Comparison of Measured Resting Energy Expenditure (mREE) from a Metabolic Cart to a Portable Handheld Device in Maintenance Hemodialysis Patients: A Feasibility Study

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Key Words: mREE, metabolic cart, portable handheld device

Abstract
Background: A portable handheld device for measuring resting energy expenditure (REE) of patients on maintenance hemodialysis (MHD) compared to traditional indirect calorimetry may be a convenient, reliable estimation of the individual’s energy needs.

Objective: The purpose of this study was to determine the level of agreement in REE as measured by a metabolic cart and a portable handheld device among patients on MHD.

Design: Prospective, descriptive, cross-sectional, pilot study.

Participants: This study involved medically stable, English speaking patients receiving treatment at a single dialysis center in New Jersey. Measured REE (mREE) from both devices was completed in 16 participants (94.1%).

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Statistical Analysis: The level of agreement between the mREE from the portable handheld device compared to the metabolic cart was analyzed using paired-samples t-tests and Bland Altman analysis. Statistical significance was p<0.05. Individual mREE measurements were considered to be in agreement if the difference between the two measures was within ±10% of the mean or 147.9 kcal.

Results: The mean age of participants in the study was 60.6 ± 10.2 years and 70.6% were male. The mean BMI was 30.0 ± 7.1 kg/m². The most common etiology of CKD was hypertension (41.2%). There was agreement between the mREE from the portable device when compared to the metabolic cart with 68.8% of measurements falling within the band of acceptability. All of the patients who fell outside the band of acceptability were overweight or obese. There was no statistically significant difference in the mean scores of the mREE from the two devices (p=0.759). The majority of participants (94.1%) found the procedures for obtaining mREE from the portable handheld device to be comfortable.

Conclusions: In this sample of patients receiving MHD, there was agreement between the mREE from the two devices. The portable handheld device may be a reasonable option for clinicians to use in the assessment of energy requirements for patients on MHD as it was acceptable to participants. Further research is needed to evaluate the accuracy of the portable device for measuring REE in this population.

Introduction
An accurate determination of daily energy expenditure is important for determining an effective nutrition prescription. Indirect calorimetry is considered the “gold standard” for measuring resting energy expenditure (REE) within the clinical setting (1,2). This technique determines energy expenditure by measuring oxygen consumption and/or carbon dioxide production, which are then entered into the Weir equation (1,3). The measured REE (mREE) obtained from indirect calorimetry is then adjusted with the addition of activity or stress factors to account for total energy expenditure (4). In current renal nutrition practice, energy needs are usually calculated by standardized formulas, such as that recommended by the National Kidney Foundation’s Kidney Disease Outcomes Quality Initiative (NKF KDOQI) Guidelines, which suggests 35 kilocalories per kilogram of body weight per day for patients on maintenance hemodialysis (MHD) under the age of 60 years, and 30 kilocalories per kilogram of body weight per day for patients 60 years and older (5). At this time, only a small number of studies have attempted to explore the development of a predictive energy equation that has practical clinical use in the hemodialysis patient but further research is required for validation of these formulas (6,7).

Given the importance of accurately determining energy expenditure in the nutrition assessment of a patient on MHD, a more precise form of estimating energy needs is necessary. While indirect calorimetry (IC) is considered the gold standard for mREE in the clinical setting, dialysis centers are not equipped with the necessary equipment or trained staff needed for its operation. Similarly, although portable handheld IC devices (e.g., MedGem®) are available, there are currently no studies validating its use in patients on MHD, and the studies conducted in the general population are not representative of this unique patient group. Energy expenditure measured by a portable handheld IC device may be an additional tool to use in the determination of energy needs for this population, but it must first be validated as a reliable measure of REE in the dialysis patient. As the initial step in such validation, the purpose of this study was two-fold: 1) to evaluate the level of agreement in mREE between an indirect calorimeter (metabolic cart) and a portable handheld device measurement among patients on MHD and 2) to identify the feasibility of these measurements within this specific patient population. Since there was a dearth of literature on this topic, it was hypothesized that there would be no level of agreement between the mREE values measured from the portable handheld device compared to those values from the metabolic cart in adult patients on MHD.

