University of Verona,

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Laurea magistrale in Scienze motorie preventive ed adattate

(Laurea magistrale in Scienze dello sport individuali e squadra,

Laurea magistrale in Scienze dello sport e montagna)

Metodologia delle misure delle attività sportive

Wednesday 23/10/2019 14÷15:30

Luca P. Ardigò Ph.D.

A class within an eight-class module

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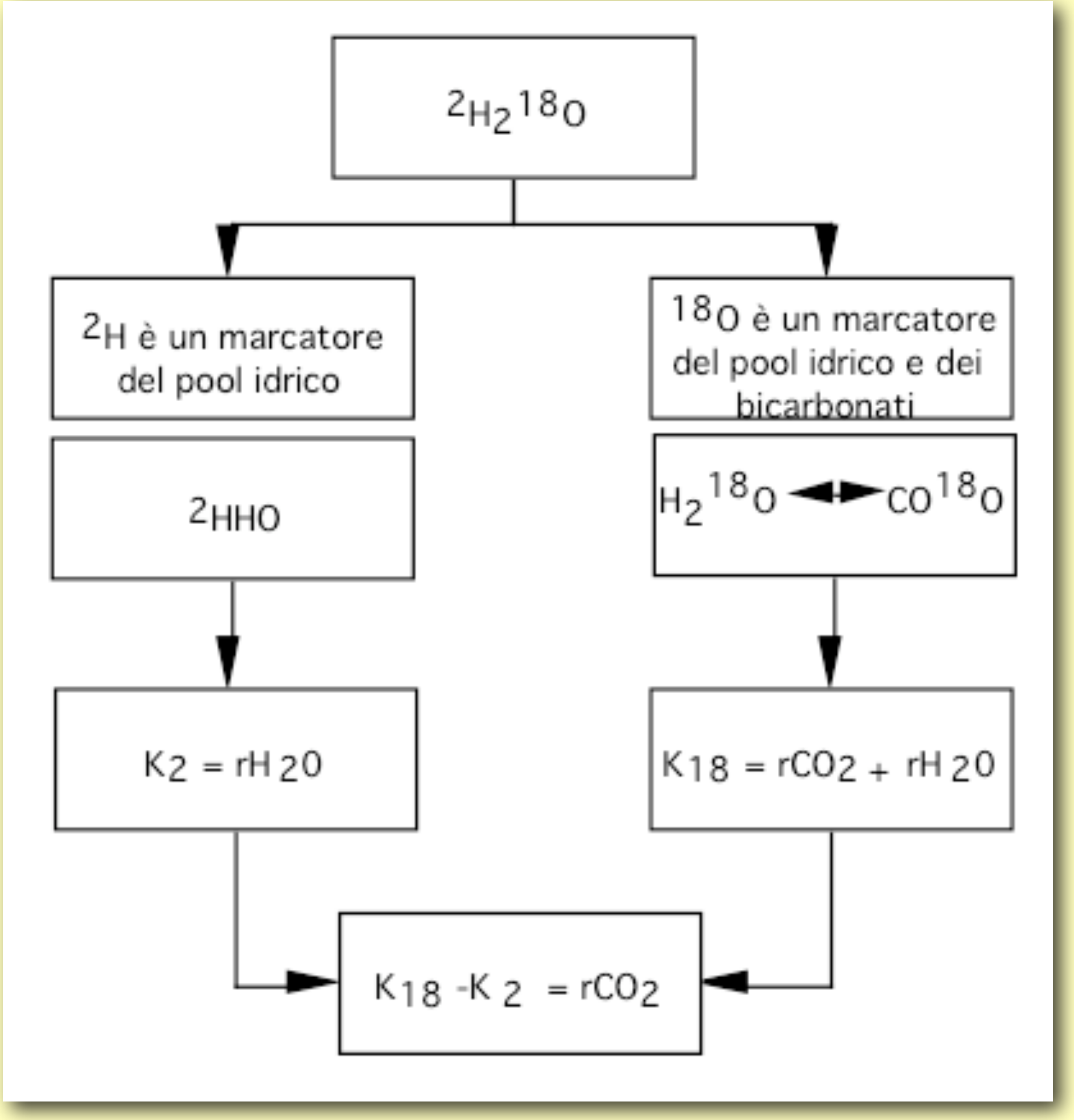
DLW method

- Lifson et al., 1955;
- (small animals) 1975;
- validation by Scholler et al., 1982;
- (premature infants, children, pregnant and lactating women, elderly, obese people, hospitalized patients);
- subject is administered a dose of stable isotope $^{2}H_{2}{}^{18}O$, which (^{2}H, ^{18}O) equilibrates relatively quickly with body water (H, O);
- ^{2}H is eliminated as $^{2}H_{2}O$ (breath, urine, sweat, perspiratio insensibilis), while the ^{18}O is eliminated either as $H_{2}{}^{18}O$ (breath, ...) and as $C^{18}O_{2}$ (breathe only);
- difference between the two rates of elimination -> V'CO2 -> ME

DLW method


$^2H_2{}^{18}O$
^2H è un marcatore del pool idrico
^{18}O è un marcatore del pool idrico e dei bicarbonati
^2HHO
$H_2{}^{18}O \leftrightarrow CO^{18}O$
$K_2 = rH_2O$
$K_{18} = rCO_2 + rH_2O$
$K_{18} - K_2 = rCO_2$

DLW method

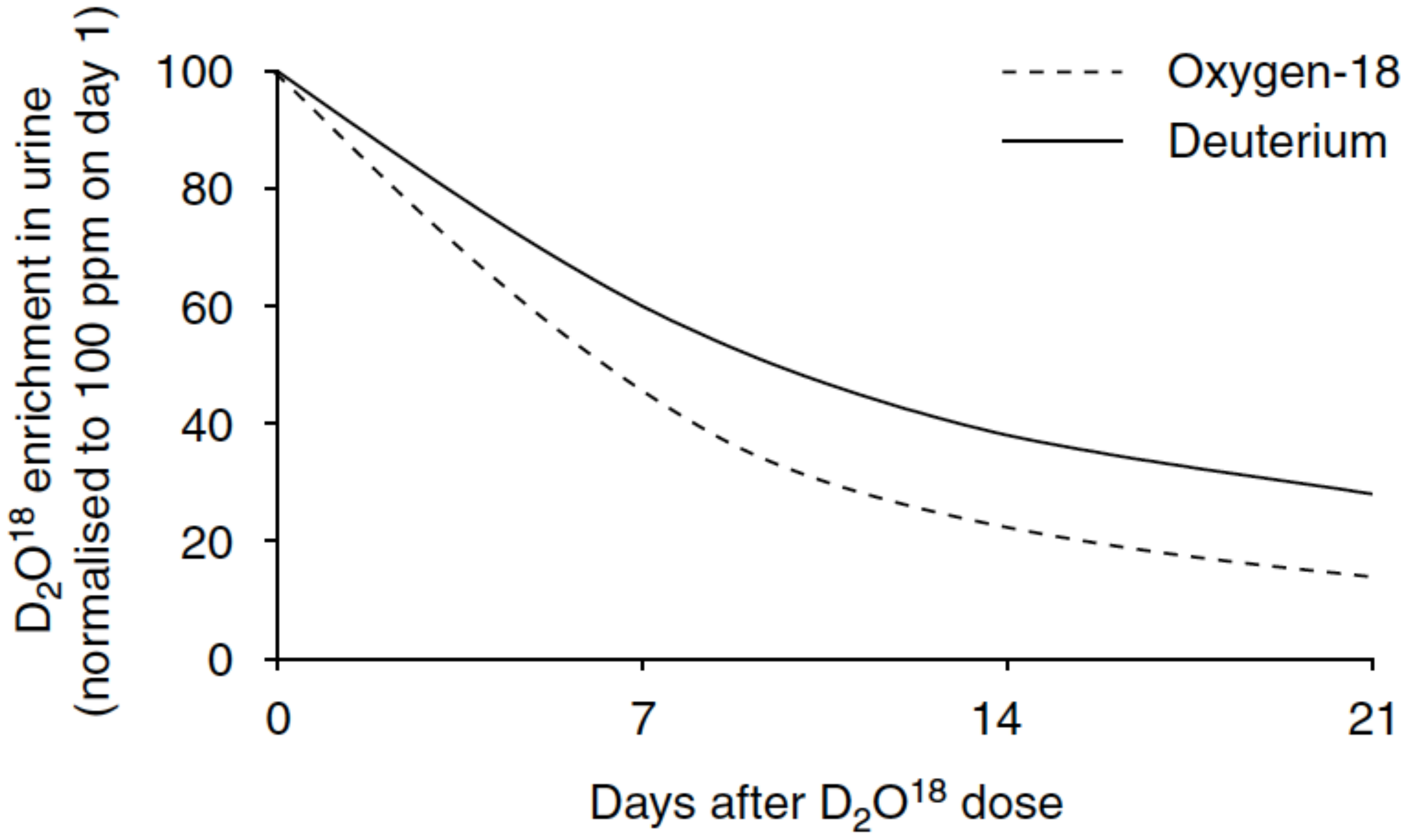


Fig. 1. Decline of ^2H (deuterium [D]) and ^{18}O in body fluids (urine, plasma or saliva) during a hypothetical doubly labelled water experiment.

DLW method

- RQ (= V'CO2 / V'O2) estimate -> accuracy:
  . standard Western diet -> RQ estimate;
  . food intake diary -> RQ estimate (i.e., food quotient ≈ RQ);
  . indirect calorimetry -> RQ

$$FQ = 1.0 \times CA + 0.7 \times F + 0.79 \times P + 0.66 \times A \qquad (7)$$

where CA is the percent of energy in the diet consisting of carbohydrates, F is the percent that is fat, P is the percent protein, and A is the percent alcohol. Data on human macronutrient intake for the USA, based

DLW method

DLW method issues

- inability to discriminate the contribution of individual PAs (types, amount, intensity of each type) to ME;
- costs: isotopes and tools to detect them (i.e., mass spectrophotometers) still have considerable costs;
- -> only 3-4 ÷ 21 d ME;
- unknown RQ -> 5% e

