ENERGY EXPENDITURE DURING CHEWING: A COMPARISON OF TWO MEASUREMENT METHODS

A Thesis by

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ENERGY EXPENDITURE DURING CHEWING: A COMPARISON OF TWO MEASUREMENT METHODS

The following faculty members have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Arts with a major in Communication Sciences and Disorders.

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Jeremy Patterson, Committee Member

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Julie Scherz, Committee Member
ABSTRACT

Older adults with chewing and swallowing difficulties frequently report increased fatigue and effort, or energy expenditure, during eating. Energy is defined as the ability to perform work. It is most accurately measured through an examination of the gaseous composition of inhaled and exhaled air at rest and during activity using laboratory-based indirect calorimetry. There is a need for a valid measure of energy expenditure that can be used to document the effort involved in eating and swallowing in natural contexts. The purpose of the current study was to determine the concurrent validity of the portable SenseWear® system compared to indirect calorimetry during a simulated eating task. Nineteen university students served as participants. Each was connected simultaneously to indirect calorimetry and SenseWear® systems. Energy expenditure was obtained while participants chewed gum and swallowed repeatedly. Pearson product-moment correlations showed a close relationship ($p < 0.05$) between the two measurement methods. Mean Mid-Arm Muscle Circumference measures also correlated positively with both measurement methods, reflecting the influence of body mass on energy expenditure. Results support the use of the SenseWear® system to measure energy expenditure in chewing and swallowing in natural contexts, particularly for adults with chewing and swallowing difficulties.

KEYWORDS: Indirect calorimetry; SenseWear®; Mid-Arm Muscle Circumference; dysphagia; energy expenditure; chewing; simulated eating
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CHAPTER I
REVIEW OF THE LITERATURE

This is an instrumental study to investigate the concurrent validity of two measurement methods. It is motivated by the need to identify a valid and reliable way to measure energy expenditure during eating in a natural, non-laboratory context. The accurate measurement of energy expenditure in a natural context is particularly important for older adults with, or at-risk for, eating and swallowing difficulties (dysphagia). These adults frequently report increased fatigue during eating, decreased coordination of oro-pharyngeal musculature, decreased tongue strength after a meal, and a general feeling of increased effort (Bardan, Kern, Arndorfer, Hofman, & Shaker, 2006; Kays, Hind, Gangnon, & Robbins, 2010; McHorney et al., 2002). The development of an objective way to quantify the perceptions of these adults and document the energy each expends during a meal is needed for caregivers and clinicians to intervene effectively to maintain a high quality of life for these older adults.

Energy is defined as the ability to perform work. It is derived from the intake, digestion, metabolism, and absorption of adequate carbohydrate, fat, and protein food nutrients along with sufficient hydration. It is critical for the maintenance of general health and the uninterrupted operation of internal organs, systems, and brain function, including cognition (Jeukendrup & Wallis, 2005; Koren, 2006; Wilson & Morley, 2003; Wright, Cotter, Hickson, & Frost, 2005). In the breakdown of food nutrients, the energy value of the food is measured in units of kilocalories, abbreviated as kcal, reflecting the heat generated in food combustion. Whenever humans are involved in an activity, including eating, they generate heat and this heat production can be measured directly in a calorimeter, an airtight, temperature-controlled chamber. As direct calorimetry is impractical for the measurement of energy expenditure during recreational
activities and in other natural contexts, the measurement of oxygen consumption and carbon dioxide production at rest and during exercise can be used as an indirect measure of heat energy. Although there are documented limitations related to the way individuals metabolize fat, indirect calorimetry, has been shown to be a valid and reliable measurement of the energy metabolism of humans at rest and during physical activity (Jeukendrup & Wallis, 2005; Westerterp, 1999, 2009).

Indirect Calorimetry

Indirect calorimetry uses spirometry to measure oxygen consumption at rest and during activity. Spirometry is a powerful tool that measures changes in lung volume. These lung volume measures include the amount of air that can be inhaled (Inspiratory Capacity, IC), total lung capacity (TLC), the amount of air that can be exhaled (Vital Capacity, VC), and the amount of air that can be forcibly exhaled in a specific amount of time ( Forced Expiratory Volume, FEV).

