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Measurement of Daily Energy Expenditure in Individuals with Chronic Heart Failure

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Being able to accurately monitor and quantify the amount of physical activity an individual with chronic heart failure (CHF) performs can be of assistance in developing appropriate interventions. This thesis attempted to evaluate the validity of the RT3 accelerometer (RT3) and 7-day Physical Activity Recall Questionnaire (7 day PAR) in measuring the daily activity levels of community dwelling individuals with CHF. Fifty-four individuals with CHF participated in a 7 day session to estimate their daily physical activity by using the RT3 accelerometer and 7-day PAR questionnaire. In addition, 15 of the 54 individuals participated in a second study in with the validity of RT3was compared to oxygen consumption (VO2) measured by a MedGraphics VO2000 gas analyzer during typical daily activities. Although there was no significant difference between the RT3 and VO2 on mean caloric (Kcal) expenditure (p=0.67), the accelerometer tended to underestimate the energy expenditure (EE) and its validity was affected by activity intensity, movement patterns, placement location and soft tissue adhesion. The 7-day PAR overestimated EE by 22%, when compared to the RT3. There was no significant difference in the outcomes if the 7-day PAR only focused on day time activity versus 24-hour activity which included sleep. The second study revealed that the resting metabolic rate in individuals with CHF is significantly lower than 3.5 ml/kg/min, which indicates this metabolic constant for the general population is probably not appropriate for estimating daily energy expenditure in individuals with CHF.

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Introduction:

Chronic disease is now seen as one of as the primary factors causing death or disability in both developing and developed countries. In addition, chronic diseases greatly affect individuals' living situations and daily activity levels. For those who have been diagnosed with a chronic disease or a functional limitation the most common problem is decreased physical activity tolerance. For those with multiple illnesses or various stages of symptoms, activity tolerance becomes an even greater problem.[1] A decrease in activity can have a negative impact on an individual's cognitive abilities and moods as well.[2]

In the past these individuals were typically treated with bedrest, activity restrictions, and medication with the goals of preventing the progression of the disease and maintaining function. However, individuals who followed this regimen demonstrated rapid decrease in their functional abilities along with further disease progression. Therefore, their caregiver started to wonder if decreasing their activity level might be the reason for the additional decline in these individuals' physical condition and the exacerbation of their symptoms.

A great deal of research has investigated whether there is a relationship between an individual's activity level and the prevalence of disability. Dianna Carroll and Elizabeth Courtney-Long[3] compared adults with a disability to adults without disabilities. They found that inactivity was more prevalent among adults with a disability (47.1% versus 26.1%). In addition, inactive adults with disabilities were 50% more likely to report one or more chronic diseases than were those who were physically active. Today more and more healthcare providers and researchers are coming to believe that maintaining an individual's activity level helps him/her maintain an independent level of function and decreases mortality.

Therefore, it is vital for physical therapists to encourage individuals to exercise to maintain their level of function, and to monitor and increase levels of activity during treatment sessions. To achieve these goals, it is critical for physical therapists to evaluate an individual's physical activity capacity and to estimate daily energy expenditures based on an individual's ability under varied environmental conditions. When making such assessments physical therapists must utilize accurate measurement methods. By doing this, physical therapists can help prevent/delay the onset of chronic disease, delay the progression of functional impairments, and improve an individual's functional abilities.

According to the World Health Organization's definition, physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure. Based on this definition there are currently many methods that can be used to measure or evaluate physical activity from different perspectives. For example, individuals can complete subjective questionnaires, diaries, and surveys regarding their daily activity. Pedometers, doubly-labeled water tests, indirect calorimetry measurements and accelerometer data can also provide objective results. The validity and reliability of most of these measurement methods have been widely tested and validated. Some have limited practical application in the clinic due to the time and/or expense required to administer them. This paper reviews the most common methods that have been used to estimate physical activity capacity and then analyzes the characteristics of these measurement methods based on former research

Background of measurement methods

Measurement is the assignment of a number to a characteristic of an object or an event in order to describe its details or to make it comparable to other objects or events. Measurement can be completed via two different approaches: objective quantification and subjective assessment. Measurement systems utilize both of these approaches to varying degrees therefore all measurement methods may be classified into two main categories: objective measurement and subjective measurement.

Subjective measurement

Subjective measurement methods that address physical activity include: questionnaires, diaries, logs, and surveys. They estimate physical activity based on an individual's perception of the intensity and duration of the activity; his/her ability to use the measurement tool; and interaction with a researcher or therapist while completing the tool. Because using subjective measurement tools is relatively inexpensive and they are easier to use in large-scale studies[4], they have been widely employed for measuring physical activity and for energy expenditure estimation. Although test results come primarily from an individual's subjective recall researchers can still treat them as reliable data and use them for comparisons among different studies. To that end, many subjective measurement methods include a standardized administration procedure[5]. Such standardized processes decrease the variability caused by an individual's personal feelings or researcher bias, thus increasing the reliability of the data/results

Based on former studies,[4,6,7] there are five factors predominantly responsible for the validity of a subjective measurement: (1) the level of accuracy with which an individual can recall a particular memory,(2) the degree of clarity with which an individual can classify an activity by intensity, (3) an individual's confidence level when reporting an activity during an interview,(4) the appropriate interpretation based on an individual's report, and (5)the formula used for the energy expenditure calculation. These factors may affect test results to varying degrees depending on the protocol used during the subjective testing.

Therapists and researchers have made extensive use of subjective measurement techniques to gauge physical activity levels. Questionnaire-based evaluation methods and diaries have the advantage of being time efficient and easy to use. They do not require specialized knowledge on the part of the individual or the examiner regarding the proper use of a device (e.g., how to adjust the device or how to properly wear it). By simply reviewing an individual's diaries or examining a completed survey or questionnaire, evaluators can calculate an individual's activity level based on the formula associated with the measurement tool in question. Furthermore, such methods do not require an extended evaluation time on the part of either the evaluator or the individual; all that is needed is for the individual to regularly record his or her activities and report to the evaluator.

The validity and reliability of these measurement methods has been tested and the findings indicate a strong correlation between the results gathered from subjective reporting and the "gold standard" of doubly labeled water. For example, HervéBesson and SørenBrage used doubly labeled water as a benchmark by which to gauge the validity and reliability of the Recent Physical Activity Questionnaire in terms of its ability to accurately measure energy expenditure. They found that the questionnaire had a significant association with this benchmark method[8]. However other studies have noted limitations that may affect the validity of questionnaires, diaries, and surveys. Rajna Golubic and Anne M. May[9]conducted a study often European countries and found that the questionnaire underestimated physical activity energy expenditures. That said, the researchers suggested that questionnaires and surveys could be a good fit for large-scale epidemiological studies. Other studies such as the one conducted by David Donaire-Gonzalez[10] have indicated that surveys can be a valid tool to classify but not to quantify activity level.

Such results may be due to many factors. For example, questionnaires might not have the ability to identify those in special populations because their questions and scoring systems are based on the entire population being studied including those without disabilities or chronic diseases. Moreover, the use of these methods is highly limited by region, culture, language, and target population. As of yet, no study has shown that evaluation methods can be universally applied. Furthermore, such measurement methods require patients to use their memories to recall what activities they performed, and thus validity may be affected by incorrect recall or even by fabricated memories. In summary, such restrictions may have an impact on measurement results therefore affecting the validity of these methods

Objective Measurement

Segen’s Medical Dictionary defines objective measure as, “the quantification of a physiologic or medical variable by instrumentation rather than by subjective human assessment.” Compared to subjective assessment, objective measurement methods can provide more consistent and unchanging estimates that can reflect real-time performance.

Because an objective measurement directly quantifies and records biomechanical or physiological consequences it should not be affected by characteristics of either the subject or the examiner, or by the type of the instrument that is used in measuring.

Methods for objectively measuring human physical activity capacity and energy expenditure (EE) can be categorized into two major groups: direct physical measurement and direct/indirect physiological measurement. Direct physical measurement of a subject's biomechanical performance utilizes tools such as accelerometers, pedometers, or Actiheart (an accelerometer combined with a heart rate monitor). Such instruments allow researchers and therapists to estimate an individual's physical activity level based on the motion data generated from body movement over a given period of time. Generally speaking, high-intensity activity isreflected by high-motion data (activity count/step count). By using the relevant estimation equation developed throughlaboratory research therapists can transfer the activity count into energy expenditure (EE),therebymonitoring an individual's activity level and establishing a treatment plan.

The second technique for assessing the physiological results of performing physical activity is direct/indirect physiological measurement. Common methods include doubly-labeled water tests and direct/indirect calorimetry. These approaches follow varying protocols but primarily focus on measuring the human body's metabolic rate in order to estimate an individual's energy expenditure (EE) during a certain period of time. For example, the doubly-labeled water method uses isotope-labeled water to calculatecarbon metabolism. By monitoring deuterium losses, the researcher can calculate the total amount of oxygen lost from the body's water pool via conversion to carbon dioxide, and thus estimate energy production. In contrast, calorimetry measures the heat eliminated or stored in the body system. Researchers can estimate the subject's energy expenditure (EE) either by directly measuring the amount of heat production in an enclosed space or by an indirect method that usesa gas analyzer to calculate oxygen consumption and carbon dioxide elimination.

Since doubly-labeled water and direct/indirect calorimetry are based on physiological changesthey provide highly reliable and valid data. Due to their high accuracy, many researchers utilize these methods and consider them to be the "gold standard" by which to compare other measurement techniques. However, since these methods necessitate that special criteria be met in order to achieve valid results, they are more commonly applied in laboratory settings rather than in clinics.

The goal of this project is to identify a method that is both highly practical for use in clinics and that can provide valid measurement results that are as accurate as direct/indirect physiological measurement. After comparing various measurement methods, the accelerometer appears to be the best choice. It appears to be able to cover both the practicability and validity aspects in clinical physical activity measurement since this method does not require special training, and its validity has already been tested on a healthy population.

The accelerometer is the primary topic of this section. Its basic principles of operation are discussed along with its validity, reliability, and influence factors. The accelerometer is also compared with other measurement methods in order to identify the practicability and validity in physical activity measurement.(For references, please see Appendix A)

Accelerometer

An accelerometer is a device that can record acceleration generated by motion along a reference axis. It was first used to investigate gait velocity and acceleration in 1950[11].Since then and especially following technological advances in the 1970'sand going forward many studies have been conducted with the clinical utilization of the accelerometer. Research topics have included energy estimations, fall assessment/monitoring, gait assessment and posture control[11, 12, 13] and the monitoring of respiration rates.[14,15]

In spite of all of these applications, the most common usage of accelerometers is to estimate daily activity levels and energy expenditure (EE). Compared to other procedures accelerometry has shown promising possibilities when used to objectively estimate physical activity behavior[16]. Colbert et al. using the doubly-labeled water method as a benchmark compared it with the outcomes from 7 different energy expenditure (EE) measurement methods. They found that with an appropriate estimation equation, accelerometers provided data that was more accurate than that provided by other measurement approaches[17]. Moreover, the accelerometer is more economical and easier to operate than either doubly-labeled water(DLW) or direct/indirect calorimetry since it does not require an expensive or complicated device and does not requirespecific training. Because of these advantages, many European countries have incorporated accelerometers into their physical activity monitoring systems.[18]

In addition, due to the amount of progress that has been made regarding measurement protocols for healthy populations, current research is able to target more specific populations such as those with physical limitations or specific diseases. This field of research – which has seen considerable activity – seeks to test the accelerometer's validity and practicability in these populations. It also aims to develop a standard measurement protocol for clinical evaluation and to identify the possible influence factors and limitations of the accelerometer with community dwelling populations.

1. Basic Principle of Accelerometer

1.1 Structure

TThe accelerometer can monitor body motion from various angles and directions by measuring acceleration along reference axes in different planes. It can provide a real-time assessment of magnitude and the total volume of movement. In addition, the accelerometer can filter out "noise" – the vibrational forces irrelevant to normal body movement[19] – via apreset cutoff frequency. Piezoresistive, piezoelectric, and differential capacitive accelerometers are the most common types of accelerometers found on the market. The piezoresistive accelerometer responds to constant acceleration and is simpler and less expensive than other types of accelerometers. Its drawbacks are temperature-sensitive drift and alower output level. The piezoelectric accelerometer is unmatched in terms of its upper frequency range, low packaged weight, and high temperature range but it is unable to detect the constant component of acceleration. Finally, the differential capacitive accelerometer is commonly used in mobile and portable systems and in consumer electronics. This is due to its low power consumption, large output level and fast response to motion.[11]

Although many types of accelerometers are available on the market, they all operate on the same principle. An accelerometer's basic structure includes a horizontal cantilevered mass and a seismic mass. When there is an applied acceleration, the inertial force generated from acceleration or gravity causes the seismic mass to bend or compress which causes a voltage to be sent that is proportional to the acceleration change. By calculating, transcoding, and calibrating this signal therapists and researchers can arrive at a clear picture of a patient's activity ability.[11]

2. Guidelines for Accelerometer Selection and Placement

2.1 Accelerometer Selection

When utilizing a device as a measurement tool in research or clinical settings the most important concern is its validity and reliability. Various research studies have been conducted to confirm the accelerometer's validity and reliability. Some researchers have argued that the accelerometer and its estimation equation cannot provide a very accurate measurement estimate.[21, 22, 23]As evidence, they point out that some measurement processes only deliver reliable outcomes either under certain laboratory conditions[24] or in a preset community environment. According to such researchers, the accelerometer tends to underestimate activity levels [21, 22] when used to approximate daily energy expenditures (EE's) in community dwelling living situations. They also hold that its validity is highly dependent on the type of activity that has been measured[25]. Even so the accelerometer is still able to demonstrate a good correlation with the "gold standard." Guy Plasquiet.al.[26] has reviewed 25 articles that confirmed the accelerometer's validity via the use of DLW as a reference. They found that correlation results varied based on age group, demographic, location of accelerometer placement and research environment. Many of the studies that were reviewed (17/25) showed that the accelerometer had a moderate to good correlation (R>60%) with the DLW test in measuring physical activity or energy expenditure (EE). Furthermore, the accelerometer displayed a high level of validity and reliability in measuring an activity's intensity over time. Therefore, by using calibrated estimation equations the accelerometer should be able to provide more specific measurement results by adapting to specific characteristics of a sample based on a particular age group or disease.

Besides validity, other factors also need to be taken into account before selecting the accelerometer. One such factor is the varying level of practicability offered by different types of accelerometers. Today three kinds of accelerometers are commonly used for research and clinical applications: uniaxial, biaxial, and triaxial. All three have the same basic structure. The only difference between them is the number of dimensions that they can measure. Generally speaking, the more axes/dimensions that the accelerometer can track, the more complex activities the accelerometer can record. However, this does not mean that the triaxial accelerometer is always the best choice. Since the triaxial accelerometer is more complicated than the uniaxial accelerometer, there is a huge price difference between these devices. In order to maximize the cost/effect ratio, many studies have been conducted to determine whether the different types of accelerometers are able to provide similar results. Since these studies have had dissimilar objectives and have used different measurement parameters the results have varied.