Methods
Sample and Study Design
This cross-sectional, prospective pilot study included a sample of 17 patients on MHD receiving treatment at a single center that is part of a large dialysis organization (LDO) in Essex County, New Jersey. A power analysis was calculated using G*Power software version 3.1.9. Utilizing a matched paired t-test, an effect size of 1.105, and a two-sided alpha level of 0.05 at 95% power, an estimated sample size of 13 participants was required to achieve statistical power. Participants were enrolled into the study until the sample size was reached or December 2014, whichever came first.

Study Methods and Procedures
Rutgers Biomedical and Health Sciences Newark Institutional Review Board (IRB) approval was obtained along with approval from the LDO’s corporate research office before patients were approached for study enrollment. All patients treated at the dialysis center between September 2014 and December 2014 were screened by the principal investigator (PI) for eligibility based on the inclusion/exclusion criteria. Patients were considered eligible for participation in the study if they were older than 18 years of age and were diagnosed with CKD stage 5 and received MHD three times a week for a minimum of three months at the time of enrollment. To participate, patients needed to speak and understand English since language interpreters were not available at the study site. Patients were excluded from the study if they were less than 18 years of age; had been on MHD for less than three months at the time of recruitment; hospitalized within 30 days prior to research appointment; had an active infection (defined as receiving antibiotics and/or presence of fever) or non-healing wound; had undergone surgical/elective procedures in less than 30 days prior to recruitment (graft revision; access placement, etc.); had any cardiac-related events less than 30 days prior to enrollment; currently not treated...
with conventional MHD (three times weekly); pregnant, lactating, or up to three months post-partum; self-reported routine use of dietary supplements or recreational drugs known to impact the metabolic rate; and if they could not speak or understand English. Attending nephrologists consulted the list of prospective participants and gave medical approval for recruiting them into the study, resulting in a total of 91 patients eligible for enrollment into the study, however, 52 of these individuals did not meet the inclusion criteria and were excluded from enrollment. The total number of patients approached for the study were 39, out of which 17 signed informed consents.

Demographic characteristics (age, race, ethnicity, etiology of CKD disease, dialysis access, number of years on dialysis, dry weight and pertinent medications) were obtained from the participant’s medical record prior to the research appointment by the PI. Research appointments were scheduled by a trained, study coordinator (EP) on a non-dialysis treatment day, at the Clinic Research Lab of the School of Health Related Professions, Rutgers University, Newark, NJ. Prior to the appointment, participants were instructed to not eat any food or liquid after midnight, or if fasting was not possible, refrain from eating at least four hours before the appointment. Patients were instructed to avoid moderate to heavy exercise 12 hours before appointment, and avoid smoking two hours before the appointment. Appointments lasted approximately one-hour and all measurements followed the evidence-based practice guidelines published by Academy of Nutrition and Dietetics (8,9).

Several clinical measurements were taken at the research appointment (ie, blood pressure, height, weight). The REE measurements were initiated by having participants sit in a quiet comfortable room for a minimum of 10 minutes. Two REE measurements were obtained in random order using the 1) metabolic cart (Quark RMR®) and 2) portable handheld indirect calorimeter (MedGem®) (10,11). For the metabolic cart measurement, after the Quark was calibrated per manufacturers’ instructions, participants sat on a reclined exam table in a comfortable position and a rigid plastic canopy was placed over their head. For the total IC test, lasting up to 30 minutes, participants were instructed to avoid talking, fidgeting or sleeping. The first five minutes of data were automatically discarded. To establish a precise measurement of REE, the values for oxygen consumption and carbon dioxide production had to achieve a steady state threshold of <10% coefficient of variation (CV) within a five minute time period (12,13).

