

# A review of accelerometry-based wearable motion detectors for physical activity monitoring

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# Outline

- **Introduction**
- **Design fundamentals for accelerometry-based wearable motion detectors**
- **Capabilities of wearable systems using accelerometry measurement**
- **Current products overview**
- **Conclusion**



*Keywords:*

Motion detector, accelerometry, accelerometer, physical activity (PA), energy expenditure (EE), fall detection, gait

# Introduction

- ✓ **Physical activity (PA):** any bodily movement produced by skeletal muscles which results in energy expenditure

## Pathological status

- an independent risk factor for chronic and several common noncommunicable diseases (NCDs)

## Energy expenditure (EE)

- a key determinant of energy balance and weight control

## Physical impairment (Mobility)

- a determinant of motor control, strength, balance, which are factors contributing to fall risk

## Ageing process

- is related to functional status and quality of live for older adults



[World Health Organization (WHO), 2010]

# How to Measure/Evaluate Physical Activity?

- ✓ **Subjective methods:** Diaries, questionnaires, surveys, scales based on observation (e.g., the Berg Balance Scale)
  - ➔ Largely rely on individual observation and subjective interpretation
- ✓ **Objective methods:** by means of a range of sensors and tools using metrological technologies
  - ➔ Sensor-based, or technology-enabled measurement makes long-term, continuous, automatic, and quantitative PA monitoring and evaluation possible, even in a free-living environment
  - ➔ Attempts have been demonstrated based on video recording, optical, acoustical and magnetic measurements using ambient (spatial) sensing techniques



e.g., the VICON System

# Why Wearable Sensors ?

- ✓ The major drawbacks of ambient sensing systems:
  - ➔ Expensive, complex instrument setting, use in limited range and closed environment , privacy issue (video recording)
- ✓ *Wearable, or body-fix sensors*
  - ➔ Small, easy to wear/carry, unobtrusive
  - ➔ Available technologies greatly advance the performance of wearable systems:
    - Accurate sensors
    - Reduced size and overall layout
    - Enhanced computation capability
    - Wireless telecom.
    - Low power component/circuitry

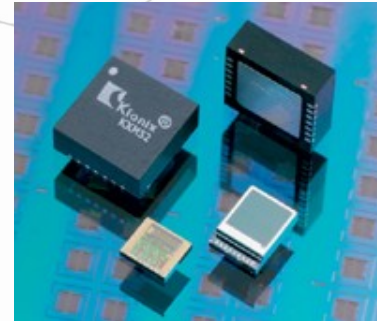


# Why Accelerometry-based Wearable Systems ?

- ✓ **Accelerometry:** The quantitative determination of acceleration in the entire human body or a part of the body in the performance of a task.
- ✓ **Accelerometers** are sensors capable of detecting acceleration and orientation (tilt) of objects in either motion or in static state