For example, Jérémy Vanhelst and Laurent Béghin[27] compared uniaxial accelerometers and triaxial accelerometers for measuring the percentage of time that adolescent in community dwelling situations spent at different physical activity levels. All participants wore the uniaxial accelerometer and the triaxial accelerometer at the right hip simultaneously for seven days. These researchers found that the two accelerometers demonstrated a very good reliability in measuring the percentage of time spent engaged in assorted activity levels (sedentary, light, moderate, and vigorous). The Intra Class Correlation was higher than 95%. The difference between the data obtained from the two accelerometers never exceeded 2.1%, and the difference decreased as physical activity levels increased. Based on their findings, they claimed that there is no significant difference between the uniaxial accelerometer and triaxial accelerometer when measuring physical activities in community dwelling situations.

In contrast, Ott et.al[28]compared the validity of the uniaxial accelerometer (CSA) and the triaxial accelerometer (Tritrac-R3D) among 28 children aged 9-11 as they performed eight different free-play activities. These were playing a video game, throwing and catching, walking, bench stepping, hopscotch, basketball, aerobic dance, and running. Subjects spent five minutes at each activity station. Heart rate and activity count were recorded for the last three minutes of each activity in order to minimize the effect of prior activities. They found that both kinds of accelerometers demonstrated a significant correlation between activity counts, heart rate, and predicted MET level. However, when the uniaxial accelerometer ($r=0.43$ with MET, $r=0.64$ with heart rate) was compared to the triaxial accelerometer, the triaxial accelerometer had a stronger correlation ($r=0.69$ with MET, $r=0.73$ with heart rate).

In another study, Leenders et al.[29]focused on adults and compared the DLW with CSA (uniaxial) and TriTrac-R3D (triaxial) in order to evaluate the correlation between these two measuring methods. Thirteen subjects participated in a seven-day experiment. The accelerometers were secured at the waist and attached to a belt. The triaxial accelerometer demonstrated a stronger correlation with DLW's results (r =0.54) than did the uniaxial accelerometer (r =0.45). This study suggested that the triaxial accelerometer is the better choice for measuring activities in a community dwelling situation and for focusing on complex activity patterns. However, if the goal is to focus solely on simple activity patterns like walking or if the research will take place in a controlled laboratory environment, both uniaxial and triaxial accelerometers can provide a strong correlation with DLW.

Hendelmanet al.[30] tested the validity of uniaxial and triaxial accelerometers against indirect calorimetry for walking and a range of household and recreational activities. They found that when focusing solely on walking, the correlation of energy expenditure results between the uniaxial accelerometer and indirect calorimetry was 0.77.For the same activities, the correlation between the triaxial accelerometer and indirect calorimetry was 0.89. Welket al.[31]conducted a similar study that investigated the validity of three different accelerometers; the ActiGraph (uniaxial), TriTrac-R3D (triaxial) and the BioTrainer (biaxial) compared to indirect calorimetry in measuring laboratory treadmill exercise and non-laboratory activities of daily living. During treadmill walking and running, all accelerometers demonstrated a strong correlation with VO2 (ActiGraph: r=0.85, TriTrac-R3D: r=0.93, BioTrainer: r=0.87). However, when the focus was on activities of daily living, the correlation for all three accelerometers decreased (0.59 for TriTrac-R3D and BioTrainer and to 0.48 for ActiGraph).These figures are similar to Leenders' correlation results.

Accelerometer selection can be influenced by multiple factors. Although many studies have found that the validity coefficients for multiple-axis accelerometers are higher than those for uniaxial models[32], many other factors need to be considered when choosing an accelerometer. These include cost effectiveness, appropriateness for the design if the study and compatibility with the research goals.

2.2Guidelines for Placement

Generally speaking, the sternum, lower back, and waist are the most common locations for placingaccelerometers.[11] Guy Plasqui and Klaas R. Westerterp[24] reviewed 28 articles that sought to test the validity of accelerometers as compared to the DLW method in the estimation of daily energy expenditures. Among these papers, nearly half of them (10) selected the lower back as their fitting location for the accelerometer. Other placement locations included the waist (6), hip (5), ankle/shoes (3), and a combination of chest and thigh (2). The correlation between each placement location and DLW can be seen in Table 1.Since researchers like to track the whole body's movement as much as possible during the measurement process, they select a location close to the body's center of gravity in order to track the total acceleration generated by the movement of the whole body. Because it is impractical to place the accelerometer inside the human body, the low back seems the optimum choice for placement because it is at the same level as the center of gravity and it is relatively easy to place the accelerometer there. This placement does not affect an individual's activities of daily living during the monitoring process.

The accelerometer placement will vary depending on the research goal or design. To get the best results a researcher may place the accelerometer in a location other than the lowback even though the low back is considered the "gold standard" for accelerometer placement[33, 34].

It is also important to take into account the limitations/characteristics of the accelerometer being used when deciding the placement.

Type	Brand	Correlation coefficient (Placement location)
Uniaxial	Life Corder	0.72-0.83 (Waist)
	Actigraph/CSA/MTI	0.58-0.96 (Lower back); 0.33-0.62 (Hip);
	Caltrac	0.26^{NS} (Waist)
Biaxial	Actiwatch	0.27^{NS} (Ankle)
Triaxial	Tritrac-R3D	0.31 (Waist)* 0.54^{NS} (Hip)
	Tracmor	0.63-0.91 (Lower back)
Combined system	ActiReg	Did not provide;(mean ± 2 SD)= 0.41±2.69
Pedometer	Foot-ground contact pedometer	$0.17\text{-}0.23^{NS}$ (Shoes)

Table 1 Correlation between the outcome of accelerometer at each placement location and DLW

NS= not significant;
*There is a difference between the days on which the accelerometer was worn (4 days) and the DLW monitoring period (10 days).

3. Limitations

3.1 Placement issue

An inappropriate placement location may result in a strong impact on the validity and reliability of the data. When testing the validity of accelerometer data for estimating daily energy expenditures via comparison with the doubly-labeled water method, Guy Plasqui and Klaas R. Westerterp[24] found a strong correlation (R>80%) between accelerometer results and

DLW results when the researcher fit the accelerometer on subjects' lower back or waist. The correlation between these two methods fell to less than 25% when the accelerometer was placed on the ankle or shoes. These findings indicate that measurement errors can result if the placement location is not carefully considered. Such miscalculations are especially likely to happen when placements are not appropriate for the research goal and design.

A second concern regarding accelerometer placement is loosening of the accelerometer. Individuals may report that their accelerometers loosened on their bodies during the monitoring period or throughout the course of the day. A loose placement may cause inaccurate measurement due to increased signal-to-noise ratios or cause inconsistencies between data collection and activities for some other reason.[35]

The final concern about placement is convenience. Many individuals report that they feel uncomfortable when performing daily activities with an accelerometer on their body. In addition, individuals need to remove the accelerometer during bathing and sleeping for both safety and comfort issues. Removal of the device can lead to data loss and also increase the possibility that individuals will either replace the device incorrectly or not at all. However, with the development of technology many accelerometers (Like the newly developed Actigraph GTG9X) have been able to provide a smaller wireless sensor that greatly improves the comfort of the device while it is being worn. Besides that, many accelerometers are now waterproofed which may help in preventing the loss of data due to removal of the device while showering or performing some other water activity.

Even if an optimal placement location has been selected, sometimes accelerometers are still not able to provide accurate measurement. For example, underestimation of activity level is a common issue in many studies, especially those that focus on measuring sedentary activity. One of the most reasonable explanations is that an accelerometer fastened at a certain position on the body (for example, the waist), might not be able to cover movement from other body parts. Some studies try to correct the problem by making use of multiple accelerometer systems during assessment. However, this technique has not been shown to improve results.

3.2 Movement Pattern

Another limitation of accelerometers is that they can only accurately assess limited types of movement patterns. For the population that uses ambulation as its major habitual activity, the accelerometer can provide relatively valid measurement results. However, for individuals who prefer non-ambulatory activities – such as cycling or performing isometric movement–measurement results may not be accurate.[36] For example, crouch walking costs more energy than walking with a normal gait due to the continuous contraction of the quadriceps. However, an accelerometer placed at the waist might result in a lower activity count for crouch walking, because this activity does not cause the body’s center of gravity to shift as much. For that reason, we need to select the devices based on the characteristics of the movement pattern in order to decrease the chance for measurement error.

3.3 Estimation Equation

Many accelerometers can convert activity counts into energy cost by using a preset energy estimation equation. Kate Lyden and Sarah L. Kozey[21] analyzed nine published and two proprietary energy expenditure (EE) prediction equations on 277 patients for six treadmill activities(1.34, 1.56,2.23 ms^{-1}, each at a 0 and a 3% grade) and five self-paced activities of daily living (ADLs). During those activities, all subjects ascended stairs, descended stairs, and moved a 6 kg box. The remaining two activities were randomly selected from a catalog of 14 possible options (cleaning a room, dusting, gardening, laundry, mopping, mowing, painting, raking, sweeping, trimming, vacuuming, washing dishes, basketball, and tennis). The results indicated that all of the equations underestimated the energy expenditure (bias -0.1 to -1.4 METs and -0.5 to -1.3 kcal, respectively). Misclassification rates ranged from 21.7 (95% CI 20.4-24.2%) to 34.3% (95% CI 32.3, 36.3%), with vigorous intensity activities misclassified the most frequently. These findings suggest that the relationship between activity counts and energy expenditure (EE) is specific to the activity being performed. This could be a limitation for measuring activities of daily living in community dwelling situations and could lead to substantial misclassification of activity levels.

3.4Frequency-based Filtering

Since accelerometers measure acceleration with a certain recording frequency and summarize this as a count over a period of time, they might not be able to specifically describe an activity's intensity level. Take, for example, an accelerometer with a 20-second recording period. Such a device would not differentiate between an activity with 1 count per second for 20 seconds and an activity with 20 activity counts in first 5 seconds and 0 activity counts for remaining 15 seconds. This weakness of the accelerometer greatly affects its ability to categorize activities' intensities. As a consequence, data analysis might underestimate the true intensity level, resulting in incorrect information reported to individuals/subjects.

4. Comparison with other Measurement Methods.

Although the accelerometer has many limitations, when it is compared with other measurement methods – like the doubly-labeled water approach or the pedometer – it still shows itself to be a more practical and simple measurement technique. For example, in the past, when researchers attempted to determine the energy cost for certain activities, they usually used doubly-labeled water under laboratory conditions[37] or portable calorimeters in the field.[30] Although these two measurement techniques were considered the "gold standard" for estimating energy expenditure, neither of them have a wide practicability in clinical settings. This is because many factors impede the use of these two methods. For example, doubly-labeled water is very expensive, and its output is highly limited. Portable calorimeters need highly trained specialists to collect and measure data. These properties restrict the use of these methods, rendering them limited to laboratory research.

The pedometer is a frequently seen device for monitoring physical activity, and it has a long history of use among different types of individuals. The pedometer's advantage is that it is easy to utilize. Individuals do not need specific training regarding its appropriate use. All they need to do is wear the device during movement. Regarding the pedometer's validity and reliability, Lara Allet and Ruud H. Knols[38] reviewed 25 articles on pedometer and accelerometer usage by individuals with osteoarthritis, cardiovascular diseases (CVD), Type-2diabetes mellitus, and chronic obstructive pulmonary disease (COPD). Their study found that pedometers can be good and reliable measurement instruments. Additionally, Lorraine S. Evangelista and Kathleen Dracup[39] observed that the pedometer was a valid indicator of exercise adherence in heart failure patients who participated in a home-based walking program. However, this latter study also pointed out a limitation of the pedometer, which is that it can only show a high correlation with the number of steps in walking activity. Moreover, research conducted by Thais Sant'Anna and Victoria C. Escobar[40] indicated the validity of pedometer data is more limited for energy expenditure during slow walking. This study also found that pedometers significantly underestimated activity time. Therefore, this device may not appropriate for at-home monitoring of individuals' daily activity levels and energy expenditure. Table 2 provides a summary of the advantages and disadvantages of various measurement methods of physical activity. (For references, please see Appendix B)

Background Information on Chronic Heart Failure (CHF)

1.1 Definition

Heart failure, as the final stage of many cardiopulmonary diseases, occurs when the heart is unable to pump in a manner that is sufficient for maintaining blood flow to meet the body's needs. According to the American Heart Association, heart failure is a complex clinical syndrome that results from any structural or functional impairment of ventricular filling or ejection of blood[42]. It has a high mortality rate and it greatly decreases an individual's functional level. The most characteristic symptom of heart failure is exercise intolerance which involves increased shortness of breath, excessive tiredness, and excessive fluid retention. Exercise intolerance greatly limits an individual's exercise capacity and daily living activities. In addition, it decreases the individual's quality of life and increases his or her mortality risk. At first, individuals may only present symptoms with strenuous activities or exercise. As the disease progresses they may complain of shortness of breath and fatigue even

Method	Advantages	Disadvantages
Doubly-labeled water test	Gold standard; high accuracy and reliability	Very expensive; requires specialized instrumentation, such as isotope ratio Mass Spectrometry to measure stable isotopes[41]
Indirect calorimetry	Classic measurement method for estimating resting energy expenditures	Needs a specialist to adjust the device; gas leaks may lead to error; primarily for assessing resting energy expenditures
Questionnaires, diaries, and surveys	Easy to apply; proven consistency with DLW	Mainly based on patient's memory; may have subjective affect; especially hard to apply to children and seniors
Pedometer	Easy to use; does not require a specialist to adjust	Only measure the count of step; cannot distinguish the intensity of an activity; only applicable to walking and running; not usable for sedentary activities
Accelerometer	Easy to use; can estimate energy expenditure by using an equation; can be applied to all types of activity, based on fitting location; shows a good reliability	Results can be affected by fitting location; activity pattern, validity varying in the field environment activity measurement;tends to underestimate energy expenditure; equationsare highly specific for different subjects

Table 2 Advantages and disadvantages of each measurement method

at rest. In severe situations, individuals may not be able to lie flat at night and during sleep due to increased fluid retention in the pulmonary system and a decrease in the supply of oxygen to the body. Since heart failure is an irreversible process the prognosis is usually poor. Because of this individual with heart failure have to live with the disease and manage its symptoms for the rest of their lives.

1.2 Types of Heart Failure

Today most cardiologists and researchers use the ejection fraction as their primary measurement to categorize heart failure.[43] Patients with CHF might have reduced or preserved ejection fractions based on their condition. The ejection fraction is the percentage of blood pumped out of a filled ventricle as a result of a heartbeat. To be considered normal it should be between 55% and 75%.[44]

Based on different ejection fractions individuals with heart failure can be categorized into two main groups. The first group contains individuals with preserved ejection fraction (HFpEF), and the second group contains individuals with reduced ejection fraction (HFrEF). In the first group the individuals' systolic functions are preserved. Their hearts are able to pump out blood within the normal ejection fraction range which means the heart muscle contracts normally. However, in these individuals the left ventricle does not relax as it should during the refilling process. This decreases the volume of blood that returns to left ventricle thus limiting heart function in these individuals. The second type of heart failure, HFrEF, is also known as systolic heart failure. Here the ejection fraction is usually lower than40%, which means the left ventricle does not contract effectively. This decreases the circulation of oxygen-rich blood in the body which restricts the individual's ability to physically function in their daily lives.