For the portable handheld indirect calorimeter, the device was placed on a flat surface to calibrate. A single-use mouthpiece was attached to the device. Each participant was instructed to ensure a tight seal within the mouth to prevent airleaks and a nose clip was used to prevent loss of expired gas through the nasal cavity (10). Participants were seated upright in a comfortable chair and given a pillow to rest their arm. They were instructed to hold the device and breathe normally through their mouth throughout the testing period (10). The test ceased when a three minute steady-state period was achieved or after 10 minutes, whichever occurred first. At the end of the test, the device produced an estimated RQ using only oxygen consumption data for calculating the mREE values.

At the conclusion of the energy expenditure measurements and the research appointment, the study coordinator asked the participant to rate their comfort level and acceptability of each device using a Likert-type scale.

Statistical Analysis

Statistical analyses were completed using IBM SPSS Version 22. Descriptive statistics were performed on demographic and clinical characteristics, as well as the acceptability ratings for each device for the participants. A paired t-test was completed to compare the difference in means between the mREE from the two devices to determine if the mean mREE from the metabolic cart versus the portable IC were significantly different. Bland Altman plots were used to determine if the difference observed between the mREE from the two devices fell within the predetermined level of acceptability and were therefore in agreement. The plots were used to determine if the variation in the sample was acceptable. Based on the review of the literature and studies utilizing Bland Altman plots in their analyses, the predetermined band of acceptability calculated was ±10% where individual differences that fall within this range are considered valid or accurate (13).

Results

Seventeen participants gave consent and completed study measurements. However, one participant was unable to obtain a reliable value from the portable IC device so the final sample for comparison of the mREE from the two devices was 16 participants. Their ages ranged from 45-80 years old (mean=60.6, SD=10.2) with an average dialysis vintage ranging between 6.0-85.0 months, or 0.5-6.5 years (Table 1). Body Mass Index (BMI) was calculated for all 17 participants and ranged between 19 and 46 kg/m² with most participants’ BMI falling in the obese category (n=8, 47.1%) (Table 2).

Table 1: Age, BMI, and Dialysis Vintage Time of Study Participants (n=17)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean± SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>17</td>
<td>60.6±10.2</td>
<td>59.0</td>
<td>45.0-80.0</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>27.9±5.7</td>
<td>27.4</td>
<td>19.0-39.0</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>35.1±8.2</td>
<td>35.8</td>
<td>23.0-46.0</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>30.0±7.1</td>
<td>28.4</td>
<td>19.0-46.0</td>
</tr>
<tr>
<td>Dialysis Vintage (months)</td>
<td>16</td>
<td>30.0±22.5</td>
<td>20.0</td>
<td>6.0-85.0</td>
</tr>
</tbody>
</table>
The participants were stratified by age, BMI, dialysis vintage time, ethnicity, etiology of CKD, gender and race to attempt to further characterize the individuals that did not fall within the band of acceptability. No commonalities or patterns emerged. All of the five participants who fell outside the band of acceptability were overweight or obese, but there were seven overweight or obese individuals that fell within the band as well. One of the participants who fell outside the band of acceptability was older than 75 years of age, and another participant experienced some restlessness during the mREE measurement by the metabolic cart.

Table 2: Age Groups, BMI Categories, Ethnicity, Race, Etiology of CKD, and Gender of Study Participants (n=17)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-54 years old</td>
<td>5</td>
<td>29.4</td>
</tr>
<tr>
<td>55-64 years old</td>
<td>8</td>
<td>47.1</td>
</tr>
<tr>
<td>Over 75 years old</td>
<td>4</td>
<td>23.5</td>
</tr>
<tr>
<td>BMI Categories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal (BMI 18.5-24.9)</td>
<td>5</td>
<td>29.4</td>
</tr>
<tr>
<td>Overweight (BMI 25-29.9)</td>
<td>4</td>
<td>23.5</td>
</tr>
<tr>
<td>Obese (BMI&gt;30)</td>
<td>8</td>
<td>47.1</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Hispanic/Latino</td>
<td>15</td>
<td>88.2</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black/African American</td>
<td>9</td>
<td>52.9</td>
</tr>
<tr>
<td>White</td>
<td>7</td>
<td>41.2</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>Etiology of CKD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>7</td>
<td>41.2</td>
</tr>
<tr>
<td>Diabetes</td>
<td>6</td>
<td>35.3</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>23.5</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>70.6</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>29.4</td>
</tr>
</tbody>
</table>