- **Bulk housing**
- **High g/impact**

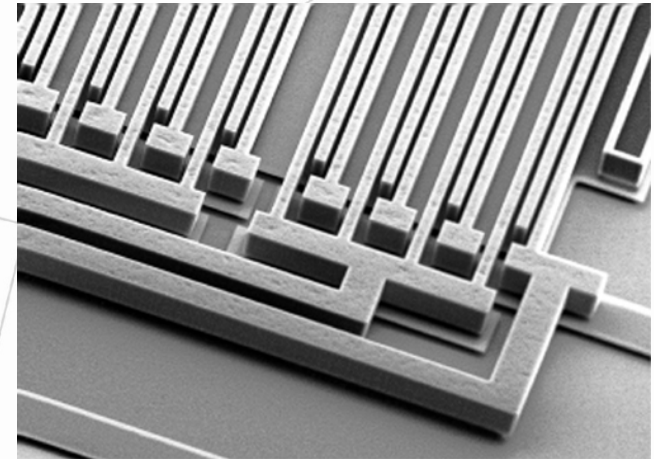
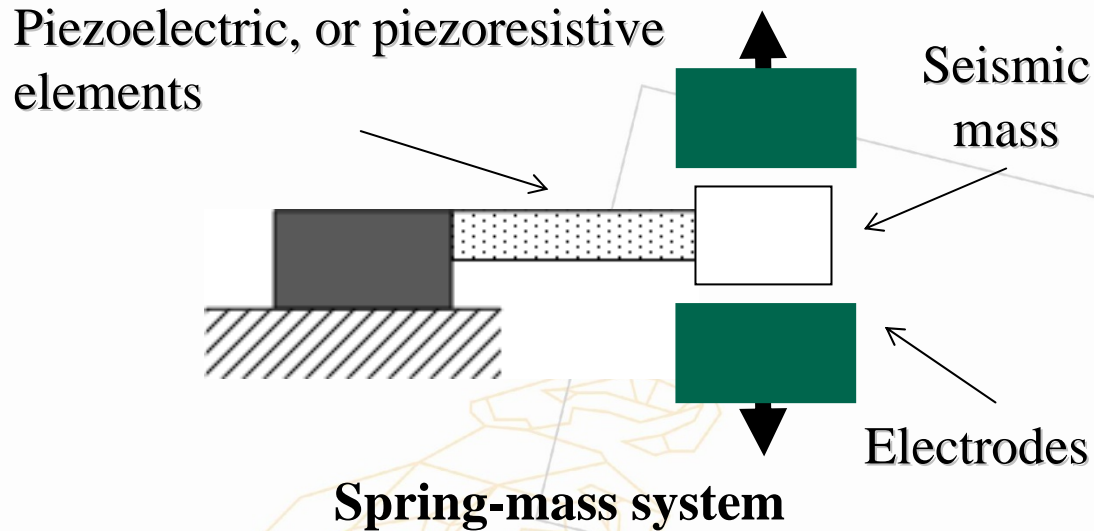


- **Miniature form factor**
- **High precision**
- **Low power consumption**

Accelerometric data provides sufficient information of human motion characteristics: acceleration, velocity, position, orientation (tilt), frequency, duration and intensity