Despite the fact that HFpEF and HFrEF differ based on the level of ejection fraction the clinical symptoms can be the same. According to Michael R. Zile,[45] there was a similar impairment in the ability to increase cardiac output and maintain low-LV diastolic pressure sufficiently in individuals with or without reduced ejection fraction. Both groups demonstrated decreased physical activity levels and functional levels in their normal daily lives.

2. Pathophysiology

Any conditions that reduce the efficiency of the heart muscle may cause heart failure. Due do direct damage to the heart muscle or prolonged overloading, the heart's workload surpasses its normal functional capacity. This forces the heart to initiate a remodeling process to adapt to the overloading and to maintain function. The first pathological change is always related to vascular endothelium remodeling. There modeling process can be initiated in two ways. The first is via a change in local hemodynamic or in response to circulating chemical signals.[46]After the endothelial cells sense the change from the environment they release the mediator to the vascular smooth muscle. This causes immune system cells to accumulate in response to the inflammatory process. This may change the blood flow dynamic and increase the resistance of the circulation system, thus intensifying the load on the heart. This can prompt pathophysiological changes to the ventricle and activate many endocrine processes meant to compensate for the dysfunction. If the circulatory resistance exceeds the normal systolic pressure the heart will respond by thickening the myocardial wall to increase the ventricle's force of contraction. In the initial stages these compensatory strategies will maintain cardiac output. However, these adaptations cannot sustain cardiac output for long. This is because the thickening of the myocardial wall decreases the ventricle's volume and the heart's compliance (the heart becomes stiffer) which also limits cardiac output. At this point the body needs to escalate its heart rate to compensate for the low stroke volume in order to maintain the heart's output. However, a rapid heart rate greatly reduces the myocardial cells' resting time and impedes the coronary perfusion time which damages the heart muscle. A prolonged perfusion deficit increases the risk of further damage to the heart, and finally leads to the decompensation stage – heart failure.

3. Physical Activity Changes in Patients with Heart Failure

Exercise intolerance is a cardinal sign of individuals with CHF. These individuals show fatigue and shortness of breath while performing physical activity until in end stage they have these symptoms at rest. This changing pathology greatly affects an individual's ability to participate in daily activities and decreases their quality of life. There are other factors that can contribute to a low exercise capacity[47]. In this paper we will mainly focus on hypoxia and muscle disuse.

3.1 Hypoxia and Muscle Response

Hypoxia means a decreased oxygen level or inadequate oxygen delivery at the tissue level. It can be created by the environment or a change in the pathology. Usually the human body is able to compensate to some extent for a decreased oxygen level by using alternate metabolic methods such as anaerobic metabolism and glycolysis or by increasing the total number of erythrocytes in order to improve the oxygen transfer through the blood. However, for the individual with CHF who cannot maintain their cardiac output due to irreversible changes in their heart muscle and compromised physiology a prolonged low cardiac output will decrease the peripheral vascular blood flow and decrease the oxygen delivery to the peripheral skeletal muscular system.

The blood flow through the renal system is also been decreased which triggers the renal system to enter a hypovolemic state in order to retain blood volume. The renal system then increases the production of rennin, which can be converted to angiotensin. Angiotensin can intensify peripheral vascular resistance, thereby elevating blood pressure. However, rennin can also stimulate the release of aldosterone, the hormone that increases sodium re-absorption in the proximal tubule. This causes excessive water retention and leads to peripheral edema, which may compress the arteries and cause further reduction of blood flow

The diminished left ventricular output leads to hypertension in the pulmonary capillary wedge which results in an accumulation of fluid in the alveoli and small airways. The fluid in the lungs' interstitium impedes ventilation and perfusion, thus decreases the oxygen level in the blood. All these pathology changes will severely decrease the oxygen level in the body and produce hypoxia in multiple body systems, especially the skeletal muscle system.

The traditional theories related to muscle wasting and atrophy that present in individuals with CHF suggested they were due to a deceased appetite and reduced physical activity. However, more and more evidence is accumulating that shows hypoxia itself contributes to the loss of muscle mass during chronic hypoxia[48].Many studies have been conducted in order to find out the relationship between hypoxia and skeletal muscle dysfunction[49, 50].Based on the outcomes, the findings are that chronic hypoxia leads to a negative regulation of protein balance in the skeletal muscle system which significantly changes the fiber proportions of muscle, thus impacting the individual's exercise capacity.

3.1.1 Chronic Hypoxia and Regulation of Protein Balance

The effect of hypoxia on protein balance regulation is based on its duration. Research[48] has found that hypoxia may increase the speed of protein turnover, but depending on the length of time the hypoxia lasts, the outcome is totally different. Acute hypoxia causes the increase of protein synthesis, a general increase in growth hormone, activation of satellite cells and an increase in the recruitment of type II muscle fibers. In fact it can be said that short term hypoxia improves muscle strength and endurance.

In contrast, chronic hypoxia usually triggers muscle wasting. Although chronic hypoxia also increases both protein synthesis and degradation, the increased rate of protein degradation is higher than the rate of protein synthesis which results in skeletal muscle loss[48]. Individuals with CHF who have significantly decreased cardiac output due to pathologic changes in their cardiovascular system will have widespread chronic hypoxia that affects the entire muscle system of the body. This will cause general skeletal muscle weakness and exercise intolerance.

3.1.2 Chronic Hypoxia and Muscle Alternation

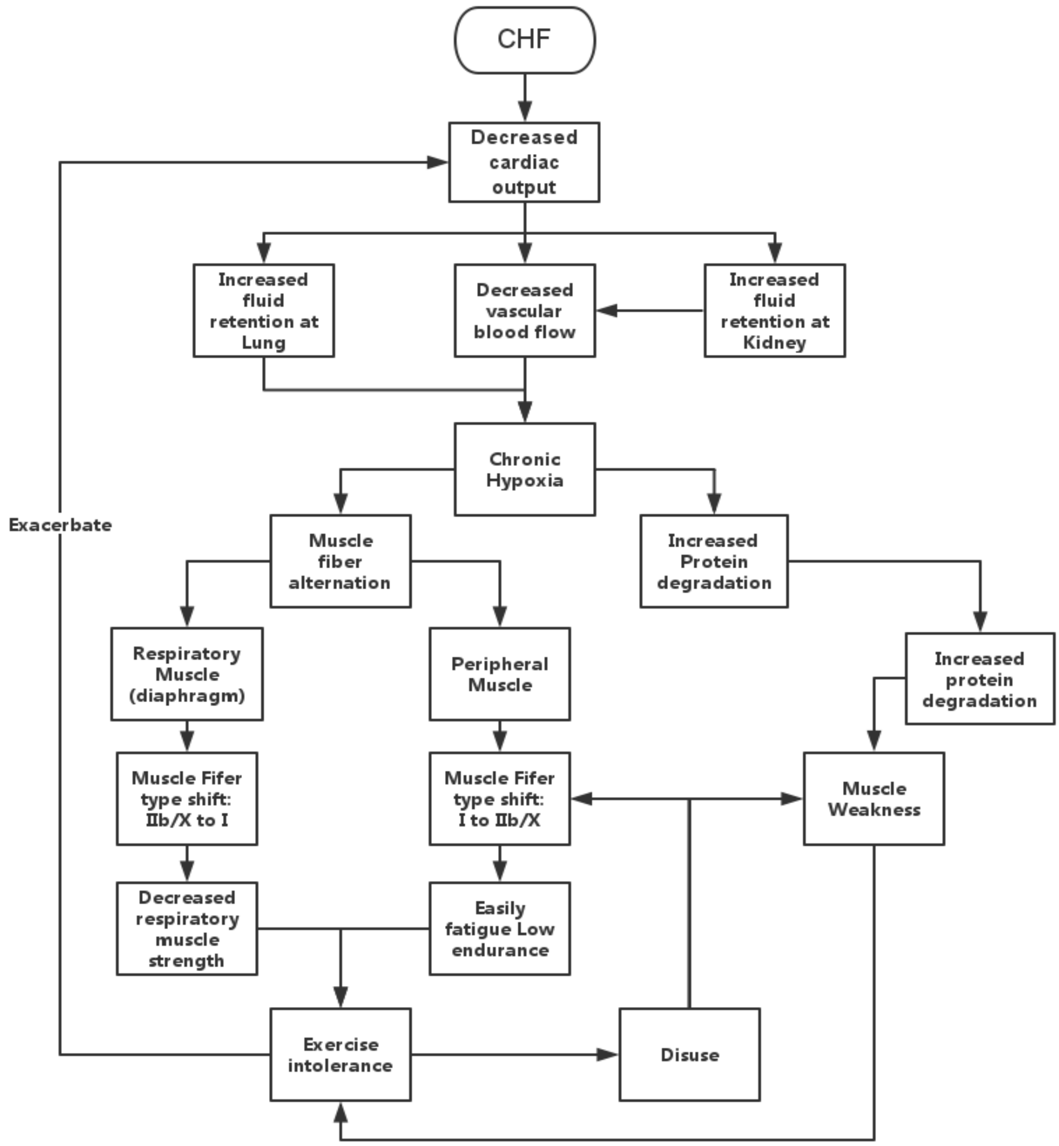
We know that human muscle contains 3 different types of myosin heavy chain fibers depending on their metabolic pathway and function: Type I, Type IIa and Type IIb. Type 1 fibers have been called “slow twitching” fibers because they depend primarily on aerobic metabolism and are able to provide long term fatigue resistant contractions. In contrast, Type IIb fibers depend primarily on anaerobic metabolism (glycolytic) and are able to quickly generate large amounts of force. Type IIa fibers have intermediate properties compared to type I and type IIb fibers. The percentage of each type of muscle fiber in a particular muscle group may be different from other muscle groups depending on the specific function of that group. Research shows that chronic hypoxia affects muscle fiber distribution[49]. Interestingly, muscle fiber composition will be totally different in the peripheral muscles and the respiratory muscles. Individuals with CHF will demonstrate a decrease in type I fibers and an increase in type IIb fibers when compared to normal individuals. In contrast, the respiratory muscles such as the diaphragm will show an increase in type I fibers and a decrease in type IIb fibers in individuals with CHF compared to normal individuals. One possible explanation is that the peripheral muscles develop anaerobic instead of aerobic metabolism to try to maintain normal functioning during prolonged hypoxemia. The respiratory muscles, on the other hand, adjusting to a constantly increasing demand for oxygen from the periphery develop more type I fibers to try to meet the demand with a more fatigue resistant aerobic system to manage the increased workload as effectively as possible. This shifting of fiber types helps the muscle groups temporarily maintain their primary function. However, due to the characteristics of the different fiber types, these changes will negatively alter the muscle performance in each area and greatly limit the individual’s level of function. For example, the individual with CHF will demonstrate decreased activity tolerance with an early onset of fatigue in the peripheral muscles due to the decreased percentage of type I fibers. Moreover, the individual will report increased dyspnea during activity as the respiratory muscles will be unable to provide enough muscle strength to increase the inhalation of oxygen due to the decreased number of type IIb fibers in the diaphragm.

3.1.3 Muscle Disuse

Besides hypoxia, muscle disuse is another factor that will exacerbate activity intolerance. The fact that muscle disuse is a consequence of activity intolerance makes it a major factor in the downward spiral of an individual with CHF. Because activity intolerance limits as individual's ability to perform daily activities, they tend to be more sedentary and do less activity compared to healthy individuals. Without proper stimulation from physical activity the peripheral muscles lose muscle mass and demonstrate increased weakness thus increasing activity intolerance which becomes a vicious cycle. Muscle weakness in the lower legs decreases the normal "muscle pump" effect on the peripheral vascular system. This increases fluid retention in the peripheral tissues and causes further hypoxia. This creates another vicious cycle as well as a risk for non-healing wounds that further debilitates the individual with CHF. The figure 1 has depicted the possible progression of exercise intolerance in patient with CHF. (For references, please see Appendix C)

4 Conclusions

An appropriate level of activity can help prevent exacerbations of CHF. It can also allow individuals with CHF to maintain their ability to perform their ADL's without difficulty. Therefore, it is helpful for physical therapists to find a valid measurement method that can be used to guide the treatment plans and home programs of individuals with CHF. Consistent follow through with a home exercise/activity program is crucial to the success of preventing a decline in the functional status of an individual with CHF. Objective measurement methods, like the accelerometer, have the potential to be very effective in monitoring daily activity levels and energy expenditures in clinical settings and at home.



Figures 1 Relationship between CHF, Hypoxia and Muscle waste

In light of that the validity of the Stay-healthy RT3 accelerometer (RT3) was tested under various measurement conditions. By comparing the RT3 accelerometer with indirect calorimetry (the “gold standard’ for measuring physical activity levels and energy expenditure), we looked at the validity of the RT3 accelerometer data for measuring special daily tasks (Aim 1).The RT3 accelerometer was also compared with the 7-day Physical Activity Recall Scale (7-dayPAR) by looking at a sample of individuals with CHF over seven days. This showed that the accelerometer is superior to the 7-day Physical Activity Recall Scale (7-day PAR) in accurately recording an individual’s activity level and energy expenditure(Aim 2).And finally, a re-evaluation of the baseline metabolic level for individuals with CHF was performed to determine whether resting metabolic rates vary between a healthy population and individuals with CHF. This showed that it is necessary to readjust the value of 1 MET for individuals with CHF because the traditional MET intensity scale is not accurate for them (Aim 3).

Methods

Research Design: A descriptive correlational design was used in this study.

Sample: A total sample of 54 subjects was recruited from the Heart Failure Clinic at BryanLGH Heart Institute in Lincoln, Nebraska. The mean age of the 54 subjects was 73.5 ± 7.6 years. There were 38 males and 16 females. The mean left ventricular ejection fraction was 31 ± 7.6%. Subjects had a mean Body Mass Index (BMI) of 29.8 ± 5.8. This study was approved by the University of Nebraska Medical Center Institutional Review Board All subjects were required to complete the consent form that was approved by the IRB prior to the study.

Procedure:

Stage 1: Subjects who met inclusion criteria were approached for participation in the study and were given the consent form. They read the form while in the clinic or took it home to read if they so desired. The RT3 accelerometers were placed on subjects at waist level in the BryanLGH Heart Institute clinic. Instructions were given regarding the 7 day wearing period of the accelerometers. Detailed written instructions for the use of the RT3 were also given to the subjects to reference during the 7 day wearing period. The RT3 accelerometer was returned by the subject to the clinic at the end of the 7 day wearing period and the 7- Day PAR questionnaire was administered via interview.(Please see Appendix D& E)

Stage 2: Fifteen subjects were recruited from the subjects who had completed Phase I to participate in Phase II of the study. A separate time was scheduled at the subject's convenience to complete the data collection. Each subject was fitted with a face mask and pneumotach from which the volume of gas exhaled was calculated and proportional samples of expired gas were taken into the MedGraphics VO2000 (Medical Graphics Corp., St. Paul, MN) for analysis of O2 and CO2 levels. The measured absolute VO2 (L•min-1)was converted to kilocalories (Kcal) and relative VO2 (ml•kg-1•min-1) for assessing the energy expenditure(EE) of subjects. At the same time the subjects also wore the RT3 at their waist to monitor the activity count during the whole test session. The subjects were randomly assigned to perform a sequence of light and moderate physical activity tasks, which included reading the paper, watching TV, dusting, vacuuming, wash dishes and stair climbing. The ratio between the light and moderate activities was 4:1 (80% light activity, 20% moderate activity). A 6 minute walk test was conducted 10 minutes before and 10 minutesafter the activity sequences. The detail of the protocol can be found in the table 3..