The majority of the participants were of non-Hispanic/Latino descent at 88.2%, 52.9% were Black/African American, and 70.6% were male (Table 2). Hypertension was the most common etiology of chronic kidney disease (CKD) followed by diabetes.

There was no statistically significant difference (t(-0.31), p=0.759) between the mREE obtained from the metabolic cart (mean=1475.1, SD =277.8) compared to the mREE from the portable handheld device (mean=1488.8, SD=280.6) (mean difference=13.7, SD=175.2). Women had higher mean mREE when measured by the metabolic cart in comparison to men. Conversely, women had lower mean mREE than men when the portable handheld device was used (Table 3).

Table 3: mREE from Two Devices for Study Participants by Gender

<table>
<thead>
<tr>
<th>mREE</th>
<th>n</th>
<th>Mean ± SD</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic Cart</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>1420.2 ± 182.7</td>
<td>1440.6</td>
<td>1117.1-1709.8</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>1584.9 ± 420.1</td>
<td>1467.8</td>
<td>1237.2-2307.2</td>
</tr>
<tr>
<td>Portable IC Device</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11</td>
<td>1491.8 ± 264.7</td>
<td>1510.0</td>
<td>1160.0-2100.0</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>1482.0 ± 346.3</td>
<td>1400.0</td>
<td>1220.0-2070.0</td>
</tr>
</tbody>
</table>

A Bland-Altman analysis and graph were also completed to determine if the individual differences observed between the mREE from the two devices fell within the predetermined 10% band of acceptability (±147.9 kcal) (Figure 1). The mREE from the two devices were within ±147.9 kcal in 11 of the participants (68.8% of study sample). The participants were stratified by age, BMI, dialysis vintage time, ethnicity, etiology of CKD, gender and race to attempt to further characterize the individuals that did not fall within the band of acceptability. No commonalities or patterns emerged. All of the five participants who fell outside the band of acceptability were overweight or obese, but there were seven overweight or obese individuals that fell within the band as well. One of the participants who fell outside the band of acceptability was older than 75 years of age, and another participant experienced some restlessness during the mREE measurement by the metabolic cart.

Acceptability Survey

Participants rated how comfortable they felt with each device. The majority of the participants strongly agreed or agreed that both devices were comfortable (n=16, 94.1%). None of the participants expressed discomfort with the metabolic cart. Similarly, the majority of the participants also strongly agreed or agreed that the portable handheld IC device was acceptable to them. However, one participant did report that the portable device was uncomfortable (n=1, 5.9%).

Discussion

The purpose of this study was to determine the level of agreement between the mREE obtained from a handheld portable IC device and the metabolic cart in a sample of patients on MHD. Based on a paired-samples t-test, there were no significant differences between the mREE measurements. Also, the Bland-Altman analyses revealed...
a fair level of agreement with 68.8% of the measurements falling within ±10% mREE mean limits of agreement from the centered mean, with 94.1% of these measurements within two standard deviations (SD). Thus, this study rejects the null hypothesis as there was some level of agreement between the mREE values from the two devices.

The lack of significant differences between the metabolic cart and a portable handheld IC device is consistent with findings from Glass and colleagues who measured a group of hospitalized cirrhotic patients. There were no significant differences between the mean differences of the MedGem and the metabolic cart measurements (14). St-Onge et al. also found no bias in the MedGem measurements compared to the metabolic cart in their study of 15 healthy subjects (15).