# Design Fundamentals (1)

- ✓ *Piezoresistive, piezoelectric, capacitive* accelerometers



Accelerometer manufactured by MEMS technology

- ✓ Piezoelectric accelerometers do not respond to constant acceleration
- ✓ Capacitive accelerometers having superior performance in low power consumption and high precision, have widely been used in many consumer electronics.



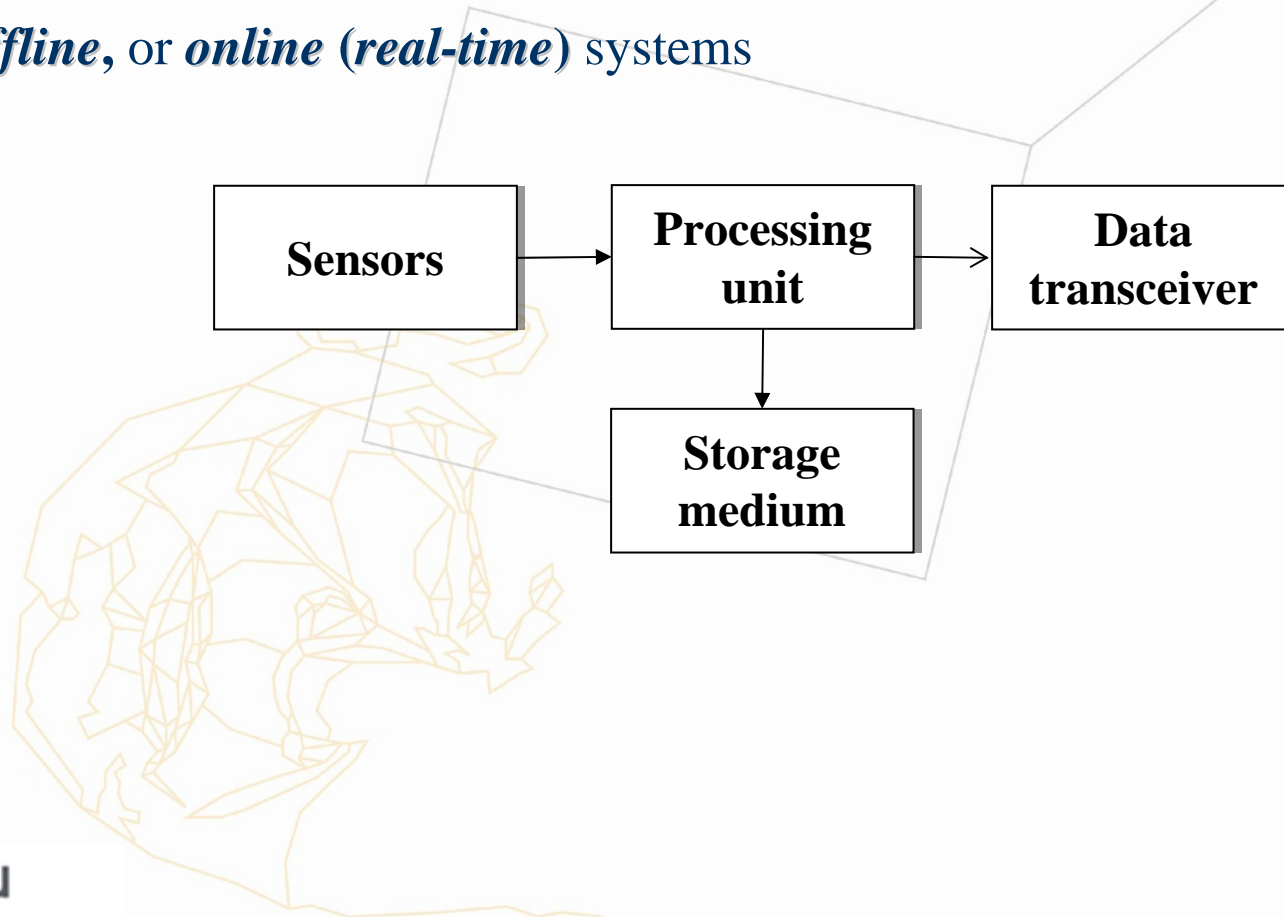
# Design Fundamentals (2)

