Mal J Nutr 17(1): 43 - 53, 2011

Assessing the Resting Energy Expenditure of Cancer Patients in the Penang General Hospital

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ABSTRACT

Introduction: Malnutrition is common in cancer patients. Generally, it is believed that the resting energy expenditure (REE) is elevated in cancer patients and this contributes to the development of malnutrition. Thus, to be able to assess the REE is important in planning adequate nutrition support. **Methods:** A cross-sectional study was carried out to assess the REE in patients with solid tumour (n=25), leukemia (n=25) and healthy subjects (n=50) by using the indirect calorimetry method under standard conditions. **Results:** There was no significant difference between the measured REE among patients with solid tumour, leukemia and the control group (*p*=0.534). By contrast, there was a significant difference between the REE / kg FFM in solid tumour patients compared to the leukemia group and the healthy subjects, (*p*=0.049 and *p*=0.002). The REE derived from the Harris Benedict Equation was found to be significantly higher than the measured REE. The stress factor for patients with solid tumour was 1.35 and that for leukemia patients was 1.36. **Conclusion:** The REE / kg FFM in the cancer patients undergoing anticancer therapy appeared to be higher than expected compared to healthy subjects. The Harris Benedict Equation (HBE) was found to over-estimate the REE of cancer patients in the study. As the total energy expenditure (TEE) is estimated by multiplying the REE with the stress factor and physical activity factor, the overestimated REE from HBE will further increase the risk of overfeeding in this population.

Keywords: Cancer patients, resting energy expenditure

INTRODUCTION

Weight loss and protein-calorie malnutrition (PCM) are common problems in cancer patients (Hammerlid *et al*., 1998; Ravasco *et al*., 2003). More than 50% of cancer patients developed malnutrition and 20% of them died from malnutrition rather than malignancy (Argiles, 2005). Malnutrition reduces the quality of life, survival rates and oncologic outcome in cancer patients. Malnourished cancer patients are usually unable to tolerate anticancer therapy and are associated with higher morbidity and mortality (Federico, 2009; Lainscak, Podbregar & Anker, 2007).

The resting energy expenditure (REE) is believed to be elevated in cancer patients contributing to the development of malnutrition. While some studies did not find a significant difference in the REE between cancer patients and control subjects, even after adjustment for fat free mass (FFM) (Reeves *et al*., 2006; Fredrix *et al*., 1991), others, however, showed significant elevation in the REE of patients (Batterham

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& Edwards, 2006; Jatoi *et al.*, 2001). Those studies were carried out in Caucasian populations, and in recent years, two studies conducted in China have found no significant difference in the REE between cancer patients and the control subjects (Wu *et al.*, 2008; Cao *et al.*, 2010). However, these Chinese studies showed elevated REE levels in the cancer group when adjusted for FFM to the REE.

In general, the REE contributes about 60-70% to total energy expenditure (TEE) in normal individuals. The other components of the TEE come from energy needed for metabolic stress and physical activities. In practice, the TEE is estimated by multiplying REE with the stress factor and the physical activity factor (Reeves & Capra, 2003; Siervo, Boschi & Falconi, 2003).

The metabolic stress among cancer patients varies according to the types and stages of cancers (Elia, 2005). This has led to difficulty in estimating the stress factor in clinical practice resulting in inaccurate estimation of the TEE (Green, Smith & Whelan, 2007; Reeves & Capra, 2003). In order to improve the estimation of the REE and TEE values, various methods have been utilised. However, indirect calorimetry remains the gold standard in the measurement of the TEE and the REE values (Schoeller, 2007; Haugen, Chan & Li, 2007). In recent years, indirect calorimetry has become more precise, portable, rapid, affordable and available in clinical settings (Dale, 2007) and this will provide a better estimation of the REE and TEE values.

The aim of this study was to measure and compare the REE in patients with solid tumour and leukemia with control subjects using a portable Indirect Calorimeter (CardioCoach, Model 9001-RMR, from KORR Medical Technologies Inc). Based on the data obtained, disease specific stress factors can be calculated. The result can be applied in the Harris Benedict Equation (HBE) which is helpful for estimating the TEE (Reeves & Capra, 2003).

