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Anatomy of a Body Monitor

BodyMedia, Inc's High-Tech Sensor Takes Off Pounds

Pittsburgh, PA (May 2011) – Angie Wallace looks at her watch-size wrist display to check her calorie burn for the day as she finishes her dinner at Pollo Tropical Grill in Tampa, Florida. After paying the check, Angie and her husband, Bryan, drive down the street to The Roundup Country-Western Club for an evening of line dancing. On the way, she uses her Android smartphone to upload the grilled chicken with black beans and tossed salad she had for dinner to her personal Activity Manager on the BodyMedia website. With her account updated, the web interface tells her she has expended 1,915 calories and consumed 1,629 so far today - a total of 286 fewer calories into her body than out. The petite blonde beams as she recalls the day sixteen months ago when she first strapped her new BodyMedia FIT Armand onto her left arm after a lifetime of struggling with her weight. Since that moment, 38-year-old Angie has lost 96 pounds. By the end of next week she wants to make it 100.

Inside the club, fifty-or-so head-turning, shoulder shrugging, patrons keep time with a Western heel-toe time step for sixteen measures as a crescendo of horns followed by a driving drum beat and a steady walking bass proclaims the start of *Last Night,* anthem for a popular line dance known as *Chill Factor*. On the seventeenth measure, hips, legs, feet, arms, hearts and lungs dance into action.

The mechanical energy of the music's acoustic pulses is transduced to electrochemical energy as the tiny cilial hairs in Angie's inner ear move to the music. A stream of electrochemical pulses speeds through her nervous system to the end of her motor neurons where excited nerves meet dancing muscles, separated by a gap of just 20 nanometers. When the electrical potential becomes high enough, sparks of the neurotransmitter, acetylcholine, jump from neuron to muscle causing the intertwined muscle fibrils, actin and myosin, to spring into action. Angie's muscles contract in concert with the beat of the music.

As Angie's arms, legs, hips and trunk move faster her cells need more food and oxygen to make energy. As though performing a metabolic line dance of their own, Angie's breathing, heart rate, and blood flow increase. Her blood brings food and oxygen to her cells, where low energy molecules of adenosine diphosphate (ADP) are upgraded to their high-energy counterpart, adenosine triphosphate (ATP) which are, in turn, burned as Angie dances. As they burn, they

once again become low-energy ADP to be recycled to form ATP in a repeating series of heat-producing, millisecond-long, oxidation-reduction reactions. All told, the processes of digesting, absorbing, transporting and converting the energy in the grilled chicken and black beans that Angie had for dinner into an evening of line dancing are only about 20 percent efficient, which means that of the 1,300-odd calories she will expend while dancing only about 300 will become motion; the other 1,000 will be spent as heat. So naturally, as she dances more, Angie's body begins to get warm. She starts to sweat.

On the back of her armband, a pair of galvanic skin response (GSR) sensors detects an increase in Angie's skin conductivity, the result of her perspiration. The GSR signal is processed in the armband's thumbnail-sized, 16 bit RISC microcontroller and stored in the 2 megabyte memory chip. Just a few millimeters away a heat sensor detects an increase in her skin temperature and sends an electronic signal to the armband's integrated circuit (IC). At the same time, a heat flux sensor compares the temperature on the surface of Angie's skin with that outside the armband case to derive the rate at which heat is flowing from her body. The armband's 3-axis accelerometer detects the direction, force and frequency of each of the 18,000-odd steps Angie takes while dancing.

The armband's main processor compiles 9 data points at a rate of 32 samples per second – 288 data points per second in all. Once a minute the processor analyzes and summarizes over 17,000 data points and sends them to the memory chip for subsequent analysis and reporting. Between 6:33PM, when Angie entered The Roundup, and 11:47PM, when she leaves, her BodyMedia FIT Armband has collected 5,425,920 data points with its sensors and processed them with its algorithm.

The BodyMedia algorithm predicts total energy expenditure (TEE) as the mathematical product of nine variables: six motion variables - orientation, movement and turning points in the X and Y axes and; three thermal variables - skin temperature (which indicates cellular and circulatory activity), galvanic skin response (which detects perspiration resultant of increased body heat) and heat-flux (which indicates the rate at which heat is radiated from the body).