These and other measures, including individuals’ height, weight, gender, age, and racial or ethnic background, can be used to quantify aspects of the respiratory system that may adversely affect lung function and thus energy expenditure (Barreiro & Perillo, 2004; Margolis, Montoya, & Palma, 1997; Petty, 2001). During indirect calorimetry, the nose and mouth are sealed from room air, generally through the face being covered with a form-fitting triangular-shaped mask. By means of a two-way breathing valve, the individual is able to inhale ambient air that has a constant composition of 20.93% oxygen, 0.03% carbon dioxide, and 79.04% nitrogen while the exhaled air passes through a gas meter that samples the volume and changes in gas composition (Akner & Flöistrup, 2003; Fruin & Walberg Rankin, 2004; King, Torres, Potter, Brooks, & Coleman, 2004; Westerterp, 2009).
Any calculations of energy expenditure during an activity are best measured in comparison to an established baseline (Adriaens, Schoffelen, & Westerterp, 2003). The preferred baseline value is an individual’s basal metabolic rate (BMR). BMR is the amount of energy an individual expends to perform only the most vital functions necessary for life. BMR is best measured in a controlled situation after food intake is withheld for 10-12 hours and physical activity is prevented. Individuals are tested in a supine position, and once acclimatized, measurements are taken over a 10-20 minute period. Accurate BMR measures also can be obtained if individuals fast at home and then drive themselves to the testing laboratory (Adriaens et al., 2003). Resting metabolic rate (RMR, or Resting Energy Expenditure [REE]) is calculated from an individual’s BMR plus measured surface area (body size), body mass, age, and gender. These factors affect how body fat is metabolized (Jeukendrup & Wallis, 2005). RMR values measured several hours after a light meal have been found to be higher but close to BMR values. McArdle et al. (1991) argued that BMR and RMR values thus can be considered synonymous. However, Adriaens et al. (2003) advised against this. Body mass and fat metabolism affect energy expenditure due to the heat generated during each particular activity. The heat generated during food consumption is termed diet-induced thermogenesis (Adriaens et al., 2003). Additional variables affecting diet-induced thermogenesis include the type and quantity of food being consumed and the time taken to consume the food (Kays et al., 2010).

During indirect calorimetry the mouth and nose must be fitted snugly using a mask. Thus, this procedure cannot be used to assess energy expenditure during eating when food is introduced repeatedly into the mouth. There is an indirect calorimetry system that employs a “helmet surround,” a clear disc canopy that fits over the head and enables the measurement of energy expenditure during eating. This canopy system obviates the need for the breathing valve
and mouthpiece for testing RMR (Adriaens et al., 2003; Fruin & Walberg Rankin, 2004). However, indirect calorimetry, with or without a mask, is not easily available outside the laboratory for the measurement of energy expenditure during chewing and swallowing in daily activities. The ability to measure energy expenditure during these essential life activities in natural contexts speaks to the need for an alternate and valid system.

The SenseWear® System

The SenseWear® system (BodyMedia Inc., Pittsburgh, PA) is a relatively inexpensive, person-friendly, portable, and noninvasive approach to measuring energy expenditure (Andre et al., 2006). Thus, the SenseWear® system lends itself to data collection during eating in natural contexts, providing that its measurements initially are validated with those from indirect calorimetry. The SenseWear® computerized device is worn on the upper arm. It collects physiologic data through multiple sensors to estimate energy expenditure by tracking movement/body position, body heat loss, skin temperature, and electrical resistance of the skin (Andre et al., 2006; Fruin & Walberg Rankin, 2004). These data then are compared with demographic data (e.g., the individual’s gender, age, height, and weight) to estimate energy expenditure (in total kcal) according to a general, or global, equation developed and protected by the manufacturer. In a personal communication with the investigator, Rachel Jackson, the clinical research coordinator for BodyMedia Inc., reported:

The software calculates the energy expenditure for each minute of data. A Naive Bays classifier is used to match the armband data to the activity class that best describes the current minute. The classes are walking, running, stationary bike, road bike, rest, resistance, other activity, and motoring. Each activity class has a linear regression model mapping the sensor values and body parameters to
energy expenditure. There are separate regression models for subjects ≤ 18 and > 18 years old. Calories and METS are converted using the equation METS = kcal/hour/kg. The inputs to the Naive Bays classifier and the regression models include the data recorded in the armband and derived inputs such as the standard deviation of the data over a number of minutes before and after the minute in question (May 6, 2011).

The SenseWear® system has been used to measure energy expenditure at rest (Malavolti et al., 2007) and in a variety of activities that have involved healthy adults in moderate to vigorous exercise, such as pedaling on a stationary cycle, walking on a treadmill, climbing stairs, and making rapid arm movements (Berntsen et al., 2010; Fruin & Walberg Rankin, 2004; Jakicic et al., 2004; King et al., 2004). Results of these studies documented that SenseWear® measurements, when compared to indirect calorimetry, were reliable and valid in estimating RMR/REE (Malavolti et al., 2007). However, in the measurement of energy during exercise, SenseWear® under- and over-estimated energy expenditure during the various activities that were studied (Fruin & Walberg Rankin, 2004; Jakicic et al., 2004). Jakicic et al. (2004) then developed corrective activity-specific algorithms. When these activity-specific algorithms were applied to the SenseWear® armband, the accuracy of estimating energy expenditure increased to the point where there were no significant measurement differences between indirect calorimetry and the SenseWear® device. King et al. (2004) reported that the SenseWear® armband correlated well with indirect calorimetry in estimating total energy expenditure during treadmill walking and running. In a recent study, Berntsen et al. (2010) found that the SenseWear® armband under-estimated total energy expenditure in healthy adults during vigorous endurance exercise (bicycling, brisk walking, and playing table tennis) from 5-21% compared to indirect
calorimetry. However, Berntsen et al. concurred with Jeukendrup and Wallis (2005) that a large part of the variance was explained by differences among the participants in the study and stressed that these individual differences in metabolism warranted further study. A search of the literature, using PubMed, in spring 2011 showed no published documentation of the SenseWear® system in estimating energy expenditure during eating and swallowing.