DLW method

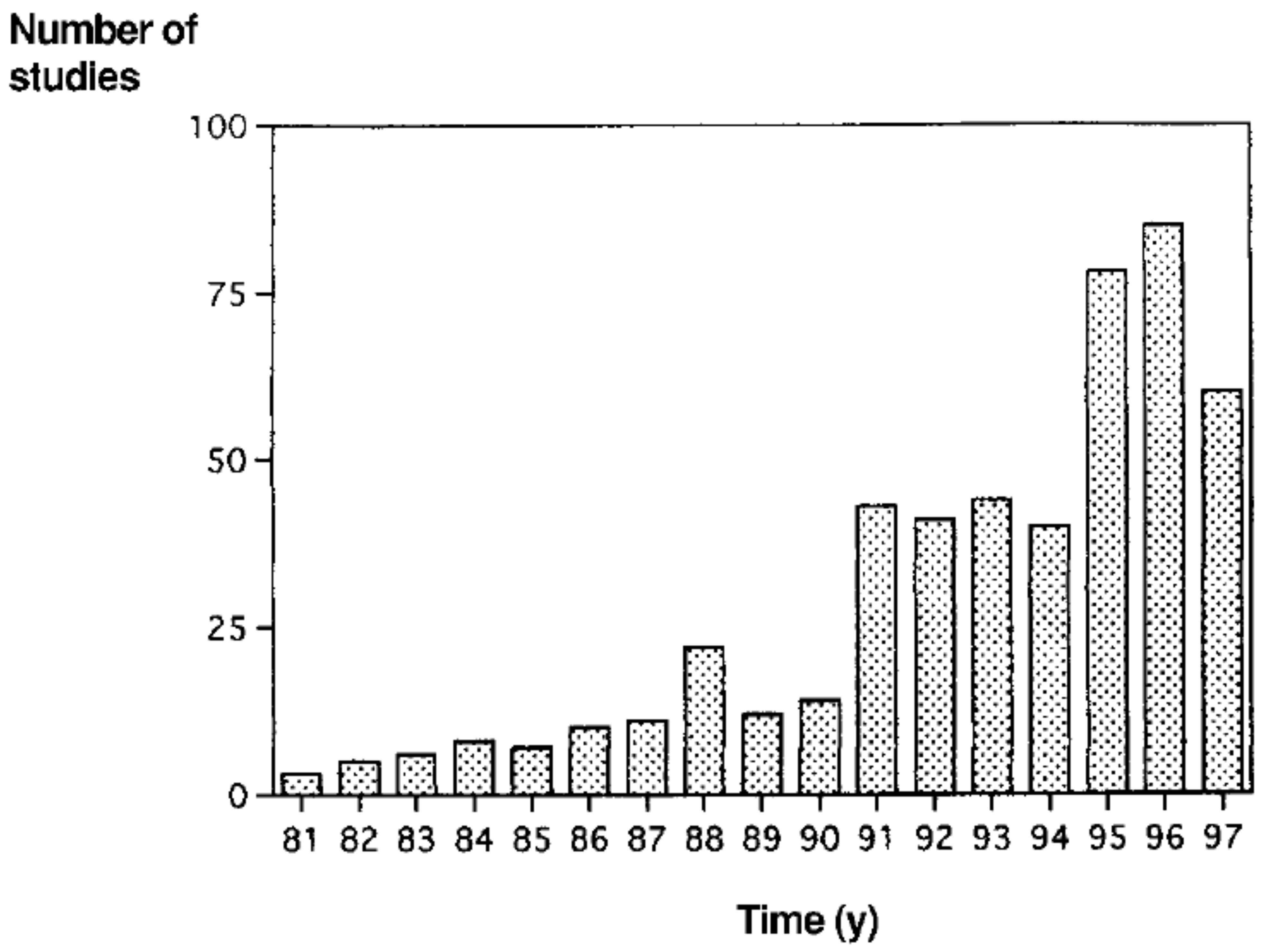
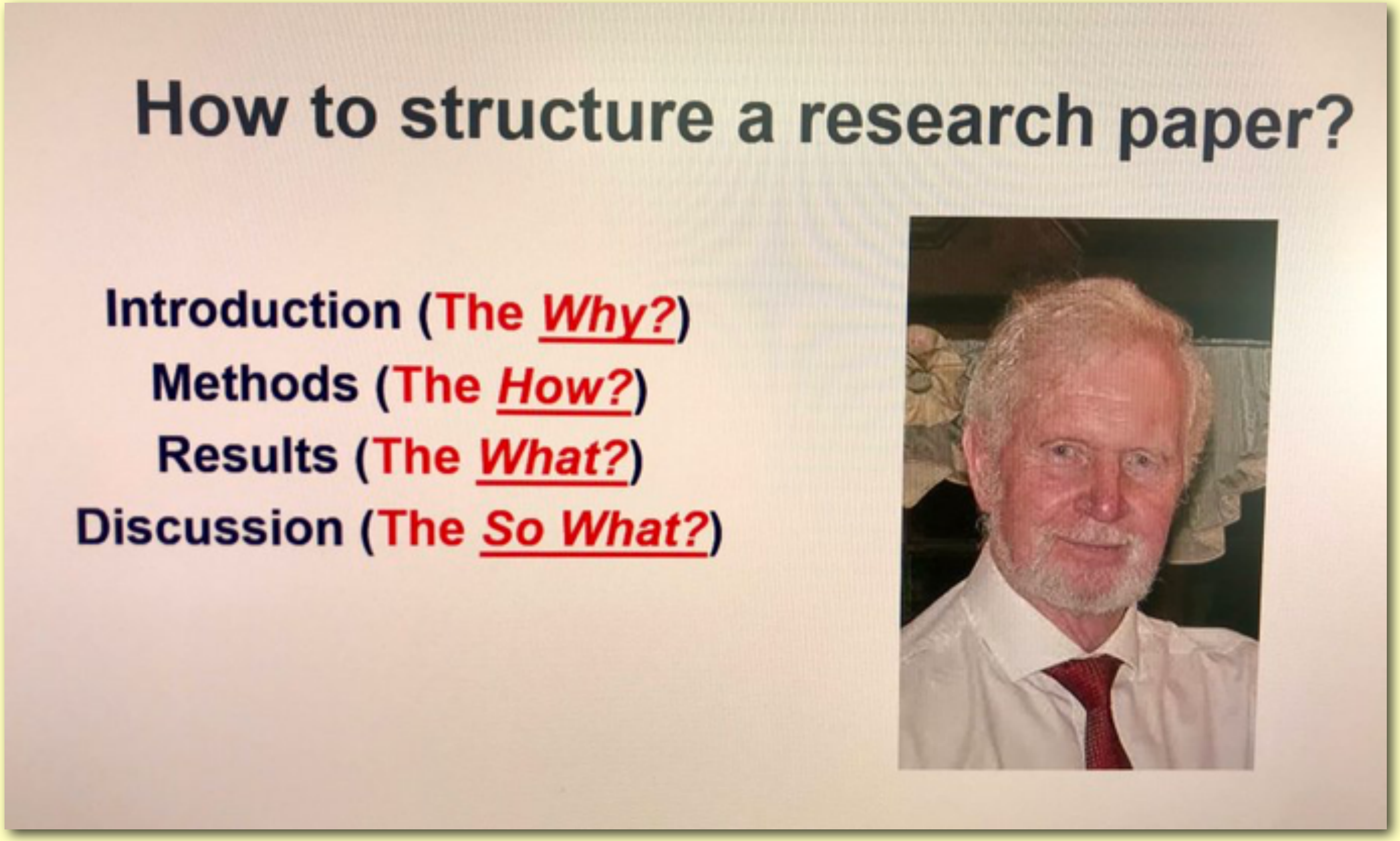


FIGURE 1. Number of studies in peer-reviewed journals (excluding abstracts) that used the doubly labeled water technique in the years 1981–1997 (through June) from the *Science Citation Index* (Institute for Scientific Information, University of Aukland, New Zealand). Since the first study in humans in 1982 the use of the technique has continued to grow.

Prof. Brian James Whipp, 1937–2011



Accelerometer & PAR vs. DLW

2018 study example 1

European Journal of Applied Physiology
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ORIGINAL ARTICLE

CrossMark

Validity of a triaxial accelerometer and simplified physical activity record in older adults aged 64–96 years: a doubly labeled water study

Yosuke Yamada[1] · Yukako Hashii-Arishima[2,3] · Keiichi Yokoyama[4] · Aya Itoi[1,5] · Tetsuji Adachi[6] · Misaka Kimura[7,8]

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Abstract

Background The aim was to examine the validity of a triaxial accelerometer (ACCTRI) and a simplified physical activity record (sPAR) in estimating total energy expenditure (TEE) and physical activity level (PAL) in older adults with the doubly labeled water (DLW) method.

Methods A total of 44 Japanese elderly individuals (64–96 years), of which 28 were community-dwelling healthy adults with or without sporting habits (S or NS group) and 16 were care home residents with frailty (F group), were included in the study. Basal metabolic rate (BMR) was measured by indirect calorimetry, TEE was obtained by the DLW method, and PAL was calculated as TEE/BMR. Daily step count was monitored by a pedometer (Lifecorder). The 24-h average metabolic

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Accelerometer & PAR vs. DLW

2018 study example 1

Table 1 Physical characteristics, body composition, energy expenditure, and physical activity of the subjects ($n = 44$)

	Community-dwelling older adults with sporting habits $n = 9$ (M6/W3)	Community-dwelling older adults without sporting habits $n = 19$ (M6/W13)	Care home residents with frailty $n = 16$ (M8/W8)
Age (years)	71 ± 5	74 ± 7	84 ± 8
Height (cm)	162.8 ± 7.7	150.8 ± 6.9	150.9 ± 9.5
Weight (kg)	55.9 ± 10.1	51.3 ± 8.0	50.6 ± 9.5
BMI	21.0 ± 2.1	22.4 ± 2.5	22.4 ± 4.6
Percent fat (%)	26.7 ± 7.0	33.8 ± 5.7	27.9 ± 11.1
TBW (kg)	29.8 ± 4.9	24.8 ± 4.5	26.4 ± 4.3
FFM (kg)	40.8 ± 6.7	33.9 ± 6.2	36.0 ± 5.9
FM (kg)	15.2 ± 5.6	17.4 ± 4.0	14.6 ± 7.5
mBMR (kcal d^{-1})	1210 ± 154	1084 ± 169	1046 ± 192
eBMR (kcal d^{-1})	1188 ± 135	1067 ± 137	1036 ± 103
TEE_{DLW} (kcal d^{-1})	2556 ± 372	2044 ± 377	1608 ± 354
AEE_{DLW} (kcal d^{-1})	1091 ± 263	756 ± 258	401 ± 226
AEE_{DLW}/Wt (kcal kg^{-1} d^{-1})	19.7 ± 4.1	15.1 ± 6.3	8.2 ± 5.1
PAL_{DLW}	2.12 ± 0.23	1.90 ± 0.29	1.54 ± 0.24
24-h average METs of ACCTRI	1.80 ± 0.17	1.66 ± 0.14	1.27 ± 0.10
TEE of ACCTRI without DIT (kcal d^{-1})	2128 ± 258	1771 ± 251	1317 ± 377
$(TEE_{DLW} - TEE_{ACCTRI})/TEE_{DLW} \times 100$ (%)	− 16.2 ± 8.8	− 12.2 ± 10.5	− 15.6 ± 14.3
TEE of ACCTRI with DIT (kcal d^{-1})	2364 ± 287	1968 ± 279	1463 ± 173
PAL of ACCTRI corrected with DIT	2.00 ± 0.19	1.85 ± 0.15	1.41 ± 0.11
TEE of sPAR without DIT (kcal d^{-1})	2153 ± 359	1729 ± 319	1347 ± 185
$(TEE_{DLW} - TEE_{sPAR})/TEE_{DL} \times 100$ (%)	− 15.6 ± 8.2	− 14.6 ± 11.3	− 16.1 ± 16.4
TEE of sPAR with DIT (kcal d^{-1})	2393 ± 399	1921 ± 354	1497 ± 205
PAL of sPAR corrected with DIT	2.01 ± 0.21	1.80 ± 0.20	1.44 ± 0.09
Step count (d^{-1})	9568 ± 4496	8334 ± 3591	2130 ± 2075
Nd/No	1.037 ± 0.011	1.034 ± 0.012	1.038 ± 0.010

BMI body mass index, *TBW* total body water, *FFM* fat-free mass, *FM* fat mass, *BMR* measured basal metabolic rate, *eBMR* estimated BMR by the fifth Japanese recommended dietary allowance equation, *TEE* total energy expenditure, *AEE* activity energy expenditure, *AEE/Wt* AEE divided by weight, *PAL* physical activity level, *ACCTRI* triaxial accelerometer, *DIT* diet-induced thermogenesis, *sPAR* simplified physical activity record, *Nd/No* stable isotope dilution space ratio of ^{2}H and ^{18}O

Accelerometer & PAR vs. DLW

2018 study example 1

Table 2 Physical characteristics, body composition, energy expenditure, and physical activity of men ($n=20$) and women ($n=24$)

	Men ($n=20$)			Women ($n=24$)		
	Community-dwelling older adults with sporting habits	Community-dwelling older adults without sporting habits	Care home residents with frailty	Community-dwelling older adults with sporting habits	Community-dwelling older adults without sporting habits	Care home residents with frailty
	$n=6$	$n=6$	$n=8$	$n=3$	$n=13$	$n=8$
Age (years)	73 ± 5	73 ± 9	82 ± 8	69 ± 4	75 ± 6	87 ± 7
Height (cm)	165.7 ± 7.3	157.2 ± 7.4	158.8 ± 4.9	157.0 ± 5.6	147.9 ± 4.4	143.0 ± 5.0
Weight (kg)	60.3 ± 9.8	58.4 ± 5.7	49.7 ± 9.2	47.2 ± 1.2	48.0 ± 6.8	51.5 ± 10.3
BMI	21.8 ± 2.0	23.6 ± 1.3	19.7 ± 3.4	19.2 ± 1.0	21.9 ± 2.8	25.1 ± 4.2
Percent fat (%)	27.2 ± 6.3	29.0 ± 2.3	20.4 ± 9.1	25.8 ± 9.7	36.0 ± 5.4	35.3 ± 7.4
TBW (kg)	31.9 ± 4.0	30.4 ± 3.6	28.6 ± 3.3	25.7 ± 4.1	22.3 ± 1.7	24.2 ± 4.2
FFM (kg)	43.6 ± 5.5	41.5 ± 4.9	39.0 ± 4.6	35.1 ± 5.5	30.4 ± 2.3	33.0 ± 5.7
FM (kg)	16.7 ± 5.8	16.9 ± 1.4	10.7 ± 6.3	12.1 ± 4.3	17.6 ± 4.8	18.5 ± 6.8
mBMR (kcal d^{-1})	1269 ± 145	1242 ± 167	1117 ± 144	1090 ± 103	1011 ± 114	975 ± 217
eBMR (kcal d^{-1})	1255 ± 112	1205 ± 124	1082 ± 90	1054 ± 36	1003 ± 88	990 ± 99
TEE_{DLW} (kcal d^{-1})	2704 ± 353	2308 ± 442	1795 ± 338	2260 ± 208	1922 ± 285	1421 ± 274
AEE_{DLW} (kcal d^{-1})	1165 ± 295	835 ± 281	498 ± 259	944 ± 97	719 ± 250	303 ± 144
AEE_{DLW}/Wt (kcal kg^{-1} d^{-1})	19.6 ± 5.1	14.2 ± 4.6	10.5 ± 6.0	20.0 ± 1.6	15.6 ± 7.0	5.8 ± 2.7
PAL_{DLW}	2.14 ± 0.29	1.85 ± 0.23	1.61 ± 0.26	2.07 ± 0.07	1.92 ± 0.32	1.47 ± 0.21
24-h average METs of ACCTRI	1.76 ± 0.19	1.59 ± 0.14	1.26 ± 0.10	1.87 ± 0.10	1.70 ± 0.12	1.29 ± 0.11
TEE of ACCTRI without DIT (kcal d^{-1})	2209 ± 286	1924 ± 323	1357 ± 132	1966 ± 57	1700 ± 184	1277 ± 176
$(TEE_{DLW} - TEE_{ACCTRI})/TEE_{DLW} \times 100$ (%)	− 17.9 ± 9.9	− 16.2 ± 5.2	− 22.5 ± 13.4	− 12.6 ± 6.2	− 10.3 ± 11.9	− 8.8 ± 12.4
TEE of ACCTRI with DIT (kcal d^{-1})	2454 ± 318	2138 ± 358	1508 ± 147	2185 ± 63	1889 ± 204	1418 ± 195
PAL of ACCTRI corrected with DIT	1.96 ± 0.21	1.76 ± 0.15	1.39 ± 0.11	2.07 ± 0.11	1.88 ± 0.14	1.43 ± 0.11
TEE of sPAR without DIT (kcal d^{-1})	2245 ± 388	1959 ± 448	1414 ± 180	1971 ± 250	1622 ± 173	1281 ± 176
$(TEE_{DLW} - TEE_{sPAR})/TEE_{DLW} \times 100$ (%)	− 16.9 ± 9.5	− 15.3 ± 9.6	− 24.4 ± 17.9	− 12.9 ± 5.4	− 14.4 ± 12.3	− 9.1 ± 12.2
TEE of sPAR with DIT (kcal d^{-1})	2494 ± 431	2177 ± 498	1571 ± 200	2409 ± 306	1983 ± 212	1565 ± 216
PAL of sPAR corrected with DIT	1.98 ± 0.22	1.79 ± 0.31	1.44 ± 0.09	20.7 ± 0.11	1.80 ± 0.13	1.44 ± 0.09
Step count (d^{-1})	9034 ± 5022	7925 ± 4625	3028 ± 2398	10637 ± 3903	8523 ± 3211	1231 ± 1276
Nd/no	1.035 ± 0.012	1.033 ± 0.011	1.038 ± 0.009	1.041 ± 0.009	1.034 ± 0.012	1.037 ± 0.011

