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ARAŞTIRMA / RESEARCH

Comparison of energy consumptions measured by metabolic monitor with standard equations in intensive care patients

Yoğun bakım hastalarında metabolik monitör ile ölçülen enerji tüketiminin standart denklemlerle karşılaştırılması

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Abstract

Purpose: The aim of this study was to determine parameters affecting the energy consumption in intensive care patients, and the most reliable formulas for calculation of energy consumption.
Materials and Methods: This prospective study was carried out in the intensive care unit of the Internal Medicine Department of Çukurova University Hospital. Total 71 patients above 18 years of age, with hemodynamical and respirational stability, and being followed up on a mechanical ventilator for more than 24 hours, were included to this study. We analyzed the correlation of calculated energy consumption values obtained from formulas, with the energy consumption values measured by indirect calorimeter.
Results: The study was executed on 71 patients. The mean energy consumption of the patients was 2078±794 kcal and the mean energy need per kilogram was found as 31.64±13.82 kcal. Indirect calorimeter measurements showed the strongest correlation with Swinamer formula.
Conclusion: Indirect calorimetry has become not only a "gold standard" but an "achievable gold standard" in determining energy consumption. We recommend that the indirect calorimeter method should be used in intensive care patients to maintain nutrition properly. Under conditions where indirect calorimeter cannot be used, or it is not desirable to wait for 24 hours; feeding can be started according to the results of a 2-hour measurement, or reliable predictive equations.

Keywords: Nutritional support, indirect calorimetry, malnutrition, intensive care unit

Öz

Amaç: Bu çalışmda yoğun bakım hastalarında enerji tüketimini etkileyen parametreleri ve enerji tüketiminin hesaplanması için en güvenilir formüllerin belirlenmesi amaçlanmıştır.
Gereç ve Yöntem: Bu prospektif çalışma Çukurova Üniversitesi Hastanesi İç Hastalıkları Anabilim Dalı yoğun bakım ünitesinde yapıldı. Çalışmaya, hemodinamik ve solunum stabilitesi olan, mekanik ventilatörde 24 saatten fazla izlenen 18 yaş üstü toplam 71 hasta dahil edildi. Formüllerden elde edilen hesaplanan enerji tüketim değerlerinin, indirekt kalorimetre ile ölçülen enerji tüketim değerleri ile korelasyonunu inceledik.
Bulgular: Çalışma 71 hasta üzerinde gerçekleştirildi. Hastaların ortalama enerji tüketimi 2078 ± 794 kcal ve kilogram başına ortalama enerji ihtiyacı 31.64 ± 13.82 kcal olarak bulundu. İndirekt kalorimetre ölçümleri Swinamer formülü ile en güçlü korelasyonu gösterdi.
Sonuç: İndirekt kalorimetri, enerji tüketiminin belirlenmesinde sadece "altın standart" değil, "ulaşılabilir altın standart" haline geldi. Yoğun bakım hastalarında beslenmenin doğru şekilde sürdürülmesi için indirekt kalorimetre yönteminin kullanılmasını öneriyoruz. İndirekt kalorimetrenin kullanılamadığı veya 24 saat beklemenin istenmediği koşullar altında; 2 saatlik bir ölçümün sonuçlarına göre veya güvenilir tahmin denklemlerine göre besleme başlatılabilir.

Anahtar kelimeler: Beslenme desteği, indirekt kalorimetre, yetersiz beslenme, yoğun bakım ünitesi

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INTRODUCTION

Malnutrition is a common problem in intensive care patients[1,2]. In intensive care patients, malnutrition is associated with various problems such as prolonged hospitalization and increased healthcare costs in patients[3,4]. Underestimation of energy need may lead to disruption of the tissue functions and repair capability, and immune system. It may also prolong the length of hospitalization or post-op follow-up period, significantly[3,5,6]. Calculating energy consumption more than the needs of patients, or feeding patients more than they need may also cause various problems. Complications of over feeding, including prolonged stay in the mechanical ventilator, hyperglycemia, hepatic dysfunction, delayed surgical wound healing, suture and anastomosis complications, hyperosmolar condition, azotemia, difficulty weaning, and immune system disorders have been reported[7,8].