In healthy adults, sufficient caloric intake and hydration presume that each adult has effective and efficient chewing and swallowing abilities. As adults age, natural changes occur in cellular structure and nerve and muscle function in the body and brain and these changes affect activities, including those of chewing and swallowing. The body works harder to perform the same functions it performed when younger. Cardiac rate increases while metabolic activity decreases (Timiras, 2003). With particular regard to chewing and swallowing, as measured by electromyography (EMG) and tongue pressures, the use of tongue, jaw, and cheek muscles is prolonged, and tongue strength decreases following a meal (Kays et al., 2010; Woda, Mishellany, & Peyron, 2006). The coordination of breathing and swallowing also can become slower, more effortful, and less efficient (Bardan et al., 2006; Hiss, Teole, & Stuart, 2001; Kays et al., 2010). These changes can be associated with subtle decreases in (a) the sensations of taste, smell, and lingual pressures, (b) lubrication of the mucosal tissues lining the mouth and pharynx, (c) responsiveness of the smooth muscles lining the esophagus, and (d) lung volumes (Ney, Weiss, Kind, & Robbins, 2009). Uncorrected visual impairments associated with aging, as well as changes in dentition and posture, also can adversely affect chewing and swallowing abilities.

When older adults experience chewing and swallowing difficulties as a result of neurological trauma or disease (e.g., stroke), infections, or treatment for head and neck cancer, the subsequent dysphagia can be characterized by evident changes in the strength and/or
coordination of gross and fine oro-pharyngo-esophageal musculature, sensory processing, cognitive status, and general health (Crary & Groher, 2003; Leonard & Kendall, 2008). If the coordination of breathing and swallowing and the expected period of swallow apnea (cessation of breathing) during a swallow are compromised, these older adults are at particular risk for the repeated aspiration of bolus material into the lungs and consequent infections (Wheeler Hegland, Huber, Pitts, & Sapienza, 2009). All of the adverse changes experienced by healthy older adults and those with dysphagia may result in older adults expending more effort in chewing and swallowing than younger adults. This increased effort (or energy expenditure) in chewing and swallowing may, in turn, increase vulnerability to fatigue and decrease quality of life (Kays et al., 2010; McHorney et al., 2002; McHorney, Martin-Harris, Robbins, & Rosenbek, 2006).

Purpose of the Study

Despite published descriptive reports of the effort involved in eating and swallowing during a meal, particularly for older adults with swallowing difficulties (Bardan et al., 2006; Kays et al., 2010; Woda et al., 2006), the energy involved in eating and swallowing has not been measured using validated energy expenditure techniques. The ability to eat and swallow safely and effectively is necessary for life. Disorders in eating and swallowing can result in aspiration and related life-threatening issues such as pneumonia, malnutrition, dehydration, and death. There is a need to be able to measure, as objectively and easily as possible, the effort, or energy, involved in chewing and swallowing in natural contexts. The purpose of the current study was to determine the concurrent validity of the SenseWear® system, compared to indirect calorimetry, as a method suitable for estimating energy expenditure during chewing and swallowing.
CHAPTER II
METHODOLOGY

Participants

Twenty-two university students, 15 females and 7 males, volunteered for this study. Their ages ranged from 19.1-33.6 years (mean = 24.3, ± 3.6). The majority of participants (n = 16) were Caucasian; three were Asian; two were Hispanic; and one was African American. Twenty were right-handed and two were left-handed. Handedness was documented as placement of the SenseWear® and Mid-Arm Muscle Circumference measurements required the use of the dominant arm. Participants were recruited through announcements about the study posted across campus and announcements made in classes. Each participant reviewed and signed an informed consent form (Appendix A) prior to any data collection. This informed consent stated clearly that students’ willingness to participate or decision not to participate in the study would not affect their grade for any course in any way. Each participant received $20. The Institutional Review Board of the university approved the study.

Prior to data collection, a 17-item Screening Questionnaire (Appendix B), adapted by the investigator from work by Adriaens et al. (2003), Godin and Shephard (1985), and Wareham et al. (2003) and was completed to provide additional information about each participant. Participants’ responses documented that they were in good health, chewed gum, had no known allergies to gum, were not averse to breathing through a mask while chewing gum, and had not undergone any recent surgery, treatment, or taken medications that would compromise chewing, swallowing, or breathing functions during testing. Participants reported whether they smoked and exercised regularly and provided information on their level of activity and food consumption prior to testing. No participant was pregnant at the time of data collection. This Screening
Questionnaire was completed in person in the investigator’s office on campus or completed and returned via e-mail.