BMI body mass index, *TBW* total body water, *FFM* fat-free mass, *FM* fat mass, *mBMR* measured basal metabolic rate, *eBMR* estimated BMR by the fifth Japanese recommended dietary allowance equation, *TEE* total energy expenditure, *AEE* activity energy expenditure, *AEE/Wt* AEE divided by weight, *PAL* physical activity level, *ACCTRI* triaxial accelerometer, *DIT* diet-induced thermogenesis, *sPAR* simplified physical activity record, *Nd/No* stable isotope dilution space ratio of ^{2}H and ^{18}O

Accelerometer & PAR vs. DLW

2018 study example 1

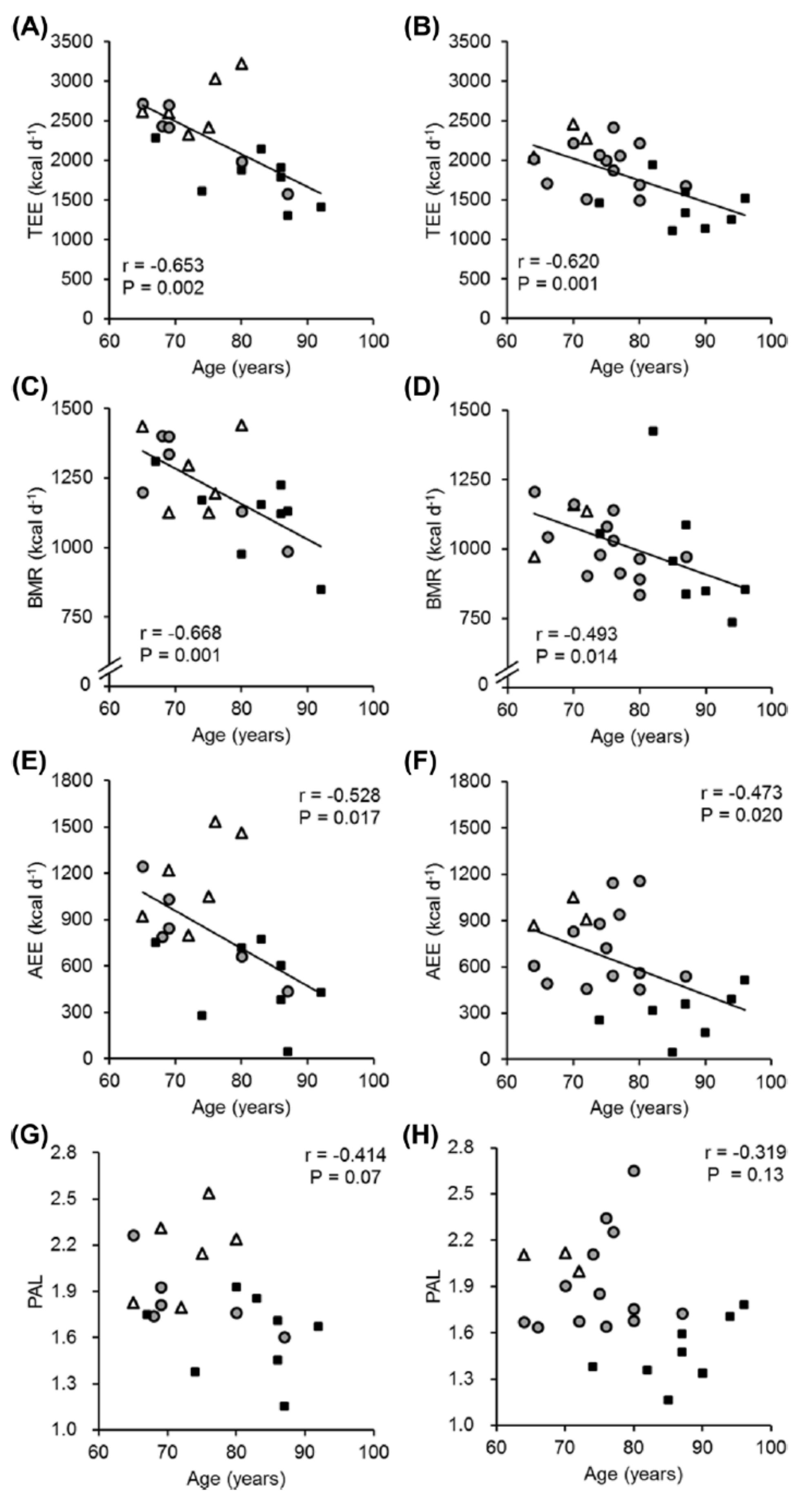


Fig. 1 Relationship between age and total energy expenditure (TEE) in men (**a**) and women (**b**), relationship between age and basal metabolic rate (BMR) in men (**c**) and women (**d**), relationship between age and physical activity energy expenditure (AEE) in men (**e**) and women (**f**), and relationship between age and physical activity level (PAL) in men (**g**) and women (**h**). Circles indicate community-dwelling healthy older adults without sporting habits, triangles indicate community-dwelling healthy older adults with sporting habits, and squares indicate care home residents

Accelerometer & PAR vs. DLW

2018 study example 1

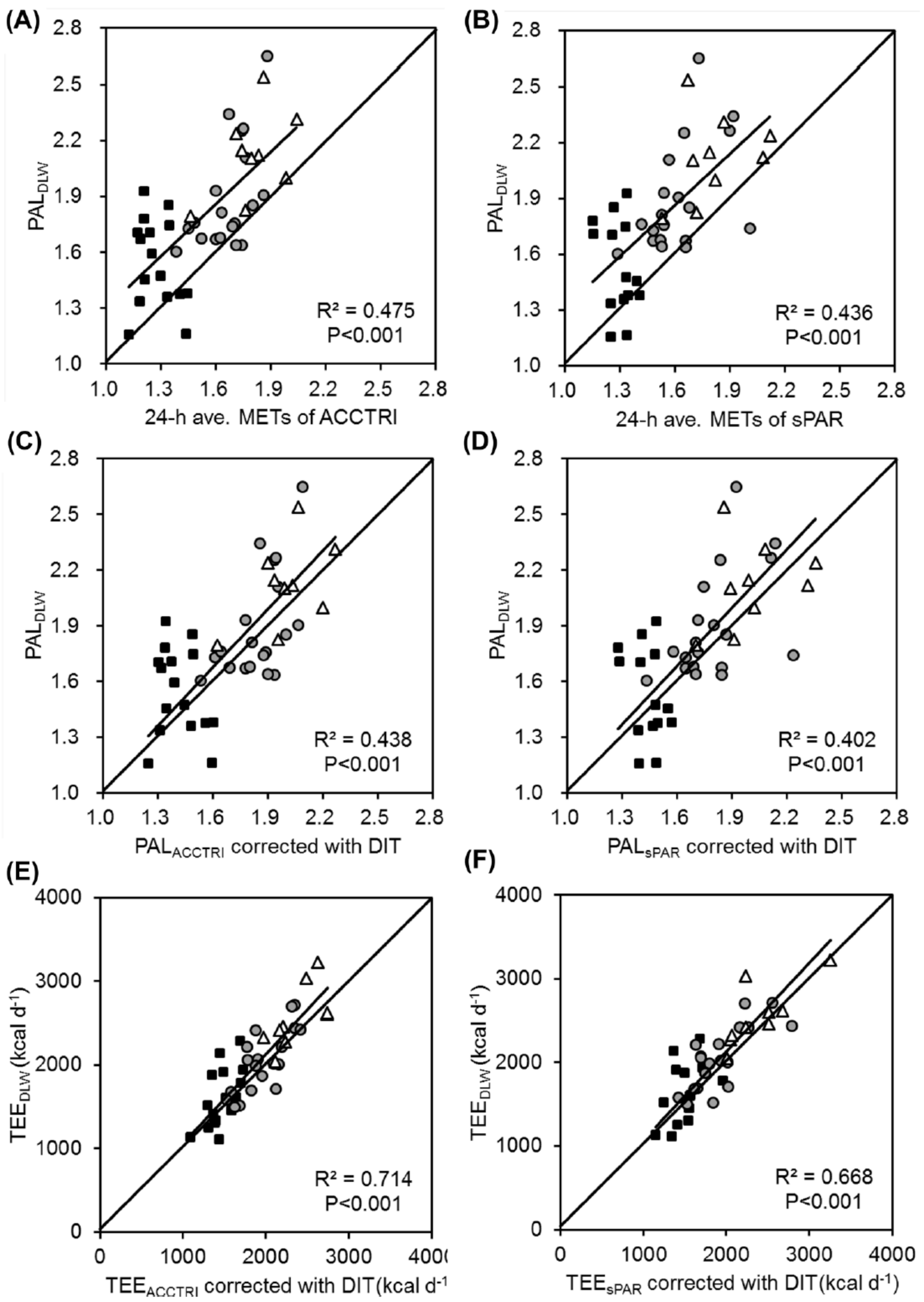
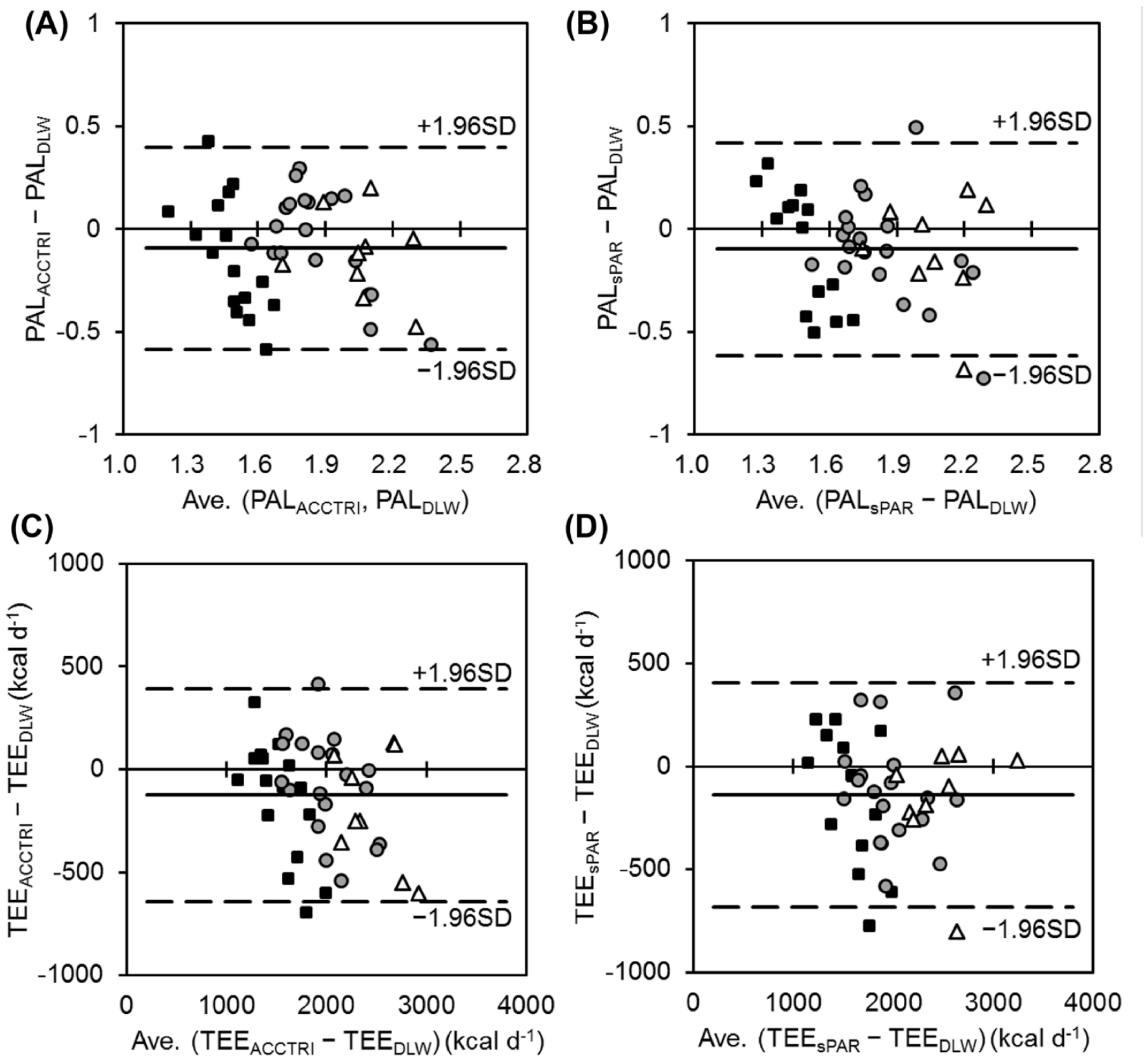