- ✓ Four basic elements constructing a wearable system:

*Sensors, processing unit, storage medium, and data transceiver*

- ✓ *Data logging, data forwarding, and data processing* systems

- ✓ *Offline, or online (real-time)* systems

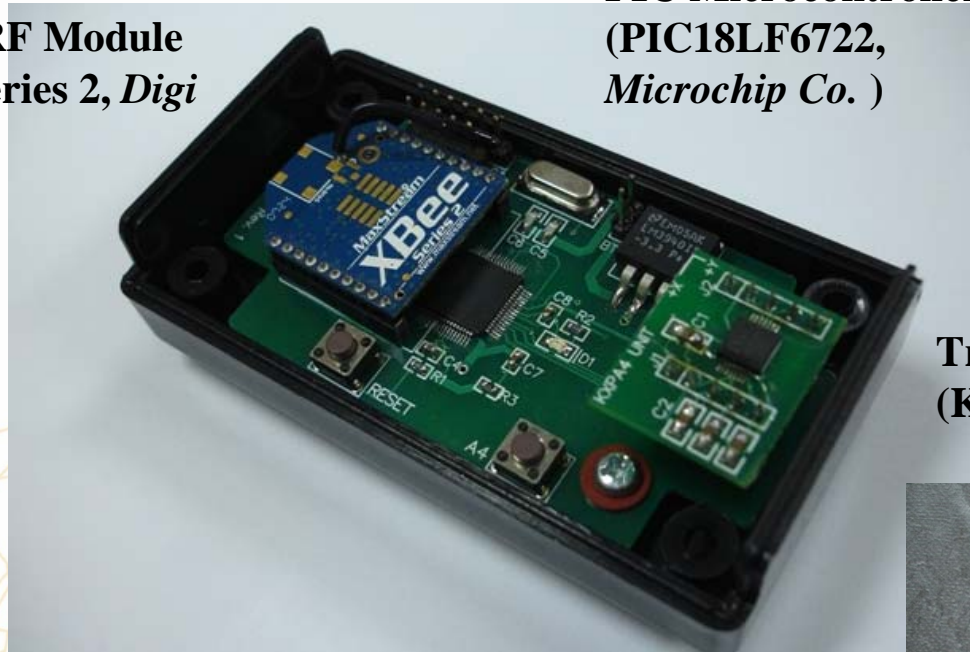


# Design Fundamentals (2)

- ✓ Example of a data forwarding system

**ZigBee RF Module**  
(XBee Series 2, *Digi Int'l*)

**PIC Microcontroller**  
(PIC18LF6722, *Microchip Co.*)



**Triaxial Accelerometer**  
(KXPA4, *Kionix*)



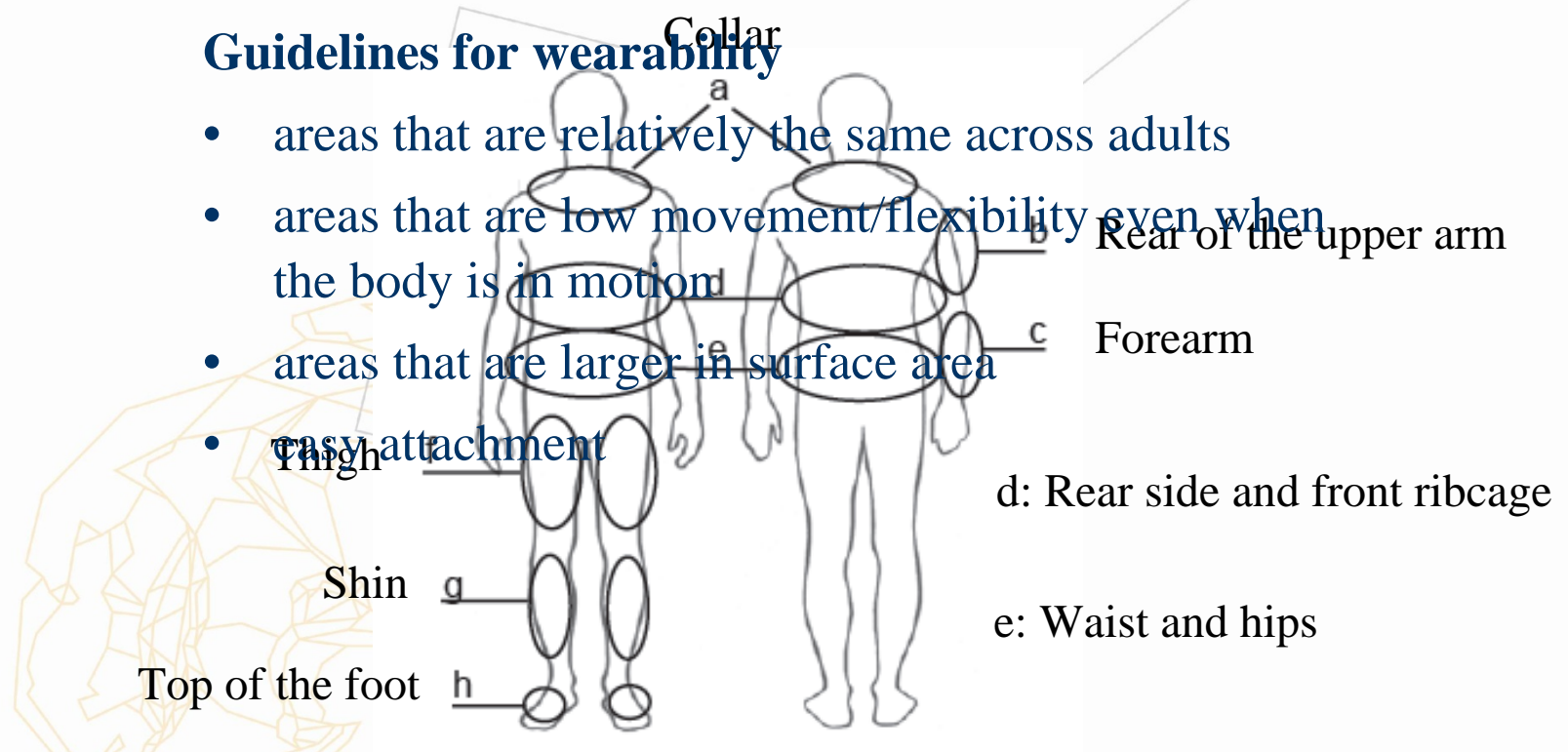
**Wearable Activity Detector developed by GRC**

# Design Fundamentals (3)

- ✓ **Wearability** — Wearability map generalizes the proper locations of a human body for unobtrusive sensor placement

## Guidelines for wearability

- areas that are relatively the same across adults
- areas that are low movement/flexibility even when the body is in motion
- areas that are larger in surface area
- easy attachment



