42]. An alternative explanation is that hormonal changes associated with chronic undernutrition may, in part, affect autonomic nerve output. Energy restriction, for instance, is associated with a reduction in 3,3',5-triiodothyronine levels [43,44]. Hypothyroidism is associated with a reduction in total power, a decrease in normalized high-frequency power and an increase in normalized low-frequency power, which are reversed by treatment [45]. In addition, a decrease in baroreflex sensitivity has been shown in hypothyroid rats [46], and a reduction in baroreflex sensitivity has been linked to a reduction in heart rate variability [20]. The interplay of subtle changes in the endocrine system could possibly explain some of the changes that we have seen in chronic undernutrition, although the present study did not specifically investigate this.

Are the changes that we have described essentially the same as those seen in conditions of acute weight loss? Changes in heart rate variability have indeed been documented in conditions of acute weight loss, although the results have been variable. Thus patients with anorexia nervosa have been described as having higher [47] as well as lower [48] heart rate variability measures than subjects of normal weight. In laboratory-based studies, a 10% experimental weight loss in human subjects was not associated with any change in heart rate variability, although the high-frequency component of heart rate power declined [49]. It is important, however, to note that acute weight loss, no matter how severe, is not analogous to chronic undernutrition. In chronic undernutrition, weight loss may, indeed, never have occurred; the low BMI of the individual is primarily the result of slower growth over a lifetime, which may or may not be interspersed with intermittent periods of weight loss related to illness. Several earlier studies support the notion that underweight but well nourished subjects and anthropometrically similar undernourished subjects, identified based on the criteria that we have used (BMI and socio-economic status), are physiologically distinct. For instance, basal metabolic rate adjusted for fat-free mass is significantly lower in undernourished subjects compared with underweight but well nourished subjects [50]. Similarly, increments in oxygen consumption following low doses of intravenous noradrenaline in undernourished subjects were statistically lower, and close to half the increment in underweight, well nourished subjects [51]. In both of these studies [50,51], the measurements in the underweight, well nourished subjects were no different from those of normal-weight controls. Blood pressure responses in underweight, well nourished subjects to intravenous infusions of noradrenaline were intermediate between those of normal-weight controls and undernourished subjects [52], while the SBP increment following physiological manoeuvres such as sustained hand grip was significantly higher in underweight, well nourished compared with undernourished subjects [53]. In the present study, measures of heart rate variability and baroreflex sensitivity were no different between our UW/UN and UW/WN subjects. This suggests that there is some value in adding socio-economic status to BMI for the classification of undernourished subjects, although some misclassification can clearly not be ruled out in the absence of other objective markers of the undernourished state.

In conclusion, the present study demonstrates that the total power, absolute low-frequency power and absolute high-frequency power of RR interval variability, as well as baroreflex sensitivity, were reduced in UW/UN subjects as compared with NW/WN controls. Normalized low- and high-frequency power, as well as the
low-frequency/high-frequency ratio, were no different between the two groups. The mechanisms of these changes and the functional implications remain to be elucidated.

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REFERENCES


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