Fig. 2 Relationship between physical activity level (PAL) calculated by the doubly labeled water (DLW) method with the measured basal metabolic rate (BMR) and 24-h average MET of the triaxial accelerometer (ACCTRI) (**a**) or 24-h average MET of the simplified physical activity record (sPAR) (**b**), relationship between PAL by DLW and PAL of ACCTRI (**c**) or sPAR (**d**) corrected with estimated diet-induced thermogenesis (DIT), and relationship between total energy expenditure (TEE) by DLW and TEE of ACCTRI (**c**) or sPAR (**d**) corrected with DIT. Circles indicate community-dwelling healthy older adults without sporting habits, triangles indicate community-dwelling healthy older adults with sporting habits, and squares indicate care home residents

Accelerometer & PAR vs. DLW

2018 study example 1

Fig. 3 Bland–Altman agreement plots showing the difference between the physical activity level (PAL_{DLW}) and total energy expenditure (TEE_{DLW}) measured using doubly labeled water and estimated by (**a** and **c**) a triaxial accelerometer (ACCTRI) and (**b** and **d**) simplified physical activity record (sPAR). A negative sign for the difference indicates an underestimation and a positive sign denotes an overestimation. No statistical differences were observed in the estimation error between ACCTRI and sPAR in both PAL and TEE. Circles indicate community-dwelling healthy older adults without sporting habits, triangles indicate community-dwelling healthy older adults with sporting habits, and squares indicate care home residents



Accelerometer & PAR vs. DLW

2018 study example 1

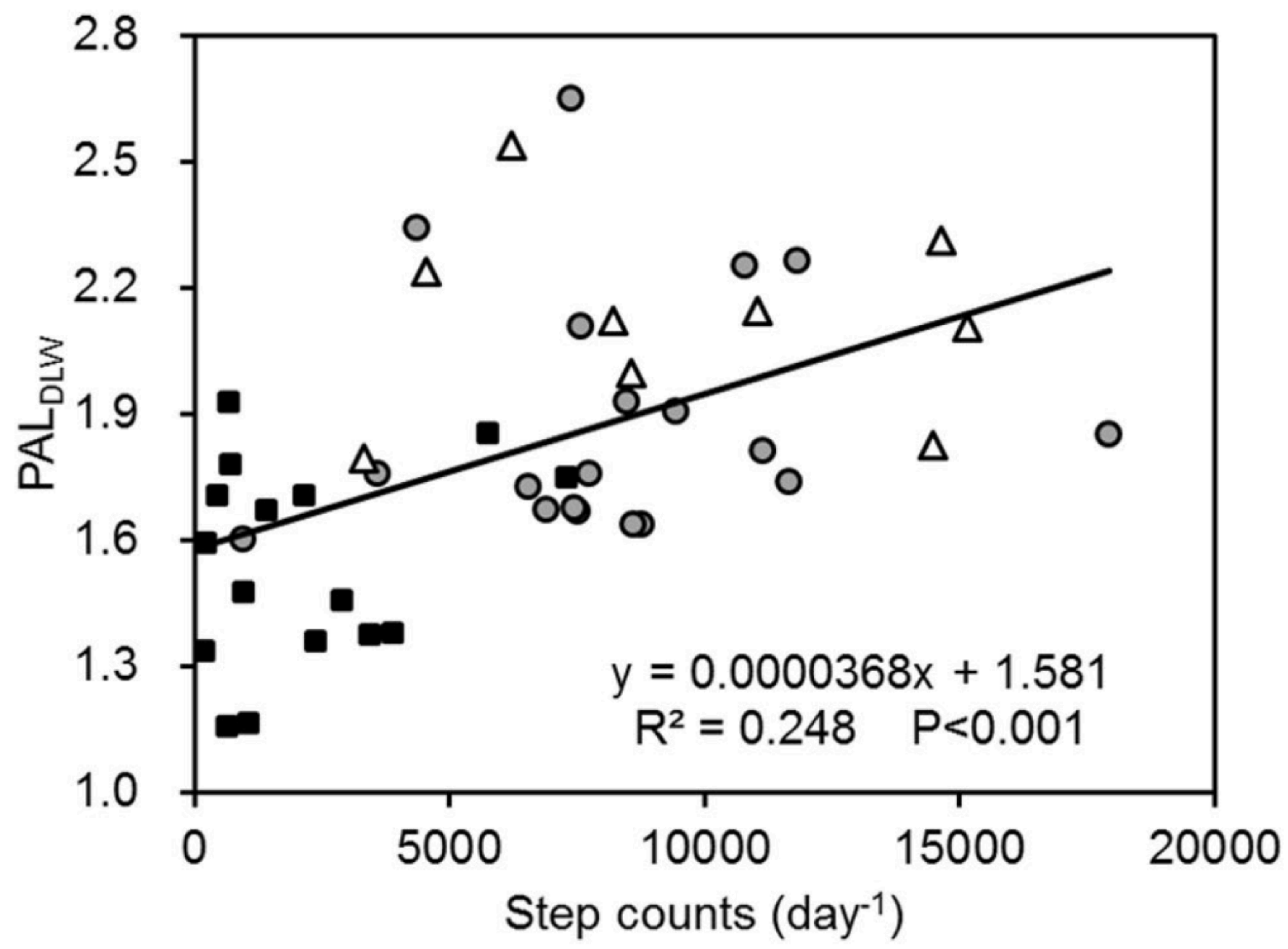


Fig. 4 Relationship between daily step counts by Lifecorder and physical activity level (PAL) calculated by the doubly labeled water (DLW) method with measured basal metabolic rate (mBMR). Circles indicate community-dwelling healthy older adults without sporting habits, triangles indicate community-dwelling healthy older adults with sporting habits, and squares indicate care home residents

Accelerometer & PAR vs. DLW

2018 study example 1

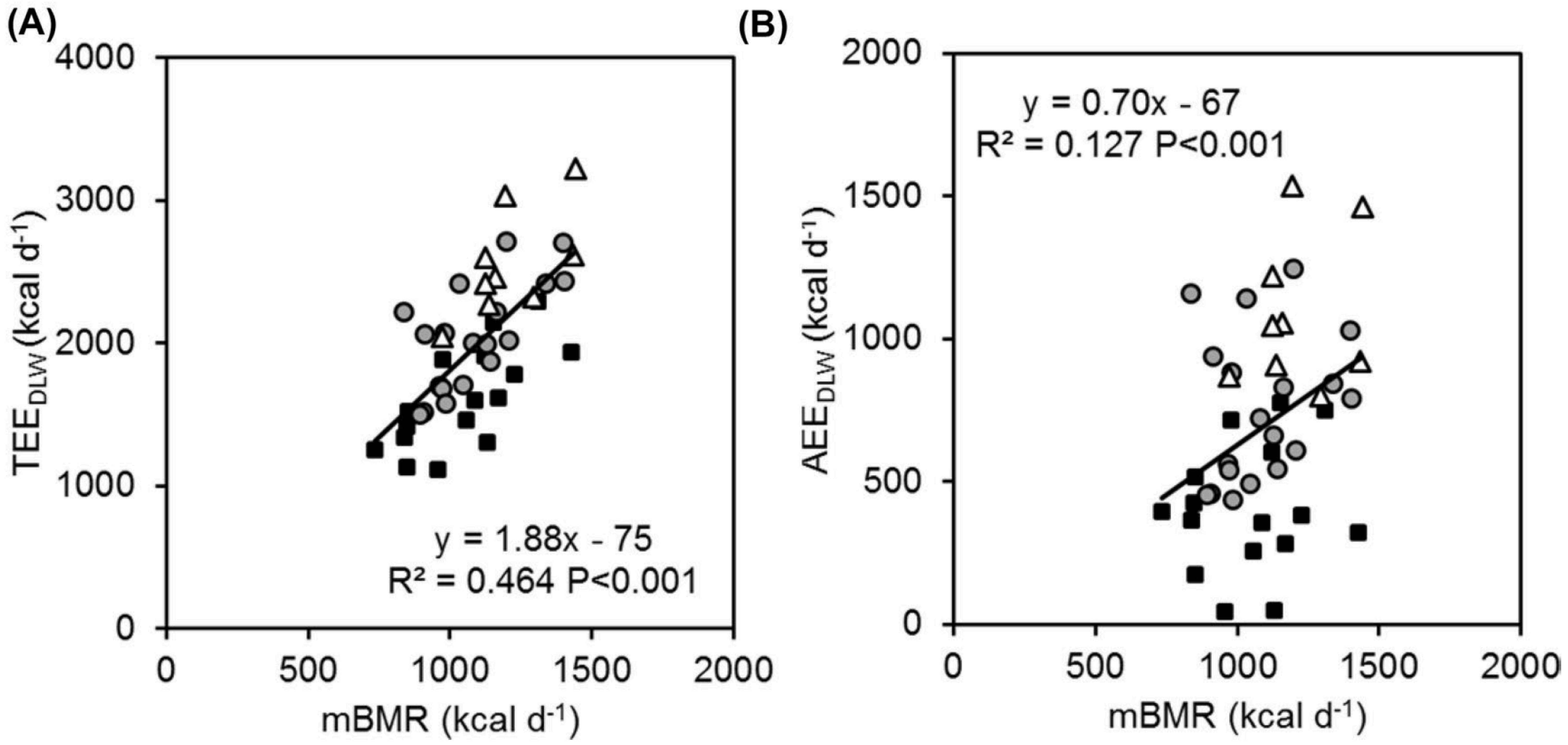


Fig. 5 Relationship between measured BMR (mBMR) and **a** total energy expenditure (TEE) and **b** physical activity energy expenditure (AEE). Circles indicate community-dwelling healthy older adults without sporting habits, triangles indicate community-dwelling healthy older adults with sporting habits, and squares indicate care home residents. The *Y*-intercept did not significantly differ from zero in both TEE and AEE