Energy consumption can be measured by direct and indirect calorimetry, as well as calculated by various formulas. The indirect calorimetry method has been accepted as the gold standard in determination of energy consumption[9]. Despite its status as the gold standard, indirect calorimetry is not yet widely used due to the long measurement time, its standardization problems and lack of coverage by some health insurances[10]. Therefore, standard (predictive) formulas are frequently used in clinics for the prediction of energy consumption. However, these formulas were created by the studies on healthy people. Therefore, it is thought that these calculations may be wrong in patients, whose energy needs are significantly increase (e.g. intensive care patients). Only a few formulas have been studied on patients on the ventilator[11,12]. Since the superiority of the formulas cannot be clearly determined in the previous studies, there is not an established consensus on which formula is the most useful[2].

In our study, we compared the energy consumptions measured by indirect calorimetry (metabolic monitor) and calculated by standard formulas. We made our measurements and calculation in intensive care patients, who were intubated and followed on mechanical ventilator. We aimed to determine which parameters will affect the energy consumption in intensive care patients, and which formula is the most reliable among the current energy consumption measurement formulas.

MATERIALS AND METHODS

This prospective study was carried out in the intensive care unit (ICU) of the Internal Medicine Department of a university hospital, between 2013-2014. Approval for the study was granted by the Local Ethics Committee of Çukurova University Medicine Faculty (decision no: 27, dated: 03/01/2014). Informed consent was obtained from all patients or their legal guardians.

After the permission of the ethics committee, 71 patients above 18 years of age, with hemodynamical and respirational stability, and being followed up on a mechanical ventilator for more than 24 hours, were included to this study. The patients who had respiratory quotient (RQ) values outside the physiological limits, received more than 0.25 mcg/kg/min of noradrenaline or 20 mcg/kg/ min of dopamine, without 24 hours of measurement due to extubation or death, had pneumonectomy, or had fractional inspired oxygen (Fi02) ≥ 55%, positive end expiratory pressure (PEEP) ≥20 mbar, respiratory rate ≥ 35/minute during admission or follow-up, were excluded. Of patients, 21 were excluded from the study due to death and 18 were excluded because of extubation. Furthermore, 12 patients were set to FiO2 > 60% or respiratory rate ≥ 35/minute during measurement, and were excluded from this study. Of patients, 7 were excluded due to their RQ rate outside physiological limits (<0.7 or> 1.3). Finally, 2 patients were excluded from the study because of the insertion of a thorax tube.

Measurements and calculations

Patients were inhaled under pressure or volume control, consistent with the cause of respiratory failure. Indirect calorimeter measurements were made with the E-COVX module with Datex-Ohmeda gas technology, which was attached to GE Carescape™ modular monitors for 24 hours continuously, following the stabilization of patients after connection to the ventilator. The naming of the modules is done in line with the measured parameters, namely "C" for end-tidal carbon dioxide (EtCO2), fractional inspired carbon dioxide (FiCO2) and nitrous oxide (N2O); "O" for FiO2, end-tidal oxygen (EtO2) and FiO2 / EtO2 difference; "V" for pressure, volumes, current and compliance, resistance; and "X" for O_2 consumption (VO_2) and carbon dioxide production (VCO2).

Measurement of energy consumption values in 2nd, 6th, 12th and 24th hours were recorded. All patients were measured by the same researcher according to the manufacturer's recommendations. During the measurement, there was no air leakage from the circuits except for the cases of obstruction and short-term tracheal aspiration attempts in the sampling tube.

Routine nursing care such as daily body care and position changes were performed in accordance with the general treatment principles. Age, height, body weight, ideal weight, body surface area (BSI) and body mass index (BMI) of patients, malnutrition status at the time of application according to British Association for Parenteral and Enteral Nutrition (BAPEN) malnutrition scale, type of nutrition, acute physiology and chronic health evaluation 2 (APACHE II) score within 24 hours of measurement, the sequential organ failure assessment (SOFA) and simplified acute physiology score 2 (SAPS II) scores, admission categories, energy consumptions in 2nd, 6th, 12th, and 24th hours (in kcal), RQ, VCO_2, VO_2 values, body temperature, minute ventilation, tidal volume, and breathing frequency were recorded[13-16]. At the time of admission; lactate, albumin, procalcitonin, brain natriuretic peptide (BNP), blood urea nitrogen (BUN), creatinine (Cr), magnesium (Mg), phosphate (P), neutrophil and lymphocyte percentages, and white blood cell count (WBC), hemoglobin (Hgb), hematocrit (Htc), platelet (Plt), mean platelet volume (MPV), red cell distribution width (RDW) and mean corpuscular volume (MCV) values were recorded.

