Arm Band Heart Rate Monitors

✓ They are produced by few companies. This could be due to the assumption that increased movement in the sensors from arm swinging produces too many artifacts.

Polar OH1

✓ **Optical heart rate tracking via 6 LEDs**. Works with all Polar BLE devices and a range of fitness apps.
✓ Waterproof to 30m.
✓ Machine-washable textile band is comfortable and easy to use.

✓ Built-in memory for up to 200 hours of training data.
✓ Rechargeable battery, with up to 12 hours of life per charge.

Smartwatches

Apple Watch Series 4

OS: watchOS 5
Display: OLED
Size: 40mm/44mm
Battery: 2 days
Water resistance: 50m
Heart rate: Yes (ECG)
Connectivity: LTE, GPS, NFC, Wi-Fi, Bluetooth
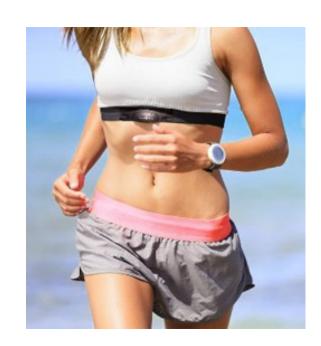**Works with:** iOS

Headline features:

✓ **new ECG monitor** that unlocks the ability for serious heart health monitoring. It's been FDA cleared, so the feature can be used to detect heart rhythm irregularities

✓ **new fall detection mode** that can let users access Siri to contact emergency services or an emergency contact.

Chest Strap Monitors

✓ Measure electrical signals generated by your heart when it contracts.

✓ The **strap** around the chest **(transmitter)** can often be purchased separately to the wireless **wristwatch (receiver).**

✓ Many of the best chest strap HRMs also use **Bluetooth technology** or **ANT+ transmission**, to sync your pulse rate to other devices and fitness apps.

Limitations:

COMFORT: If chest straps are not wrapped around the chest tightly enough they can quickly slip out of place, and it's not easy to reposition them while you're in motion.

Wireless In-ear HR Monitors

- ✓ Earbud heart rate monitors track your pulse rate using PPG.
- ✓ A small light is shone against your skin to measure blood flow based on how light reflects off blood vessels.
- ✓ It's a similar process to the green LEDs used by wrist-based HRMs.

- ✓ Sweat-proof headphones deliver your favorite workout music while tracking your heart rate.
- ✓ The over-ear design remains comfortable throughout your workout.
- ✓ Battery life tends to be relatively short, with a full charge lasting 3 to 5 hours on average, for the best devices.
- ✓ Android and iOS compatibility.
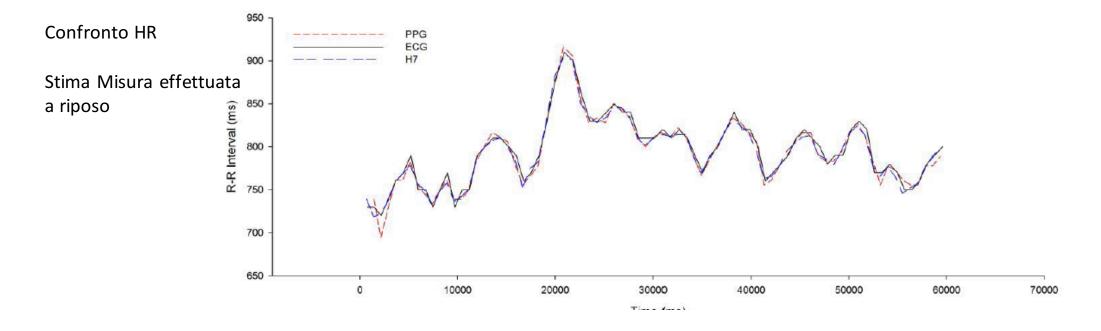
Confronto HR

Stima Misura effettuata a riposo

Figure 1: Simultaneous R-R interval of an individual subject during 60 seconds of recording for photoplethysmographic (PPG), Polar chest strap (H7) and electrocardiogram (ECG).