Wearables vs. DLW

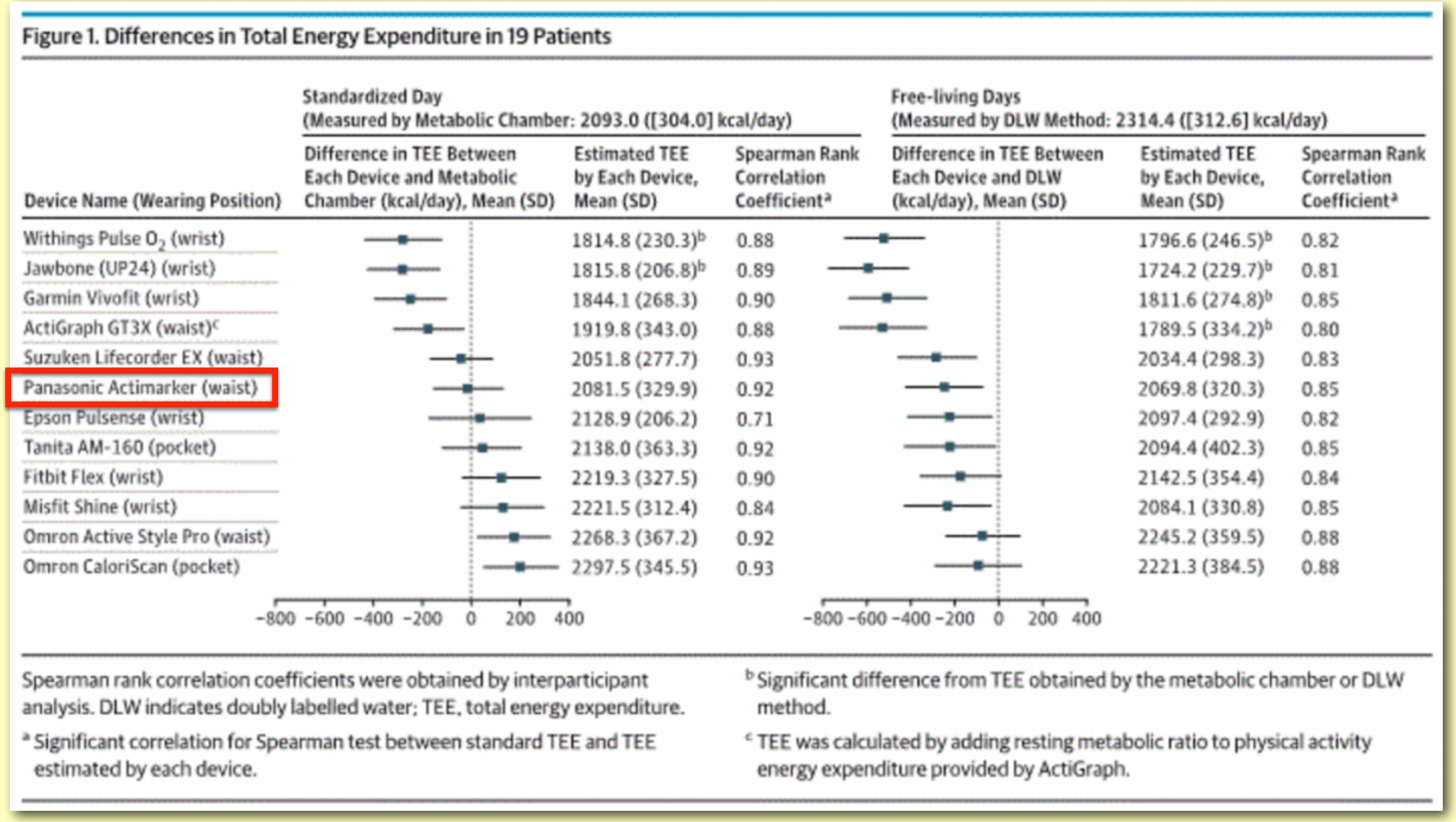


Figure 1. Differences in Total Energy Expenditure in 19 Patients

Device Name (Wearing Position)	Standardized Day (Measured by Metabolic Chamber: 2093.0 ([304.0] kcal/day)) Estimated TEE by Each Device, Mean (SD)	Spearman Rank Correlation Coefficient[a]	Free-living Days (Measured by DLW Method: 2314.4 ([312.6] kcal/day)) Estimated TEE by Each Device, Mean (SD)	Spearman Rank Correlation Coefficient[a]
Withings Pulse O_2 (wrist)	1814.8 (230.3)[b]	0.88	1796.6 (246.5)[b]	0.82
Jawbone (UP24) (wrist)	1815.8 (206.8)[b]	0.89	1724.2 (229.7)[b]	0.81
Garmin Vivofit (wrist)	1844.1 (268.3)	0.90	1811.6 (274.8)[b]	0.85
ActiGraph GT3X (waist)[c]	1919.8 (343.0)	0.88	1789.5 (334.2)[b]	0.80
Suzuken Lifecorder EX (waist)	2051.8 (277.7)	0.93	2034.4 (298.3)	0.83
Panasonic Actimarker (waist)	2081.5 (329.9)	0.92	2069.8 (320.3)	0.85
Epson Pulsense (wrist)	2128.9 (206.2)	0.71	2097.4 (292.9)	0.82
Tanita AM-160 (pocket)	2138.0 (363.3)	0.92	2094.4 (402.3)	0.85
Fitbit Flex (wrist)	2219.3 (327.5)	0.90	2142.5 (354.4)	0.84
Misfit Shine (wrist)	2221.5 (312.4)	0.84	2084.1 (330.8)	0.85
Omron Active Style Pro (waist)	2268.3 (367.2)	0.92	2245.2 (359.5)	0.88
Omron CaloriScan (pocket)	2297.5 (345.5)	0.93	2221.3 (384.5)	0.88

Spearman rank correlation coefficients were obtained by interparticipant analysis. DLW indicates doubly labelled water; TEE, total energy expenditure.

[a] Significant correlation for Spearman test between standard TEE and TEE estimated by each device.

[b] Significant difference from TEE obtained by the metabolic chamber or DLW method.

[c] TEE was calculated by adding resting metabolic ratio to physical activity energy expenditure provided by ActiGraph.

Wearables vs. DLW

From: **Accuracy of Wearable Devices for Estimating Total Energy ExpenditureComparison With Metabolic Chamber and Doubly Labeled Water Method**

JAMA Intern Med. 2016;176(5):702-703. doi:10.1001/jamainternmed.2016.0152

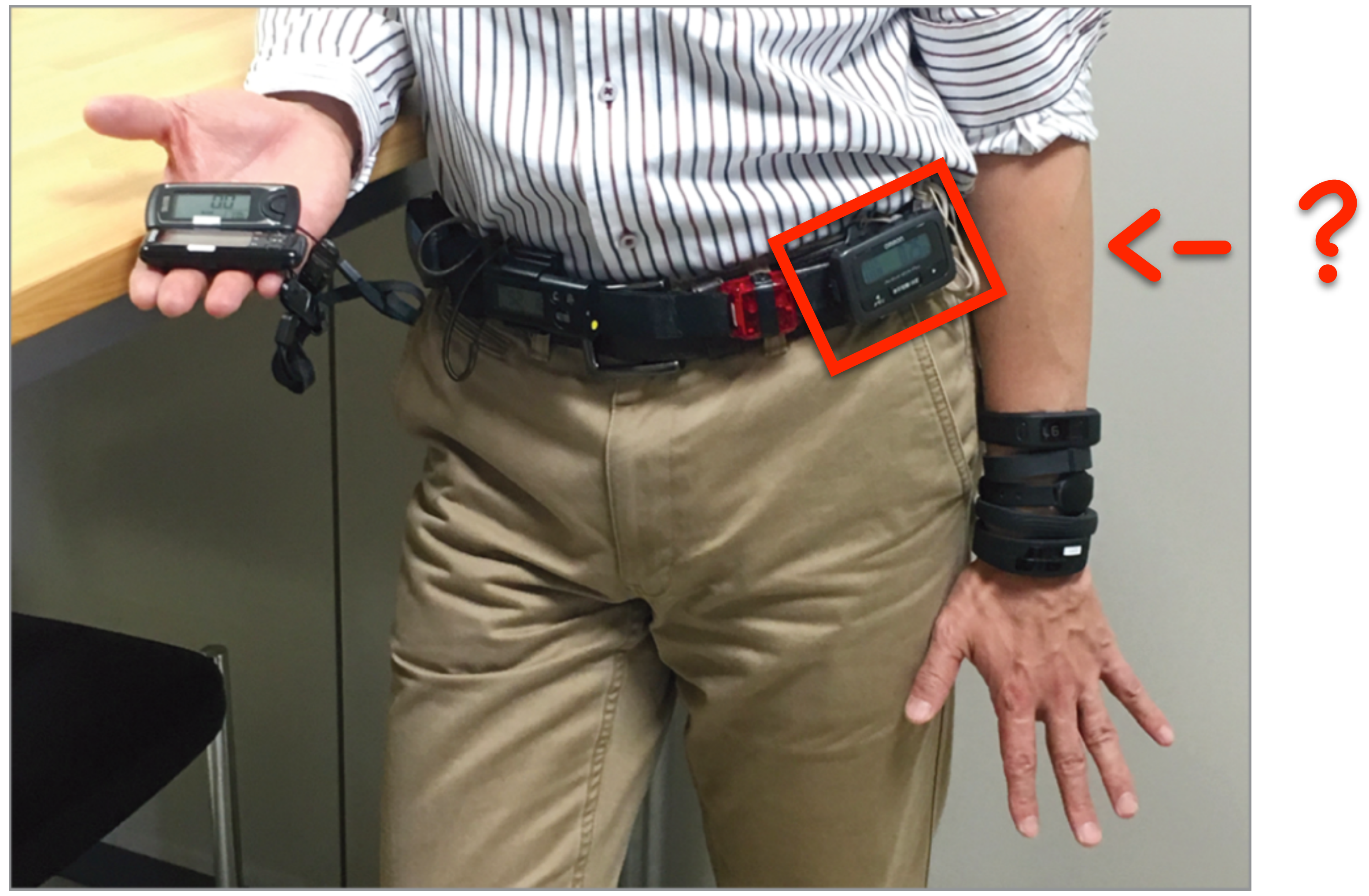


Figure Legend:

All 12 Wearable Devices on the BodyPhoto of all 12 wearable devices: Fitbit Flex, JAWBONE UP24, Misfit Shine, EPSON PULSENCE PS-100, Garmin Vivofit (wrist), TANITA AM-160, OMRON CaloriScan HJA-403C (hand-held), and Withings Pulse O2, OMRON Active style Pro HJA-350IT, Panasonic Actimarker EW4800, SUZUKEN Lifecorder EX, and ActiGraph GT3X (waist).

Second generation accelerometers

Accelerometer issues

- SINGLE-SITE PLACEMENT;
- waist placement -> PA underestimate during upper limb movement, standing, vertical activity (i.e., climbing stairs, uphill walking), pushing or pulling objects, carrying loads (e.g., books or laptops), body-supported exercise (e.g., cycling), water PA (e.g., swimming), running faster than 9 km/h, horizontal speed rapid changes activities (e.g., tennis)

Second generation accelerometers

measures

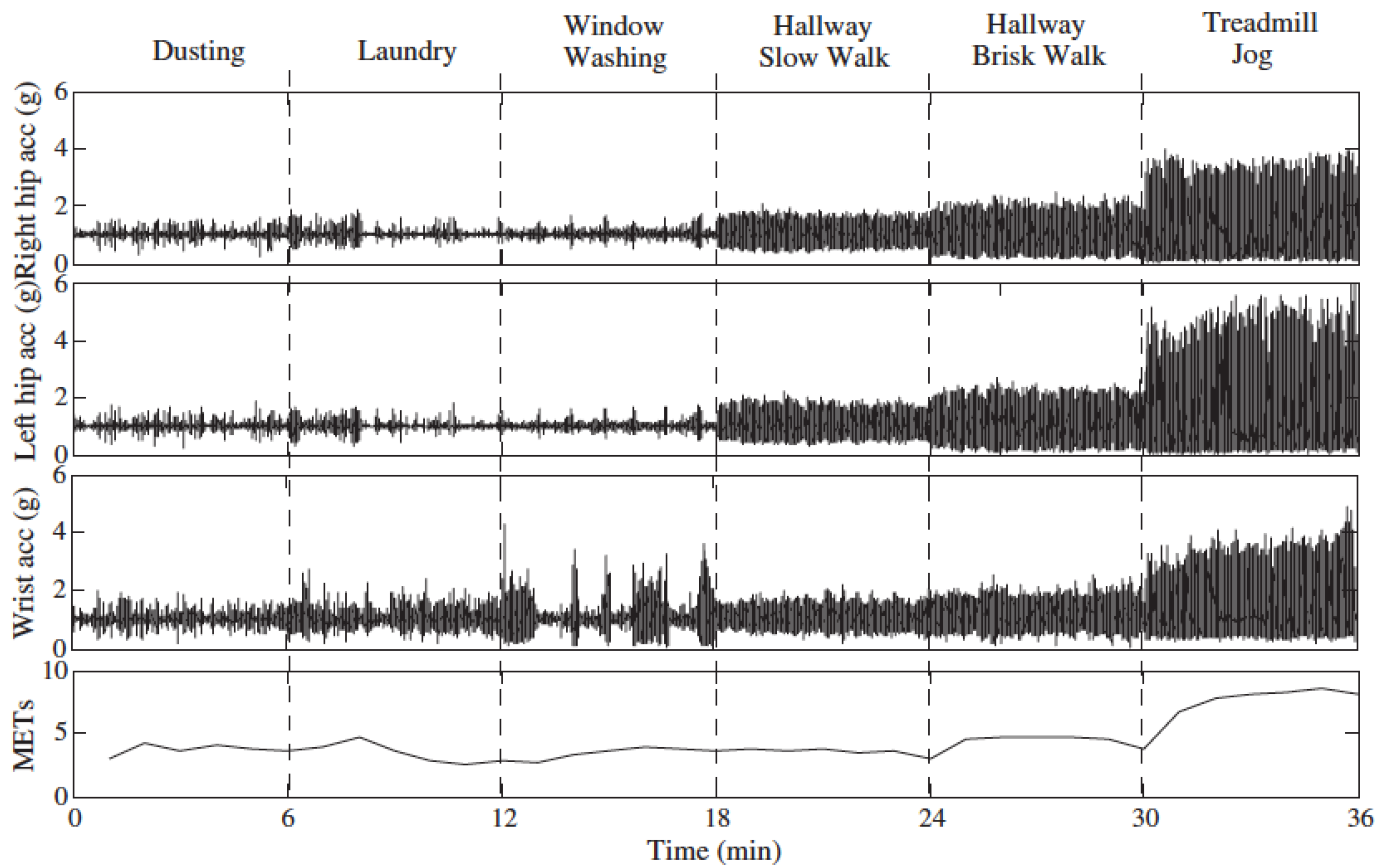


Figure 1. An example of accelerometer and MET measurements for one participant performing an activity routine. Data was not captured between activities.