All patients underwent sedation with fentanyl-propofol or fentanyl-midazolam with a Riker sedation score of 2-3 to adapt to the ventilator. After the clinical evaluation, nutritional support was provided by choosing the most appropriate way based on the European Society for Clinical Nutrition and Metabolism (ESPEN) intensive care nutrition guide. The amount of targeted calorie of nutritional support was achieved in three days[17]. Total parenteral nutrition was performed with ready-made commercial products or mixer prepared solutions, according to the patient's needs via a central catheter. For enteral feeding, ready-made standard commercial products (1ml / 1kcal) were delivered by nasogastric or nasojejunal tubes. Heights of patients were measured in the supine position. Body weights were measured and recorded using weight-measuring beds, after calibration. Patients were classified as underweight (BMI <19), normal weight (BMI = 19 to 24.9), overweight (BMI 25 to 29.9) and obese (BMI ≥ 30) according to their BMI values. In the weight calculation, Devine and Robinson formulas were used for men and women, respectively[13,14]. After obtaining of all parameters, energy consumption was calculated with Harris-Benedict, Owen, Mifflin - St Joir 1990, Obesity, Ireton-Jones specific to 1992 and 1997, Penn-State specific to 1998-2003 and 2010, Swinamer 1990, Brandi 1999, Faisy and Schofield 2003 formulas by using ideal and measured weights. Energy consumption values measured at the 2nd, 6th and 12th hours were compared with 24-hour measurements, by using Pearson correlation and Bland Altman analysis[18]. We also aimed to analyze the compliance of values obtained through formulas, with the energy consumption measured by an indirect calorimeter (measured energy consumption-MEC), by using Pearson correlation and Bland-Altman analysis.

Since "malnutrition" and "overfeeding" can be observed in patients, who received feeding according to the calculated energy consumption by using the predictive equations, the adequacy of these calculations was examined. Values obtained from standard formulas (calculated energy consumption-CEC) were divided by the MEC, and percentage values were presented. As stated in the previous literature, these ratios were divided into 3 groups, namely a ratio less than <80% was considered as "inadequate", ratios between 80% and 110% were considered "sufficient", a ratio more than <110% was considered as "high"[19].

Another research topic for our study was to evaluate the relationship between disease severity and energy consumption. Due to the multiple factors capable to affect energy consumption, the energy consumption for unit surface in patients was calculated by dividing the measured 24-hour average energy consumption value by BMI and BSA values. Then, these values were compared with APACHE II, SAPS II and SOFA scores, by using Pearson correlation.

Statistical analysis

Statistical analyzes were performed by using SPSS (version 18.0.0, July 30th 2009, SPSS Inc. Chicago. IL). The compliance of the CEC values with the MEC values was evaluated by Bland-Altman analysis. For Pearson correlation, a p value of <0.05 was considered statistically significant. For Bland-Altman analysis, a p value of <0.001 was considered statistically significant. Frequencies of CEC:MEC ratio groups, namely <80%, 80-110%, > 110%, were presented. Continuous variables were presented as mean ± standard deviation (SD).

RESULTS

The study was executed on 71 patients. Of these patients, n = 26 (36.3%) were female, n = 45 (63.4%) were male. Patients were aged between 19 and 88, with a mean age of 60.35± 18.00. The mean body mass index value was calculated as 24.25±5.09 kg/m2, ranging between 13.60 and 45 kg/m^2. The mean body surface area of patients was found as 1.76±0.22, ranging between 1,38-2,35 m^2. The mean APACHE II, SOFA and SAPS II scores were calculated as 22.32±7.44, 10.45±3.79 and 52.25±16.93, respectively (Table 1). The majority of the patients (n=41; 57.7%) received parenteral nutrition, and a large fraction of the patients (n=43; 60.6) had malnutrition. Furthermore, an important fraction of patents (n=40, 56.3%) needed vasopressors. The most common reasons for hospitalization were related to either sepsis (without malignancy n=26; 36.6%, and with malignancy n=17; 23.9%) or septic shock (n=10; 14.1%) (Table 2).