Confronto variabilità cardiaca
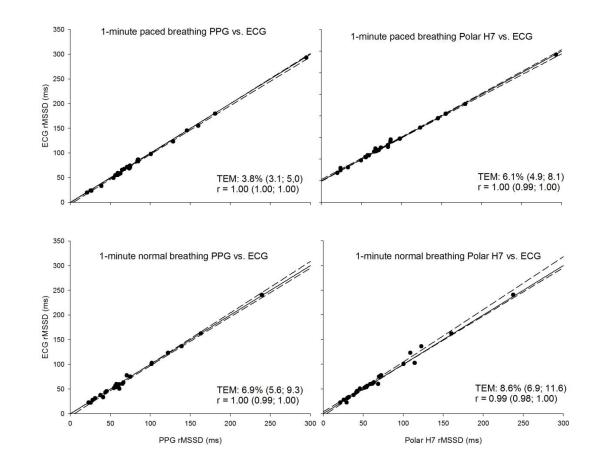
Stima Misura effettuata
a riposo
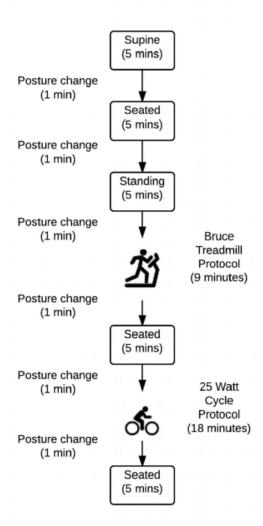
La correlazione trovata è praticam

Accuracy of Heart Rate Watches: Implications for Weight Management

Matthew P. Wallen[1], Sjaan R. Gomersall[1], Shelley E. Keating[1], Ulrik Wisløff[2], Jeff S. Coombes[1]*

Accuracy of Heart Rate Watches:
Implications for Weight Management

Matthew P. Wallen[1][...] S. Coombes[1]*

Table 1. Sample size, mean, correlation, agreement between device and reference methods and Bland-Altman outcomes for heart rate (bpm) and energy expenditure (kcal).

		Apple Watch	Fitbit Charge HR	Samsung Gear S	Mio ALPHA
Heart rate	N	22	22	22	22
(bpm)	Device mean ± SD	100.7 ±14.0	92.7 ± 11.5	93.4 ± 13.9	97.7 ± 14.6
	ECG mean ± SD	102.0 ± 14.4	102.0 ± 14.5	100.5 ± 14.6	102.0 ± 13.4
	r/Rho (95% CI)	0.95 (0.88 to 0.98)	0.81 (0.59 to 0.92)	0.67* (0.35 to 0.85)	0.87 (0.71 to 0.94)
	ICC (95% CI)	0.98 (0.94 to 0.99)	0.78 (-0.02 to 0.93)	0.80 (0.40 to 0.93)	0.91 (0.72 to 0.97)
	Mean difference ± SD	-1.3 ± 4.4	-9.3 ± 8.5	-7.1 ± 10.3	-4.3 ± 7.2
	Upper LoA	7.3	7.4	13.1	$-0.44.\text{avg} + 52.69^{\dagger}$
	Lower LoA	-9.9	-26.0	-27.3	$0.4.\text{avg}—61.2^{\dagger}$
Energy Expenditure	N	22	22	19^	22
(kcal)	Device mean ± SD	162.6 ± 33.0	236.8 ± 77.0	261.4 ± 47.5	189.5 ± 95.3
	Indirect calorimetry mean ± SD	285.7 ± 50.2	299.1 ± 46.0	287.5 ± 45.1	290.3 ± 46.3
	r/Rho (95% CI)	0.16 (-0.28 to 0.54)	0.64 (0.30 to 0.84)	0.86 (0.67 to 0.95)	0.46* (0.05 to 0.74)
	ICC (95% CI)	0.05 (-0.05 to 0.17)	0.56 (-0.18 to 0.83)	0.86 (0.15 to 0.96)	0.32 (-0.24 to 0.68)
	Mean difference ± SD	-123.1 ± 55.6	$0.61.\text{avg}—224.6 ± 59.1^{\dagger}$	-26.1 ± 24.2	$0.91.\text{avg} -318.77 ± 84.8^{\dagger}$
	Upper LoA	-14.1	$1.3.\text{avg}—334.28^{\dagger}$	21.3	$0.91.\text{avg} -318.77 + 166.2^{\dagger}$
	Lower LoA	-232.1	$-0.11.\text{avg}—114.92^{\dagger}$	-73.5	$0.91.\text{avg} -318.77—166.2^{\dagger}$