METHODS

Participants

Twenty five patients with solid tumour and 25 leukemia patients aged 18- 60 years with body mass index (BMI) of 18.5 to 25.0 kg / m^2, who had been admitted to the Oncology and Hematology Ward, Penang General Hospital, from December 2009 to April 2010, were randomly chosen for the study. A list of eligible oncology patients who fulfilled the above inclusion criteria were obtained from the wards. One of every 5 patients was randomly chosen from among those with tumour, and likewise from among the leukemia patients, until the required numbers were obtained.

Patients with breast, prostate and brain cancer were excluded from this study due to significantly higher REE values in this group of patients (Platz, 2002, Demark-Wahnefried *et al.*, 2001). Besides, patients who had undergone surgery within one month prior to the study, had hypo / hyperthyroidism, were on ventilator or enteral feeding, dialysis and who were treated with steroids or morphine were also excluded from this study. These exclusion criteria were set as these conditions and treatments have independent effects on energy expenditure.

Between April to June 2010, 50 healthy volunteers were recruited as control subjects. They were in good health based on self-report, had no surgery in the past one month prior to the study and not on steroid medications. They were matched with the cancer patients for sex and ethnicity. Also, the healthy volunteers were matched to the cancer patients for age within ±10 years, body weight ± 10 kg and having BMI within the normal range of 18.5 to 25 kg / m^2.

Measurement protocol

Measurements were taken for the cancer patients and healthy subjects under a standard protocol. For each subject, height without shoes was measured to the nearest 0.1 cm and weight was measured to the

nearest 0.1 kg with light cloth, without shoes by using the Detecto, USA, weighing scale.

The REE and TEE were measured by breathing through a tube with a mouse piece and nose clip connected to an Indirect Calorimetry (CardioCoach, Model 9001-RMR, from KORR Medical Technologies Inc). The measurements were taken between 6-9 a.m. after 30 minutes rest in bed at room temperature after an overnight fasting of 10-12 hours. The subjects were measured for 12 minutes. The steady state period was determined by a computer software and was defined as a 3-minute period. Besides, the device was auto- calibrated for 3 minutes before each test. After the measurement, the device provided the reading of TEE, REE, respiratory quotient (RQ), volume of oxygen consumption (VO2) and the carbon dioxide production (VCO2).

The fat free mass of the subjects was also auto estimated by the Indirect Calorimetry. A previous study had shown that a proprietary algorithm using a handheld Indirect Calorimetry appeared to be accurate and reliable in assessing the FFM (McDoniel *et al.*, 2009). The estimated FFM was taken directly from the Indirect Calorimetry without measuring the FFM by dual-energy X-ray absorptiometry (DEXA) or bioelectrical impedance (BIA).

The nutritional status of the cancer and healthy subjects was determined using the Subjective Global Assessment (SGA), which categories people into well nourished (A), at risk of malnutrition or moderately malnourished (B), or severely malnourished (C) (Detsky *et al.*, 1987).

Predicted REE by Harris Benedict Equation and stress factor

The predicted REE (pREE) was calculated from the Harris Benedict equation (Harris & Benedict, 1919) for both groups as follows:

REE Male = 66.47 + 13.75 x wt + 5.0 x ht – 6.75 x age

REE Female = 655.09 +9.56 x wt + 1.84 x ht – 4.67 x age

where REE represents Resting Energy Expenditure in kcal / day, wt represents weight in kilogram, ht represents height in centimeter.

The stress factor was calculated according to Long *et al.* (1979) by dividing the TEE by the pREE from the HBE. To compare the stress factor measured from IC and stress factor derived from HBE, the TEE was divided by measured REE (TEE / mREE) from the IC and compared to the TEE / pREE from HBE. Generally, the TEE consists of two components: the metabolic rate and physical activity (PA) factor. It is calculated as REE multiplied by stress factor and physical activity (PA) factor. The PA factor for estimating the TEE is fixed at 1.0 for sedentary subjects (no exercise); 1.11-1.12 for low active subjects; 1.25-1.27 for active subjects and 1.45-1.48 for very active subjects. In this study, the PA was taken as 1.0 (as all the patients were rested on the bed) (Smolin & Grosvenor, 2008).