# Capabilities of Wearable Activity Monitors (1)

## ✓ *Posture and movement classification*

- Static postures: upright, lying
- Dynamic activities: postural transitions (sit-stand, sit-lie), turning, bed movement, walking (level, stairs up/down)
- For the purpose of understanding the behavior pattern of daily activities

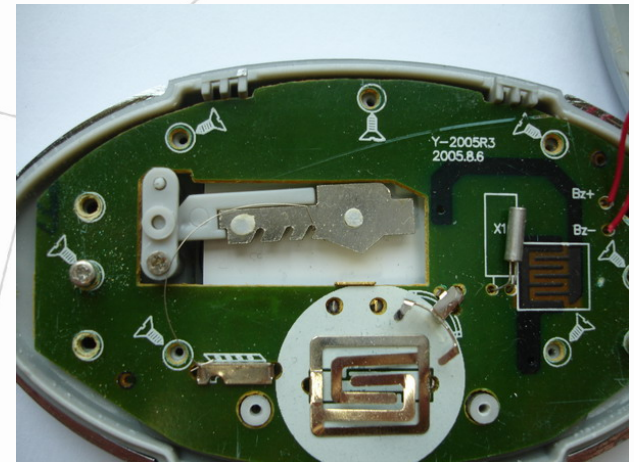
## ✓ *Fall detection*

- The first trial of fall detector design was published in 1998 [Williams et al., 1998]
- Falls can be identified by utilizing dual-state detection scheme:  
(1) Impact, and (2) post-impact lying posture and inactivity
- An essential application for personal emergency response system (PERS)

# Capabilities of Wearable Activity Monitors (2)

## ✓ *Estimation of energy expenditure*

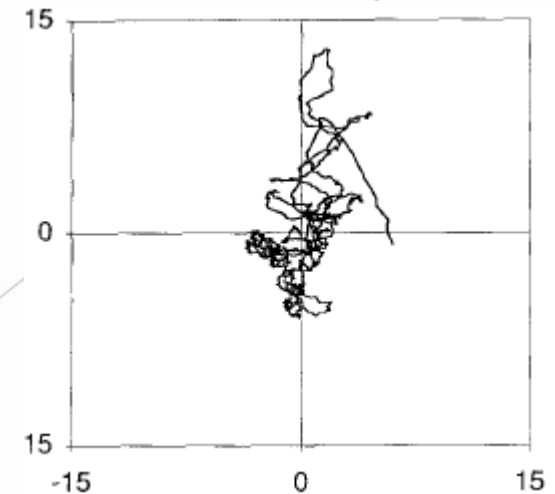
- Gold standard method: *Doubly-labeled water (DLW)* method
- Simple measure: Mechanical *pedometer*
  - ➔ Mechanical pedometers (step counters) cannot reflect intensity of physical activities, a major accuracy problem
- The integral of acceleration (signal ,magnitude area, SMA) data has been found to be linearly correlated to EE due to activities
- The most common application provided by wearable activity monitors for diet modification, weight control.



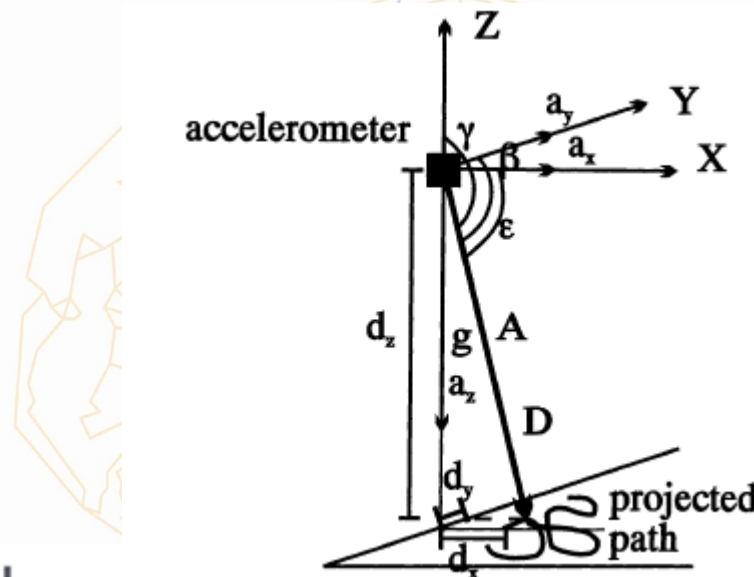
# Capabilities of Wearable Activity Monitors (3)