Ellis et al., 2014

Second generation accelerometers

Solution?

- A combination of variables describing:
  1) upper limbs-focused high frequency components (upper limbs movements feature sedentary PA);
  2) a trunk-focused posture variable featuring locomotion;
  3) lower limbs-focused high intensity components (lower limbs have largest, most powerful muscles);

Second generation accelerometers

- More than ONE accelerometer together, as well
  (e.g., waist TriTrac-R3D + dominant arm wrist Actiwatch, Actiwatch + Actical, ...);
- accelerometers based activity logger:
  . two (@sternum, front thigh) biaxial accelerometers + analog data-logger;

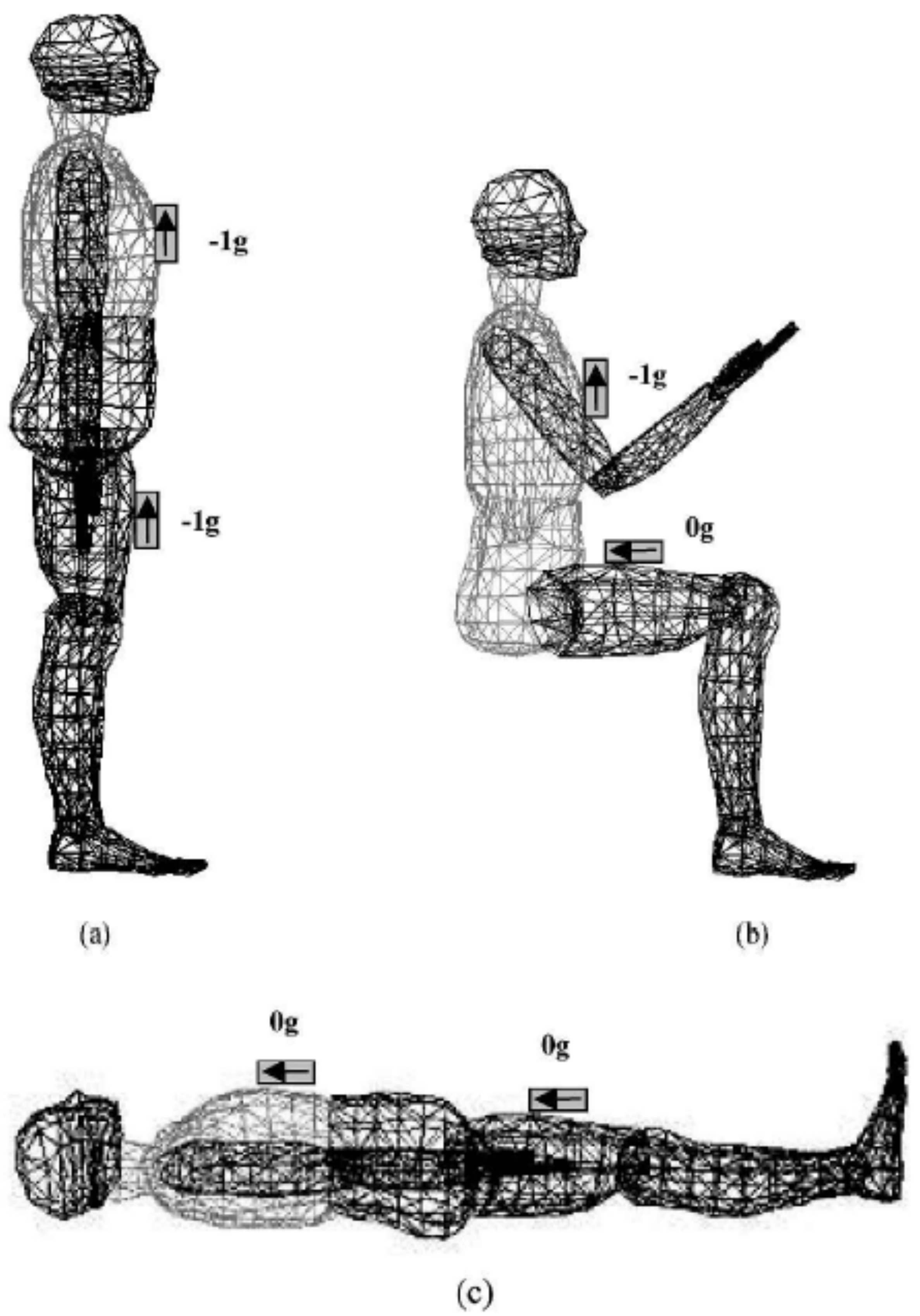


Figure 1 Discriminating postures: (a) standing, (b) sitting, (c) lying. The arrows indicate the investigated direction of the active axis of the accelerometers. The acceleration values correspond to the accelerometer output at each orientation in units of ***g***.

Culhane et al., 2004

Second generation accelerometers

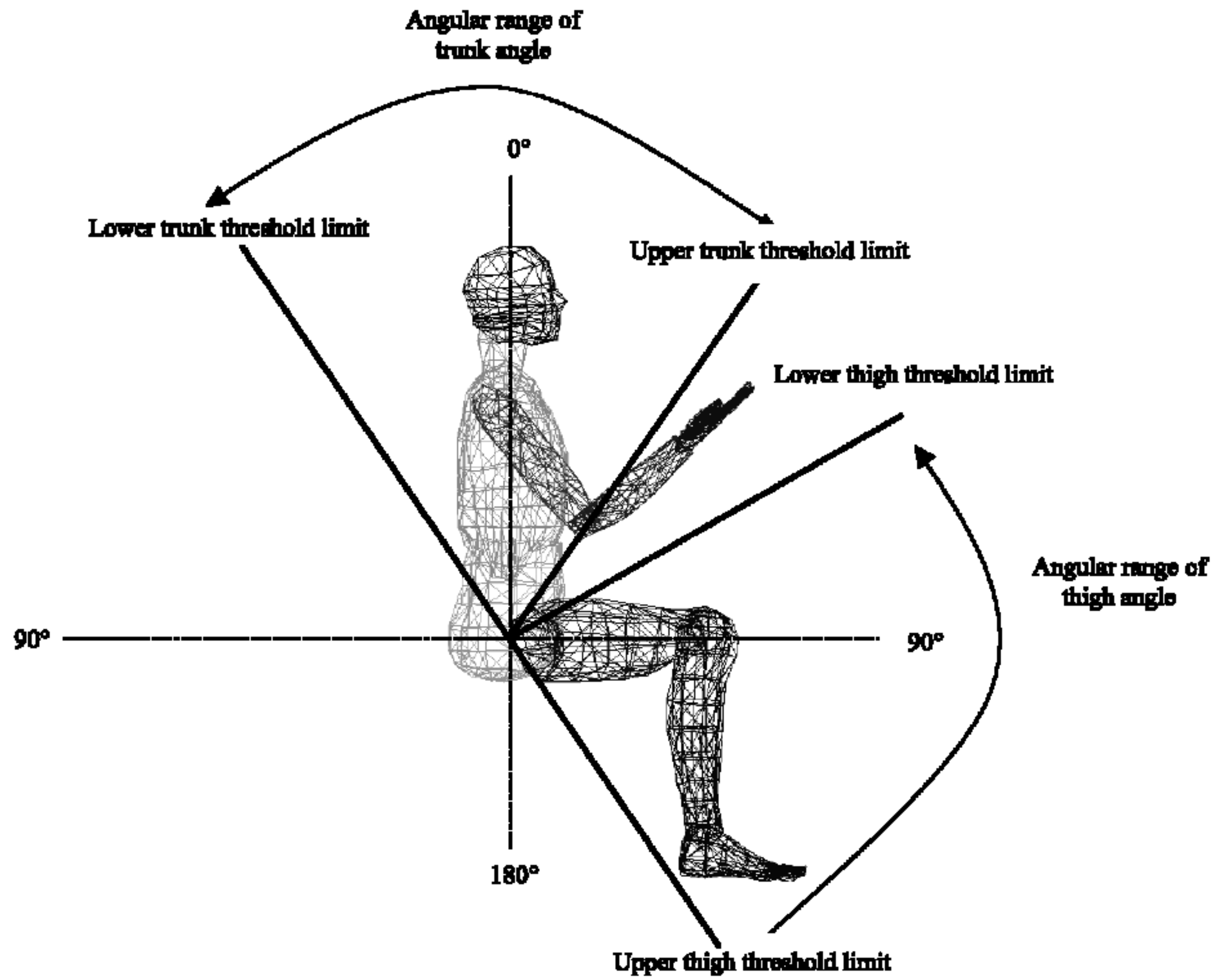


Figure 2 Sitting criteria.

Culhane et al., 2004

Second generation accelerometers

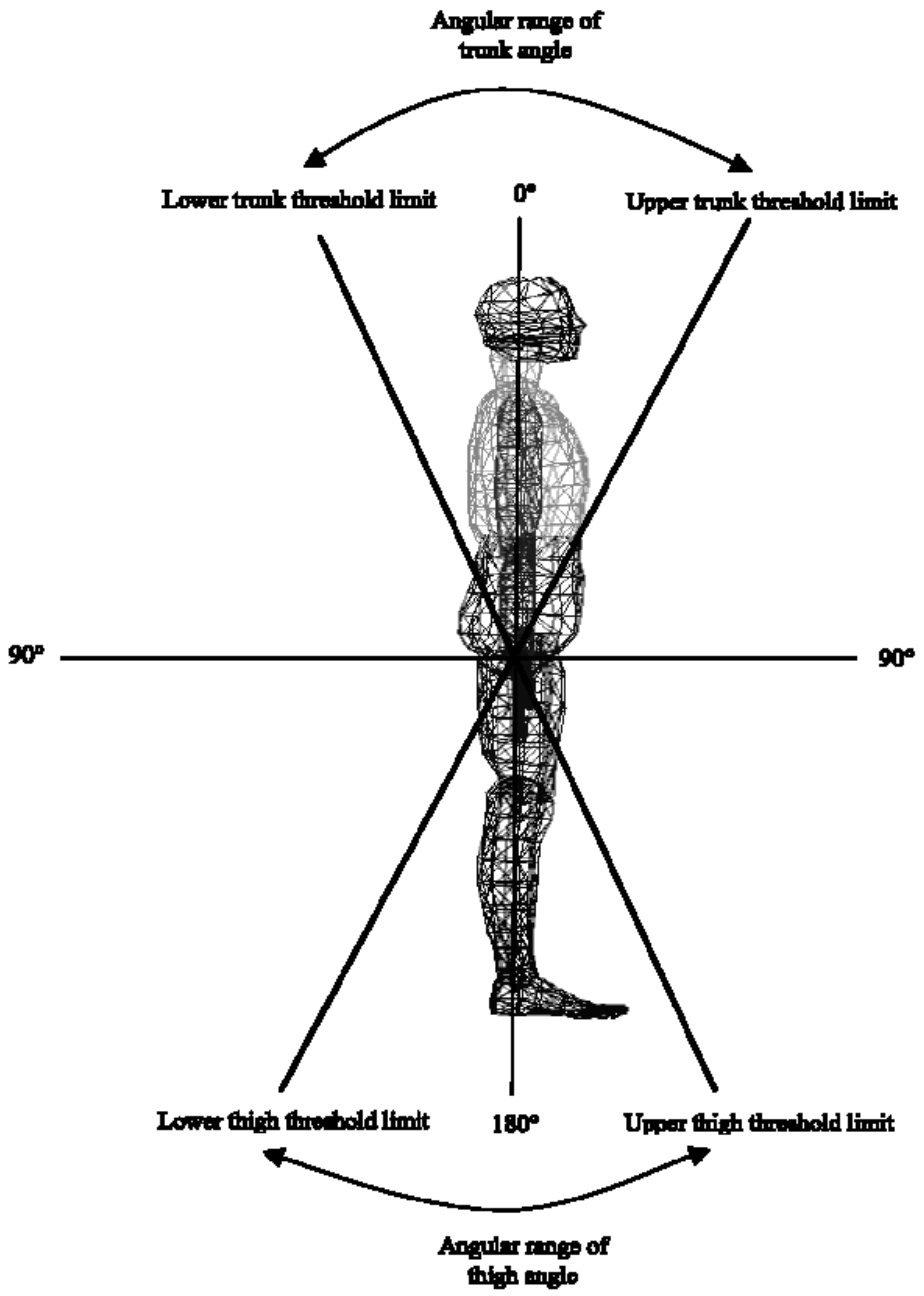


Figure 3 Standing criteria.