Anthropometric Measures

The following indirect, noninvasive measures were obtained to provide data on body composition:

Body Mass Index

Body weight was measured in kilograms (kg) using a Seca® calibrated electronic scale (H & C Weighing Systems, Columbia, MD). Height was measured in centimeters (cm) using a portable stadiometer (Pearson Surgical Supplies, Sylmar, CA). Body mass index (BMI) was calculated by dividing weight by height squared, i.e., kg/m² (Akner & Flöistrup, 2003). BMI measures ranged from 18.30 to 32.30 (mean = 23.77, ± 4.20). Each participant’s BMI was compared to normative data and ranked according to one of four categories: underweight, normal range, overweight, and obese. Of the 22 participants, one was considered underweight, 16 were within the normal BMI range, two were overweight, and three were obese. These measures are reported with the understanding that excess weight in some persons can be associated with increased muscle mass (Adriaens et al., 2003).

Mid-Arm Muscle Circumference

Mid-Arm Muscle Circumference (MAMC) is considered a useful measure to estimate body fat by measuring muscle girth (Sungurtekin, Sungurtekin, Oner, & Okke, 2008). Each participant was asked to extend his/her dominant arm in front of the body with the palm up. The mid-point between the glenohumeral (shoulder) and elbow joint was identified, following procedures reported by Sungurtekin et al. (2008). A plastic measuring tape was placed taut but
not tight around the arm at the identified mid-point and the measure was documented in centimeters (cm). Duplicate measurements were taken and the average used. MAMC measures ranged from 22.5 to 38.5 cm (mean=29.14 cm, ± 4.54 cm).

**Skin Fold Thickness**

As an additional measure of body fat, skin fold thickness was measured in millimeters (mm) at the mid-point of the tricep, bicep, subscapular, and suprailiac areas using a Harpenden Caliper, following procedures reported by Durnin and Wormersley (1974) and Orphanidou, McCardar, Birmingham, Mathieson, and Goldner (1994). All measures were taken on the right side of each participant’s body while each participant was standing. Three measures were taken of each skin fold. The values of each skin fold then were averaged and summed as an indication of each participant’s relative degree of fatness.

**Instrumental Measures**

**Indirect Calorimetry**

Each participant’s nose and mouth were covered with a form-fitting triangular-shaped mask that was connected to a two-way, non-re-breathing Hans Rudolph valve. Participants breathed ambient air with a constant gaseous composition of oxygen, carbon dioxide (CO₂), and nitrogen (Akner & Flöistrup, 2003). Participants’ exhaled air was collected and transferred, via tubing from the mask, to a mixing chamber (Appendix C). The comparison of participants’ oxygen and CO₂ content in inhaled and exhaled air enabled an indirect measurement of energy metabolism. Oxygen and carbon dioxide analyzers and gas flow meters were calibrated against gases of known concentrations before testing, according to the recommendations of the manufacturer of the indirect calorimetry equipment being used. The indirect calorimetry system
reported values every 30 seconds. These values were averaged over the two-minute testing period.

**SenseWear® System**

This computerized armband device was calibrated with each participant’s gender, age, height, and weight and then placed comfortably on each participant’s upper dominant arm (Appendix D). A brief buzzing sound indicated that adequate contact had been made between the device and the participant’s skin and that the device was ready to record data on energy expenditure. The device was time-stamped by pushing a button to activate and then terminate data collection over the two-minute testing period. Following data collection, the device was removed from each participant and connected to a laptop computer for the data to be downloaded. A total number of kcalories was reported for the testing period.

**Procedures**

All testing was completed in the Human Performance Studies laboratory at Wichita State University. Participants were e-mailed or telephoned to schedule testing. Each was asked to take the elevator to the laboratory to minimize energy expenditure prior to testing. After arriving in the laboratory, participants completed any remaining paperwork and then underwent the series of body composition measurements. These measurements were made by experienced faculty or the investigator under faculty supervision. The measurements were not invasive and took no longer than 15 minutes. Each participant was measured individually in a private laboratory in the presence of the investigator.

Following body composition measurements, the SenseWear® device was positioned on the mid-point of the tricep of the dominant arm. Each participant was asked to relax for 10
minutes on a reclined dental chair in a darkened room adjacent to the testing area. Due to participants’ work and study schedules, it was not possible to collect data at the beginning of the day and after a 12-hour fast to document Basal Metabolic Rate. The 10-minute reclining period was used to facilitate as relaxed a metabolic state as possible prior to the measurement of energy expenditure in the indirect calorimetry and SenseWear® conditions.