Table 1. Demographic characteristics and clinical scores of the patients

Characteristic	Mean± Standard Deviation	Minimum-Maximum
Age (year)	60.35± 18.00	19-88
Height (cm)	167.38±7.68	152-185
Weight (kg)	68.28±16.56	38-130
BMI (kg/m2)	24.25±5.09	13.60-45
BSA (m2)	1.76±0.22	1.38-2.35
APACHE II	22.32±7.44	6-38
SOFA	10.45±3.79	3-18
SAPS II	52.25±16.93	15-99

BMI: Body mass index, BSA: Body surface area, APACHE II: Acute Physiology and Chronic Health Evaluation 2, SOFA: The Sequential Organ Failure Assessment, SAPS II: Simplified Acute Physiology Score 2.

Table 2. Patients characteristics on nutritional support, malnutrition and hospitalization

Characteristic	n	%
Nutritional support		
Enteral	30	42.3
Parenteral	41	57.7
Malnutrition		
Present	43	60.6
Absent	28	39.4
Need for vasopressors		
Present	40	56.3
Absent	31	43.7
Reason for hospitalization		
Sepsis without malignity	26	36.6
Sepsis with malignity	17	23.9
Septic shock with malignity	10	14.1
Acute renal failure	8	11.3
Amyotrophic Lateral Sclerosis& Respiratory Failure	3	4.2
Chronical liver disease	3	4.2
Hyponatremia	2	2.8
Thrombotic thrombocytopenic purpura	1	1.4
Peptic Ulcer Perforation	1	1.4

The measured laboratory values of the patients were summarized in Table 3. The mean energy consumption of the patients was measured as 2078 ± 794 kcal and the mean weight was found as 68.28 ± 16.56 kg. The mean energy need per kilogram was calculated as 31.6 ± 13.82 kcal. (Table 4) Measurements taken at 2nd, 6th, and 12th hours were compared with 24-hour measurements by using Pearson correlation analysis, and r values were 0.877, 0.877 and 0.899, respectively. The correlation of measured energy consumption values obtained from indirect calorimeter measurements, with values derived from standard formulas (calculated energy consumption) was examined. Indirect calorimeter measurements showed the strongest correlation with Swinamer formula (a significant positive moderate correlation, with p value of <0.001, and r value of 0.510), and weak to moderate correlations with the other standard formulas developed for calculation of energy consumption (r is ranging from 0.308 to 0.499, all p values are <0.05) (Table 5).

Table 3. Laboratory measurements of patients

Laboratory value	Mean± Standard Deviation	Minimum-Maximum
*Lactate (mmol/l)	2.70±1.56	0.40-8.40
Procalcitonin (ng/dl)	16.43±27.72	0.01-100
Albumin (gr/dl)	2.24±0.60	1-4.10
BNP (pg/ml)	13.837±13.838	59-35000
BUN (mg/dl)	41.5±35.7	3-239
Cr (mg/dl)	2.0±41.9	0.13-8.65
P (mg/dl)	4.6±1.94	1.40-10.10
Mg (mg/dl)	2.06 ±0.48	1.3-3.69
WBC (x1000/uL)	18.1± 30.8	0.1 - 252
Hgb(gr/dl)	9.7 ± 2.15	3.2-14.9
Htc (%)	29.48±6.3	15.5-44.1
Plt (x1000/uL):	*175 ±139*	*4 - 534*

BNP: Brain natriuretic peptide, BUN; Blood urea nitrogen, Cr: Creatinine, P: phosphorus, Mg: magnesium, WBC: White blood cell, Hgb: Hemoglobin, Htc: Hematocrit, Plt: Platelet; *Highest value in 24-hour measurement

