VALIDATION OF BASIS HEART RATE DETECTION VERSUS GOLD STANDARD

Firmware Version 1.18.3

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ABSTRACT

In November 2014, Basis, an Intel Company, launched the Basis Peak fitness and sleep tracker. The Basis Peak provides users with the ability to continuously monitor heart rate from the wrist, even during exercise, and over the past year, Basis has continued to develop its proprietary calorie expenditure algorithm to provide users with a high quality calorie tracking experience.

In order to further validate Basis's updated calorie expenditure detection feature, Basis commissioned a validation study at the Human Performance Center at UCSF Medical Center to assess the accuracy of the Basis Peak relative to laboratory measurements for heart rate and calorie expenditure, also known as energy expenditure, during exercise.

Researchers monitored heart rate and calorie expenditure as detected by both the Basis Peak and clinical grade laboratory equipment while subjects executed an exercise protocol that included stationary biking as well as walking, jogging and running on a treadmill. The output of the Basis Peak was then compared to the clinical values obtained using electrocardiography (ECG) and indirect calorimetry.

Strong correlation ($r = 0.94$, $p < 0.001$) was observed between the heart rate measured by the Basis Peak and that measured by the ECG, with an average difference of 3.6%. Consistent coverage was also demonstrated, with the Basis Peak reporting heart rate values for 99.5% of the testing period. Moreover, the Basis Peak calorie expenditure algorithm demonstrated a 11.4% average difference relative to the energy expenditure values obtained using the laboratory equipment.

INTRODUCTION

Monitoring energy expenditure provides an individual with valuable information to promote personal health and wellness. Self-monitoring of energy expenditure can act as a significant motivating factor, contributing to healthy weight regulation and promoting lifestyle changes that reduce the emergence of health problems associated with inactivity, such as obesity and type 2 diabetes [1, 2, 3, 4].

Monitoring heart rate, especially during exercise, can provide individuals with similarly beneficial information. The use of heart rate monitors by endurance athletes as they strive to achieve maximal athletic performance is well documented, and throughout the general population, heart rate monitoring during exercise functions as a meaningful way to gauge workout intensity [5, 6].

In 2008, the Federal Government published exercise guidelines for adults, advising individuals to engage in at least 150 minutes of moderate intensity physical activity or 75 minutes of vigorous aerobic activity each week in order to promote good health. Globally, there are similar physical activity recommendations that make use of this inverse relationship between physical activity duration and intensity, allowing individuals to meet these guidelines by modulating the length and rigor of their workouts [8, 9, 10, 11, 12]. Typically, this distinction between moderate and vigorous activity is based on working out at a percentage of one's age-predicted maximum heart rate [13]. Despite the global prevalence of physical activity guidelines based on workout intensity, researchers have shown that individuals frequently underestimate what qualifies as moderate and vigorous activities, and therefore, misjudge the expected health outcomes and performance impacts of their workouts [14]. Using a heart rate monitor during activity enables a more accurate understanding of workout intensity, facilitating maximum performance outcomes and health benefits [15].

Beyond serving as an effective gauge of workout intensity, heart rate has been shown to be a key tool in predicting energy expenditure [16, 17]. Previously, it has been difficult to obtain consistent and accurate heart rate data during exercise, especially in wrist-worn devices, due to motion and light interference; however, the heart rate monitoring capabilities of Basis Peak contribute to significant advancements in calorie tracking.

In a laboratory environment, the gold-standard for measuring heart rate is through the use of electrocardiography (ECG) where the heart's electrical activity is monitored using a series of wired electrodes, typically ranging from one to twelve in number, that are placed on the body, enabling the electrical activity of the heart to be traced; however, this is an expensive, time-consuming protocol that is restricted to the laboratory environment [18]. Outside of the lab, heart rate monitoring is usually accomplished through use of a chest strap. Chest straps fasten around the torso and transmit continuous heart rate signals to a wireless receiver; however, many individuals find chest straps inconvenient and uncomfortable to wear. In addition, due to both battery life and comfort constraints, chest straps can only be worn for a limited period of time, preventing passive, continuous heart rate monitoring.