Order of Activities										
Sequence	**First6MWTTrial**		**#1**	**#2**	**#3**	**#4**	**#5**	**#6**		**Second 6MWTTrial**
1	6-MWT	**R**	Read6 min.	Wash6 min.	Vac3 min	TV6 min.	Dust6 min.	Stairs 3 min	**R**	6-MWT
2	6-MWT	**E**	Wash6 min.	Vac3 min	TV6 min.	Dust6 min.	Stair3 min	Read 6 min.	**E**	6-MWT
3	6-MWT	**S**	Vac3 min.	TV6 min.	Dust6 min.	Stairs 3 min	Read6 min.	Wash 6 min.	**S**	6-MWT
4	6-MWT	**T**	TV6 min.	Dust6 min.	Stairs 3 min	Read6 min.	Wash6 min.	Vac3 min	**T**	6-MWT
5	6-MWT		Dust6 min.	Stairs3 min	Read6 min.	Wash 6 min.	Vac3 min	TV6 min.		6-MWT
6	6-MWT		Stairs3 min	Read6 min.	Wash 6 min.	Vac3 min	TV6 min.	Dust 6 min.		6-MWT

Table 3 Testing Protocol

Data Analysis

The SPSS 20.0 software was used to analyze the data. The level of significance was set at <0.05. To look at the validity of the energy expenditure (EE) data from the RT3 accelerometer, it was compared with the energy expenditure (EE) data from the MedGraphics VO-2000 (includes Total EE and Active EE) to find out if there was a significant difference between them. The activity recorded by the RT3 and the activity recorded by the MedGraphics VO-2000 were also compared to see if there was a correlation between them.

The active energy expenditure (EE) as estimated by both the 7-day PAR and RT3 were averaged in order to find the activity level for the individuals with CHF. Then, the energy as estimated both by the 7-PAR and the RT3 accelerometer were paired to determine the reliability of the 7-day PAR and see if there was a significant difference between the two methods.

For the subjects who participated in the Phase II study, the O2 and CO2 levels were recorded during the seated rest periods by MedGraphics VO-2000 (Medical Graphics Corp., St. Paul, MN). The data was analyzed by SPSS 20.0 and compared to standard data from a healthy population (3.5 ml/kg/min = 1 Metabolic Equivalent (MET)) to see if there was a difference in the metabolic rate between the healthy population and individuals with CHF.

Results

1. Validity of RT3 Accelerometer

There were14 valid records for RT3and MedGraphics VO-2000which included total energy expenditure and active energy expenditure for each individual. These were all transferred into Kcal in order to make the data comparable. The summary of the energy expenditure for each activity can be seen in table 4.

Next the correlation between the recorded Activity levels of the RT3 and the MedGraphics VO-2000 for each of the activities was calculated. The result of the Spearman rank order correlation test is shown in table 5.

(Kcal/min)	Total EE*		Active EE**	
	RT3	MedGraphics VO-2000	RT3	MedGraphics VO-2000
resting EE	1.0793	1.0297	NA	NA
1st 6 mwt	21.4667	21.6876	14.8223	15.5094
read paper	7.1313	7.3005	0.7122	1.3801
wash dishes	8.471	10.8482	1.6934	4.7521
vacuum	5.4225	8.1495	2.1433	5.1278
watch TV	6.9271	6.4274	0.355	1.3798
dust	8.6031	12.0936	2.1406	7.1507
stairs	7.8027	12.8097	4.5518	9.7203
2nd 6 mwt	19.3203	15.0897	13.4484	11.8894

Table 4 Summary of energy expenditure for each activity

*Total energy expenditure (EE) includes both resting energy expenditure and the energy used to perform the activities of the study protocol.

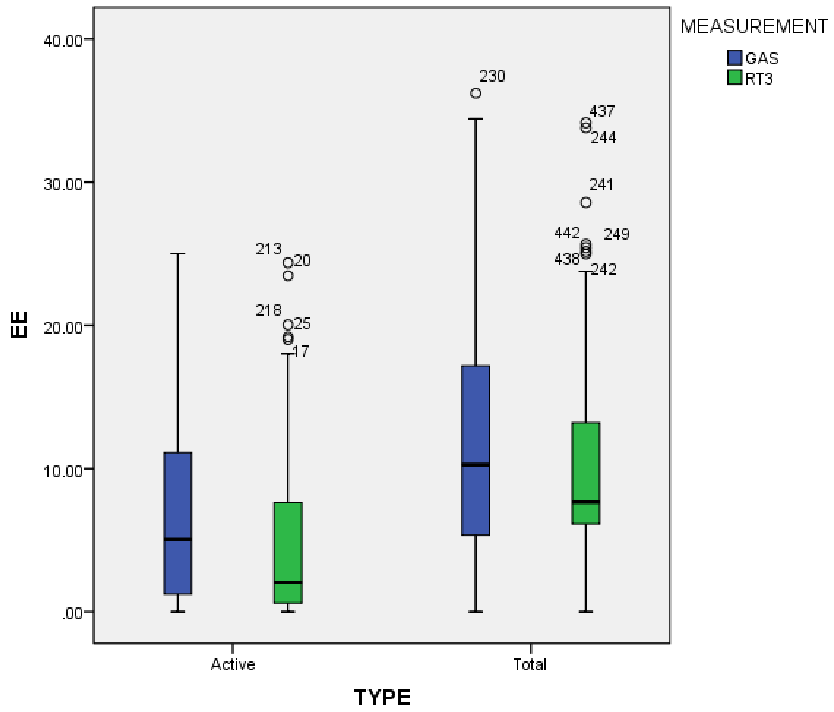
**Active EE is only the energy used to perform the activities of the study protocol. It was calculated by using the total energy expenditure minus the resting energy expenditure.

The results demonstrate that the total energy expenditure (EE)as recorded by the RT3 accelerometer shows a moderate to strong correlation ($0.67<r<0.91$) to the total EE recorded by the MedGraphics VO-2000 and the only activity that demonstrated a weak correlation was reading the paper (r=0.31).On other hand, when testing the correlation between the active energy expenditure results from the MedGraphicsVO-2000 and activity level recorded by the RT3 there was little or no correlation between MedGraphics VO-2000 and RT3 in reading the paper, washing the dishes and watching TV. All of the other activities show a moderate to strong correlation ($0.6<r<0.9$) between the two methods

	1st 6MWT	read paper	wash dishes	stairs	watch TV	dust	vacuum	2nd 6MWT
TOT Gas vs. RT-3	0.807	0.318	0.782	0.811	0.674	0.689	0.911	0.737
P value	<0.001	0.248	0.001	<0.001	0.006	0.005	<0.001	0.002
ACT Gas vs. RT-3	0.732	0.051	0.168	0.657	0.422	0.662	0.908	0.705
P value	0.002	0.856	0.549	0.008	0.117	0.01	<0.001	0.003

Table 5 Spearman rank order correlation test

Since the RT3 is able to covert activity levels into kilo calories by using a preset equation the outcomes between the RT3 and MedGraphics VO-2000 could be compared directly to each other. In order to find out the general validity of the RT3,the results of all 8 activities had to be combined and the Wilcoxon signed ranks test must be used to compare the mean outcome level from all 8 activities. The statistical results showed that there was no significant difference between the two methods for both total energy expenditure and active energy expenditure measurements. ($total_{all}$: $p=0.674$, $p>0.06$; $active_{all}$: $p=0.161$, $p>0.05$). Figure 2 has demonstrated the outcome of Wilcoxon test.



Figures 2 Wilcoxon test results of total energy expenditure and active energy expenditure measurements

Since the two methods showed no significant difference in the measurement of general energy expenditure, it was felt that it would be helpful to determine if different intensity levels of activity or movement patterns would affect the validity of the RT3. In order to test those influences, each activity had to be compared separately to see if there was a significant difference between the two methods. The results are shown in table 6.

The results showed that the RT3 showed good validity when measuring activities which have low intensity and a simple activity pattern. When increasing the intensity or performing more complex movement patterns the results demonstrated significant differences between the RT3 and the MedGraphics VO-2000.

	P value $_{TOT}$	P value $_{ACT}$
resting	0.594	NA
1st 6mwt	0.73	0.638
2nd 6mwt	0.06	0.084
read paper	0.975	0.198
watch TV	0.917	0.308
wash dishes	0.221	0.03
dust	0.023	0.03
vacuum	0.005	0.003
stair	0.003	0.002

Table 6 Wilcoxon signed ranks test

2. Average daily active energy expenditure baseline for people who have CHF

Both the RT3 accelerometer and the 7-day PAR questionnaire were used during the 7 days of daily activity energy expenditure estimation in Phase 1. All the results were recorded or calculated in Kcal. The statistical results for active energy expenditure are included in table 7.

3. Comparison between the seven-day PAR and RT3 accelerometer

When the 7-dayPAR was compared with the RT3 accelerometer there was a significant different between the total energy expenditure estimated by the 7-day PAR (7-days PAR TOT) and the energy expenditure level recorded by the RT3 (RT3 TOT) ($p<0.05$). Because the RT3 was only able to record the daily activity, and the 7-day PAR TOT included the energy expenditure measurement for time asleep. The difference may be due to the missing sleep data. In order to eliminate bias, the data was adjusted from the 7-day PAR TOT to 7-day PAR daytime by subtracting the night energy expenditure from the total energy expenditure. Comparing the two measurements again with only daytime activity the results showed that there was no significant difference between the results of the RT3 and the 7-day PAR for the measurement of daily activity estimation ($p=0.387>0.05$).

	Mean (Kcal)	SD.	95% Confidence Interval for Mean	
RT3 AEE	309.8351	192.6193	256.2095	363.4606
RT3 TOT	1956.79	460.0294	1836.9396	2091.0204
7 days PAR (day time)	2040.2774	814.7396	1827.6217	2293.1596
7 days PAR (Total)	2517.1504	870.5340	2292.2928	2787.8313

Table 7 Statistical results for 7 days energy expenditure estimation

The correlation between the two measurement methods demonstrates a moderated correlation between the RT3 and seven-day PAR in estimating energy expenditure ($r=0.58$, $p<0.05$). There is a weak ($r=0.35$), but significant correlation ($p=0.014<0.05$) between the 7-day PAR (estimated energy expenditure) and the RT3 (activity level) measurement methods.

4. Resting energy expenditure

The results of the MedGraphics VO-2000data were used to estimate the mean resting energy expenditure level of individuals with CHF and compare it to the value for MET resting levels in a healthy population (3.5ml/kg/min). The results are shown in table 8.

The results show that the mean resting energy expenditure for individuals with CHF is 2.72 ml/kg/min vs. 3.5 ml/kg/min in healthy individuals. This is a significant difference as shown by the p- value of 0.006<0.05.

One-Sample Test

	Test Value = 3.5						
	Mean value	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Resting	2.72	-3.213	14	.006	-.77933	-1.2995	-.2591

Table 8 Statistical result of resting energy expenditure for CHF patient

Discussion:

Compared to other measurement methods, the accelerometer provides a promising approach in measurement of energy expenditure in healthy populations due to its high validity. Although there have been many studies conducted to test its measurement validity and reliability, only a few of them have focused on the heart failure population. Moreover, since most of the studies have been in a controlled environment, the results of these studies do not show the true validity of the accelerometer particularly while measuring an individual's daily energy expenditure in a community dwelling situation. This project has shown that the accelerometer (RT3) has good potential to be used as a valid measurement tool to estimate daily energy expenditure for individuals with CHF in a community dwelling environment.

1. The validity of RT3

The RT3 accelerometer has demonstrated reasonable reliability and validity in estimating daily activities of individuals with CHF based on the results of this research project. TheRT3 has shown a moderate to good correlation (r =0.67-0.91) with the MedGraphicsVO-2000 when estimating the energy expenditure for most daily activities (Table 5). However, if we only focus on active energy expenditure, we find that the 6 minute walk test demonstrates a stronger correlation than most of the daily activities. This finding is similar to previous research conducted by Hendelman et.al[30]. They studied the correlation between a portable metabolic system and an accelerometer in evaluating the metabolic cost of four overground walking activities at self-selected speeds and a series of indoor and outdoor household activities. They found that the accelerometer demonstrated a better correlation with the portable metabolic system while measuring walking (r=0.89) than with all of the activities combined (r=0.62). Welk et.al[31]has also found that compared to daily activities, walking on the treadmill generated a better correlation with the VO2 measurement than the daily activities did. A possible explanation may be related to the design of the device and/or the selection of the calibrated parameter. Since most of the accelerometers were designed and calibrated for use during lab based activities those activities which are similar to lab activities may have better results than those that are more similar to activities in community dwelling environments. And although the accelerometer used in that study includes multiple calibration optionsand preset estimation equations that cover many different activities, none of them were able to provide an option that could be used universally.

The only daily activity that showed an insignificant correlation in total energy expenditure between the results of the RT3 accelerometer and the VO-2000 is “reading the paper”. The probable reasons for this are the location of the accelerometer placement and the lack of motion that occurs at the site during this activity. It is difficult for an accelerometer placed at the waist to register upper extremity activities. A similar result occurred when measuring active energy expenditure. The results show that the active energy expenditure outcomes of the RT3 and the VO-2000 measurements related to “reading the paper”, “watching TV” and “washing the dishes” (Reading the paper: $p=0.856$, Watching TV: $p=0.117$, Washing the dishes $p= 0.549$) showed insignificant correlations with $P>0.05$.Because those activities require more upper extremity movement than whole body movement, an accelerometer that has been placed at the waist will not be able to measure the energy expenditure as accurately as the VO-2000.

Another possible reason affecting the accelerometer measurements may be the movement “pattern” during measurement. Reading the paper is a relatively low intensity activity when compared to the other selected activities. It requires the subject to maintain the upper extremities in a stable position so that the eyes are able to read the content of the paper. This means that the arms do not generate much movement. Most of the muscles in the upper arm perform isometric contractions to “hold” the paper in place. Since the accelerometer measures energy by calculating the acceleration that is generated by movement, it is difficult for the accelerometer to measure the energy that generated by isometric contractions.

Besides looking at the correlation of the RT3 to the VO-2000, the actual energy expenditure measured by these two methods was compared. The results showed that there is no significant difference between the outcomes of the two methods when they measure total energy expenditure for all 8 activities. However, when comparing each activity separately there was a pattern of increasing disparity between the measurements of the RT3 and VO-2000 shown with the increasing of activity intensity and complexity. This finding is similar to the findings of Lyden's research[21]. They found that with increasing intensity, the accelerometer demonstrates more misclassifications when compared to indirect calorimetry. One possible reason is the equation being used to calculate the energy expenditures measured by the accelerometer. As mentioned before, most of the energy estimation equations were created from test results generated in a laboratory setting. The accelerometer will generate a better outcome if the measured activity is similar to the activity that was used to create the equation. However, compared to community dwelling environments, the lab environment is highly controlled. Because of this it is unlikely the accelerometer will be able to cover all of the possible daily activity movements with one of its preset equations.