Statistical analysis

Statistical analysis was performed using SPSS version 16.0 (SPSS Inc., Chicago, USA), a statistical software package for windows. Data was shown as mean ±S.D. and statistical significant defined as $p<0.05$. Data was analysed by using one way ANOVA to compare weight, height, BMI and FFM and age among the patients with solid tumour, leukemia and the control group. Paired *t*-test was used to compare the mean difference between the pREE (from HBE) to mREE. The Pearson correlation coefficient was used to examine the relations between age, weight, height, BMI and FFM and the measured REE. Stepwise linear regression model was used to derive regression equation for the REE values in all the subjects.

Ethical approval

This study was approved by Clinical Research Center (CRC) (Reference no. being NMRR-09-762-4575) and Medical Research Ethics Committee (MREC) of Ministry of

Table 1. Demographics of the solid tumor, leukemia and control group

	Solid tumour (n=25)	*Leukemia (n=25)*	*Control (n=50)*	*p value*
Age, years	43.5±12.3	35.8±12.0	39.7±13.5	p=0.111 [a]
Gender, Male: Female	12:13	9:16	21:29	p=0.832 [b]
Ethnic, Malay: Chinese: Indian	9 :13:3	15:7 :3	23:22:5	p=0.485 [b]
Weight, kg	55.4±9.0	55.1±8.6	59.6±8.2	p=0.043 [a]
Height, cm	158.2±8.9	158.0±9.2	162.8±7.7	p=0.025 [a]
BMI, kg / m^2	22.0±1.9	22.0±2.2	22.4±2.0	p=0.556 [a]
FFM, kg	29.1±7.3	27.4±7.1	34.0±10.5	p=0.006[a]
Weight status				
weight gain	12	5	5	-
weight stable	6	14	42	-
5% weight loss	4	6	3	-
>5% weight loss	3	0	0	-
SGA				
Well nourished (A)	13	17	49	-
Moderately malnourished (B)	10	8	1	-
Severely malnourished ©	2	0	0	-

Data are shown as mean ±SD
[a] One Way ANOVA test
[b] Pearson Chi-Square test
BMI: Body Mass Index; FFM: Fat Free Mass; SGA: Subjective Global Assessment

Health Malaysia in November 2009. A consent form was signed by each subject prior to commencement of any data collection.

RESULTS

Subject characteristics

Twenty-five patients with solid tumour, 25 leukemia patients and 50 control subjects were recruited for the study from December 2009 to June 2010 in Penang Hospital. Patients with solid tumor consisted of 17 patients with tumour of the colon, 3 with germ cell and 5 other tumours (thymoma, cervix, stomach, nasopharyngeal carcinoma and lung). Six of the patients had metastases while 3 were relapse cases.

In the case of leukemia patients, 8 had Non Hodgkin Leukemia (NHL), 7 Acute Lymphoblastic Leukemia (ALL), 6 Acute Myeloid Leukemia (AML), 2 Chronic Myeloid Leukemia (CML) and 2 Acute Promyelocytic Leukemia (APML). Of these patients, 7 had metastases but none were relapse cases. All the patients with solid tumour and leukemia were undergoing chemotherapy or / and radiotherapy at the time of the study.

Table 1 shows the demographics of these subjects. One way ANOVA test showed a significant difference in weight (p=0.043), height (p=0.025) and FFM (p=0.006) for leukemia patients, patients with solid tumour and the control subjects. The Turkey HSD Post Hoc comparison showed that the FFM for leukemia patients were significantly different from the control subjects (p=0.010) and the patients with solid tumours were not significantly different from either the leukemia patients (p=0.78) or the control subjects (p=0.073).

Since all the patients were on treatment (radiotherapy and / or chemotherapy), more patients reported weight gain (34%) or stable weight (48%) than weight loss (12% lost less

Table 2. Comparison measured REE and REE/FFM in solid tumour, leukemia and control group

	Solid tumour (n=25)	*Leukemia (n=25)*	*Control (n=50)*	*p value*
Measured REE	1014±178	1062±143	1059±191	p=0.534[a]
Measured REE / FFM	36.7±10.5	40.3±7.1	33.2±7.8	p=0.003[a]

[a] One way ANOVA
mREE: measured Resting Energy Expenditure; FFM: Fat Free Mass

Table 3. Correlation coefficient between age, weight, height, BMI and FFM to mREE for all subjects (n=100)

Variable	*Correlation coefficient, mREE*	*p value*
Age, y	-0.456	**
Weight, kg	0.692	**
Height, cm	0.638	**
BMI, kg / m^2	0.410	**
FFM, kg	0.621	**

** p< 0.01
BMI: Body Mass Index; FFM: Fat Free Mass

than 5% body weight and 6% lost more than 5% of body weight).