## ✓ *Postural stability evaluation*

- Center of pressure (COP) trajectory pattern can be measured by a foot force plate.
- COP trajectory can be calculated from the output of a triaxial accelerometer worn around the trunk [Mayagoitia et al., 2002]



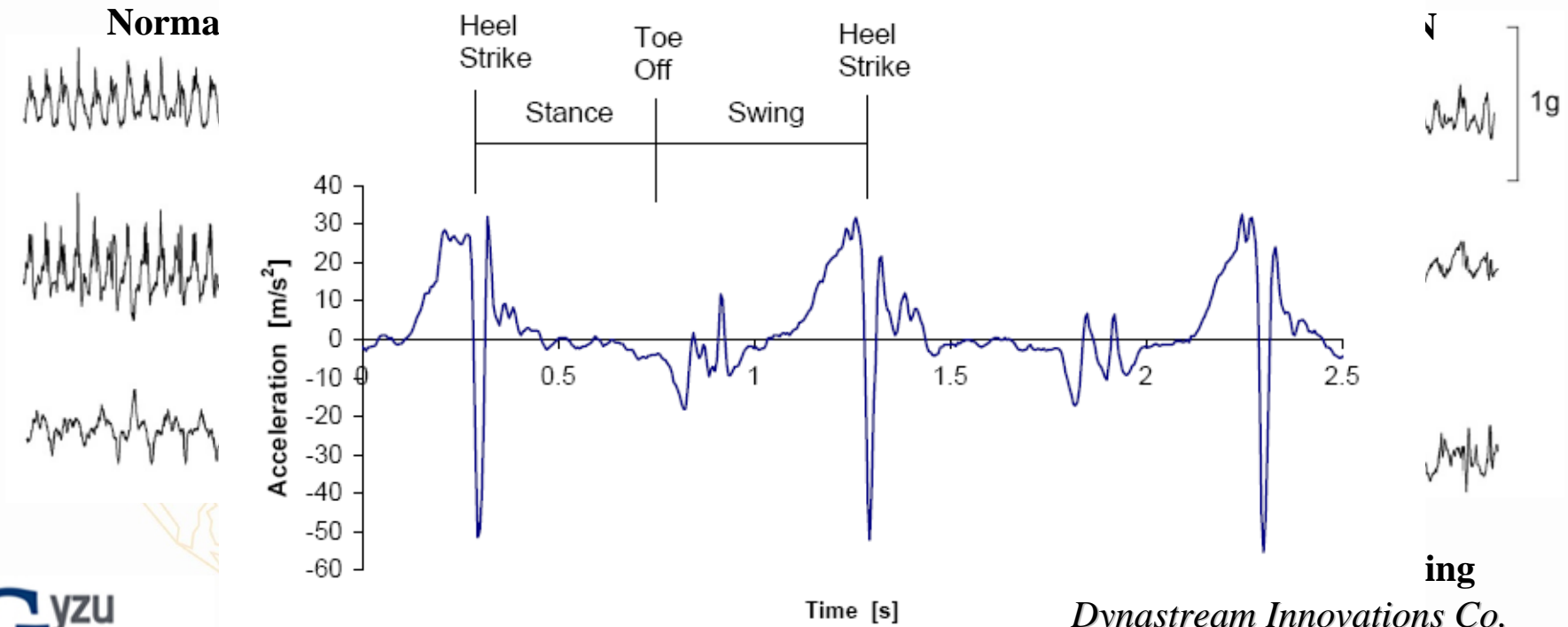
[Collins, et al., 1992]



# Capabilities of Wearable Activity Monitors (4)

## ✓ *Gait pattern analysis*

- Gait pattern features are indicative of mobility and balance stability → fall risk
- *Spatio-temporal parameters* of gait, such as lower limb velocity, heel strike, heel/toe off can be measured by accelerometry.