After relaxing, each participant was walked slowly to the testing area and seated on a comfortable chair. Participants were asked to select a piece of sugar-free gum from a variety of flavors, place this gum in the mouth and chew and swallow normally. Participants then were instructed to count 10 chews silently and swallow (without swallowing the gum) and repeat this activity as many times as necessary as a practice for the protocol during the two-minute data collection period. Participants were assured that they would be able to breathe without difficulty while chewing the gum when the form-fitting, indirect calorimetry mask was fitted. After participants had begun to chew the gum, the indirect calorimetry mask was placed over the face and secured with a band around the head. Participants were given a minimum of two (2) minutes to adjust to the experience of wearing the mask. The indirect calorimetry system recorded data throughout this adjustment period. When the recordings stabilized, indicating that the participant was comfortable, acclimatized to the condition, and had ceased extraneous movement, the SenseWear® device was activated. Caloric expenditure data from the SenseWear® and indirect calorimetry systems were collected simultaneously over the two-minute test period.

Data Analysis

The SenseWear® and indirect calorimetry provided interval data. Pearson product-moment correlations were used to compare the degree of agreement between the two energy expenditure measurement methods during chewing.
CHAPTER III
RESULTS

A visual inspection of the raw data for the 22 participants showed that indirect calorimetry data for two of these participants (#1 and #2) were problematic. The indirect calorimetry values of 16.96 and 12.49 kcalories were far outside the range of values for all other participants (Appendix E). When participants 1 and 2 were tested, the study protocol included an estimate of BMR using the MedGem system (St-Onge, Rubiano, Jones, & Heymsfield, 2004). Using MedGem, each participant breathed into a closed system with lips tightly closed around a valve and the nose occluded. They were attached to this system for a minimum of five minutes. The discomfort with the system and the time needed for data collection may have increased the measure of these two participants’ energy expenditure. The data for these two participants were excluded from the analysis and the MedGem was discontinued. Data from a third participant, (#17) also were excluded as the value for indirect calorimetry (6.89 kcal) and SenseWear® (1 kcal) differed notably from the values for the remaining participants (Appendix E). Table 1 presents the body composition and kcalorie data for the remaining 19 participants.
TABLE 1
BODY COMPOSITION AND KCALORIE DATA (n = 19)

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>157.5</td>
<td>180.5</td>
<td>23.00</td>
<td>168.71</td>
<td>7.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>46.20</td>
<td>90.80</td>
<td>44.60</td>
<td>66.83</td>
<td>11.74</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>18.30</td>
<td>30.10</td>
<td>11.80</td>
<td>23.02</td>
<td>3.21</td>
</tr>
<tr>
<td>MAMC (cm)</td>
<td>22.50</td>
<td>34.25</td>
<td>11.75</td>
<td>28.17</td>
<td>3.99</td>
</tr>
<tr>
<td>Skin Fold (mm)</td>
<td>30.90</td>
<td>154.50</td>
<td>123.60</td>
<td>71.40</td>
<td>33.61</td>
</tr>
<tr>
<td>Indirect Calorimetry (kcal)</td>
<td>2.62</td>
<td>5.15</td>
<td>2.53</td>
<td>4.25</td>
<td>1.20</td>
</tr>
<tr>
<td>SenseWear® (kcal)</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2.42</td>
<td>0.51</td>
</tr>
</tbody>
</table>

The means and standard deviations for indirect calorimetry and SenseWear® measures were 4.25 (± 1.20) and 2.42 (± 0.51) respectively. The correlation analysis for the 19 participants was significant at the 0.05 level. These results are detailed in Table 2.

TABLE 2
DEGREE OF AGREEMENT BETWEEN INDIRECT CALORIMETRY AND SENSEWEAR® MEASURES OF ENERGY EXPENDITURE (n = 19)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Pearson Correlation</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect Calorimetry</td>
<td>4.25</td>
<td>1.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SenseWear®</td>
<td>2.42</td>
<td>0.51</td>
<td>0.49</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

*p < 0.05.
Given the significant relationship between indirect calorimetry and SenseWear® measures for the 19 participants, Mid-Arm Muscle Circumference (MAMC) and skin fold data were added to the correlation matrix to note the relationship of body fat to energy expenditure. The MAMC mean (and standard deviation) for the 19 participants was 29.17 cm (± 4.67). The skin fold mean (and standard deviation) for the 19 participants was 71.40 mm (± 33.61). There was a statistically significant relationship for MAMC data for both indirect calorimetry ($r = 0.47$, $p = 0.04$) and SenseWear® ($r = 0.77$, $p = 0.01$) measures of energy expenditure. A regression analysis documented that for each 1 cm increase in MAMC, calorie expenditure recorded under indirect calorimetry increased by 0.12 calories. Similarly, for each 1 cm increase in MAMC, calorie expenditure recorded with SenseWear® increased by 0.08 calories. There was no statistically significant relationship for skin fold measurements with the other variables under study, i.e., indirect calorimetry, SenseWear® measurement, and MAMC. These results are detailed in Table 3.
TABLE 3

