Positional accuracy of six portable GPS receivers

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* Satellite-based navigation system
* Can be used to monitor location over multiple days
* Often combined with accelerometer
* Increasingly portable and cheap standalone units

Introducing GPS

Portable Global Positioning Units to Complement Accelerometry-Based Physical Activity Monitors

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ABSTRACT

RODRÍGUEZ, D. A., A. L. BROWN, and P. J. TROPED. Portable Global Positioning Units to Complement Accelerometry-Based Physical Activity Monitors. *Med. Sci. Sports Exerc.*, Vol. 37, No. 11(Suppl), pp. S572–S581, 2005. **Purpose:** This study examines the usefulness of complementing accelerometry-based physical activity measurement with spatial data from portable global positioning system (GPS) units to determine where physical activity occurs. **Methods:** First, using the geographic distribution of data points and Bland–Altman plots, we examined GPS units' validity and interunit reliability by measuring the distance to a geodetic point. We also assessed interunit reliability by comparing GPS data collected in three built environment contexts. Second, we conducted a pilot study in which 35 participants wore GPS units and accelerometers in free-living conditions for 3 d. Moderate and vigorous physical activity (MVPA) bouts were matched to GPS data. We classified each bout as occurring inside or outside the participant's home neighborhood. Using unpaired *t*-tests and Fisher's exact tests, we compared neighborhood attributes for participants having the majority of MVPA bouts within their home neighborhood, relative to those with most bouts away from their home neighborhood. **Results:** Average distance from each unit to the geodetic point was 3.02 m (SD 2.51). Average bias among units using Bland–Altman plots was 0.90 m, ranging from −0.22 to 1.86 m, within the limits of agreement. For interunit reliability in the built environment contexts, the mean distance difference among units ranged between 10.7 m (SD 11.9) and 20.1 m (SD 21.8). For the pilot study involving participants, GPS data were available for 59.3% of all bouts (67% of MVPA time), of which 46% were in the participants' neighborhood. Participants obtaining most of their MVPA in their neighborhoods tend to live in areas with higher population density, housing unit density, street connectivity, and more public parks. **Conclusion:** Data recorded by portable GPS units is sufficiently precise to track participants' movements. Successful matching of activity monitor and locational data suggests GPS is a promising tool for complementing accelerometry-based physical activity measures. Our pilot analysis shows evidence that the relationship between environment and activity can be clarified by examining where physical activity occurs. **Key Words:** PHYSICAL ACTIVITY, GLOBAL POSITIONING SYSTEM, ACCELEROMETER, BUILT ENVIRONMENT, GEOGRAPHICAL INFORMATION SYSTEMS

Emerging theoretical models aimed at understanding the role of neighborhood contextual factors as barriers or supporters for physical activity have shown promise in explaining individual behavior (14,25). An expanded set of factors hypothesized to influence physical activity behavior, such as social, social-environmental, and physical environmental factors, are now being studied with the aim of identifying relationships and testing potential interventions.

Through its relevance as a social-environmental factor or community-level factor, the built environment has emerged as an area of interest to promote physical activity. Prevailing development patterns, with separated residential and commercial land uses, increased reliance on automobile travel, and a lack of adequate infrastructure to support bicycling and walking, may act as barriers or inhibitors to physical activity (20). Indeed, built environment interventions may be one of the most effective strategies for improving physical activity and weight status (5,21). Despite finding moderately positive relationships between environmental factors and physical activity behavior among adults, recent reviews also have identified a considerable number of studies showing no statistical association (8,11,15).

Several explanations for discrepancies among the findings of recent research are likely. First, physical activity is measured and analyzed in different ways. Similarly, objective environmental measures are often disparate, limiting comparability and the ability to replicate results across studies (11,19). Second, the environments examined tend to be limited to the vicinity of participants' place of residence even though individuals may be physically active at other locations. A third explanation is that, faced with an intervention that removes physical activity barriers, some individuals may shift the locations where their physical activity occurs, from elsewhere to the environment with lowered barriers. The latter may explain why recent studies evaluating trail interventions have shown increased trail use but no changes in total physical activity (1,12).