# Current Products

- Use biaxial or triaxial accelerometers and microprocessors
- Price range from USD199-1599
- Offer similar and comparable function regarding activity monitoring:
  - Calorie burn (EE estimation)
  - Activity/inactivity
  - Step count
  - Travelled distance
  - Sleep duration
- Various activity sensors have been compared in a number of research and study
- Some sensors are exclusively for fall detection, as a PERS application



## ✓ AMP 331 Activity Monitor

- Dynastrem Innovations, a fully owned subsidiary of Garmin (台灣國際航電) has expertise in inertial and wireless sensor/communication devices
- Core technology: SpeedMax Platform

### AMP Link

- Dynastrem's Picotank (ANT) RF protocol, 916MHz
- USB 1.1 to PC



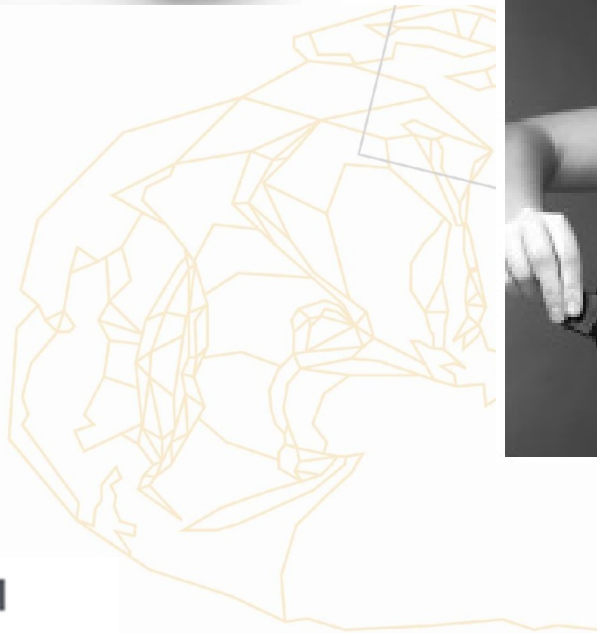
### AMP Ware

- Data analysis and management

### AMP 331

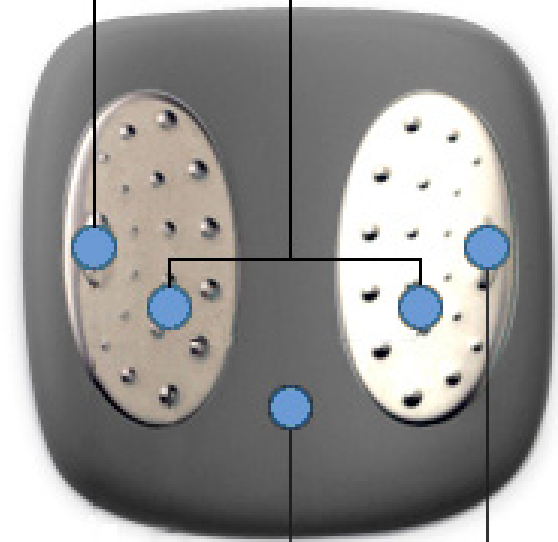
- “Foot Pod” design
- 2-axis accelerometers, DSP unit and wireless

## ✓ GoWare Fit Armband (BodyMedia Inc.)



**Skin Temperature**  
measures the surface  
temperature of the body

**Galvanic Skin Response**  
measures skin impedance  
which reflects water content  
of the skin and the con-  
striction or dilation of the  
vascular periphery



**3-axis Accelerometer**  
measures motion

**Heat Flux**  
measures the rate at  
which heat is dissipating  
from the body

✓ **CT1 & RT3** (StayHealthy Inc.)

- CT1 is a FDA cleared CLASS II medical device for accurate EE estimation
- RT3 (previously known as Tritrac-R3D) has widely been used in research use



✓ **GT3X & GT1M ActiGraph**  
(ActiGraph)



✓ **Fall Detector**  
(Tunstall)



✓ **StepWatch** (OrthoCare  
Innovations)



✓ **iLife Fall Detection Sensor**  
(AlertOne)



# Conclusion

- Sensor-based, objective measurement can provide continuous, automatic, and quantitative assessment of physical activity in long-term monitoring basis.
- Wearable accelerometry-based sensors are low cost, and can offer several capabilities regarding physical activity monitoring, as well as fall detection in a free-living environment.
- Most consumer products are data-logging systems, and the single-device seems the preferred approach
- Calorie calculation is the major application
- There is few product offering complete package of connecting to telecare/telehealth services
- Activity monitoring in conjunction with versatile sensing techniques may widen the scope and applicability in the study of human movement



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**Thank you for your listening**

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