Culhane et al., 2004

Second generation accelerometers

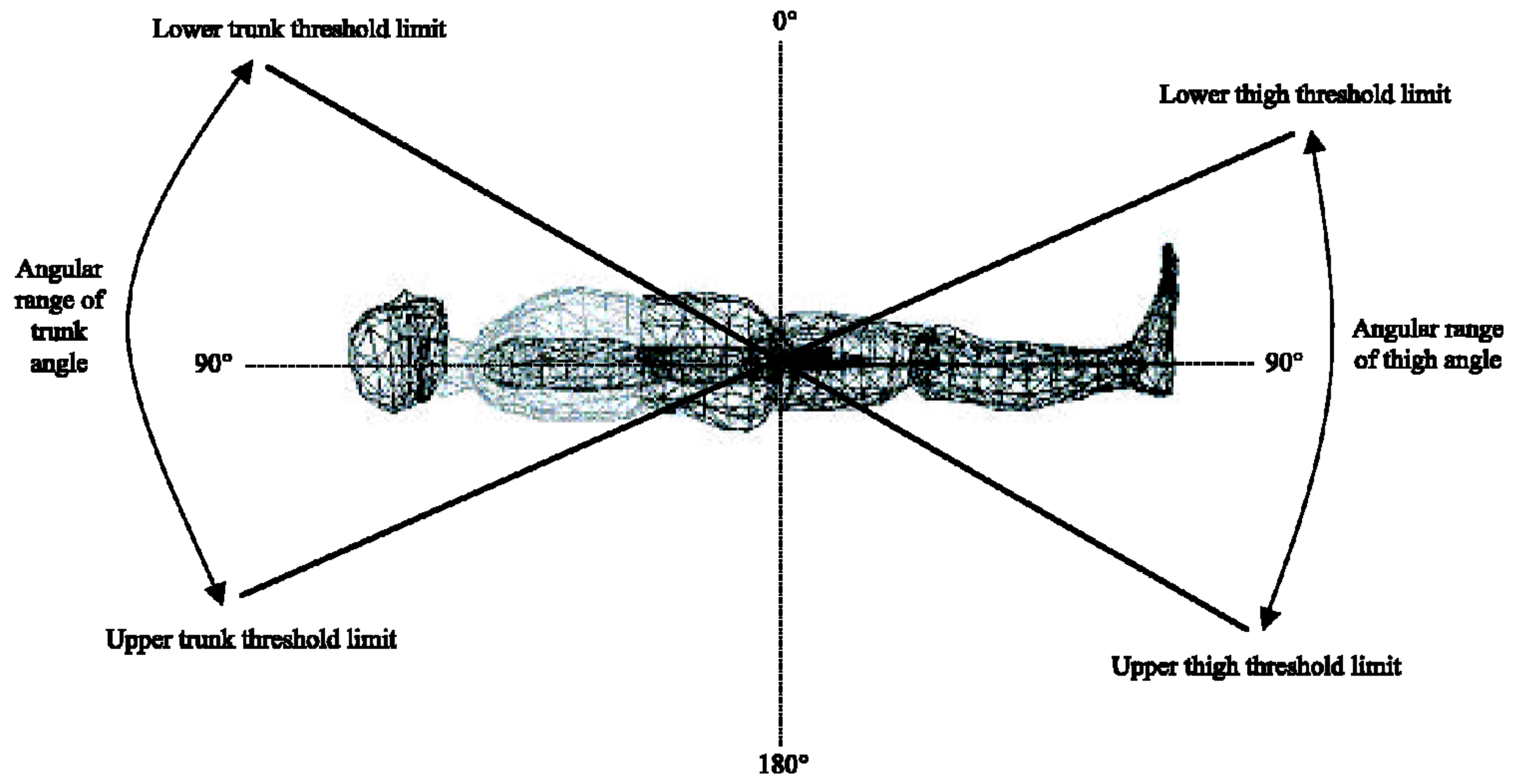


Figure 4 Lying criteria.

-> sitting, standing, lying, moving 83% detection;

Culhane et al., 2004

Second generation accelerometers

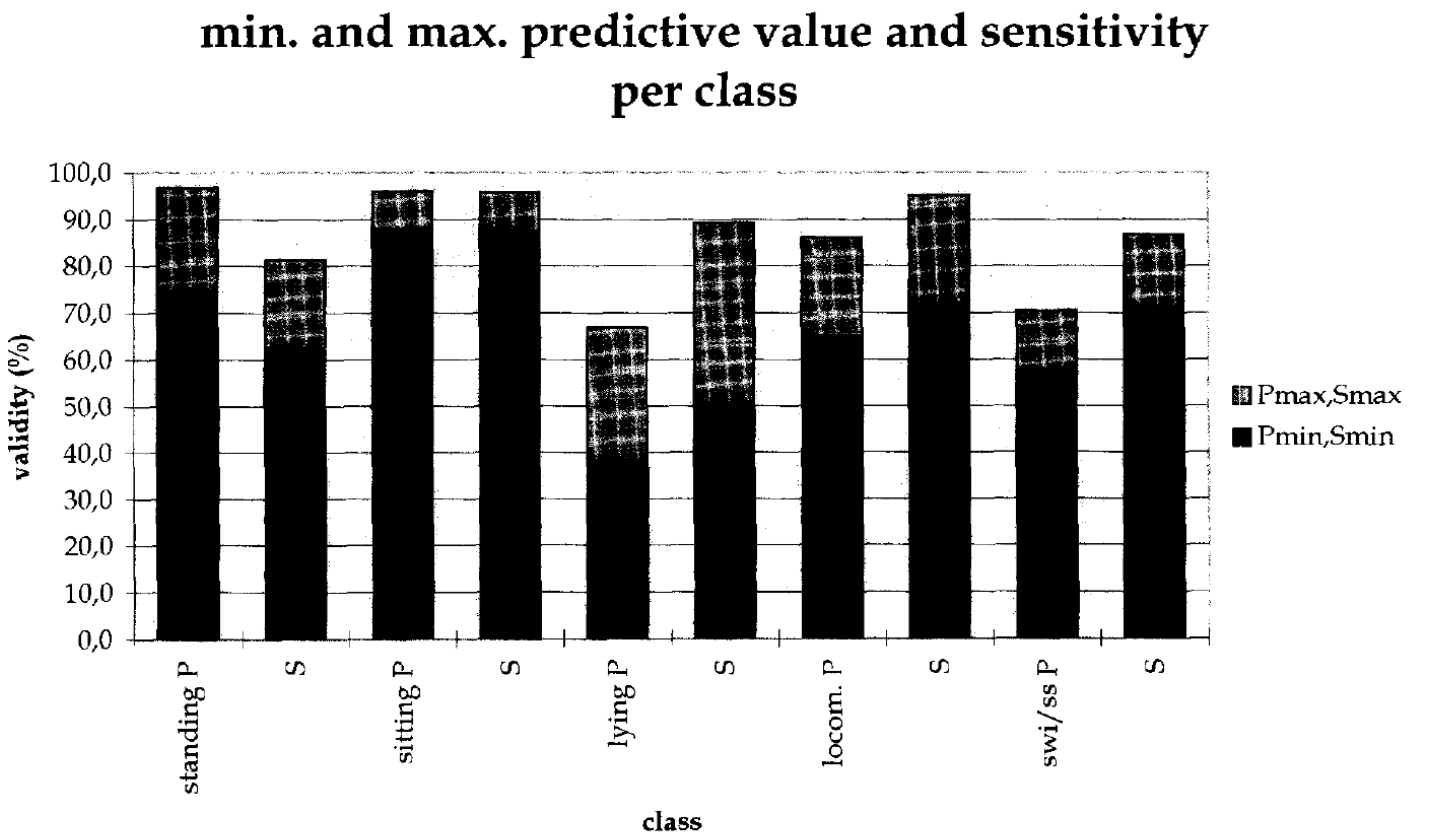


Figure 6 Minimal and maximal validity of the individual ADL categories based on the monitor's sensitivity (S_{min} and S_{max}, respectively) and predictive value (P_{min} and P_{max}, respectively). Sensitivity indicates how often the monitor recognizes a category; the predictive value indicates how often the decision of the monitor is correct. A lack of sensitivity indicates a false negative; a lack of predictive value indicates a false positive.

Busser et al., 1997

. uniaxial accelerometer (@front thigh) + 2 unixial accelerometer/digital data-logger (backpack)
-> sitting, standing, lying, crawling, walking, running, going on a swing 73÷91% detection;

Second generation accelerometers

. three uniaxial accelerometers (2@sternum, front thigh) + digital recorder;
-> sitting, standing, lying, walking, climbing/going down stairs, cycling 80% detection (Veltink et al., 1996);
. four biaxial accelerometers (@lateral thighs, sternum or front forearms) + HR monitor + digital recorder;
-> more than twenty different postures/locomotions 83÷88% detection;

Figure 1. An extended configuration of the Activity Monitor, with accelerometers at the thighs, trunk, and lower arms.

Bussmann et al., 2001

Second generation accelerometers

- Introduction of another type of physical sensor:
  . (@sternum) two biaxial accelerometers + piezoelectric gyroscope + digital recorder (@wrist);

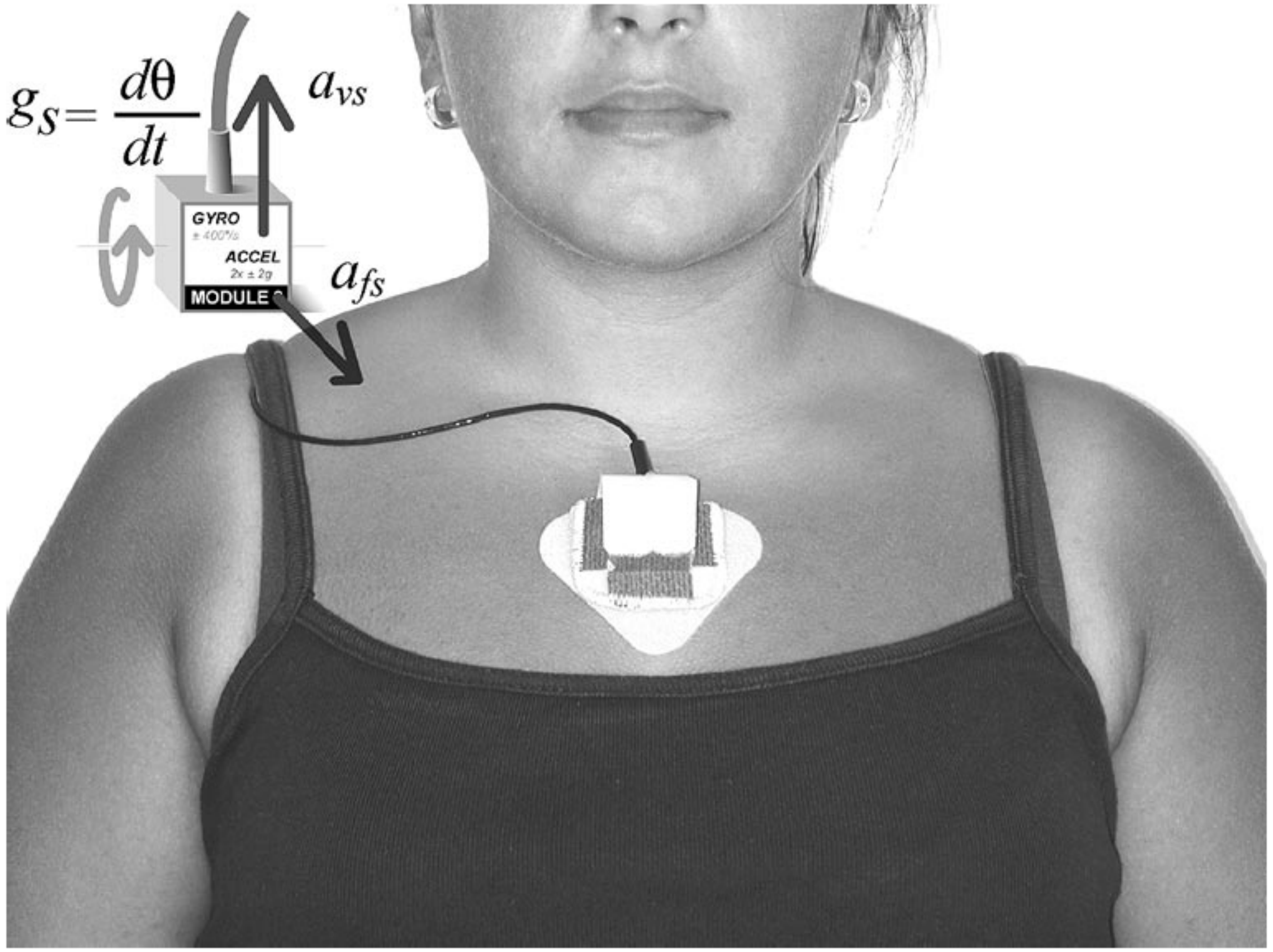


Fig. 1. Sensor attachment. Vertical and frontal acceleration (a_{vs} and a_{fs}) as well as angular velocity (g_s) are measured using a kinematic sensor attached to the subject's chest.