The nutritional assessment of these patients indicated that only 2 (4%) patients were severely malnourished.

REE in solid tumor, leukemia and control group

Table 2 shows a comparison of REE among the patients with solid tumour and leukemia and the control subjects. There was no significant difference in mREE in the patients with solid tumour, leukemia and control subjects. However, there were significant differences in mREE / FFM between the groups. The Tukey HSD Post Hoc showed that the mean REE / FFM of the leukemia patients was significantly different from that of the control subjects (p=0.002), and between the patients with solid tumour and the control subjects (p=0.049). However, there was no significant difference between the patients with solid tumour and leukemia.

Predicted REE from HBE and mREE

The mean pREE from HBE for patients with solid tumour was 1324±190 kcal / day, and 1345±148 kcal / day and 1389 ± 149 kcal / day respectively for the leukemia patients and the control subjects. The mean differences between pREE and mREE in these three groups were 310 ± 90 kcal / day, 283 ± 64 kcal / day and 330 ± 96 kcal / day, respectively. The paired *t*-test showed that the pREE was significantly higher than mREE for these three groups.

Relationship between patient's demographic data and the mREE

The relationships between age, weight, height, BMI and FFM to mREE are shown in Table 3. The mREE was negatively correlated with age but positively correlated with weight, height, BMI and FFM. Stepwise linear regression showed that only sex and body weight affected the mREE and pREE.

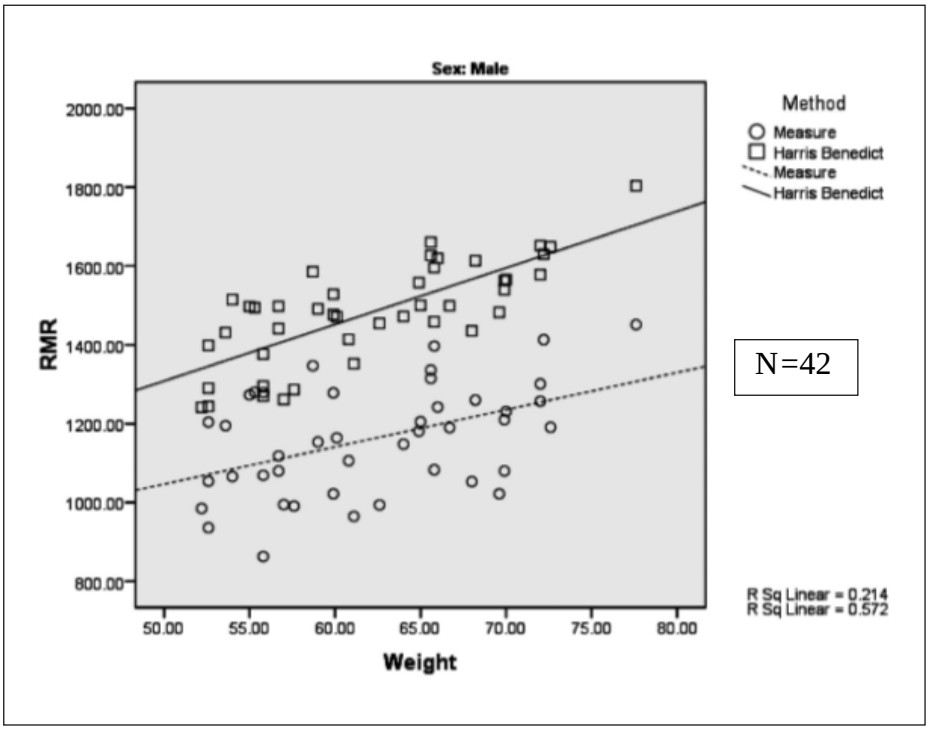

Figure 1. Comparison between mREE and pREE by Harris Benedict Equation in males

The formula derived from the stepwise linear regression based on sex and weight for all subjects (n=100) are as follows:

Males (Figure 1):
pREE = 1266 + 14.35 (weight) (R Square = 0.572)
mREE = 1089 + 9.43 (weight0 (R square = 0.214)

Females (Figure 2):
pRMR = 956 + 11.22 (weight) (R Square = 0.650)
mRMR = 643 + 10.85 (weight) (R square = 0.415)

Both Figures 1 and 2 showed that the pREE values were significantly higher than the mREE for all the subjects (cancer patients and control). The stress factor from pREE was lower than the stress factor from mREE for patients with solid tumour and leukemia (Table 4).