Even though we did not observe any significant differences between the two mREE measurements, we did observe that the MedGem® overestimated mREE when compared to the metabolic cart. Frankenfield and Coleman attempted to explain the possible effect of posture (sitting or semi-recumbent versus supine) on measuring resting metabolic rate (RMR) from a metabolic cart in overweight/obese and normal weight adults (16). The RMR in the semi-recumbent position was lower than the RMR in the supine position as well as the MedGem® (16). This could suggest that breathing is easier in the semi-recumbent position and therefore requires less work of breathing for the individual (16). In the present study, participants were asked to lay in the supine position, which may account for the lower measurements observed with the metabolic cart. In addition, the amount of energy expended in holding the MedGem has also been suggested as a reason for the differences observed between the handheld device and the metabolic cart (16).

The level of agreement observed in this study was similar to the findings of Compher and colleagues, in which 60% of the MedGem measurements were within ±10% of the metabolic cart in patients receiving home parenteral nutrition support (13). In the present study, attempts were made to further characterize the individuals who did not fall within the band of acceptability. Although the portable handheld IC device was acceptable for measuring the REE of patients on MHD at the group level in the sample, further research is needed to determine how factors such as BMI, age, and gender may influence the accuracy of these measurements. Although all the individuals falling outside the limits of acceptability were overweight or obese, there were participants in the overweight or obese categories whose individual mREE differences were within the predetermined limits of agreement. Additional factors are likely involved affecting the mREE of these individuals that were not measured.

Several studies comparing the mREE from the metabolic cart and the portable device have also evaluated the acceptability or comfort level of the participants with each device (3,14,17). In the current study, the majority of the participants did not experience any discomfort with the portable handheld device (88.2%), with only one participant finding the portable device uncomfortable (5.9%). In the study by Fares and colleagues, older adults (mean age=79.9 years) found the metabolic cart to be more acceptable with less physical discomfort than the MedGem® (3). Similarly, Anderson et al. found 61.4% of the participants in their study preferred the metabolic cart to the handheld IC device (mean age=51.7 ± 7.9 years; mean BMI=31.8 ± 4.2 kg/m²) (17). In a study of hospitalized patients with cirrhosis, 62.6-66.7% did not experience any discomfort with the portable handheld IC device (14). However, there were limitations of the metabolic cart outlined by the researchers, such as fear of becoming claustrophobic under the canopy by participants and the prolonged time required for the indirect calorimetry measurement compared to the portable device (14). Similarly, in the present study four participants experienced symptoms of restlessness during the metabolic cart measurements, which may be attributed to the fact that they were randomly assigned to have the metabolic cart measurements taken first before the portable device. Given that the majority of participants found it to be comfortable, the portable device may be a reasonable option for dietitians to use in clinical practice for the measurement of REE as it is relatively inexpensive, requires minimal time, and there is fair agreement between the mREE from the portable handheld device and the metabolic cart in the sample of MHD patients.

Conclusion

This is the first known study to compare the level of agreement for mREE values obtained from the portable handheld IC device to the metabolic cart in a population of patients on MHD. This pilot study also demonstrated the feasibility of using the portable handheld IC device for obtaining REE measurements in this population. The majority of the participants had mREE values that fell within the band of acceptability, and there were no statistically significant differences in the mean scores between the two devices. Thus, the portable handheld IC device may be an acceptable alternative to measuring REE using a metabolic cart in patients on MHD. Recognizing that the conclusions from this study must be cautiously applied due to the small sample size, dietitians and other healthcare practitioners may consider using the portable handheld IC device to determine mREE for patients on MHD. Larger studies to validate the portable handheld IC device in MHD patients will be of great clinical use. Further research comparing the mREE from a portable handheld IC device to REE calculated from predictive energy equations in patients on MHD would be beneficial as well.

Acknowledgements

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Feature Article...

Further Details
During the article review, several specific questions were proposed by our peer reviewers and then answered by the authors. Please refer to the RPG website for more information.

References

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*Renal Dietitians Dietetic Practice Group*

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