Najafi et al., 2003

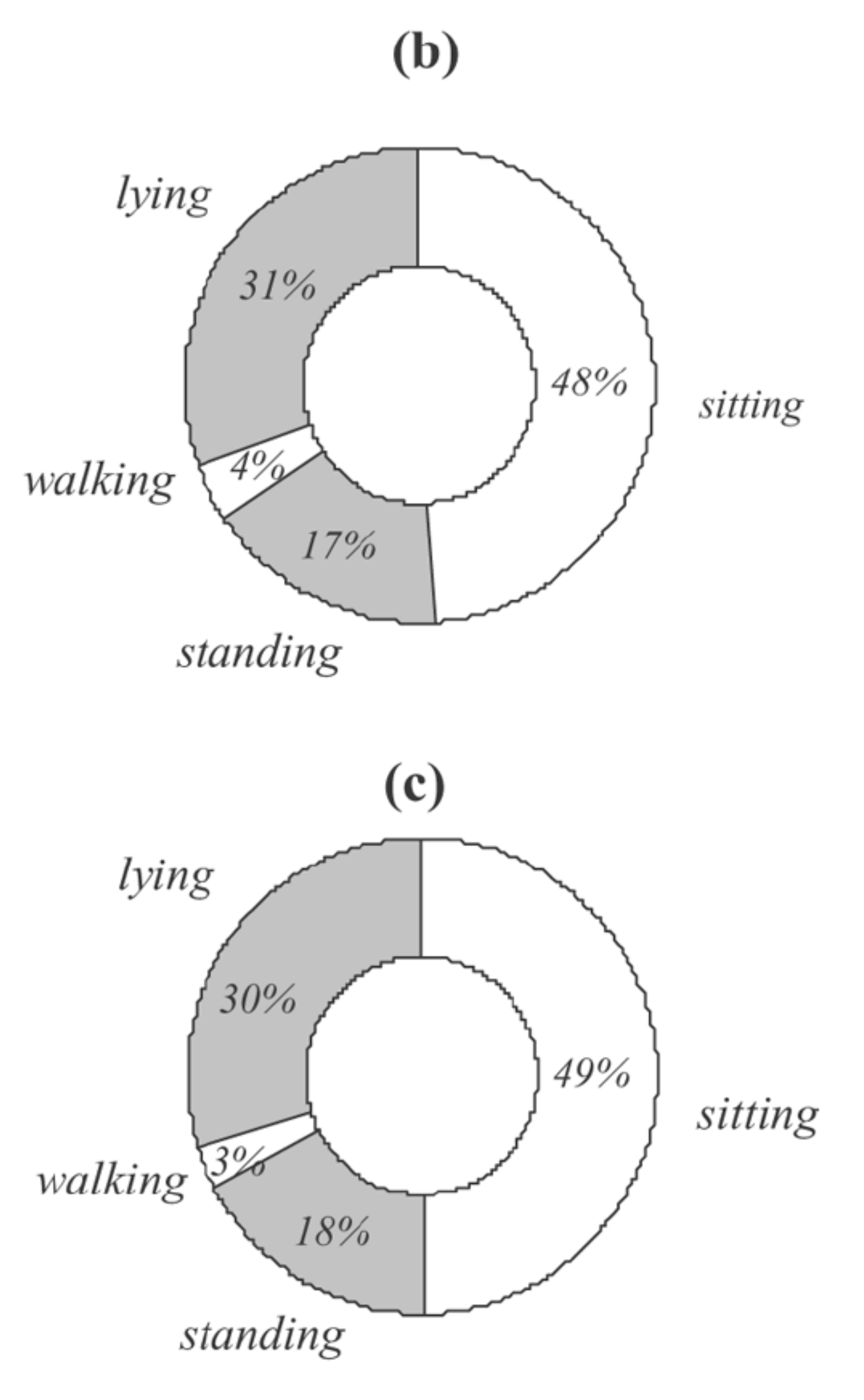
Second generation accelerometers

measures

TABLE II
OVERALL SENSITIVITY AND SPECIFICITY OF TRANSITION DETECTION FOR THE 11 ELDERLY (FIRST STUDY)

# Test	Total PT*	Sensitivity, %					Specificity, %	
		PT	SiSt**	StSi	Lying	Walking	SiSt	StSi
1	40	100	100	100	100	95±4	100	100
2	66	98±5	100	97±10	-	97±3	95±12	100±0
3	58	100	97±10	63±29	-	-	63±29	97±10
4	58	100	88±25	75±29	-	-	75±29	88±25
5	64	96±9	89±18	86±19	-	-	86±19	94±13
6	57	100	85±19	72±24	-	-	72±24	85±19
Mean	***57±9***	***99±2***	***93±7***	***82±15***	***100***	***96±1***	***82±15***	***94±6***

* PT: Postural transition.
** SiSt: sit-to-stand transition.
† StSi: stand-to-sit transition.



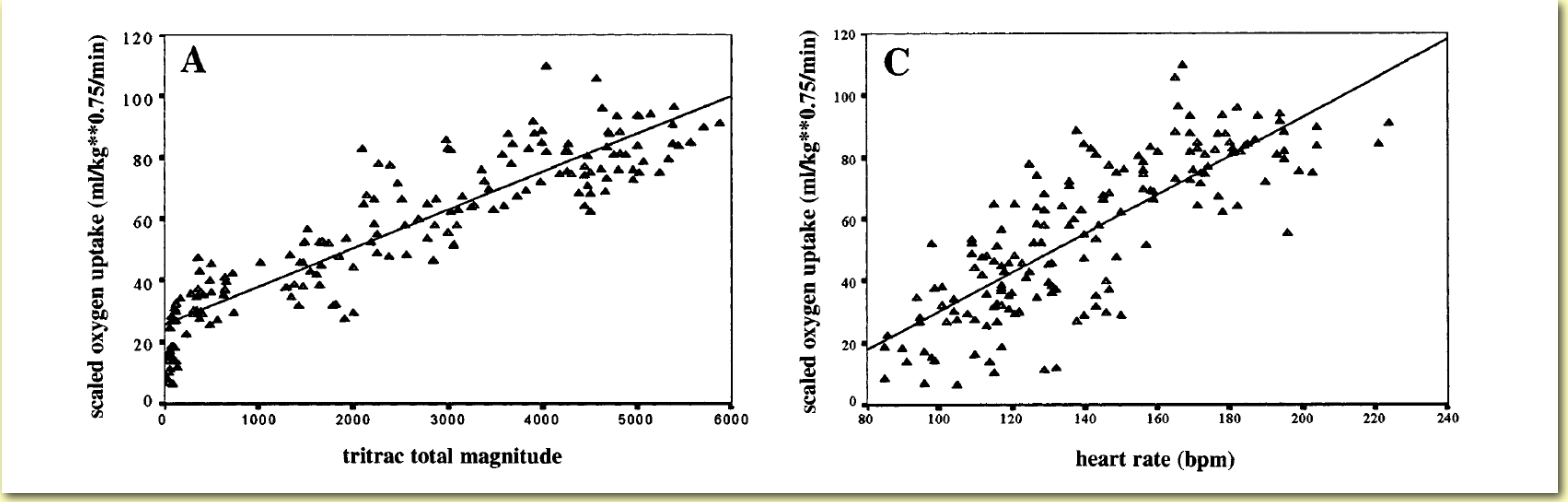
Najafi et al., 2003

-> posture change, walking detection;

Second generation accelerometers

- Accelerometry (-> movement) + physiological measure (e.g., HR measure, thermometry, ventilation measure):
  . e.g., HR monitor (-> ME) + motion sensor(s) (-> motion-sensor-sensitive PA);
- accelerometers + inclinometers -> body position over time -> 85% unstructured exercise thermogenesis estimate:
  . total internal heat produced ≈ 75÷80% energy intake;
  . partial internal heat produced <- sitting, standing, walking, working, any other unstructured exercise;
  . proposal: (during the day) wearing motion sensor, (structured exercise) wearing HR monitor;
  . i.e., motion sensor -> yes/not time to use HR monitor for ME estimate;

Second generation accelerometers



Eston et al., 1998

. exception: children (i.e., V'O2 [ml O2/kg$^{.75}$ min] correlated w/both counts, HR, but w/counts r^2 > w/HR r^2);

Second generation accelerometers (re: children HR)

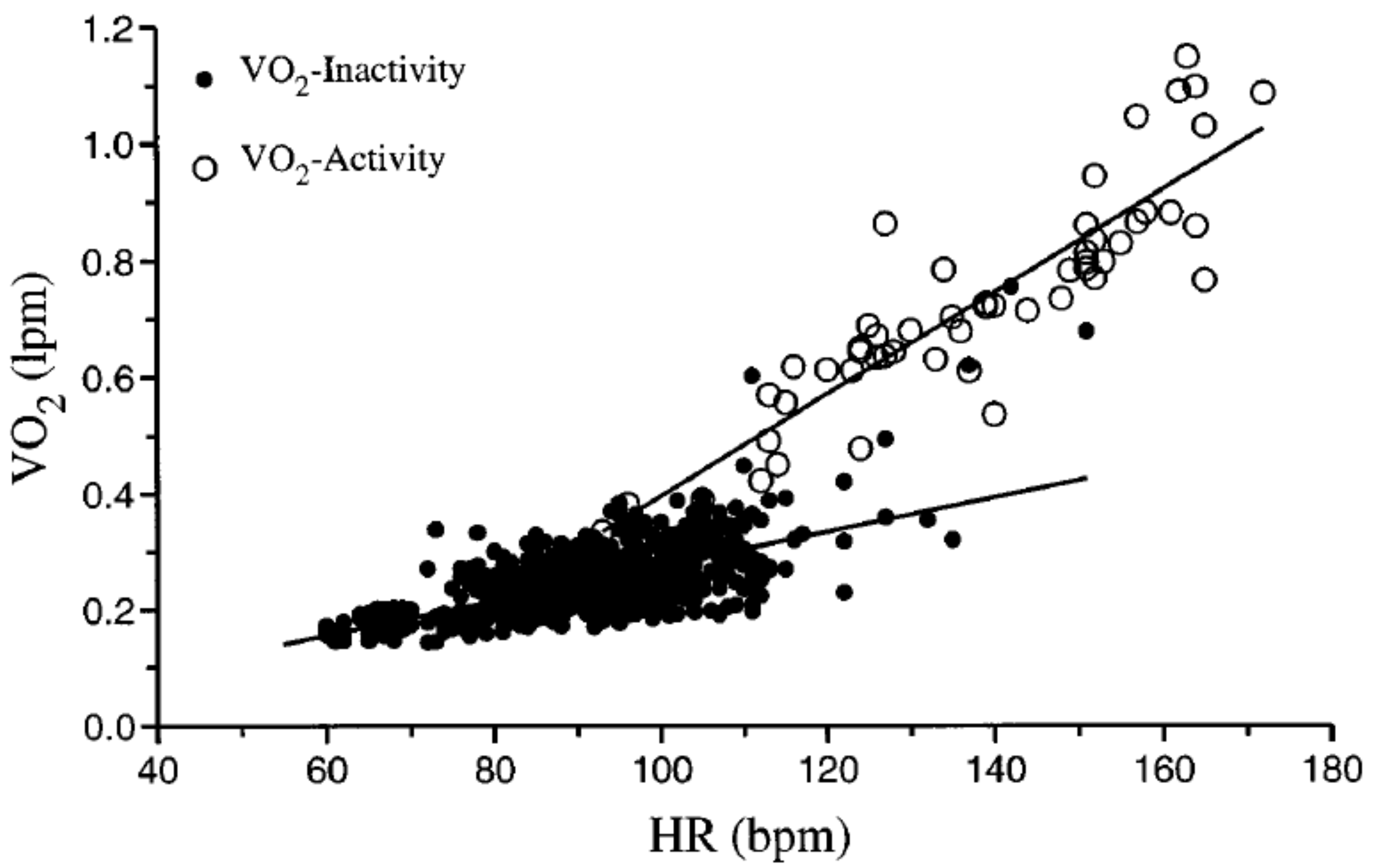


Fig. 1. Oxygen consumption ($\dot{V}O_2$) and heart rate (HR) relationship in the room calorimeter for one subject, with separate curves for active vs. inactive data for awake portion of the day (*method 3*).

Treuth et al., 1998

. solution: two different individual V'O2 vs. HR relationships, one for inactivity, one for PA;