There also are numerous challenges associated with monitoring energy expenditure outside of the laboratory and thus, the continued development of affordable wearable technologies that enable accurate energy expenditure monitoring is of high value to both individuals and researchers [19]. Previously, researchers have been forced to rely on either energy expenditure surveys (which tend to mis-estimate these values) or the use of doubly labeled water, which although accurate, is an expensive and unrealistic method for everyday use in individuals [20, 21].

With its re-engineered optical sensor, Basis Peak provides users with the ability to continuously track heart rate from the wrist - even during exercise, and as such, enables advancements in remote calorie monitoring. Given the high value of accurate heart rate and energy expenditure monitoring outside of the laboratory environment, validation tests were commissioned by Basis at UCSF Medical Center to further demonstrate the accuracy of the Basis Peak.

METHODOLOGY

Prior to executing a validation study, Basis internally developed and validated its re-engineered heart rate detection and energy expenditure feature over hundreds of hours of testing. During development, heart rate detection of the Basis Peak was compared to data collected on a Zephyr BioHarness™ 3 (Zephyr Technology, Annapolis, MD). The Zephyr BioHarness is a heart rate monitoring device that has been tested against ECGs to assess its validity and accuracy [22]. During development, energy expenditure measures of the Basis peak were compared to a Cosmed K4B2 Portable Gas Analysis System™ which has previously been evaluated for its reliability and accuracy [23].

For external validation of Basis Peak heart rate and energy expenditure monitoring, exercise physiology trials were commissioned to be carried out at UCSF Medical Center with 20 subjects. 10 men and 10 women participated in testing, with an age range of 21-39 years and average age of 28.4 years. Testing was conducted by UCSF Medical Center staff. Each participant wore two watches during the trial, for a total of 40 Basis Peak data collection events. The protocol was approximately 40 minutes long and consisted of an inactive rest period, walking, jogging, and running on a treadmill and stationary biking. The subjects wore the Basis Peak for 30 seconds before t=0 to allow an initial signal to be established. Subjects walked at 3 miles per hour (mph), jogged at 5 mph, and ran at a pace comfortable to the individual, ranging from 6 to 8 mph. Subjects biked at 70-125 watts for moderate cycling and 140-200 watts for intense cycling. Heart rate was monitored by both the Basis Peak and electrocardiography simultaneously. Calorie expenditure was monitored with the laboratory equipment using indirect calorimetry, where the volume of O2 and CO2 exchanged is used to quantify energy expenditure. Analysis of coverage and accuracy of Basis data relative to that collected by laboratory equipment was performed by Basis. In the analysis, Basis Peak heart rate data was time-shifted to allow comparison to values obtained with the ECG.

RESULTS AND DISCUSSION

Heart Rate:

Strong correlation (r = 0.94) was observed between values for heart rate monitored with ECG and the Basis Peak (see Figure 1). These results were statistically significant ($p<0.001$), and the least squares fit line for the data set has a slope of 0.99 and an intercept of 0.38.

Throughout the entire testing interval, there was an average difference of 3.6% between the values measured by the Basis Peak and the ECG (see Table 1). In addition, the Basis Peak measured heart rate values over 99.5% of the testing period, illustrating very good reliability at reporting heart rate across a variety of activities.

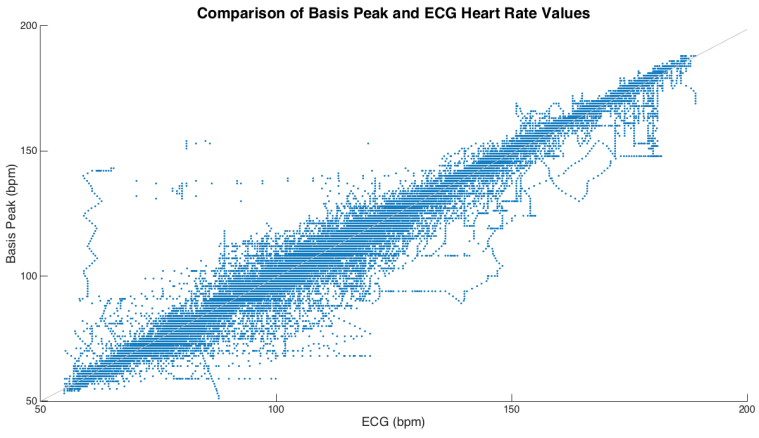

Figure 1 | *Comparison of Basis Peak and ECG Heart Rate Values*

Heart Rate Value Comparisons were evaluated per subject for the duration of the test period as well as on a per activity level. Numbers reported at right are averages across all subjects. "All" refers to the entire testing interval during which both the ECG and the Basis Peak were turned on to collect data. "Average difference" is the absolute value of the difference between the two measured values as a percentage.