Notes: ICC = intraclass correlation coefficient, CI = confidence interval, kcal = kilocalories, ECG = electrocardiography, bpm = beats per minute, SD = standard deviation, avg = average. Correlations r/Rho are Pearson's correlation coefficient (r) except where indicated by * where they are Spearman rank correlation coefficients (Rho) due to non-normally distributed data.

[†] Where Bland-Altman parameters were systematically biased (mean difference/limits of agreement), values are presented as linear equations rather than point estimates.
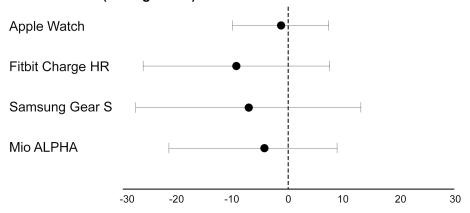
[^] Missing values (n = 3) due to a data recording error.

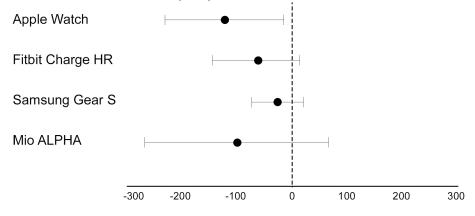# Accuracy of Heart Rate Watches: Implications for Weight Management

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A. HEART RATE (average BPM)

B. ENERGY EXPENDITURE (kcal)

Variable Accuracy of Wearable Heart Rate Monitors during Aerobic Exercise

STEPHEN GILLINOV, MUHAMMAD ETIWY, ROBERT WANG, GORDON BLACKBURN, DERMOT PHELAN,
A. MARC GILLINOV, PENNY HOUGHTALING, HODA JAVADIKASGARI, and MILIND Y. DESAI

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HR Monitors

All participants wore standard ECG leads (Mason-Likar electrode placement of torso-mounted limb leads), a Polar H7 chest strap monitor, and a Scosche Rhythm+ on the forearm. In addition, each participant was randomly assigned by a computer program to wear two different wrist-worn HR monitors, one on each wrist; this enabled the assessment of each type of wrist-worn monitor in 25 subjects. The wrist-worn monitors assessed included Fitbit Blaze (Fitbit), Apple Watch (Apple), Garmin Forerunner 235 (Garmin), and TomTom Spark Cardio (TomTom). Four units of each type of monitor were purchased from retail outlets and studied in random order. Each of these optically based wearable monitors measures HR via an optically obtained plethysmogram that is processed according to proprietary algorithms.