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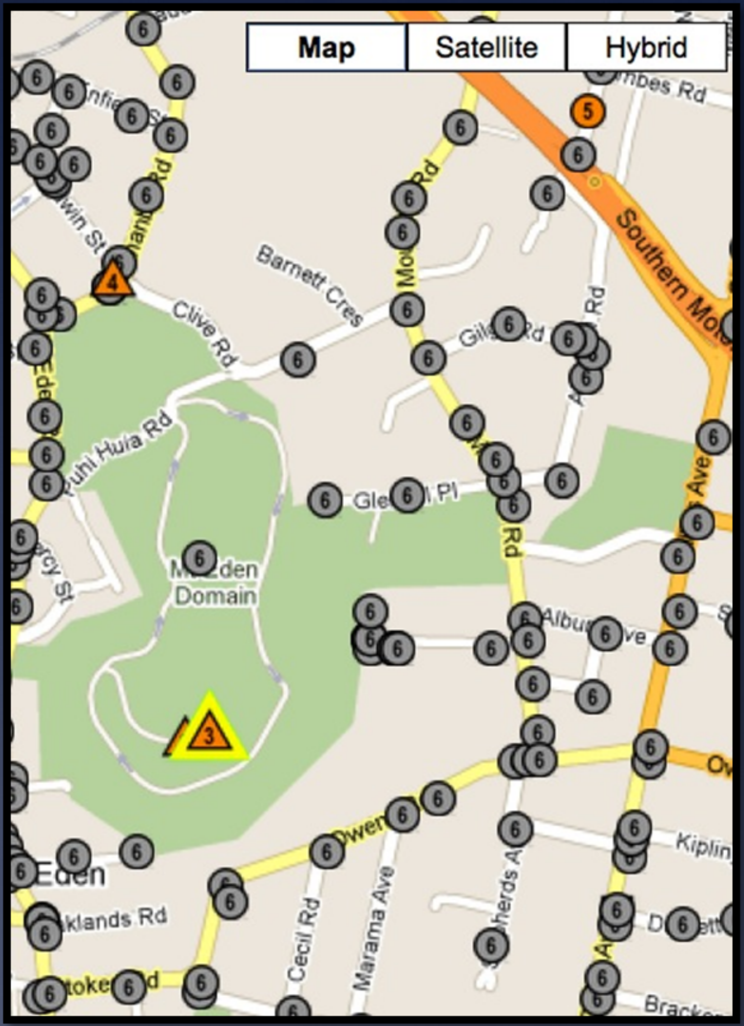
- Tested accuracy of Garmin Foretrex 201
- Static tests placed GPS units on geodetic points
- Mean distance from units to geodetic point was 3.02 m (SD 2.51)
- 81.1% of observations within 5 m and 99.4% within 15 m

Rodriguez et al, MSSE, 37:S572, 2005

- Expand on previous work
  - More GPS units
  - More geodetic points
  - Variety of environmental conditions
- Eight GPS models initially selected
  - Three units for each model
- Tested for battery life and signal acquisition times
- Units placed on geodetic points for 60 min, collecting data in 1 sec epochs



Our idea...

- Price: US$65
- Size: 76 x 46 x 20 mm
- Connection: USB
- Advertised accuracy: 7 m (90%)
- Recording intervals: 1 s to 30 min
- Data storage: 4-16 MB (optional)
- Advertised battery life: 22 h
- Advertised acquisition time: Hot = 3-6 s, warm = 38 s, cold = 42 s
- Key features: Voice feedback, auto on/off function

StarsNav BTS-110 (Taiwan)

- Price: US$200
- Size: 95 x 55 x 15 mm
- Connection: Bluetooth (to computer or mobile phone)
- Advertised accuracy: 3 m
- Recording intervals: 1-6 s
- Data storage: 16 MB
- Advertised battery life: 12 h
- Advertised acquisition time: Information not available
- Key features: Shockproof and splash waterproof, armband and back satchel available

FRWD B100 (Finland)