DISCUSSION

The alterations of metabolic stress and energy expenditure in cancer patients, facing weight loss and undergoing anticancer therapy, are unpredictable. It is important to determine the metabolic patterns and energy expenditure levels of cancer patients in order to accurately estimate their nutrition requirements. Several studies have been carried out to compare the REE among cancer patients and a healthy control group. A few studies observed elevated REE (Staal-van den Brekel *et al.*, 1997; Jatoi *et al.*, 2001), while others found no change in the REE in cancer patients (Nixon *et al.*, 1988; Reeves *et al.*, 2006). Furthermore, there is limited information about the REE levels in Malaysian cancer patients probably due to the unavailability of Indirect Calorimetry.

This study found similar results as those of Cao *et al.* (2010) where there were no

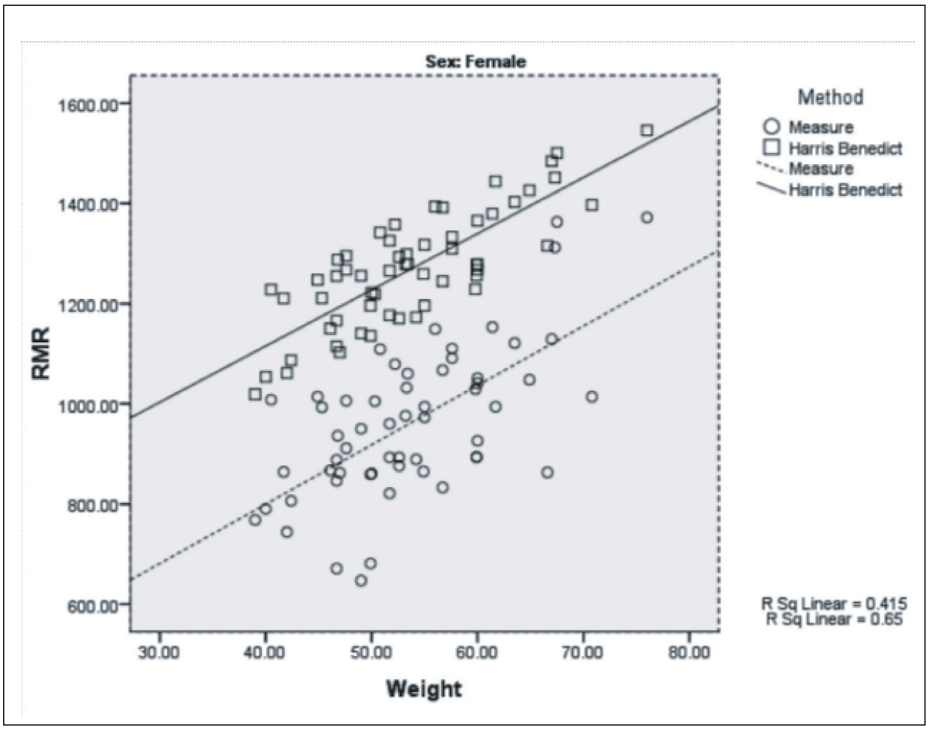

Figure 2. Comparison between mREE and pREE by Harris Benedict Equation in females

Table 4. Stress factor for solid tumour and leukemia patients

Diagnosis	*n*	*TEE*	*pREE*	*mREE*	*TEE/pREE*	*TEE/mREE*
Solid tumour	25	1364±227	1324±190	1014±178	1.03±0.1[a]	1.35±0.2[a]
Leukemia	25	1442±207	1345 ±148	1062±143	1.07±0.9[a]	1.36±0.1[a]

[a]Mann Whitney test, TEE / pREE: p >0.05 and TEE / mREE: p>0.05
pREE : predicted Resting Energy Expenditure from Harris Benedict Equation; mREE: measured Resting Energy Expenditure; TEE: Total Energy Expenditure;

significant differences in the mREE between cancer patients and controls. However, there were significant differences in the REE after adjustment for FFM between these two groups. FFM was the major factor determining the REE in the studies by Wu, Huang & Cai (2009) and Wang *et al* (2000). Johnstone *et al.* (2005) found that FFM contributed 63% of variance to the REE, 6% by fat mass and 2% in age between subjects. Both fat mass and age only significantly affect REE in very obese or elderly subjects (Johnstone *et al.*, 2005; Nelson *et al.*, 1992). Since this study used subjects with normal weight, thus the higher adjusted mREE in cancer patients (solid tumors and leukemia) showed that the cancer patients had relatively higher metabolic rates.