Confronti con un sistema di telemetria Quinton Q-tel RMS

Scosche

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- Treadmill
  - 2 mph for 1.5 min
  - 3.5 mph for 1.5 min
  - 6 mph for 1.5 min

- Stationary bicycle
  - 25 W for 1.5 min
  - 55 W for 1.5 min
  - 125 W for 1.5 min

- Elliptical (without arm levers)
  - Light for 1.5 min: crossramp $= 1$, resistance $= 1$, cadence $= 60$–70 min^{-1}
  - Moderate for 1.5 min: crossramp $= 1$, resistance $= 5$, cadence $= 90$–100 min^{-1}
  - Vigorous for 1.5 min: crossramp $= 10$, resistance $= 10$, cadence $= 90$–100 min^{-1}

- Elliptical (with arm levers)
  - Light for 1.5 min: crossramp $= 1$, resistance $= 1$, cadence $= 60$–70 min^{-1}
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TABLE 2. HR monitor differences from ECG according to activity.

| Activity | *n* | Device | HR (bpm) Differences from ECG | | | | | | Agreement |
| | | | Paired Relative Difference | | Paired Absolute Difference | | Absolute Percent (%) Difference | | |
			Mean	SD	Mean	SD	Mean	SD	r_c
Treadmill	150	Polar Chest Strap	0.4	3.1	1.2	2.9	1.1	2.4	0.99
	149	Scosche Rhythm+	−2.8	11.3	6.3	9.8	5.9	9.7	0.92
	71	Apple Watch	−1.7	9.6	5.6	8.0	4.9	6.7	0.93
	74	Fitbit	5.9	17.5	12.4	13.7	10.4	10.8	0.76
	74	Garmin	−0.3	11.2	7.3	8.5	6.1	7.0	0.92
	75	TomTom	1.4	13.3	7.2	11.2	6.2	9.5	0.88
Bike	150	Polar Chest Strap	0.1	1.9	0.6	1.8	0.6	1.6	0.99
	149	Scosche Rhythm+	3.9	12.6	5.5	11.9	4.8	8.8	0.84
	75	Apple Watch	3.1	10.2	4.6	9.6	4.1	7.8	0.88
	73	Fitbit	18.2	25.2	18.9	24.6	15.9	18.2	0.41
	75	Garmin	3.4	9.2	4.8	8.5	4.6	7.7	0.91
	75	TomTom	6.7	14.3	7.0	14.2	5.9	10.7	0.77

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Activity	n	Device	HR (bpm) Differences from ECG						Agreement r_c
			Paired Relative Difference		Paired Absolute Difference		Absolute Percent (%) Difference		
			Mean	SD	Mean	SD	Mean	SD	
Elliptical (no arms)	150	Polar Chest Strap	0.1	2.0	0.6	1.9	0.6	2.3	0.99
	150	Scosche Rhythm+	14.1	24.7	16.0	23.5	13.1	17.6	0.27
	74	Apple Watch	0.6	6.6	3.5	5.6	3.2	4.9	0.94
	74	Fitbit	10.0	15.9	11.6	14.8	9.8	11.5	0.58
	75	Garmin	7.7	18.1	11.0	16.2	9.7	13.6	0.54
	75	TomTom	7.3	19.4	8.0	19.1	6.4	13.4	0.55
Elliptical (with arms)	150	Polar Chest Strap	0.5	2.7	1.0	2.6	0.9	2.4	0.99
	150	Scosche Rhythm+	2.9	22.5	14.0	17.9	12.4	15.6	0.41
	72	Apple Watch	5.5	13.6	7.4	12.7	6.5	10.8	0.75
	75	Fitbit	2.1	20.2	13.8	14.9	11.7	12.1	0.48
	75	Garmin	2.2	23.3	14.8	18.0	13.7	16.8	0.31
	75	TomTom	1.4	14.0	8.0	11.6	6.7	9.6	0.76
Rest	200	Polar Chest Strap	−0.3	1.0	0.7	0.8	0.8	1.0	0.99
	200	Scosche Rhythm+	1.1	6.2	3.9	4.9	4.6	6.0	0.93
	100	Apple Watch	−0.4	4.2	3.0	3.0	3.5	3.4	0.96
	100	Fitbit	2.8	8.2	5.4	6.8	5.6	6.4	0.89
	100	Garmin	1.1	8.1	5.0	6.5	5.9	7.5	0.88
	100	TomTom	1.3	5.6	3.8	4.2	4.5	5.3	0.94

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