The instrument's sensors are augmented by firmware meta-sensors that differentiate specific activities by assessing the sequence, force and frequency of Angie's body movements and comparing them with body heat and perspiration. Even though the BodyMedia system measures foot-falls the way commonly available pedometers and accelerometers do, its multiple

sensors and firmware meta-sensors can discern the difference between doing a time-step and dancing the *Chill Factor* by means of frequencies, forces, turns and heat output.

On her way home, Angie logs into the BodyMedia App on her smartphone again to upload her snacks and drinks for the evening. She inputs the light beer, chips and guacamole she had at a party after line dancing. The BodyMedia algorithm crunches her minute-by-minute numbers for the day – motion-by-motion, degree-by-degree, ohm- by-ohm, activity-by-activity, meal-by-meal, calorie-by-calorie. On her phone Angie sees that the party has put her over her goal for the day. She examines a bar chart showing her calories burned, calories consumed, calorie balance, physical activity, steps taken, sleep duration and sleep efficiency. (Sleep deprivation has been correlated with obesity in numerous studies.) She drills down to a graph of her calories burned by minute. It shows that during the evening she engaged in one hour, forty-four minutes of moderate activity and fifteen minutes of vigorous activity.

Set on achieving her weight loss objective, Angie has set her personal activity levels high at 5 to 7 METs (Metabolic Equivalent) for moderate activity, and more than 7 METs for vigorous activity. METs are the scientifically accepted standard measure of energy expenditure (EE). A MET is the amount of energy it takes for a person to sit in a chair and do nothing. Any activity can be rated in multiples of one MET. Sleeping consumes 0.9 METs. Jumping rope, 10.

In clinical settings METs are determined by one of two methods: the *double-labeled water* method and the *VO2* method. The double-labeled water method measures residual traces of isotopes in a dose of water containing non-radioactive isotopes of hydrogen and oxygen over a period of weeks. Since water is composed of hydrogen and oxygen atoms, two of the principal ingredients in cell respiration, the fraction of artificially introduced isotopes of each element remaining in urine after a period of time serves as an indicator of total cellular energy production. The VO2 method requires the subject to exercise vigorously while wearing a respiratory mask to derive energy expenditure from cardiovascular oxygen consumption.

Both double labeled water and VO2 require visits to professional clinics and administration by health care professionals. Angie's BodyMedia FIT Armband, on the other hand, gives her instantly actionable data about her energy expenditure while going about her daily routine, an activity known in the field of energy expenditure as *free-living*. Although the BodyMedia system is designed for use by ordinary individuals, it has been featured in more than one-hundred peer-

reviewed journals and validated in 19 clinical studies with an average accuracy of 90 percent compared to the industry gold-standards, double-labeled water and VO2 methods.

In addition to validation by academic and clinical studies, correlations between BodyMedia's sensed activity indicators and energy expenditure are corroborated by a database of hundreds of thousands users who have logged over 50 billion user-days to make the BodyMedia system the most precise, free-living energy expenditure monitoring system available. It is the only wearble device of its kind registered with the U.S. Food and Drug Administration as a Class II medical device.

Angie missed her goal the following week, but a week later, after a night of line dancing she weighed 128 pounds … a 100 pound weight loss in just over 16 months.

About BodyMedia, Inc.

When your body talks, BodyMedia listens. BodyMedia has been unlocking and deciphering secrets of the body since 1999. Headquartered in Pittsburgh, PA, BodyMedia is the pioneer in developing wearable body monitoring systems designed to help people lose weight, improve performance, and lead healthier lives. Our patented multi-sensor technology provides continuous body-monitoring that tracks physical activity levels, calories expended and sleep patterns. What sets BodyMedia technology apart is our validated accuracy, our clinically proven outcomes and our FDA status as a Class II medical device. For more information, visit www.bodymedia.com.

For the following materials:

- Full-color, high resolution, cutaway illustration of the BodyMedia FIT Armband detailing pertinent electronic components
- Before and after photos of Angie Wallace
- Interviews with Angie Wallace, BodyMedia CEO, Christine Robins, or BodyMedia co-founder and Chief Technical Officer, Ivo Stivoric

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