Table 4. Measured and calculated energy consumption values of patients

Measurement or Calculation	Mean± Standard Deviation	Minimum-Maximum
Energy in 2hr (kcal/day)	2031±908	438-5959
Energy in 6hr (kcal/ day)	2108±930	647-5978
Energy in 12hr (kcal/ day)	2062±874	442-5206
Energy in 24hr (kcal/ day):	2078±794	665-5029
Harris-Benedict(M)	1790± 688	657-3474
Harris-Benedict (I)	1679±617	663-2748
Owen (M)	1544±184	1182-2205
Owen (I)	1482±112	1291-1690
Mifflin– St Joir 1990(M)	1489±205	971-2077
Mifflin– St Joir 1990(I)	1370±153	1036-1760
Ireton-Jones Obezite (M)	1907±575	840-2880
Ireton-Jones Obezite (I)	1873±544	841-2759
Ireton-Jones 1992(M)	1849±240	1305-2563
Ireton-Jones 1992(I)	1818±235	1312-2477
Ireton-Jones 1997 (M)	1622±241	1076-2292
Ireton-Jones 1997 (I)	1592±236	1083-2206
Schofield (M)	1571±245	1049-2364
Schofield(I)	1511±181	1215-1848
Faisy(M)	2011±364	1479-3862
Faisy(I)	1962±328	1500-3731
Penn-State 1998	2161±833	704-4216
Penn-State 2003	1731±340	1181-3139
Penn-State 2010	1857±404	1386-4371
Brandi	2343±758	842-4793
Swinamer	1237±328	615-2517

M: Calculation with measured weight, I: Calculation with ideal weight

Table 5. Correlation of energy consumption in 24-hour measurement with energy consumption calculated with measured (M) or ideal (I) weights

Energy consumption formula	p value	r value
Harris-Benedict (M)	p<0.001	0.425
Harris-Benedict (I)	p=0.001	0.395
Owen (M)	p=0.009	0.308
Owen (I)	p=0.009	0.310
Mifflin(M)	p=0.009	0.308
Mifflin(I)	p<0.001	0.415
Ireton-Jones Obezite (M)	p<0.001	0.435
Ireton-Jones Obezite (I)	p<0.001	0.415
Ireton-Jones 1992(M)	p<0.001	0.499
Ireton-Jones 1992 (I)	p<0.001	0.464
Ireton-Jones 1997 (M)	p<0.001	0.495
Ireton-Jones 1997 (I)	p<0.001	0.459
Schofield (M)	p=0.003	0.346
Schofield (I)	p=0.005	0.327
Faisy (M)	p<0.001	0.473
Faisy(I)	p<0.001	0.473
Swinamer	p<0.001	0.510
Brandi	P=0.002	0.362
Penn-State 1998	p<0.001	0.494
Penn-State 2003	p<0.001	0.447
Penn-State 2010	p<0.001	0.484

M: Calculation with measured weight, I: Calculation with ideal weight

The measured and calculated energy consumptions were compared by using the Bland Altman analysis with an average trend and 95% confidence interval. The mean differences of standard formula were ranged from -1876±788 to 707±743 (Table 6). The highest frequency of sufficiency in terms of MEC:CEC ratios was found in Owen formula (46.5%), calculated for ideal weight and multiplied with long factor 1.3. Owen formula was closely followed by Mifflin SJ (calculated for ideal weight and multiplied by x 1.3), Ireton Jones 1992 formulas (calculated for measured weight), with sufficiency frequencies of 43.7% and 43.7%, respectively (Table 7). The energy consumption measured by indirect calorimeter were compared among the groups with and without malnutrition, and there was no significant difference in energy consumption between these groups (p = 0.776, t = 0.286). Measured energy consumption was correlated with APACHE II, SAPS II and SOFA scores. No correlations were found with significant (p = 0.875, p = 0.162 and p = 0.683, respectively). Since there may be many factors that may affect the energy consumption, the energy consumption for the unit surface was calculated in each patient, by dividing the measured 24-hour energy consumption value by BMI and BSA values. Obtained values were correlated with APACHE II, SAPS II and SOFA scores; however, no significant correlation was found (p> 0.05). The diet types (enteral or parenteral) were compared for mean energy consumption, but there was no significant difference among diet types (p = 0.304, t = 1.035).