PEARSON CORRELATION COEFFICIENTS FOR INDIRECT CALORIMETRY AND SENSEWEAR® MEASURES OF ENERGY EXPENDITURE, MID-ARM MUSCLE CIRCUMFERENCE, AND SKIN FOLD MEASUREMENT (n = 19)

<table>
<thead>
<tr>
<th>Indirect Calorimetry</th>
<th>SenseWear®</th>
<th>MAMC (cm)</th>
<th>Skin Fold (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pearson Correlation</strong></td>
<td><strong>Significance (2-t)</strong></td>
<td><strong>Pearson Correlation</strong></td>
<td><strong>Significance (2-t)</strong></td>
</tr>
<tr>
<td>Indirect Calorimetry</td>
<td>1</td>
<td>0.49*</td>
<td>0.47*</td>
</tr>
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<td>1</td>
<td>0.77**</td>
</tr>
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<td>0.77**</td>
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* p < 0.05. ** p < 0.01.

Each of the 19 participant’s energy expenditure as measured by the indirect calorimetry and SenseWear® systems was plotted according to BMI ranking, i.e., underweight, normal range, overweight, or obese to examine the relationship of BMI to energy expenditure. These data are detailed in the scatterplot in Figure 1. Participant numbers are inserted beside each data point (participant #6 [#17 in Appendix E] is excluded). A trend was evident in that two of the three obese participants and the two overweight participants expended more energy than the majority of their normal range and underweight counterparts.
Figure 1. Relationship of BMI to energy expenditure in kcalories under two measurement methods
CHAPTER IV
DISCUSSION

The purpose of this study was to investigate the concurrent validity of the SenseWear® measure of energy expenditure compared to the gold standard indirect calorimetry measurement method during a chewing task. The chewing task was selected to simulate eating, a function that is difficult for adults with dysphagia.

Results documented a significant correlation between measures of energy expenditure using SenseWear® and indirect calorimetry during a two-minute period of simulated eating. To this investigator’s knowledge, the current study is the first to document the concurrent validity of SenseWear® and indirect calorimetry during chewing. The data were obtained from healthy young adults with no chewing or swallowing difficulties. While replication is warranted, results support the use of the SenseWear® system in natural contexts, particularly as an objective measurement of the effort expended by adults as they consume a meal. Results have particular potential value in verifying the descriptive and perceptual reports of the increased effort and fatigue experienced by older adults with chewing and swallowing difficulties (Bardan et al., 2006; Kays et al., 2010; McHorney et al., 2006).

To strengthen the argument for the use of the SenseWear® system in natural contexts, optimal replication of the current study may include a longer period of data collection. While the measurement of energy expenditure of young, healthy adults during simulated eating over a two-minute period showed that SenseWear® data correlated positively with data from indirect calorimetry, two minutes could be viewed as a comparatively short period of time in which to collect data. Dua, Ren, Bardan, Xie, and Shaker (1997) showed that, on average, healthy young adults swallowed 44 times, over more than two minutes, while eating a 1,000 calorie meal. Such
data suggest that the time needed to chew various textures and swallow multiple times can be classified as an endurance task and thus needs to be measured over longer periods of time. In addition, the nature of the food being chewed and swallowed, the time taken to chew, and the number of swallows attempted would provide valuable information to factor into the accurate measurement of energy expended during eating and swallowing in natural contexts.

Further factors that need to be considered in the evaluation of energy expenditure are each adult’s gender and body fat. Gender is an influential factor as women have a higher average percentage of essential fat (8-14%) compared to men (3-5%) (Kravitz & Heyward, retrieved from http://www.unm.edu/~lkravitz/Article%20folder/underbodycomp.html, accessed on May 11, 2011; McArdle et al., 1991). In the current study, the positive correlation between participants’ body mass, as measured by their Mid-Arm Muscle Circumference, and energy expenditure was in accordance with published findings, as reported by Bin, Flores, Alves-r-da-Silva, and Francesconi (2009), McArdle et al. (1991), and Sungurtekin et al. (2008). However, the energy expenditure values, as documented on indirect calorimetry, were higher than expected. The mean weight for male participants was 80.03 kg. McArdle et al. (1991) reported that for this weight, the expected energy expended during two minutes of eating while seated would be 3.6 kcal (i.e., 1.8 kcal per minute x 2 minutes of activity). Data from the male participants in the study indicated a mean energy expenditure of 4.66 kcal on indirect calorimetry. The mean weight for female participants in the current study was 65.68 kg. The expected energy expenditure, on indirect calorimetry, for this weight per time was 3.0 kcal. Data from the female participants in the study indicated a mean energy expenditure of 4.10 kcal. A plausible explanation for these higher-than-expected energy expenditure values could reflect the increased weight of some participants. An additional explanation could relate to the fact that
each participant’s Resting Metabolic Rate was not controlled as specifically as it could have been prior to data collection. Thus, application of the SenseWear® system in measuring the food consumption energy expended by male and female older adults with chewing and swallowing difficulties needs to be predicated on the body fat composition of each older adult and measured after a substantial resting period.