We have also found that the RT3 tends to underestimate the actual energy expenditure when compared to the VO-2000. This finding is similar to prior research[30, 31, 40]. This is in addition to the location of the accelerometer placement and the effect movement patterns may have on the accuracy of the measurement. One other possible reason for the underestimation of energy expenditure is that the accelerometer cannot be 100 % attached to the skin so there will always some minimal movement between the accelerometer and the individual's skin. The amount of movement will increase as the intensity of the activity goes up, and it may cause inaccurate acceleration input to the accelerometer.

2. The difference between seven-day PAR and RT3 in measurement of free-living activities

Many research studies have been conducted to compare the validity of the 7-day PAR with objective measurement protocols. In Leenders' research[4], the author compared the 7-day PAR with an accelerometer (Tritrac-R3D) and found that the 7-day PAR overestimated energy expenditure by 25% when compared to the accelerometer. In this study the total energy expenditure estimated by the 7-day PARwas 22% higher than the accelerometer which is similar to Leenders' findings. However, since the formula that was used to calculate total energy expenditure also included sleeping time and our participants did not wear the accelerometer while sleeping, which may have caused the discrepancy in the results. Because of this only the daytime activity energy expenditure was used (7-day PARday) instead of the total energy expenditure for a 24 hour period (7-day PARtot).With that modification no significant difference was shown between the two measurements. This means that the 7-dayPAR was able to measure the daily energy expenditure accurately when it was used to describe the physical activity characteristics of a special population. Moreover, there was a strong correlation between the 7-dayPARdayand the accelerometer, which means the 7-day PAR was also able to measure each individual's physical activity information within a discreet group of people. Although the 7-day PAR did not show intensity changes during daily activities (poor correlation with VM), it still showed a relatively accurate estimate when comparedto data from an objective measurementtool.

3. The Resting Metabolic Rate in patient with CHF

The metabolic rate has been defined as a physiological measure expressing the energy cost of a physical activity. It has been widely used to evaluate an individual's functional level, categorize different activities into light, moderate and high intensity groups and to monitor the level of a workload. Many researchers and therapists have applied the classic MET level scale in their treatments to guide an individual's treatment progression, especially for individuals with CHF. Because the activity capacity of individuals with heart failure is lower than that of healthy individuals, the normal MET scale may not be appropriate for those individuals with CHF due to the difference in their metabolic rate. Savage et al.[51] found that compared to healthy individuals, the individual with coronary heart disease demonstrated a lower resting metabolic rate (23% to 36% lower) than the widely accepted 3.5 ml/kg/min based on a healthy individual's BMI. This study showed that individuals with CHF show significantly lower resting energy expenditure than the criteria for a healthy individual (2.7 ml/kg/min vs. 3.5ml/kg/min, decreased 22.9%). This may be due to the decreased metabolic rate of these patients. If individuals with CHF have a lower metabolic rate, it maybe inappropriate to use 3.5 ml/kg/min as their default measurement criteria. Their MET level criteria may not be the same as that of healthy individuals which means the normal MET level categorization of activities might actually be harder for individuals with CHF than was thought. For example, based on the compendium, walking on a firm level surface at the speed of 2.0 MPH is considered to be a light activity (2.5MET). However, walking at that same speed on a firm level surface, based on this study appears to be too difficult for an individual with CHF and possibly increases the risk of secondary injury. The MET level of this activity should be recalibrated to 3.2 MET for this type of individual, which would make it a moderate intensity activity (3-6 METs). Further research is needed to study the possibility of modifying the MET classification for specific populations, especially those with CHF, to get a more accurate measurement of their abilities and to set up more appropriate treatment programs for these individuals.

Conclusion

Overall, this study reveals that the accelerometer has demonstrated a good capacity for estimating daily activities. The measurement results that measured by accelerometer have shown a moderate to good correlation with the outcome of indirect calorimetry when measuring total daily energy expenditure. However, the validity of accelerometer may be influenced by activity intensity, movement patterns, placement location and adhesion. For the 7 days PAR questionnaire, the results of this study agree with previous studies that indicate PAR overestimated the energy expenditure by 22%. However, if we only focus on daily activities energy expenditure, there is no significant difference between the outcome of 7 days PAR and accelerometer. Although there are considerable errors in some of the estimations, both of the accelerometer and 7 days PAR questionnaire are still able to provide valid measurement outcome record of physical activity for evaluation patient’s behavior and epidemiologic research.

In our research, we also found that the rest energy expenditures of CHF patients is significant lower than normal criteria, which indicate the assumed metabolic constant may not appropriate to be used to estimate daily energy expenditure in patient with CHF. However, due to the small sample size, further research is needed to better understand how the CHF will affect the resting metabolic rate, and find out if it is necessary to re-adjust the MET criterion in treating the patient with CHF.

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Appendix A

Article Name	Author	Purpose	Methods	Result	Common	Citation
Quantitating physical activity in COPD using a triaxial accelerometer.	Steele, B.G.; Holt, R.N.L.; Belza, B.; Ferris, S.; Lakshminaryan S.; Buchner, D.M.	To determine the reliability, validity, and stability of a triaxial accelerometer for walking and daily activity measurement in a COPD sample.	47 outpatients with stable COPD and dyspnea were recruited. The accelerometer was placed on patients' waist. There were 3 6mwt been tested for the reliability of accelerometer. The authors also measured daily activity over 3 full days at home to test validity.	For the reliability, The intraclass correlation coefficient of 3 6mwt is 0.84. For Concurrent validity, Significant correlations were evident between accelerometer activity at home, level of obstructive pulmonary disease ($r = 0.62$; $p < 0.001$), exercise capacity ($r = 0.74$; $p < 0.001$), dyspnea over the past 30 days ($r = -0.29$; $p < 0.05$), and self-efficacy for activity ($r = 0.43$; $p < 0.01$)	Subjects were mainly male. There are only test 3 days of the Home daily activities. Author also uses Modified Activity Recall Questionnaire as one of the factor to test validity but the result was not significant.	Chest 2000, 117, 1359-1367
Executive dysfunction and depressive symptoms associated with	Foster ER, Cunnane KB, Edwards DF,	To investigated participation levels and relationships among cognition, depression, and participation for people	27 People with severe CHF (New York Heart Association Class III or IV) completed standardized tests of	Possible depression (64%) and cognitive impairment (15%–59%) were prevalent. Participants reported significant reductions in	CHF patient demonstrated significant reduction in activity participation; this	Am J OccupTher. 2011 May-Ju

reduced participation of people with severe congestive heart failure.	Morrison MT, et.al.	with severe congestive heart failure (CHF).	cognition and self-report measures of executive dysfunction, depressive symptoms, and participation	participation across all activity domains since CHF diagnosis (ps $< .001$). Worse executive dysfunction and depressive symptoms were associated with reduced participation and together accounted for 35%–46% of the variance in participation (ps $< .01$).	could be due to impaired executive function or cognitive level. In the other hand, a prolonged disabled condition will continue worsen the cognition and participation, this will lead patient fall in vicious circle.	n;65(3): 306-13
Vital signs: disability and physical activity - United States, 2009-2012. MMWR Morb Mortal Wkly	Carroll DD, Courtney-Long EA, Stevens AC, Sloan ML	Using 2009-2012 National Health Interview Survey to estimate the prevalence of disability and its relationship with Physical inactivity	Data from the 2009-2012 National Health Interview Survey (NHIS) were used to estimate the prevalence of, and association between, aerobic physical activity (inactive, insufficiently active, or active) and chronic diseases (heart disease, stroke, diabetes, and cancer) among adults aged 18-64 years by disability status and type	Overall, 11.6% of U.S. adults aged 18-64 years reported a disability. Compared with adults without disabilities, inactivity was more prevalent among adults with any disability (47.1% versus 26.1%) and for adults with each type of disability. Inactive adults with disabilities were 50% more likely to report one or more chronic diseases than those who were physically active.	Background for chronic disease and physical inactivity.	MMWR Morb Mortal Wkly Rep. 2014 May 9;63(18):407-13.

			(hearing, vision, cognitive, and mobility). The prevalence of, and association between, receiving a health professional recommendation for physical activity and level of aerobic physical activity was assessed using 2010 data.	Approximately 44% of adults with disabilities received a recommendation from a health professional for physical activity in the past 12 months		
Comparisons of four methods of estimating physical activity in adult women.	Leenders NYJM, Sherman WM, Nagaraja HN	Determine the relative validity among estimates of physical activity using the 7-d Physical Activity Recall questionnaire and three activity monitors (CSA and Tritrac accelerometers, Yamax pedometer).	Twelve healthy college-aged women participate the research, Subjects wore at the waist a Tritrac-R3D accelerometer, a Computer Science Application Inc. activity monitor (CSA), both of which measure bodily accelerations in various planes, and a Yamax Digi-Walker-500 that records steps. After the 7-d period subjects	EE determined by PAR was significant higher than PAEE estimated from either the Tritrac, CSA, or the Yamax data. Time spent in light, moderate, and hard physical activity was not significantly different between PAR, CSA, and Tritrac.	It would be good if there is a measurement be a “golden standard”	Med Sci Sports Exerc. 2000 Jul;32(7):1320-6.

			responded to a 7-d Physical Activity Recall interview (PAR)			
Seven-Day Physical Activity Recall.	SALLIS, J. F	Clinical Guideline for 7 days PAR			Background information	
Overestimation of physical activity level is associated with lower BMI: a cross-sectional analysis.	Watkinson C, van Sluijs EM, Sutton S, Hardeman W, Corder K, Griffin SJ	To investigate the discrepancy between objective and self-rated physical activity in different population	Exploratory cross-sectional analysis of PA awareness using baseline data collected from 365 ProActive participants between 2001 and 2003 in East Anglia, England. Self-rated PA was defined as 'active' or 'inactive' (assessed via questionnaire). Objective PA was defined according to achievement of guideline activity levels (≥30 minutes or <30 minutes spent at least moderate intensity PA, assessed by heart rate monitoring)	45.9% of inactivity population (according to objective measurement) are overestimate their activity level, multiple logistic regression model adjusted for age and smoking, males (OR = 2.11, 95% CI = 1.12, 3.98), those with lower BMI (OR = 0.89, 95% CI = 0.84, 0.95), younger age at completion of full-time education (OR = 0.83, 95% CI = 0.74, 0.93) and higher general health perception (OR = 1.02 CI = 1.00, 1.04) were more likely to overestimate their PA	This article shown the reason why we need a objective measurement method during clinical treatment, people tend to overestimate their activity level when they using subjective measurement.	International Journal of Behavioral Nutrition and Physical Activity 2010, 7:68
Self-reported	Cust AE,	To identify the	97 men and 80 women	Participants in the	This article show	Epidemi

Confidence in Recall as a Predictor of Validity and Repeatability of Physical Activity Questionnaire Data	Armstrong BK, Smith BJ, Chau J, van der Ploeg HP, Bauman A.	applicability of Self-reported confidence ratings in epidemiologic studies	completed European Prospective Investigation into Cancer and Nutrition (EPIC) past-year questionnaire and the International Physical Activity Questionnaire (IPAQ) last-7-day questionnaire. at baseline and at 10 months and wore an accelerometer as an objective comparison measure for three 7-day periods during the same timeframe. Participants rated their confidence in recalling physical activity for each question using a 5-point scale and were dichotomized at the median confidence value.	high-confidence group had higher validity and repeatability coefficients than those in the low-confidence group for most comparisons. For IPAQ: rho = 0.34 (95% confidence interval [CI] = 0.08 to 0.55) and 0.01 (-0.17 to 0.20) for high- and low-confidence groups, respectively. For Epic: rho = 0.81 (0.72 to 0.87) and 0.63 (0.48 to 0.74), respectively	another possible affect factor for subjective measurement, the most interesting thing in the results id that Women were less likely than men to report high recall confidence of past-year activity, which means they result may have lower validity compare to male.	ology 2009;20 : 433–441
Estimating physical activity energy expenditure, sedentary time,	Besson H, Brage S, Jakes RW, Ekelund U, Wareham	assess the validity and reliability of the Recent Physical Activity Questionnaire (RPAQ), which assesses usual	Total energy expenditure (TEE) was measured for 14 d by using the doubly labeled water technique combined with a measure	Estimated TEE and PAEE were significantly associated with criterion measures (TEE: r = 0.67; PAEE: r = 0.39) The correlation	Back ground info	Am J ClinNutr. 2010 Jan;91(1):106-14

and physical activity intensity by self-report in adults	NJ	physical activity (PA) in 4 domains (work, travel, recreation, and domestic life)	of resting metabolic rate to yield PA energy expenditure (PAEE) in 25 men and 25 women. Simultaneously, intensity of activity was measured by using combined heart rate and movement sensing for 11 d. Repeatability of the RPAQ was assessed in an independent sample of 71 women and 60 men aged 31-57 y.	between self-reported and measured time spent was significant for vigorous PA (r = 0.70) and marginally insignificant for sedentary time (r = 0.27, P = 0.06. The intraclass correlation coefficient for repeatability of total PAEE (kJ/d) was 0.76 (P < 0.0001).		
Validity of Electronically Administered Recent Physical Activity Questionnaire (RPAQ) in Ten European Countries.	Golubic R, May AM, BenjaminsennBorch K, Overvad K, Charles MA, Diaz MJ, Amiano P, Palli D, Valanou E, Vigl M,	To examine the validity of the Recent Physical Activity Questionnaire (RPAQ) which assesses physical activity (PA) in 4 domains (leisure, work, commuting, home) during past month	580 men and 1343 women from 10 European countries attended 2 visits at which PA energy expenditure (PAEE), time at moderate-to-vigorous PA (MVPA) and sedentary time were measured using individually-calibrated combined heart-rate and movement sensing. At the	RPAQ significantly underestimated PAEE and MVPA in women and men. (using individualized definition of 1MET for MVPA) Correlations (95%CI) between subjective and objective estimates were statistically. When using non-individualized definition of 1MET (3.5 mlO2/kg/min), MVPA was substantially	Background info, individualized definition of 1MET and non-individualized definition of 1METmay bring in different for the test result.	PLoS One. 2014 Mar 25;9(3): e92829.