The mean energy consumptions of patients who received inotropic therapy and those who did not, were compared, and no significant difference was found (p = 0.596, t = -0.532). The correlations between procalcitonin, albumin, BNP and lactate values at admission, and energy consumption were examined, and these correlations were statistically not significant (p = 0.52, p = 0.536, p = 0.487, p = 0.622, respectively). In addition, relationships between the white blood cell count, hematocrit and platelet count of the patients at the time of admission, and the MEC were examined. MEC had a moderate correlation with the white blood cell count, but this correlation was statistically not significant (p=0.08, r=0.312). MEC value had no significant correlation with hematocrit and platelet values (p=0.565, and p=0.396, respectively). Finally, the correlations between thyroid function tests (TSH, fT4, fT3) and MEC were analyzed, and there was a significant weak negative correlation with TSH (p = 0.025, r = -0,267)

Table 6. Bland Altman analysis results for 24-hour energy consumption value and calculated energy consumptions

Standard Formula	**Mean Difference ± SD (CI 95%)**	**Upper Limit of Agreement (CI 95%)**	**Lower Limit of Agreement (CI 95%)**
HB(M)	287±799	1853	-1279.04
HB(I)	398±790	1946	-1150
HB(M) x 1.3	-249±909	1533	-2030.64
HB(M) x 1.6	-786±1048	1268	-2840.08
HB(I) x 1.3	-105±878	1616	-1825.88
HB(I) x 1.6	-609±993	1337	-2555.28
Owen (M)	533±757	2017	-950
Owen (I)	595±766	2096	-906
Owen (M) x 1.3	69±755	1549	-1410.8
Owen (M) x 1.6	-393±757	1091	-1876.72
Owen (I) x 1.3	151±761	1643	-1340.56
Owen (I) x 1.6	-1876±788	-332	-3420.48
Mifflin SJ.(M)	588±756	2070	-893.76
Mifflin SJ.(I)	707±743	2163	-749.28
Mifflin SJ.(M) x 1.3	142±755	1622	-1337.8
Mifflin SJ.(M) x 1.6	-304±760	1186	-1793.6
Mifflin SJ.(I) x 1.3	295±734	1734	-1143.64
Mifflin SJ.(I) x 1.6	-115±727	1310	-1539.92
Iret.J.Ob.(M)	202±1014	2189	-1785.44
Iret.J.Ob.(I)	237±1012	2221	-1746.52
Iret.J.Ob.(M) x1.3	-402±820	1205	-2009.2
Iret.J.Ob.(M) x1.6	-974±918	825	-2773.28
Iret.J.Ob.(I) x1.3	-356±815	1241	-1953.4
Iret.J.Ob.(I) x1.6	-918±902	850	-2685.92
Iret.J.92(M)	260±946	2114	-1594.16
Iret.J.92(I)	291±957	2167	-1584.72
Iret.J.92(M) x1.3	-325±693	1033	-1683.28
Iret.J.92(M) x1.6	-880±688	468	-2228.48
Iret.J.92(I) x1.3	-286±706	1098	-1669.76
Iret.J.92(I) x1.6	-831±703	547	-2208.88

HB: Harris-Benedict, MifflinSJ: Mifflin–St Joir 1990, Iret.J: Ireton-Jones, Ob:Obesity
M: Calculation with measured weight, I: Calculation with ideal weight

Table 7. The frequencies of measured and calculate energy consumptions ratios

Standart Formula	Insufficient (%)	Sufficient (%)	High (%)
HB(M)	39.4	25.4	35.2
HB(I)	46.5	29.8	23.9
HB(M) x 1.3	23.9	18.3	57.7
HB(M) x 1.6	14.1	21.1	64.8
HB(I) x 1.3	29.6	21.1	49.3
HB(I) x 1.6	14.1	21.1	64.8
Owen (M)	52.1	36.6	11.3
Owen (I)	57.7	29.6	12.7
Owen (M) x 1.3	22.5	40.8	36.6
Owen (M) x 1.6	11.3	25.4	63.4
Owen (I) x 1.3	23.9	46.5	29.6
Owen (I) x 1.6	1.4	2.8	95.8
Mifflin SJ.(M)	56.3	29.6	14.1
Mifflin SJ.(I)	66.2	25.4	8.5
Mifflin SJ.(M) x 1.3	29.8	35.2	35.2
Mifflin SJ.(M) x 1.6	14.1	23.9	62.0
Mifflin SJ.(I) x 1.3	29.6	43.7	26.8
Mifflin SJ.(I) x 1.6	18.3	25.4	56.3
Iret.J.Ob.(M)	32.4	28.2	39.4
Iret.J.Ob.(I)	35.2	29.6	35.2
Iret.J.Ob.(M) x1.3	15.5	21.1	63.4
Iret.J.Ob.(M) x1.6	8.5	14.1	77.5
Iret.J.Ob.(I) x1.3	16.9	19.7	63.4
Iret.J.Ob.(I) x1.6	7.0	14.1	78.9
Iret.J.92(M)	26.8	43.7	29.6
Iret.J.92(I)	31.0	42.3	26.8
Iret.J.92(M) x1.3	12.7	25.4	62.0
Iret.J.92(M) x1.6	4.2	12.7	83.1
Iret.J.92(I) x1.3	14.1	23.9	62.0
Iret.J.92(I) x1.6	4.2	12.7	83.1