This study also found that the adjusted mREE in patients with leukemia and solid

tumour did not differ significantly. However, the adjusted REE appeared to be higher in patients with leukemia compared to patients with solid tumour. This was shown by the significant difference in the adjusted REE between leukemia patients and the control subjects, whereas the increased adjusted mREE in the patients with solid tumour was not significantly higher than that of the control. This might be due to the removal of the tumour in patients with solid tumor (Batterham & Edward, 2006). In this study, subjects who have undergone surgery within one month prior to study were excluded; however 68% of the solid tumour subjects were colon cancers and they had undergone colonectomy more than one month prior to the study. The tumour effect is not likely to persist for patients who had undergone the surgery.

In addition, our sample of cancer patients recruited was heterogeneous in terms of tumour site, stage, type of current treatment and previous weight loss. Minimal elevation of REE in this study might also be due to these heterogeneous features. This finding is supported by Cao *et al.* (2010) who found that patients in stage IV had higher mREE / FFM than those in stages I, II and III. They also found that patients with esophageal cancer, gastric cancer, pancreatic cancer and non small cell lung cancer had higher mREE / FFM than those with colorectal cancer.

TEE is usually higher than REE and the difference is contributed by the energy required for stress and activity. In practice, the TEE is estimated by multiplying REE with stress factor and activity factor (Reeves & Capra, 2003; Siervo *et al.*, 2003). The use of stress factor to account for hyper-metabolism has been widely adopted and is currently in use in many centres. However, the result of the current review indicated that this method of TEE estimation is probably inaccurate.

Currently available nomogram for the stress factor that was used to estimate TEE is derived from the pREE using HBE. The pREE from HBE was significantly higher than the measured REE. Therefore, the stress factor estimated from TEE / pREE was found to be lower than the stress factor calculated from TEE / mREE.

The stress factor for patients with solid tumour estimated using TEE / mREE was 1.35 and 1.36 for the leukemia patients. This finding is slightly higher compared to that found by Barak, Wall-Alonso & Sitrin (2002). These authors found the stress factor in the leukemia group to be 1.25 and 1.20 in patients with solid tumour which means that it was 25% and 20% more than the REE for patients with leukemia and solid tumour respectively. As the activity factor was assumed at 1.0, the increase in stress factor could be due to the increase in metabolic rate. The higher stress factor in this study might be due to the individual's metabolic rate and physical activity in these two groups of subjects. Since the physical activity level was assumed to be 1.0, the elevation of the stress factor could be contributed by the increase in metabolic rate.

CONCLUSION

In this study, cancer patients had an elevated resting energy expenditure (REE) compared to healthy subjects. Patients with leukemia had higher mean REE values compared to patients with solid tumour. The Harris Benedict Equation (HBE) is found to have overestimated the REE of the subjects. By adjusting for the stress factor in the HBE, the risk of overfeeding is further increased. It is recommended that a revised predictive equation appropriate for Malaysian cancer patients and a new nomogram for stress factor be developed to increase the accuracy of assessing their REE and total energy expenditure (TEE) values.

LIMITATIONS OF THE STUDY

This study was limited by a small sample size; therefore the findings cannot be generalised to represent the cancer patients

in Malaysia. In addition, the subjects of this study were heterogeneous in term of the tumour site, stage, type of current treatment and previous weight loss. Studies using a large sample size and homogenous subjects in terms of tumour site, stage, type of current treatment and previous weight loss are recommended to generate more accurate predictions of the stress factor.

ACKNOWLEDGEMENTS

The authors would like to thank the cancer patients and the healthy subjects for their willingness to participate in the study; the doctors and nursing staff from Penang Hospital for assisting us in data collection and the statisticians from the School of Pharmaceutical Sciences and Penang Hospital for the data analysis.

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