	Franks PW, Wareham N, Ekelund U, Brage S		second visit, RPAQ was administered electronically. Validity was assessed using agreement analysis	overestimated		
Validation of the Yale Physical Activity Survey in chronic obstructive pulmonary disease patients.	Donaire-Gonzalez D, Gimeno-Santos E, Serra I, Roca J, Balcells E, et al.	Validate the Yale Physical Activity Survey in COPD patients in order to quantify and classify their levels of physical activity.	172 COPD patients (Mean age was 70 (8) years) from 8 university hospitals in Spain wore an accelerometer (SenseWear(®)Pro(2)Armband) for 8 days and answered the questionnaire 15 days later.	Spearman correlations were low to moderate (from 0.29 to 0.52, all P<.001). ICCs showed weak agreement (from 0.34 to 0.40, all P<.001). Significant differences in accelerometer measurements were found according to questionnaire tertiles (all P<.001). The area under the ROC for identifying sedentarism was 0.71 (95% CI: 0.63-0.79).	Background info	Arch Bronconeumol. 2011 Nov;47(11):552-60

Appendix B

Article Name	Author	Purpose	Methods	Result	Common	Citation
A Review of Accelerometry-Based Wearable Motion Detectors for Physical Activity Monitoring	Yang CC, Hsu YL	This paper reviews the development of wearable accelerometry-based motion detectors. Various research using accelerometry-based wearable motion detectors for physical activity monitoring and assessment are also reviewed	The authors searched for published literature after year 2000 using a range of related keywords such as accelerometry, accelerometer, wearable, physical activity, human motion, human movement, activity classification, energy expenditure, fall detection, balance stability and gait. Selected literatures before year 2000 are also included	PA monitoring using accelerometry techniques enables automatic, continuous and long-term activity measurement of subjects in a free-living environment	Background Inof	Sensors (Basel). 2010;10 (8):7772 -88
Fall Detection and Precaution through MEMS Accelerometer.	Hung CY, Tuan PC	This is a pilot study that aim to prevent fall by integrate accelerometer into a fall detection system	The experiment designed will integrate body model, accelerometer and Lab View software to measurement the	The BPA can be calculated through MEMS accelerometer. In terms of the time of fall down will spend 2.5 second; the 40 degree is	Background Info	Journal of Nan Kai, Vol. 6, No. 2

			accelerometer output during the body model fall down. Then calculate the Body posture angle through the accelerometer output	dangerous postures angular, which have 0.5 seconds precaution time available.		(Special Issue on Gerontechnology), pp.81-88 (2009)
A description of an accelerometer-based mobility monitoring technique	Lyons GM, Culhane KM, Hilton D, Grace PA, Lyons D	To examine the accuracy of accelerometer in detecting different activities by using 2 different posture threshold methods, mid-point and best estimation	2 accelerometer were placed on one CVA patient for 4days (avg 7 hours/day). The placement locations include trunk and upper thigh. The patient stays in an uncontrolled environment	'Best estimate' thresholding improved sitting detection accuracy by 18%, to 93% and lying detection accuracy by 5%, to 84%. Compare to mip point threshold methods	Different posture threshold setting have a impact on the accuracy of mobility monitor systems.	Med Eng Phys. 2005 Jul;27(6):497-504
Respiratory rate assessments using a dual-accelerometer device	Lapi S, Lavorini F, Borgioli G, Calzolai M, Masotti L et al.	Identify the applicability of accelerometer in measuring respiratory rate for the patient who has eupnoea and stressed breathing	22 normal subjects, without any respiratory issue, 5 obesity patient and 4 patient with idiopathic scoliosis. RR was measured by visual inspection, spirometry and a pair of accelerometers positioned on the torso(T10).	spirometric and accelerometric RR values did not differ in any of the cases. RR assessment was unaffected by recumbence. During handgrip, spirometric (16.43±3.10bpm) and accelerometeric (16.22±2.76bpm) control RR values did not differ and	Another possible application of accelerometer in practical daily treatment.	RespirPhysiolNeurobiol. 2014 Jan 15;191:60-6

			Subjects were asked to perform spontaneous breathing, voluntarily modified breathing, and exercise hyperpnoea in order to test the validity and sensitivity of accelerometer.	increased to comparable levels (24.22±7.30 and 24.82±5.45bpm, respectively) by the end of exercise. At rest, visual (18.94±3.45bpm) and accelerometric (19.27±3.83bpm) RR values were compliant in normal subjects as well as in scoliotic and obese patients		
Estimation of Respiration Rate from Three-Dimensional Acceleration Data Based on Body Sensor Network	Liu GZ, Guo YW, Zhu QS, Huang BY, Wang L,	Present an adaptive band-pass filtering method combined with principal component analysis to derive the respiratory rate from three-dimensional acceleration data,	Twelve healthy subjects using BSN platform with 3d accelerometer to monitor the RR during various body activities such as sitting, walking, running, and sleeping.	Experiment results indicated the method was capable of offering pervasive respiration rate monitoring during various body activities. Furthermore, the result demonstrated that this method was more robust, resilient to motion artifact,	Background info	Telemed J E Health. 2011 Nov; 17(9): 705–711
Reliable assessment of physical activity in disease: an update on activity	Westerterp KR	Review the evidence that presented on the validity of methods to assess physical activity as applied in health and disease.		Accelerometry is the most promising method to objectively assess physical activity behavior as a reflection of metabolic health or determinant of metabolic	Although accelerometer is able to deliver a good objective measurement, there is still 30% of	CurrOpinClinNutrMetab Care. 2014Sep;17(5):4

monitors				risk. The validity of accelerometer-based activity monitors is judged with doubly labelled water-assessed activity energy expenditure or PAI as a reference, where the optimal observation time is 1 or 2 weeks. Amount all 11 accelerometers, Actigraph GT3X, Dynaport, and TracmorD, came out better validity.	variance unable to explain. Further improvement should focus on the activity other than running, walking, and light intensity activities	01-6.
Comparative Validity of Physical Activity Measures in OlderAdults	Colbert LH, Matthews CE, Havighurst TC, Kim K, Schoeller DA	To compare the validity of various physical activity measures with doubly labeled water (DLW)-measured physical activity energy expenditure (PAEE) in free-living older adults	56 adults aged ≥65 yr wore three activity monitors during a 10-d free-living period and completed three different surveys. Total energy expenditure was measured using DLW, resting metabolic rate was measured with indirect calorimetry	All three monitors were significantly correlated with PAEE ($r=0.48-0.60$, $P<0.001$). For survey, only CHAMPS was significantly correlated with PAEE ($r=0.28$, $P=0.04$). Mean SE for all correlations were high, and different tools was significantly different from DLW for all but the YPAS and regression-estimated PAEE from the ActiGraph	Based on statistical result, although all of the methods demonstrated difference when compare to DLW, it seems that the monitor was able to provide a superior result than survey.	Med Sci Sports Exerc. 2011 May;43(5):867-76

WHO Europe, Review of physical activity surveillance data sources in European Union Member States					Background info	http://www.euro.who.int/__data/assets/pdf_file/0005/148784/e95584.pdf Access time: 2015/11/27
Methodological considerations in using accelerometers toassess habitual physical activity in children aged 0–5 years	Cliff DP, Reilly JJ, Okely AD,	The purpose of the review is to outline an evidence-guided protocol for using accelerometry in young children and to identify gaps in the evidence base where further investigation is required			Background Info	Journal of Science and Medicine in Sport 12 (2009) 557–567
Physical activity-related energy	Jacobi D, Perrin AE, Grosman	To evaluate two accelerometers, the RT3 and the TriTrac-R3D for	Experiment 1, 13 overweight/obese subjects (BMI 34.2+/-6.4 kg/m2)	Experiment 1, there was no significant difference between methods in mean	Although accelerometer did not provide accurate	Obesity (Silver Spring).

expenditure with the RT3 and TriTrac accelerometers in overweight adults	N, Dor éMF	their ability to produce estimates of physical activity-related energy expenditure (PAEE) in overweight/obese adults.	were monitored over 2 weeks in everyday life, PAEE being simultaneously measured by the doubly labeled water method (DLW).Experiment 2, 8 overweight/obese subjects (BMI 34.3+/-5.0 kg/m2) and 10 normal-weight subjects (BMI 20.8+/-2.1 kg/m2) were monitored during a treadmill walking protocol, PAEE being simultaneously measured by indirect calorimetry.	PAEE (DLW: 704+/-223 kcal/d, RT3: 656+/-140 kcal/d, TriTrac-R3D 624+/-419 kcal/d).Correlation for PAEE between RT3 and DLW was higher than between TriTrac-R3D and DLW (r=0.67, p<0.05 and r=0.36, p=0.25, respectively. Experiment 2, both accelerometers were sensitive to the changes in treadmill speed, with no significant difference in mean PAEE between methods in overweight/obese subjects	estimates of PAEE at individual levels, the data suggest that RT3 has the potential to assess PAEE at group levels in overweight/obese subjects	2007 Apr;15(4):950-6.
A comprehensive evaluation of commonly used accelerometer energy expenditure and MET prediction	Lyden K, Kozey SL, Staudenmeyer JW, Freedson PS	The purpose of this study was to evaluate the validity of nine published and two proprietary EE prediction equations for three different accelerometers.	Two hundred and seventy-seven participants completed an average of six treadmill (TRD) (1.34, 1.56, 2.23 ms(-1) each at 0 and 3% grade) and five self-paced activities of daily living (ADLs). EE	Across all activities, each equation underestimated EE (bias -0.1 to -1.4 METs and -0.5 to -1.3 kcal, respectively). For ADLs EE was underestimated by all prediction models (bias -0.2 to -2.0 and -0.2 to -2.8,	The estimation equation is one of the most important part during physical activity measurement. For now, most of equation were	Eur J Appl Physiol. 2011 Feb;111(2):187-201.

equations			estimates were compared with indirect calorimetry	respectively), while TRD activities were underestimated by seven equations, and overestimated by four equations (bias -0.8 to 0.2 METs and -0.4 to 0.5 kcal, respectively).vigorous intensity activities being most often misclassified	generate from Lab result, which may demonstrate limit applicability when been used in practical clinic field.	
Estimating energy expenditure using accelerometers	Crouter SE, Churilla JR, Bassett DR Jr.	The purpose of this study was to examine the validity of published regression equations designed to predict energy expenditure (EE) from accelerometers (Actigraph, Actical, and AMP-331) compared to indirect calorimetry, over a wide range of activities	Forty-eight participants (age: 35 +/- 11.4 years) performed various activities that ranged from sedentary behaviors (lying, sitting) to vigorous exercise. The activities were split into three routines of six activities, and each participant performed at least one routine. The participants wore three devices (Actigraph, Actical, and AMP-331) and simultaneously, EE was measured with a portable	The Actigraph and Actical regressions tended to overestimate walking and sedentary activities and underestimate most other activities. The AMP-331 gave a close estimate of EE during walking, but overestimated sedentary/light activities and underestimated all other activities. The only equation not significantly different from actual time spent in both light and moderate physical activity was the Actigraph Freedson kcal equation. All equations	Another research focus on estimation equation, it has the same result like Lyden's research, the equation tend to underestimate the PA, especially in vigorous activity level,	Eur J Appl Physiol. 2006 Dec;98(6):601-12

			metabolic system	significantly underestimated time spent in vigorous physical activity (P < 0.05).		
Accelerometry analysis of physical activity and sedentary behavior in older adults: a systematic review and data analysis	Gorman E, Hanson HM, Yang PH, Khan KM,	To investigate the appropriate cut point for mod-vigorous physical activity by review former research. And use the selected cut point to analyze accelerometry data from a sample of community-dwelling older women	59 articles were reviewed	The cut-points ranging between 574 and 3,250 counts/min for MVPA and 50 and 500 counts/min for sedentary time, Based on this cut point, the median MVPA minutes per day for community-dwelling older women ranged between 4 and 80 min while percentage of sedentary time per day ranged between 62 % and 86 %	For physical activity level estimation, one of the most important parts is how to differentiate the intensity of the activity. So it is important for us to know the proper cut point to category the different activity level, However, due to the difference between the monitor devices, there is no standard cut point recommendation for us to use as reference.	Eur Rev Aging Phys Act. 2014;11: 35-49
Physical activity	Plasqui G, Westerterp	This review focuses on the ability of different	The PubMed Central database was searched	Many studies showed poor results. Only a few	Interesting article, it point out that	Obesity (Silver

assessment with accelerometers: an evaluation against doubly labeled water.	KR	accelerometers to assess daily physical activity as compared with the doubly labeled water (DLW) technique	using the following key words: doubly or double labeled or labeled water in combination with accelerometer, accelerometry, motion sensor, or activity monitor.. 41 articles were identified. 28 article have contained sufficient and new data. 8 accelerometer were included	mentioned partial correlations for accelerometer counts or the increase in R(2) caused by the accelerometer. In addition, standard errors or limits of agreement were often large or not presented. The CSA/MTI/Actigraph and the Tracmor were the two most extensively validated accelerometers.	accelerometer did not shown a good correlation with the DLW, I think it may due to many factors, like different placement location in different research, moreover, since nearly half of the selected article are using CSA and Tracmor, I think there may be individual bias during the article selection process.	Spring). 2007 Oct;15(10):237 1-9
Comparison of uniaxial and triaxialaccelero metry in the assessment of physical activity among adolescents under	Vanhelst J, B éghin L, Duhamel A, Bergman P, et.al	to compare physical activity (PA) levels and patterns obtained simultaneously by triaxial accelerometry and uniaxial accelerometry in adolescents in free-living conditions	Sixty-two participants, aged 13-16 years, were recruited in this ancillary study, All participants wore a uniaxial accelerometer (ActiGraph GT1M®, Pensacola, FL) and a triaxial accelerometer (RT3®,	The concordance correlation coefficient between two accelerometers at each intensity level was superior to 0.95.The ANOVA test showedno significant difference for vigorous intensity, Bland & Altman method showed good	ANOVA shown a significant difference in lower intensity activities, but the different never exceed 2.1%.	BMC Med Res Method ol. 2012 Mar 12;12:2 6

free-living conditions: the HELENA study.			Stayhealthy, Monrovia, CA) simultaneously for 7 days	agreement between both accelerometers ($p < 0.05$).		
The use of uniaxial and triaxial accelerometers to measure children"free play" physical activity	Ott AE, Pate RR, TrostSG,Ward DS, et al	compared the validity of uniaxial accelerometer (ActiGraph) with triaxial accelerometer (Tritrac-R3D)	28 9-11 years children when they performed eight different free-play activities. (Playing a video game, throwing and catching, walking, bench stepping, hopscotch, basketball, aerobic dance, and running)	both kinds of accelerometer were able to demonstrate a significant correlation between the activity counts, heart rate and predicted MET level. However, compare to the uniaxial accelerometer (r=0.43 with MET, r=0.64 with heart rate), triaxial accelerometer was able to provide a stronger correlation (r=0.69 with MET, r=0.73 with heart rate).	If only focus on simple activity, like walking or running, the uniaxial accelerometer was able to provide the activity count as good as triaxial accelerometer, however, triaxial accelerometer is able to monitor more complicated activities. So we should select the proper device based on our research design and goals.	Pediatr. Exerc. Sci. 12:360–370, 2000
Evaluation of methods to assess physical activity in free-living	Leenders NY, Sherman WM, Nagaraja	Compare different methods of measuring physical activity (PA) in women by the doubly labeled water method	13 subjects have participated in a 7 days experimental protocol. The accelerometer was secured at the waist and	The triaxial accelerometer has demonstrated a strong correlation with the results that measured by DLW ((r =0.54) than uniaxial	For the adult, the triaxial accelerometer demonstrated a superior validity	Med. Sci. Sports Exerc. 33:1233

conditions	HN, Kien CL	(DLW)	attached to a belt.	accelerometer ((r =0.45)	compare to uniaxial accelerometer, especially at free living environment.	–1240, 2001.
Validity of accelerometry for the assessment of moderate intensity physical activity in the field.	Hendelman D, Miller K, Baggett C, Debold E, Freedson P.	To examine the validity of accelerometry in assessing moderate intensity physical activity in the field and to evaluate the metabolic cost of various recreational and household activities	25 subjects completed four bouts of overground walking at a range of self-selected speeds, played two holes of golf, and performed indoor (window washing, dusting, vacuuming) and outdoor (lawn mowing, planting shrubs) household tasks, Energy expenditure was measured using a portable metabolic system and accelerometer.	Observed MET levels differed from values reported in the Compendium of Physical Activities. Relationships between counts and METs were stronger for walking (CSA, r = 0.77; Tritrac, r = 0.89) than for all activities combined (CSA, r = 0.59; Tritrac, r = 0.62). Metabolic costs of golf and the household activities were underestimated by 30-60% based on the equations derived from level walking.	The accelerometer is tend to underestimate activity level, this is same with other research, moreover, accelerometer was able to provide a stronger correlation only under controlled environment or Lab	Med Sci Sports Exerc. 2000;32 (Suppl 9):442–9.
A comparative evaluation of three accelerometry-b ased physicalactivity monitors	Welk GJ, Blair SN, Wood K, Jones S, Thompson RW;	The purpose of this study was to evaluate the absolute and relative validity of three contemporary activity monitors (Computer Science and Applications,	52 participants completed two 30-min choreographed routines, Three different treadmill paces were completed in both routines to evaluate reliability and validity	The correlations between the monitors and measured VO2 were higher for treadmill activity (mean r = 0.86) compared with lifestyle activity (mean r = 0.55).Correlations among the	Same with Hendelman's research, this study demonstrated that the accelerometer still has limitation when monitor	Med. Sci. Sports Exerc. 32:S489 –S497, 2000