HB: Harris-Benedict, MifflinSJ: Mifflin–St Joir 1990, Iret.J: Ireton-Jones, Ob:Obesity
M: Calculation with measured weight, I: Calculation with ideal weight

DISCUSSION

We recorded the mean of energy consumption of patients being followed up on a mechanical ventilator in the internal medicine intensive care unit of a university hospital, with our metabolic monitors compatible with the indirect calorimeter method. We found the mean energy consumption as 2078±794 kcal / day. According to the studies executed in the 1980s, the average energy need of an intensive care patient was around 1700 to 2200 kilocalories[20,21]. Nevertheless, the mean energy consumption measured with 24-hour measurements in the current studies was reported as between 1562 and 2876 calories/day[22,23].Cheng et al. reported in their study the average energy needs per kilogram of patients on mechanical ventilator as 24.5±8.6 kcal/kg[24]. In our study, we found the mean energy need per kilogram as 31.64 ± 13.82 kcal/kg. We think that this difference is due to demographic variability of patient groups. Walker et al. stated in their review published in 2009, that the predictive formulas were created according to specific patient groups. Due to the heterogeneity of intensive care patients, and rapidly changeable nature of their energy consumption levels, formulas developed in specific patient groups are often insufficient[25].

The biggest disadvantage of energy measurement with indirect calorimeter was considered as time spent for a 24-hour measurement. Thus, in our study we compared the energy consumption values measured in the 2nd, 6th, 12th and at the end of the 24th hours, and found a strong correlation between them. In addition to this strong correlation, we found near midline distributions through Bland Altman analysis. Furthermore, adequacy rates showed us, that malnutrition or overfeeding was in most of the patients. Therefore, we considered that the measurements in 2nd, 6th or 12th hour can be used in place of the 24-hour measurements. However, we thought, that waiting for the 24-hour measurement may give more accurate results and help patient management more. According to our review on previous literature, all studies were based on 24-hour measurements. Petros et al. showed in their study executed in 2001 on 46 intubated patients, that there was no significant difference between the measurements performed after a 5-minute stable period and after 30 minutes[26].

In our study, both predicted and ideal weights were used when calculating predictive equations. Studies have shown that higher accuracies can be achievable in predictive equations calculated with ideal or corrected weights[27,28]. We compared the compatibility of predictive formulas calculated with ideal and measured weights, and we found that the adequacy rates vary according to the use of the measured or ideal weights.

For the predictive equations, there is also a strategy to multiply the energy needs of the patients with correction factors, by considering the clinical conditions of the patients. However, there is no clear consensus on the increase level of energy needs in patients. According to the previous studies, the energy need in sepsis, trauma and surgery patients were increased up to 90% percent[29,30]. Similar to the study by MacDonald et al., we multiplied the calculated energy needs of patients with the factors of 1.3 and 1.6, and repeated the correlation analysis[31]. We found that this multiplication did not alter the correlation. None of the predictive equations were found to be compatible to cover all of the patients[25,32].

Predictive equations are easily accessible and inexpensive techniques; however, these formulas were developed by studies on specific patient groups. For example, Harris-Benedict formula was developed in 1919 in a group of patients consisting of 136 men and 103 women[33]. Since then, anthropometric data including weight and body mass index changed significantly. Haugen et al. emphasized the anthropometric changes in the American society, by stating that average lengths were stayed to be the same, whereas significant changes happened in weights and, thus in body mass index[34]. Reid et al. executed a study on trauma or postoperative patients on mechanical ventilation, whose energy consumption was measured with indirect calorimeter for 5 days. Similar to our study, they proportioned the MEC to CEC obtained from predictive formulas, and subdivided into three groups according to the energy intake of patients, namely insufficient, sufficient and overfed groups. They found that the energy needs of patients showing daily variations, cannot be determined by predictive equations[35]. Therefore, predictive equations may be insufficient in an intensive care patient whose energy needs may change at any time.