Another factor in the higher than expected kcal values under indirect calorimetry could be a heightened level of personal anxiety during testing. During testing, the investigator documented anecdotal data from the participants. A majority of comments showed that the indirect calorimetry was a new and uncomfortable experience for them. While none of the participants reported that they were frightened when wearing the mask, many of them stated that it was unusual and inconvenient to wear it while chewing and that silently counting the number of chews prior to each swallow made the task unnatural. Participants also perceived that the mask restricted chewing and adversely affected their management of saliva. The indirect calorimetry mask houses a saliva trap perpendicular to the wearer’s mouth to catch lost saliva. However, the perception of loss of control of saliva could have contributed to participants’ anxiety during the task. The noninvasive and nonrestrictive nature of the SenseWear® system provides two distinct practical advantages over indirect calorimetry in the measurement of energy expenditure.

The finding that SenseWear® data correlated positively with data from indirect calorimetry during simulated eating by healthy young adults validates the continued exploration of the SenseWear® system to measure energy expenditure during eating. When the SenseWear® system is applied to the measurement of energy expenditure during eating in healthy older adults and those with dysphagia, it will be valuable to gather additional data on each adult’s cardiac rate
and associated blood pressure as older adults expend more energy than younger adults in performing the same tasks (Timiras, 2003). Ideally, such data would be collected from each older adult before, during, and after their dining experience.

Further, results of the current study make a valuable contribution to the literature that supports the use of the SenseWear® system in natural contexts (Andre et al., 2006). A particularly important natural context is the continuing care communities in which many older adults reside. These older adults can be healthy residents in an independent living section of the community or dependent on others for care. Both populations include adults who are at-risk for dysphagia. The fatigue and increased effort experienced by older adults with dysphagia can compound swallowing difficulties, increase anxiety, affect food choices, lengthen the duration of a meal, and have an adverse affect on other daily activities, all of which can have a negative effect on each individual’s quality of life. Documentation of increased energy expenditure during eating in older adults with dysphagia, particularly those in continuing care communities, would support the need for these adults to eat smaller, nutrition-dense, meals more frequently throughout the day. This approach is congruent with the current move from professional or medically-oriented care to a “culture of community” model of resident-centered care that is underway in many continuing care communities (Campinha-Bacote, 2002; Hedrick et al., 2003; Kim-Godwin, Clarke, & Barton, 2001). Such a culture change frequently requires additional resources, including time for caregiver education. SenseWear® data on the effort of eating would provide valuable support in arguing for such resources to optimize and maintain the general health, nutrition, hydration, and quality of life of healthy older adults and those with dysphagia.
Conclusions

1. As determined from a group of healthy young adults, SenseWear® was a valid measure of energy expenditure during a simulated eating task compared to indirect calorimetry.

2. Data support the continued investigation of SenseWear® to measure energy expenditure in healthy older adults and those with dysphagia during eating in natural contexts.

3. Continued application of the SenseWear® system with adults needs to be accompanied by measurement of each adult’s cardiac rate, blood pressure, and the type and quantity of food being consumed, with a baseline Resting Metabolic Rate established as accurately as possible.
REFERENCES


REFERENCES (continued)


REFERENCES (continued)


APPENDICES
APPENDIX A

INFORMED CONSENT FORM

Investigating a new methodology to assess energy expenditure during simulated eating:

A pilot study

I, ________________________ , agree to participate in the pilot study, Investigating a new methodology to assess energy expenditure during simulated eating. I have been told that I will receive $20 for my participation. I understand that the data I provide will assist the investigators to determine the practicality of using the SenseWear® device to measure energy expenditure during eating. This information will be of value in future work with adults who have difficulties with swallowing.

I understand that I will complete a screening questionnaire to document that I have no known health issues that would compromise my participation in the study. Following this, I understand that I will go to the Human Performance Studies laboratory on the campus of Wichita State University. There I will work with Dr. Goldberg and/or Dr. Patterson to complete some preliminary measurements. These measurements will be my (a) weight and height to calculate my Body Mass Index (BMI), (b) mid-arm circumference (MAC) to estimate my body fat, (c) skin fold thickness at my tricep, bicep, scapular, and suprailiac areas to estimate my body composition, and (d) resting metabolic rate (by blowing into a portable device). I understand that these measurements are not invasive and should take no longer than 30 minutes. I have been told that any graduate students who are assisting in taking my measurements will be supervised by Dr. Goldberg and/or Dr. Patterson and aware of the importance of keeping my information confidential.