Representative images depicting both the heart rate detected by the Basis Peak and ECG for two study participants are shown in Figures 2 and 3. A strong level of agreement and coverage is evident.

Activity	Average difference (%)
All	3.6%
Rest	3.0%
Moderate Cycling	1.8%
Intense Cycling	2.2%
Walk	2.7%
Jog	4.4%
Run	3.0%

Table 1 | *Comparison of ECG and Basis Peak Coverage and Heart Rate Measurements*

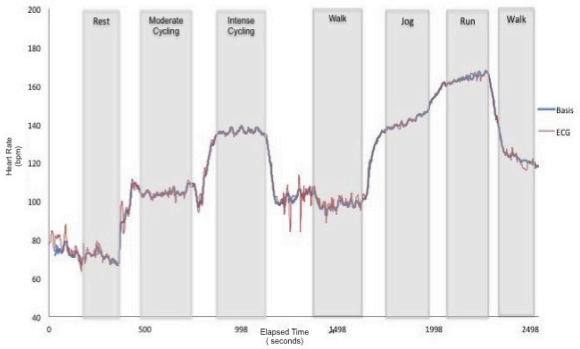

Figure 2 | *Comparison of Basis Peak Heart Rate and ECG for Female Study Subject*

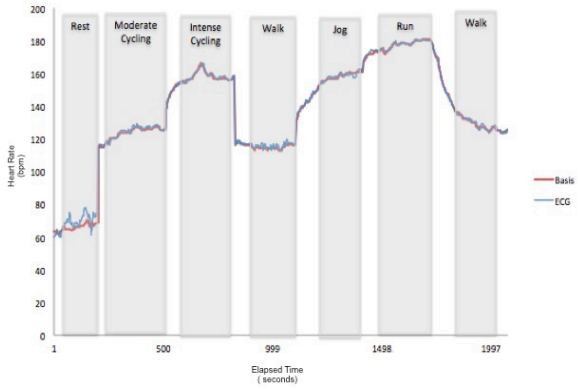

Figure 3 | *Comparison of Basis Peak Heart Rate and ECG for Male Study Subject*

Energy Expenditure:

As was observed with heart rate, strong correlation was observed between values obtained for energy expenditure with the Basis Peak algorithm and the metabolic cart. Throughout the entire testing interval, there was an average difference of 11.4% between the values measured by the Basis Peak and the metabolic chart. Energy expenditure totals from the test period (consisting of both periods of rest and working out) as calculated by the metabolic cart and Basis Peak for each of the 20 study participants are shown in figure 4.

Energy Expenditure Value Comparisons were evaluated per subject for the duration of the test period. Energy expenditure as measured by Peak is plotted in blue. Energy expenditure as measured with the metabolic cart is plotted in green.

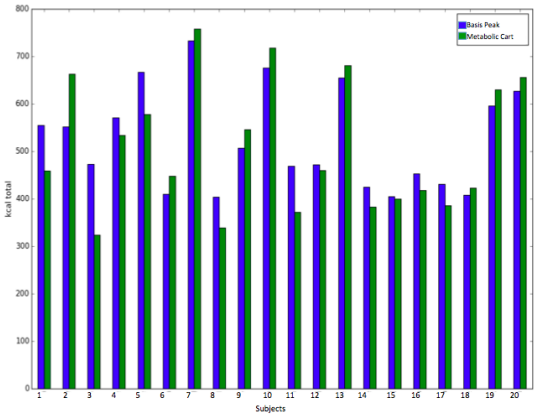

Figure 4 | *Comparison of Metabolic Cart and Basis Peak Energy Expenditure Totals*

SUMMARY

The Basis Peak fitness and sleep tracker demonstrated strong correlation with clinical-grade heart monitoring and energy expenditure equipment during a validation study executed at UCSF Medical Center. Basis Peak displayed high accuracy and reliability, on average reporting calorie and heart rate readings within 3.6 % for heart rate and 11.4% for energy expenditure of those values obtained with clinical devices across a range of activities.

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