* Price: US$100
* Size: 51 x 112 x 30 mm
* Connection: Serial
* Advertised accuracy: < 15 m (95%)
* Recording intervals: 1 s, continuous
* Data storage: 10,000 points, 10 tracks
* Advertised battery life: 22 h
* Advertised acquisition time: Warm = 15 s, cold = 45 s
* Key features: DGPS (WAAS/EGNOS) capable (<3 m accuracy), waterproof

Garmin eTrex (USA)

* Price: US$182
* Size: 84 x 43 x 18 mm
* Connection: Serial
* Advertised accuracy: < 15 m (95%)
* Recording intervals: 1 s, continuous
* Data storage: 10,000 points, 10 tracks
* Advertised battery life: 15 h
* Advertised acquisition time: Warm = 15 s, cold = 45 s
* Key features: DGPS (WAAS) capable (<3 m accuracy), waterproof

Garmin Foretrex 201 (USA)

- Price: US$150
- Size: 53 x 69 x 18 mm
- Connection: USB
- Advertised accuracy: < 10 m (50%)
- Recording interval: 1 s
- Data storage: 50 tracks, 100 waypoints
- Advertised battery life: 10 h
- Advertised acquisition time: Hot < 1 s, warm = 38 s, cold < 45 s
- Key features: Waterproof

Garmin Forerunner 205 (USA)

- Price: US$200
- Size: 79 x 42 x 18 mm
- Connection: Cellular network, USB
- Advertised accuracy: 10 m (3 m DGPS)
- Recording intervals: 1 s to 18 h
- Data storage: 150,000 points
- Advertised battery life: 12-290 h (depending on interval)
- Advertised acquisition time: Hot = 1 s, warm = 33 s, cold = 36 s
- Key features: Voice monitoring, cellular transmission, waterproof, DGPS (WAAS, EGNOS)

GlobalSat TR-203 (Taiwan)

- Price: US$100
- Size: 72 x 47 x 20 mm
- Connection: USB, bluetooth
- Advertised accuracy: 3 m (50%)
- Recording intervals: 1 s
- Data storage: 200,000 points
- Advertised battery life: 42 h
- Advertised acquisition time: Hot = 1 s, warm = 33 s, cold = 35 s
- Key features: Auto on/off function, DGPS (WAAS, EGNOS)

QStarz BT-Q1000X (Taiwan)

* Price: US$149
* Size: 114 x 32 x 19 mm
* Connection: USB
* Location accuracy: 2.5 m
* Recording intervals: 5 s, 1-15 min
* Data storage: 1 MB
* Battery life: Power save mode = 1 week, full mode = 36 h
* Acquisition time: Hot = 9 s, warm = 37 s, cold = 52 s
* Key features: Weatherproof case, detachable belt clip, direct integration with Google Earth

Telespial Trackstick II (USA)

Model	Advertised Battery Life	Observed Battery Life	% Difference
Garmin Forerunner 205	10 h	15.2 h	↑ 52%
Garmin eTrex	22 h	26.8 h	↑ 22%
GlobalSat TR-203	84 h	87.5 h	↑ 4%
Garmin Foretrex 201	15 h	14.2 h	↓ 5%
QStarz BT-Q1000X	42 h	39.8 h	↓ 5%
FRWD B100	12 h	10.6 h	↓ 12%
Telespial Trackstick II	36 h	23.2 h	↓ 36%

And the winner is...

Model	Advertised Acquisition Time	Observed Acquisition Time	% Difference
QStarz BT-Q1000X	35 s	34.0 s	↓ 3%
Garmin Forerunner 205	45 s	51.5 s	↑ 14%
Garmin Foretrex 201	45 s	57.4 s	↑ 28%
GlobalSat TR-203	36 s	59.4 s	↑ 65%
Telespial Trackstick II	52 s	136.3 s	↑ 162%
FRWD B100	-	41.7 s	-
Garmin eTrex	-	43.1 s	-

And the winner is…

Geodetic Point 1: Summit of volcano (unobstructed)

Geodetic Point 1: Summit of volcano (unobstructed)

Geodetic Point 2: Summit of volcano (under beacon)

Geodetic Point 2: Summit of volcano (under beacon)