After the preliminary measurements, I understand that my energy expenditure will be measured through a SenseWear® device and indirect calorimetry while I am chewing a piece of gum. I have been shown a picture of both of these measurement methods. I understand that I will wear the SenseWear® device on an armband that will fit comfortably on the bicep muscle of my upper arm. For the indirect calorimetry measurement, I understand that my nose and mouth will be covered with a form fitting, comfortable, triangular shaped mask that will be secured by a band around my head. I have been told that, although it may feel unfamiliar at first, I should have no difficulty breathing with the mask on. I also know that I will have a two (2) minute period to get adjusted to wearing this equipment before any data collection begins. If I do experience any discomfort with the mask, I know that I can remove it immediately. I can then decide if I want to continue with the study or stop.
APPENDIX A (continued)

Once the equipment is in place and I am comfortable with it, I understand that data will be collected while I chew a piece of gum for two (2) minutes and swallow after every 10 chews. I understand that I will have to count my own chews and then swallow after each group of 10. I understand that the fitting of the devices and the SenseWear® and indirect calorimetry measurements are expected to take no longer than 15 minutes.

I do understand that my participation in this study is voluntary. I know that I can withdraw from the study at any time. If I decide to withdraw from the study, I know my data will be shredded or deleted and that there will be no negative effects on my grade for any course in which I am, or may be, enrolled.

I have been assured that any data I provide will remain confidential and be kept in a locked cabinet in Dr. Goldberg’s office. When the investigators present or publish data from this study, I understand that my data will not be shown in any way that would enable me to be identified. I understand further that once the study is published, the data I have provided will be shredded or deleted.

I understand that I can contact Dr. Goldberg at (316) 978-6115 or by e-mail at Lyn.goldberg@wichita.edu if I have questions or concerns about the study. I can contact Dr. Patterson at (316) 978-5440 or by e-mail at Jeremy.patterson@wichita.edu. If my concern involves Dr. Goldberg or Dr. Patterson, I understand I can contact staff in the Office of Research Administration (ORA) at (316) 978-3285 for assistance.

I agree that this study has been explained to me and I understand what I will be asked to do. I have been given the opportunity to ask questions and my questions have been answered to my satisfaction.

_____________________________                                _________________________
Signature                Date

_____________________________
Printed name

_______________________________            __________ ________________
Signature of investigator              Date

_____________________________
Printed name
APPENDIX B

SCREENING QUESTIONNAIRE

Please write your name, date of birth, age, and major area of study where indicated on this form and then respond to the questions that follow:

Name:

Date of Birth: Age:

Major area of study:

E-mail address:

1. Have you had anything to eat or drink other than water in the past 12 hours? Yes No

2. How long have you been awake today? Less than one hour 1-2 hours More than 2 hours

3. Do you chew gum? Yes No
   If yes, how often: Every day At least once per week Once in a while

4. Do you have any known allergies to, or intolerances, of gum? Yes No
   If yes, you do not have to complete any more of these questions.

5. You will be asked to breathe through a mask while chewing gum. Do you have a tendency to be claustrophobic? Yes No
   If yes, you may not want to participate in the study.
   If so, you do not have to complete any more of these questions.

6. Have you had any oral, head, or neck surgery within the last year? Yes No
   If yes, please provide details:

7. Have you had chemotherapy or radiation to your mouth or neck within the past 5 years? Yes No
   If yes, please provide details:

8. Are you currently a smoker? Yes No
   If yes, how much do you currently smoke?

9. Do you have dentures of any kind? Yes No
   If yes, please provide details:
10. Do you have frequent upper respiratory infections? Yes       No
   If yes, please provide details:

11. Do you currently have a cold? Yes       No
   If yes, how long have you had this cold?

12. Do you ever experience any difficulties swallowing? Yes       No
   If yes, please provide details:

13. Do you ever experience any difficulties breathing? Yes       No
   If yes, please provide details:

14. Have you ever been treated for any lung infection or injury in the past year? Yes       No
   If yes, please provide details:

15. Do you exercise regularly? Yes       No
   If yes, how often? Every day  At least twice per week  Once per week

16. Please list the type(s) of regular exercise you enjoy:

17. Do you consider yourself to be fit? Yes       No

Thank you very much for completing this questionnaire.
SenseWear BMS to monitor energy expenditure during swallowing.

Participants wear an armband that fits comfortably on the upper arm and under clothing for continuous data collection. The display provides minute-to-minute feedback as well as a programmable target. PC-based functionality enables the documentation of Total Energy expenditure (calories burned), Active Energy Expenditure, Physical Activity Duration and Level.
APPENDIX E

RAW DATA FOR PARTICIPANTS (n = 22)

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**KEY**

Part = Participant  Gen = Gender  Ht = Height  Wt = Weight  BMI = Body Mass Index  MAMC = Mid-Arm Muscle Circumference  IC = Indirect Calorimetry  kcal = Kilocalories  SW = SenseWear®

A = Asian, AA = African American, C = Caucasian, H = Hispanic