The researchers searched for alternative methods for indirect calorimeter. Flancbaum et al compared the indirect calorimeter with the Liggett formula, by using the Fick method in postoperative intensive care unit patients, and found a weak correlation[29]. They stated that the fluctuation in SVO2 was high due to the development of sepsis in the majority of patients, and tissue oxygenation was impaired momentarily. The researchers concluded, that the Fick method was a weak alternative to indirect calorimeter[29,36]. In our study, we used the indirect calorimeter technique as a non-invasive method. The Swan-Ganz catheter can be used for measuring of energy consumption only in patients who were catheterized for other reason.

There are many studies in the previous literature on whether energy needs of patients with higher mortality rates increase[32,37]. While Flancbaum et al. claimed a relationship between disease severity and energy consumption, Weissman et al. found weak correlations between these variables[29,38]. Nevertheless, Brandi et al. could not find any correlation between these variables[39]. Similarly, in our study we could not find any significant correlation between APACHE II, SOFA, SAPS II scores and MEC. In addition, we compared the energy consumption levels in patients fed via enteral, parenteral or combined ways, and we did not find any significant difference among these feeding types, which is similar to the results of Cheng et al[24].

Frankelfield et al. found a correlation between inotropic therapy, inotropic treatment dose and energy consumption of the patients[32]. However, in our study we did not observe any association between MEC and inotropic therapy. This difference may be due to the differences of the patient populations of two studies. While our patient population were in the intensive care unit predominantly due to internal medicine pathologies, Frankelfield et al. followed the post-operative patients. Therefore, it may be useful to carry out more studies on this subject.

In our study, we examined the correlations between patients' procalcitonin, albumin, BNP, lactate, WBC, hematocrit and platelet values during admissions, and energy consumption. Except for a moderate correlation with WBC, no correlation was found between the other variables and MEC. According to our review, we did not find any similar studies in the previous literature, therefore we recommend more research focused on this research question. Previous studies demonstrated, that sepsis increases energy consumption[40,41]. Thus, the correlation between MEC and white blood cell count may be related to sepsis in these patients. Since alterations in thyroid functions can affect basal metabolic rate and energy consumption, hypothyroidism has an increased importance in intensive care patients compared to outpatients[42,43]. In our study, we found a weak negative correlation between TSH values and energy consumption. According our result, energy consumption may decrease with hypothyroidism. However, we think that further studies are needed to clarify this association. Furthermore, we compared the measured energy consumption among the groups with and without malnutrition, and found no significant difference among these groups.

The positive effects of correct calculation of energy consumption on deceasing mortality were frequently reported in the previous literature. According to these studies, even a few days of suboptimal nutrition causes weakening of the respiratory muscles. Adequate nutrition was significantly correlated inversely with ventilator dependence and intensive care hospitalization time. In a previous study, intensive care hospitalization times of sufficiently fed and undernourished patients were found as 39 ± 20 to 45 ± 25 days, respectively, and follow-up times on the ventilator were reported as 54 ± 28 and 65 ± 48 days, respectively[8,10]. Proper nutrition reduces morbidity and mortality, and also shortens the length of hospitalization in intensive care units[44,45].

Indirect calorimetry has become not only a "gold standard" but an "achievable gold standard" in determining energy consumption. In case where indirect calorimetry cannot be used, predictive equations are appropriate alternatives to use. MacDonald et al. suggested the determination of the energy need with predictive equations by avoiding malnutrition, and titration of this energy need value with an indirect calorimeter, which may be beneficial for the patients[31].

Among the limitations of our study was patient homogeneity reflecting the characteristics of a tertiary healthcare center. Furthermore, this was a single-center study with limited sample size. A small change during patient follow-up can affect energy consumption. For this reason, measuring energy consumption at more frequent intervals could give more accurate results. In this study, we may have another limitation is not making measurements more frequently.

In conclusion, we recommend that the indirect calorimeter method should be used in intensive care patients to maintain nutrition properly. Nutrition therapy protocol should be individualized for each patient. Under conditions where indirect calorimeter cannot be used, or it is not desirable to wait for 24 hours; feeding can be started according to the results of a 2-hour measurement, or reliable predictive equations. We consider that the maintenance therapy should be organized according to the 24-hour measurement.

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