		Inc. [CSA], Tritrac, and Biotrainer) under both laboratory and field conditions.	under laboratory conditions. Six different lifestyle activities were also examined to evaluate the validity of the monitors under field conditions	different monitors were high for both treadmill (r = 0.86) and lifestyle activities (r = 0.70), Under field conditions, all of the monitors underestimated EE (range: 42-67% of measured value)	activity level in free environment.	
Conducting Accelerometer-Based Activity Assessments in Field-Based Research.	Trost SG, McIver KL, Pate RR	The purpose of this review is to address important methodological issues related to conducting accelerometer-based assessments of physical activity in free-living individuals	Systemic review focus on accelerometer selection, number of accelerometers needed, placement of accelerometers, epoch length, and days of monitoring required to estimate habitual physical activity.	No definitive evidence exists currently to indicate that one make and model of accelerometer is more valid and reliable than another	Although there is no definitive evidence, the validity coefficients for multiple axis accelerometers have been found higher than uniaxial models. But this does not mean the multiple axis one will always superior to uniaxial one, the selection is highly based on research design and goal.	Med. Sci. Sports Exerc., Vol. 37, No. 11(Suppl), pp. S531–S543, 2005
An Accelerometer-based device for	Morillo, D.S.; Ojeda,	This paper presents a body-fixed-sensor-based approach to assess	A trial involving 15 patients at a sleep unit was undertaken. Vibration	Results demonstrated the feasibility of implementing an accelerometry-based	Background info	IEEE. Trans. Inf.

sleep apnea screening.	J.L.R.; Foix, L.F.C.; Jiménez, A.L.	potential sleep apnea patients.	sounds were acquired from an accelerometer sensor fixed with a noninvasive mounting in supine position	portable device as a simple and cost-effective solution for contributing to the screening of sleep apnea-hypopnea syndrome and other breathing disorders.		Technol. Biomed. 2010, 14, 491-499
Measuring distance walked and step count in children with cerebral palsy: An evaluation of two portable activity monitors.	Kuo YL, Culhane KM, Thomason P, Tirosh O, Baker R.	To investigate measurement of the distance walked and step count in children with CP who have atypical gait by using portable monitors	Twenty typically developing children and twenty children with CP, aged 4-16 years, were recruited to study, three walking conditions were performed (continuous walking, structured activity lap walking and stair climbing). Measurements of the activity monitors were compared to known walking distances and video recordings for step count	The Minimod gave more accurate measurement of continuous walking over level ground. On the other hand, the AMP performed better in detecting the walks in a structured activity lap and during stair ascent and descent	Just like the researcher's suggestion:"Researchers and clinicians need to consider different characteristics of the monitoring devices and walking conditions, and choose an appropriate device that is most reflective of what they want to measure"	Gait Posture 2009, 29, 304-310 .
A Randomized Clinical Trial of an Activity and	Steele BG, Belza B, Cain KC,	To evaluate the effectiveness of an exercise adherence	One hundred six subjects were randomly arrange into intervention and	There are less decline at 20 weeks in exercise adherence (intervention mean, +3 min;	intervention enhanced exercise adherence and	Arch Phys Med

Exercise Adherence Intervention in Chronic Pulmonary Disease.	Coppersmith J	intervention to maintain daily activity, adherence to exercise, and exercise capacity over 1 year after completion of an outpatient pulmonary rehabilitation program	usual care groups. Intervention group include Twelve-week adherence intervention (weekly phone calls and home visit) including counseling on establishing, monitoring, and problem-solving in maintaining a home exercise program. Primary outcomes included daily activity (accelerometer), exercise adherence (exercise diary), and exercise capacity (six-minute walk test). All measures were performed at baseline, after the pulmonary rehabilitation program (8 wk), after the adherence intervention (20 wk), and at 1 year.	control mean, -13 min; P=.015) and exercise capacity (intervention mean, -10.7 m; control mean, -35.4 m; P=.023). There were no differences in daily activity at 20 weeks or any differences in any primary variable at 1 year.	exercise capacity in the short term but produced no long-term benefit. The primary endpoint of daily activity measures by accelerometer did increase more during the exercise adherence intervention in the intervention group than in the control group, but after controlling for baseline differences this was not statistically significant	Rehabil. 2008 Mar;89(3):404-12.
Accelerometers and pedometers:	Corder K, Brage S,	This review examines recent literature on the		Accelerometry is able to adequately assess physical	Background for accelerometer	Current Opinion

methodology and clinical application	Ekelund U	validation of movement sensors to assess habitual physical activity.		activity but currently methods have limited accuracy for the estimation of free-living energy expenditure. Pedometers provide an inexpensive overall measure of physical activity but are unable to assess intensity, frequency and duration of activity or to estimate energy expenditure	selection	in Clinical Nutrition and Metabolic Care. ssue: Volume 10(5), September 2007, p 597–603
Assessment of physical activity with the Computer Science and Applications, Inc., accelerometer: laboratory versus field validation	Nichols JF, Morgan CG, Chabot LE, Sallis JF, Calfas KJ	compare the validity of the Computer Science and Applications, (CSA) Inc., accelerometer in laboratory and field settings and establish CSA count ranges for light, moderate, and vigorous physical activity	Validity was determined in 60 adults during treadmill exercise, using oxygen consumption (VO2) as the criterion measure, while 30 adults walked and jogged outdoors on a 400-m track.	The relationship between CSA counts and VO2 was linear (R2 = .89 SEE = 3.72 ml.kg-1.min-1), as was the relationship between velocity and counts in the field (R2 = .89, SEE = 0.89 mi.hr-1). There is a significant different between lab and field for light and vigorous intensity.	This article shown that the preset equation that based on lab finding may not appropriate for use in the field settings.	Res Q Exerc Sport. 2000;71 :36–43.
Wearable systems for	Allet L, Knols RH,	This review aims to identify the actual state of	In March 2009 a librarian performed an electronic	25 articles were included, two RCTs focusing on	feasible methods for monitoring human	Sensors (Basel).

monitoring mobility-related activities in chronic disease: a systematic review	Shirato K, de Bruin ED,	applying wearable systems for monitoring mobility-related activity in individuals with chronic disease conditions. Focus on technologies and applications, feasibility and adherence aspects, and clinical relevance of wearable motion sensing technology	search on PubMed and the Physiotherapy Evidence Database (PEDro). The keywords include: (chronic diseases OR cardiovascular disease OR CVK OR diabetes OR diabetic OR COPD OR osteoarthritis) AND (gait disorder OR walking OR kinematic OR gait analysis system OR gait analysis device) AND (accelerometer* OR pedometer* OR gyroscope* OR wearable system OR activity monitor OR motion sensing OR instrumentation OR equipment) AND (physical activity OR motor activity OR activity).	arthritis, four focusing on COPD, six focusing on CVD, and 13 focusing on Diabetes	mobility are available, evidence-based clinical applications of these methods in individuals with chronic diseases are in need of further development	2010;10 (10):9026-52
Validity of pedometers for	Evangelista LS, Dracup	Determine if pedometers offered a practical,	Exercise adherence was measured using	Patients who showed improvements in their	Subject age between 18 and 80	J Card Fail.

measuring exercise adherence in heart failure patients	K, Erickson V, McCarthy WJ	cost-effective, and acceptable assessment strategy that could be used with confidence to measure exercise adherence to a home-based walking program among HF patients	pedometers in 38 patients (74% men) age 54.1 ± 11.7 years who participated in a 12-month home-based walking program. They will have a baseline test at the beginning of research session and a comparison of functional status as measured by the 6-minute walk distance and peak oxygen uptake (VO2 max) at 6 months	pedometer scores (>10%) over 6 months had better functional status at 6 months (6-minute walk distance 1718 ± 46 versus 1012 ± 25 meters, F = 5.699, P = .022; VO2 max 17 ± 0.7 versus 10 ± 0.5 units, F = 7.162, P = .011) when compared with patients whose pedometers reflected minimal change in distance walked	years with advanced HF defined as left ventricular systolic dysfunction with a left ventricular ejection fraction ≤40% and New York Heart Association class II-IV. Pedometers were given to patients and they were also asked to complete daily activity diaries for the first 6 months of the trial.	2005 Jun;11(5):366-71
Evaluation of a new motion sensor in patients with chronic obstructive pulmonary disease	Sant'Anna T, Escobar VC, Fontana AD, Camillo CA	To assess the criterion validity and reproducibility of a new pedometer in patients with chronic obstructive pulmonary disease (COPD).	Patients with COPD (N=30; 17 men; forced expiratory volume in the first second, 44±17% predicted) were videotaped while performing 2 protocols: one including 2 slow and 2 fast 5-minute walks, and	Correlations between the pedometer and the criterion method were high for SC during slow and fast walking (r=.79 and r=.95) and for EE during fast walking (r=.83).During the ADLs circuit, the pedometer underestimated AT by an	video and the multi-sensor is criterion methods.	Arch Phys Med Rehabil. 2012 Dec;93(12):2319-25.

			another including a circuit of activities of daily living (ADLs). Concomitantly, patients wore 2 motion sensors: the new pedometer and a multi-sensor accelerometer	average of 55% but provided an acceptable EE estimation in a group basis		
The doubly labeled water method produces highly reproducible longitudinal results in nutrition studies	Wong WW, Roberts SB, Racette SB, Das SK, et.al.	This study was designed to evaluate the longitudinal reproducibility of the DLW method using 2 protocols developed and implemented in a multicenter clinical trial-the Comprehensive Assessment of Long-term Effects of Reducing Intake of Energy (CALERIE)			Background info for DLW test	J Nutr. 2014 May;144(5):777-83.

Appendix C

Article Name	Author	Purpose	Methods	Result	Common	Citation
2013 ACCF/AHA Guideline for the Management of Heart Failure: Executive Summary: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines	Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE Jr, et.al.				CHF background info	Circulation. 2013;128: 1810-1852;
Guidelines for the diagnosis and treatment of chronic heart failure: executive summary (update 2005) The Task Force for the Diagnosis and Treatment of Chronic Heart Failure of the European Society of Cardiology	Karl Swedberg, Göteborg				Background info	European Heart Journal (2005) 26, 1115–1140
Heart Rhythm Society, Ejection Fraction					Background info	http://www.hrsonli

						ne.org/Patient-Resources/The-Normal-Heart/Ejection-Fraction#axzz35ZUt3QrE, assess time, 06/22/2014
Effects of exercise on left ventricular systolic and diastolic properties in patients with heart failure and a preserved ejection fraction versus heart failure and a reduced ejection fraction	Zile MR, Kjellstrom B, Bennett T, Cho Y,	The purpose of the current study was to define exercise-induced changes in indices of left ventricular (LV) systolic and diastolic properties in patients with chronic heart failure (HF), compare these changes in patients with HF and a reduced ejection fraction (EF) versus	Subjects with HF and a preserved EF (n=8) and subjects with HF and a reduced EF (n=5) underwent symptom-limited Naughton protocol treadmill exercise tests. Implantable hemodynamic monitor data and echocardiographic data were obtained before exercise and at peak	Although exercise limitations were similar between HF and a reduced EF and HF and a preserved EF, there were significant differences in exercise-induced changes in LV systolic		Circ Heart Fail. 2013 May;6(3): 508-16.

		HF and a preserved EF, and compare the hemodynamic responses to activities of daily living with symptom-limited upright exercise.	exercise. Implantable hemodynamic monitor data were obtained during activities of daily living during a 24-hour time period.	and diastolic properties		
Cardiovascular remodelling in coronary artery disease and heart failure	Heusch G, Libby P, Gersh B, Yellon D					Lancet. 2014 May 31;383(9932):1933-43.
Effects of different training modalities on circulating anabolic/catabolic markers in chronic heart failure	Feiereisen P, Vaillant M, Gilson G, Delagardelle C	analyze the effects of 3 different training modalities (endurance training, strength training, and combined strength and endurance training [CT]) on circulating cytokines, IGF-1, and GH levels.	Patients with CHF (N = 45), NYHA class II-III, left ventricular ejection fraction < 35%, were randomly assigned to 1 of 3 training modalities. They trained for 40 sessions, 3 times weekly. Fifteen CHF patients served as a control group. Blood samples were collected at baseline and 48	Exercise training has no effects on circulating IGF-1 and GH. The decreases in cytokines are evident only when all trained patients are compared with the control group,		J CardiopulmRehabil Prev. 2013 Sep-Oct; 33(5):303-8

			hours after the last training session	independently of the modality of training intervention.		
Acute vs chronic hypoxia: what are the consequences for skeletal muscle mass?	Deldicque L, Francaux M				Based on the literature review, hypoxia itself contributes to the loss of muscle mass during chronic hypoxia	Cell MolExerc Physiol. 2013;2(1):1–23.
Skeletal muscle dysfunction in chronic obstructive pulmonary disease and chronic heart failure: underlying mechanisms and therapy perspectives.	Gosker H.R., Wouters E.F., van der Vusse G.J., Schols A.M				chronic hypoxia will cause the muscle fiber alternation and changing the muscle function based on the type of muscle	Am J ClinNutr. 71 2000:1033-1047
The response of human skeletal muscle tissue to hypoxia	Lundby C, Calbet JA, Robach P				The same to Gosker's research. chronic hypoxia will cause the muscle fiber alternation and	Cell MolLife Sci 2009, 66:3615-3623

					changing the muscle function based on the type of muscle	
A re-examination of the metabolic equivalent concept in individuals with coronary heart disease	Savage PD, Toth MJ, Ades PA	Compare the traditionally accepted value for 1 MET to direct measurements of resting metabolic rates in a group of stable individual with coronary heart disease	109 (60 men and 49 women) subjects with documented coronary heart disease and a body mass index >or=25 kg/m2. Measurements included indirect calorimetry, body composition, and exercise capacity (peak oxygen uptake [VO2]). In a sub study of 17 (10 men, 7 women) normal weight subjects (body mass index <25 kg/m2), metabolic rate in the seated position was also measured.	Mean resting value for 1 MET was a VO2 value of 2.58 +/- 0.4 mL O2.kg(-1).min (-1) for overweight subjects measured in the supine position and 2.84 +/- 0.59 mL.O2.kg(-1). min(-1) for normal weight individuals measured in the seated position. Caloric	The patient with CAD may present decreased MET level when compare to the healthy population. Future studied are required.	J Cardiopul mRehabil Prev. 2007 May-Jun; 27 (3):143-8

				expenditure value was 0.74 +/- 0.12 kcal.kg(-1).h(-1) rather than the expected value of 1 kcal.kg(-1).h(-1).		

Appendix D

Nebraska UNIVERSITY OF Medical Center

COLLEGE OF NURSING
Lincoln Division

ADULT INFORMED CONSENT FORM IRB # 394-07-FB **Page 1 of 5**

Title of this Research Study

PSYCHOMETRIC TESTING OF MEASURES TO ESTIMATE ENERGY EXPENDITURE IN ELDERLY HEART FAILURE PATIENTS

Invitation

You are invited to take part in this research study. The information in this form is meant to help you decide whether or not to take part. If you have any questions, please ask.

Why are you being asked to be in this research study?

You being asked to be in this study because you are 60 years or older and you are currently receiving treatment for heart failure from the BryanLGH Heart Institute. You must be able to speak and read English in order to complete questionnaires about your daily physical activity.

What is the reason for doing this research study?

The purpose of this study is to evaluate ways to measure daily physical activity levels in heart failure patients.

What will be done during this research study?

If you decide to participate, you will be asked to complete two questionnaires that ask you about your activity levels for the past 7 days. You will also be asked to complete two questionnaires that ask you about your sleep and one questionnaire that asks you about your mood. If you respond that you are feeling down, depressed or hopeless nearly every day we will refer you to your primary care provider for evaluation.

You will wear three activity monitors for 7 days. One of the monitors is the size of a pager or small cell phone and fastens on to the waistband of your slacks. The second monitor snaps on to two electrodes (similar to those used for an EKG) that are placed on your upper chest. The third monitor is similar to a watch and is worn on your wrist. These activity monitors are commercially available.

It will take approximately 60 minutes for you to complete the questionnaires and get the activity monitors put on. You will not need to do anything with the activity monitors other than wear them.

IRB RE-APPROVED 7/16/09
VALID UNTIL 7/16/10

Subject's Initials______

Commerce Court / P.O. Box 880220 / Lincoln, NE 68588-0220 / (402) 472-3657 / FAX (402) 472-7345

You will return to the clinic at the end of 7 days to turn in the activity monitors and complete two questionnaires about your activity over the past 7 days. This visit will take no more than 45 minutes.

What are the possible risks of being in this study?

The electrodes that are used to place one of the activity monitors on your chest could irritate your skin. Additional electrodes will be sent home with you to change where it is located on your chest so it does not irritate your skin.

It is possible that other rare side effects could occur which are not described in this consent form. It is also possible that you could have a side effect that has not occurred before.

What are the possible benefits to you?

You are not expected to get any benefit from being in this research study.

What are the possible benefits to other people?

The information obtained from this study may help other patients by providing information about ways to evaluate or measure daily physical activity in patients with heart failure.

What are the alternatives to being in this research study?

Instead of being in this research study you can choose not to participate. If you decide not to participate you would continue to receive usual care from the BryanLGH Heart Institute.

What will being in this research study cost you?

There is no cost to you to be in this research study. Travel to BryanLGH Heart Institute for testing (at the beginning and one week later) is necessary and these costs are your responsibility.

Will you be paid for being in this research study?

You will not be paid to be in this research study.

Who is paying for this research?

This research is being paid for by grant funds from the American Nurses Foundation. The University of Nebraska Medical Center receives money from the American Nurses Foundation to conduct this study.

IRB RE-APPROVED 7/16/09
VALID UNTIL 7/16/10

Subject's Initials______

What should you do if you are injured or have a medical problem during this research study?

If you are injured or have a medical problem as a result of being in this study, you should immediately contact one of the people listed at the end of this consent form.

How will information about you be protected?

You have rights regarding the privacy of your medical information collected before and during this research. This medical information, called "protected health information" (PHI), includes demographic information (like your address and birth date), the results obtained from the questionnaire and the activity monitors, as well as your medical history. You have the right to limit the use and sharing of your PHI, and you have the right to see your medical records and know who else is seeing them.

By signing this consent form, you are allowing the research team to have access to your PHI. The research team includes the investigators listed on this consent form and other personnel involved in this specific study at UNMC and the Nebraska Medical Center.

Your PHI will be used only for the purpose(s) described in the section "What is the reason for doing this research study?" Your PHI will be shared, as necessary, with the Institutional Review Board (IRB) and with any person or agency required by law. You are also allowing the research team to share your PHI with other people or groups listed below. All of these persons or groups listed below are obligated to protect your PHI.

Your health insurance company.

Your PHI may also be shared with the American Nurses Foundation, which sponsors this research and provides funds to the UNMC/THE NEBRASKA MEDICAL CENTER to conduct this research. However, this organization does not have the same obligation to protect your PHI.

You are authorizing us to use and disclose your PHI for as long as the research study is being conducted.

You may cancel this authorization to use and share your PHI at any time by contacting the principal investigator in writing. If you cancel this authorization, you may no longer participate in this research. If you cancel this authorization, use or sharing of future PHI will be stopped. The PHI which has already been collected may still be used.

The information from this study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential.

IRB RE-APPROVED 7/16/09
VALID UNTIL 7/16/10

Subject's Initials______

What are your rights as a research subject?

You have rights as a research subject. These rights are explained in this consent form and in *The Rights of Research Subjects* that you have been given. If you have any questions concerning your rights or complaints about the research, talk to the investigator or contact the Institutional Review Board (IRB) by telephone (402) 559-6463, e-mail: IRBORA@unmc.edu, or mail: UNMC Institutional Review Board, 987830 Nebraska Medical Center, Omaha, NE 68198-7830.

What will happen if you decide not to be in this research study?

You can decide not to be in this research study at any time. Deciding not to be in this research study will not affect your medical care or your relationship with the investigators, the University of Nebraska Medical Center or BryanLGH Heart Institute. Your doctor will still take care of you and you will not lose any benefits to which you are entitled.

What will happen if you decide to stop participating once you start?

You can stop being in this research study ("withdraw") at any time. Deciding to withdraw will otherwise not affect your care or your relationship with the investigator, the University of Nebraska Medical Center or BryanLGH Heart Institute. You will not lose any benefits to which you are entitled.

You may be taken off the study if you don't follow instructions of the investigator or the research team. You may also be taken off the study if your medical condition changes.

If the research team gets any new information during this research study that may affect whether you would want to continue being in the study you will be informed promptly.

Documentation of informed consent

You are freely making a decision whether to be in this research study. Signing this form means that (1) you have read and understood this consent form, (2) you have had the consent form explained to you, (3) you have had your questions answered and (4) you have decided to be in the research study.

If you have any questions during the study, you should talk to one of the investigators listed below. You will be given a copy of this consent form to keep.

Signature of Subject: ________________________ Date: _____ Time: ____

My signature certifies that all the elements of informed consent described on this consent form have been explained fully to the subject. In my judgment, the participant possesses the legal capacity to give informed consent to participate in this research and is voluntarily and knowingly giving informed consent to participate.

Person obtaining consent: ______________________ Date: ______ Time: ____

Subject's Initials______

IRB RE-APPROVED 7/16/09
VALID UNTIL 7/16/10

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IRB RE-APPROVED 7/26/09
VALID UNTIL 7/26/10

Subject's Initials______

UNIVERSITY OF Nebraska Medical Center

COLLEGE OF NURSING
Lincoln Division

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Title of this Research Study

PSYCHOMETRIC TESTING OF MEASURES TO ESTIMATE ENERGY EXPENDITURE IN ELDERLY HEART FAILURE PATIENTS

You are invited to take part in an additional 36 minutes of physical activity monitoring. The monitoring will involve wearing the activity monitors (like you wore previously) for 36 minutes of activity. You will breathe into a face mask that will monitor your oxygen levels as you participate in 24 minutes of light activity (e.g., reading the newspaper, watching television, washing dishes, dusting), 6 minutes of moderate activity (e.g., vacuuming, stair climbing), and a 6 minute walk test.

The monitoring itself will take 36 minutes to complete. Fifteen minutes will be needed to get the monitoring equipment on and you will be required to rest for 15 minutes after completion of the activity.

The 6 minutes of moderate intensity activity and the 6 minute walk test have potential associated risks of heart rate and blood pressure changes, fatigue, shortness of breath, muscle and joint discomfort. Your blood pressure, heart rate and oxygen level will be checked before and after each activity. The mouthpiece may be uncomfortable during the test and may cause some soreness in the mouth. You should be aware that these tests involve the possible risk of falls and/or muscle-joint injuries. You will be closely monitored throughout the test procedures by a nurse practitioner and an American College of Sports Medicine certified exercise physiologist. The activities and tests will be performed at the BryanLGH Heart Institute where a cardiologist is available if needed. You will be closely monitored throughout the test procedures and you will regularly be asked to rate your level of distress to help determine your response to the activity. If you need to stop because you are feeling distress your blood pressure, heart rate and oxygen level would be checked immediately. Following the 30 minutes of activity, you will be required to rest to help establish you are not experiencing any activity related changes. Your blood pressure, heart rate and oxygen level would be checked at the end of this rest period.

It is possible that other rare side effects could occur that are not described in this consent form. It is also possible that you could have a side effect that has not occurred before.

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If you are injured or have a medical problem as a direct result of being in this study, you should immediately contact one of the people listed at the end of this consent form. Immediate emergency medical treatment for this injury will be available at BryanLGH Medical Center. You or your insurance company will need to pay for any costs. The costs for any other medical problems unrelated to this research study are also your responsibility. There are no plans to provide payment for things like lost wages, disability or discomfort. Agreeing to this does not mean you have given up any legal rights.

Your willingness to complete this activity monitoring will provide you with information about your tolerance of light to moderate activity. You are not expected to get any benefit from completing this activity.

Instead of completing this activity you can choose not to participate. There is no cost to you to complete this activity. You will not be paid to do this.

You can decide not to do this activity at any time. Deciding not to do this test will not affect your medical care or your relationship with the investigators, the University of Nebraska Medical Center, or BryanLGH Heart Institute. Your doctor will still take care of you and you will not lose any benefits to which you are entitled.

Documentation of informed consent

You are freely making a decision whether to complete this 36 minutes of activity monitoring. Signing this form means that (1) you have read and understood this consent form addendum, (2) you have had the addendum form explained to you, (3) you have had your questions answered and (4) you have decided to do the test.

If you have any questions, you should talk to one of the investigators listed below. You will be given a copy of this consent form to keep.

Signature of Subject: ________________________ Date: _____ Time: ____

My signature certifies that all the elements of informed consent described on this consent form have been explained fully to the subject. In my judgment, the participant possesses the legal capacity to give informed consent to participate in this research and is voluntarily and knowingly giving informed consent to participate.

Person obtaining consent: _____________________ Date: ______ Time: ____

Subject's Initials_____

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Authorized Study Personnel

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Appendix E

Date________
Subject Code Number_______

Modified 7 Day Physical Activity Record

I would like to know about your physical activity during the past 7 days; that is, the last 5 weekdays and the last weekend, Saturday and Sunday. This should be a recall of your actual activities for the past week, not a history of what you usually do.

A. Your Sleeping Habits:

First let me ask you about your sleeping habits.

How many hours did you sleep on average each night during the last 7 nights? (Record to the nearest quarter-hour, that is 0, 15, 30 or 45 minutes).

_____ hours _____minutes/night X 7 night/week

Did you nap during the day? _____yes _____no

If yes, how much time did you spend napping?

_____ hours _____ minutes/day X _____day/week

B. Your Physical Activity:

Now I am going to ask about your physical activity during the past 7 days. I will be asking you to recall how much time you spent doing various activities. You must have spent at least 5 minutes doing the activity to include it. Do not include rest periods or breaks from the activity.

<u>**Light Activities**</u> < 2.0 METS

First, let's consider light activities or activities that involve sitting or standing with little movement. How much time did you spend:

Watching TV	_____ hours _____ minutes/day X _____ days/week
Reading	_____ hours _____ minutes/day X _____ days/week
Playing Cards	_____ hours _____ minutes/day X _____ days/week
Ironing	_____ hours _____ minutes/day X _____ days/week
Knitting	_____ hours _____ minutes/day X _____ days/week
Cooking	_____ hours _____ minutes/day X _____ days/week

Can you think of any other activities that you did this past week that are of similar intensity?

________________ (list activity)	_____ hours _____ minutes/day X _____ days/week
________________ (list activity)	_____ hours _____ minutes/day X _____ days/week
________________ (list activity)	_____ hours _____ minutes/day X _____ days/week

Moderate Activities **2-3.9 METS**

Now let's look at moderate activities. How much time did you spend:

Cleaning	_____ hours _____ minutes/day X _____ days/week
Shopping	_____ hours _____ minutes/day X _____ days/week
Raking the lawn	_____ hours _____ minutes/day X _____ days/week
Fishing	_____ hours _____ minutes/day X _____ days/week
Painting (not ceilings)	_____ hours _____ minutes/day X _____ days/week
Walking less than 3 miles per hour	_____ hours _____ minutes/day X _____ days/week
Home repair	_____ hours _____ minutes/day X _____ days/week
Riding or pushing a power lawn mower	_____ hours _____ minutes/day X _____ days/week
Golfing with a cart	_____ hours _____ minutes/day X _____ days/week

Can you think of any other activities that you did this past week that are of a similar intensity to walking at a slow pace (1 mile in more than 20 minutes)

_______________ _____ hours _____ minutes/day X _____ days/week
(list activity)

_______________ _____ hours _____ minutes/day X _____ days/week
(list activity)

Hard Activities **4.0 -5.9 METS**

Now let's look at hard activities. How much time did you spend doing hard activities:

Golfing, walking and pulling or carrying clubs	_____ hours _____ minutes/day X _____ days/week
Walking on a level surface at least 3 miles per hour	_____ hours _____ minutes/day X _____ days/week
Scrubbing floors	_____ hours _____ minutes/day X _____ days/week
Painting ceilings	_____ hours _____ minutes/day X _____ days/week
Mowing a lawn with a power mower	_____ hours _____ minutes/day X _____ days/week

Can you think of any other activities that you did this past week that are of similar intensity to walking at a brisk pace (1 miles in 20 minutes or less)?

_______________ _____ hours _____ minutes/day X _____ days/week
(list activity)

_______________ _____ hours _____ minutes/day X _____ days/week
(list activity)

<u>Very Hard Activities</u> **>6.0 METS**

Now let's look at very hard activities. How much time did you spend:

Digging	_____ hours _____ minutes/day X _____ days/week
Swimming (breast stroke)	_____ hours _____ minutes/day X _____ days/week
Walking on a hilly terrain at least 3 mph	_____ hours _____ minutes/day X _____ days/week

Can you think of any other activities that you did this past week that are of similar intensity to walking on a hilly terrain at a brisk pace (1 mile in 20 minutes or less)?

________________ (list activity)	_____ hours _____ minutes/day X _____ days/week
________________ (list activity)	_____ hours _____ minutes/day X _____ days/week

Hellman, Williams, and Thalken, 1996