Geodetic Point 3: Residential

Geodetic Point 3: Residential

Geodetic Point 4: Mixed use

Geodetic Point 4: Mixed use

Geodetic Point 5: Under canopy

Geodetic Point 5: Under canopy

Geodetic Point 6: Urban canyon

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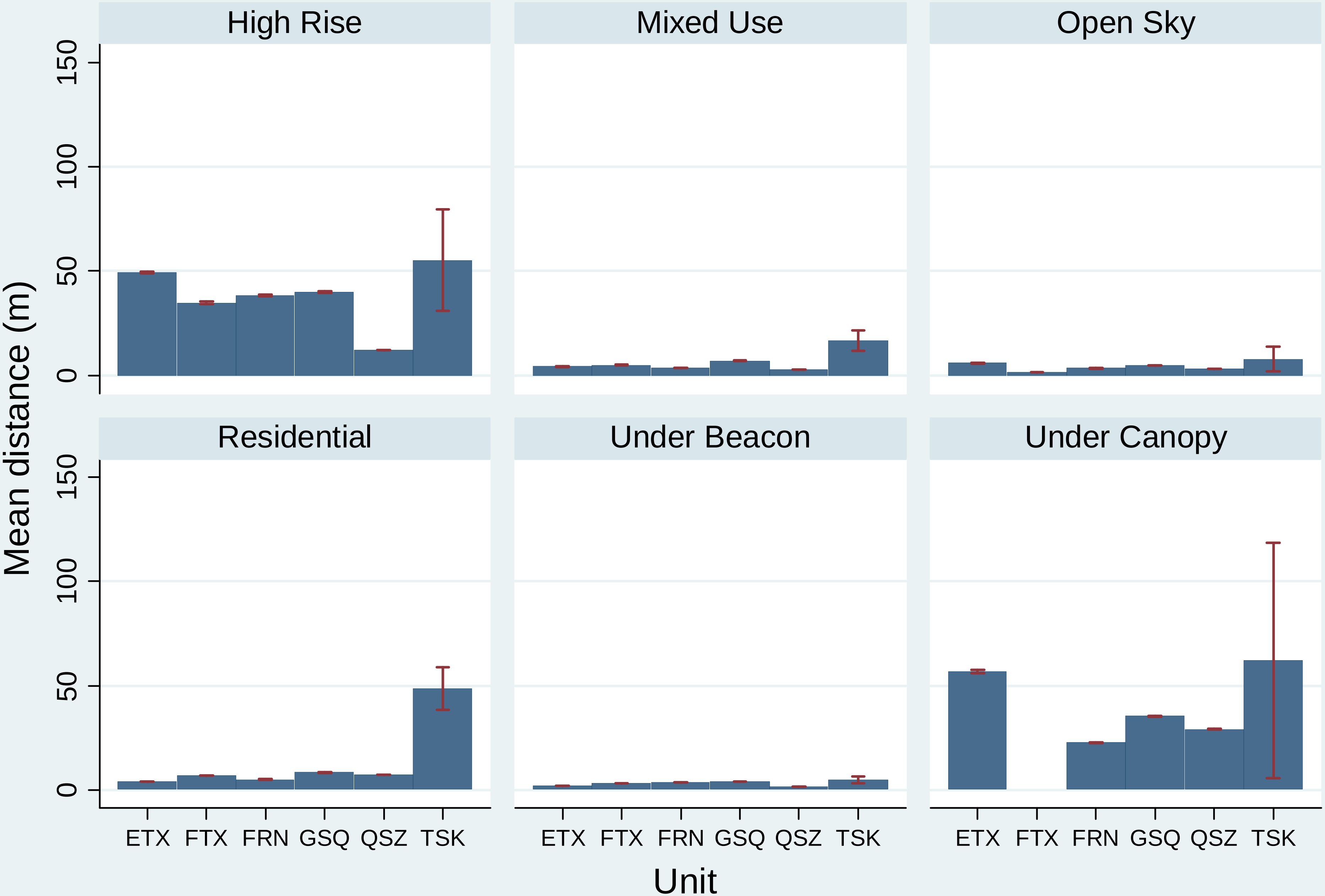
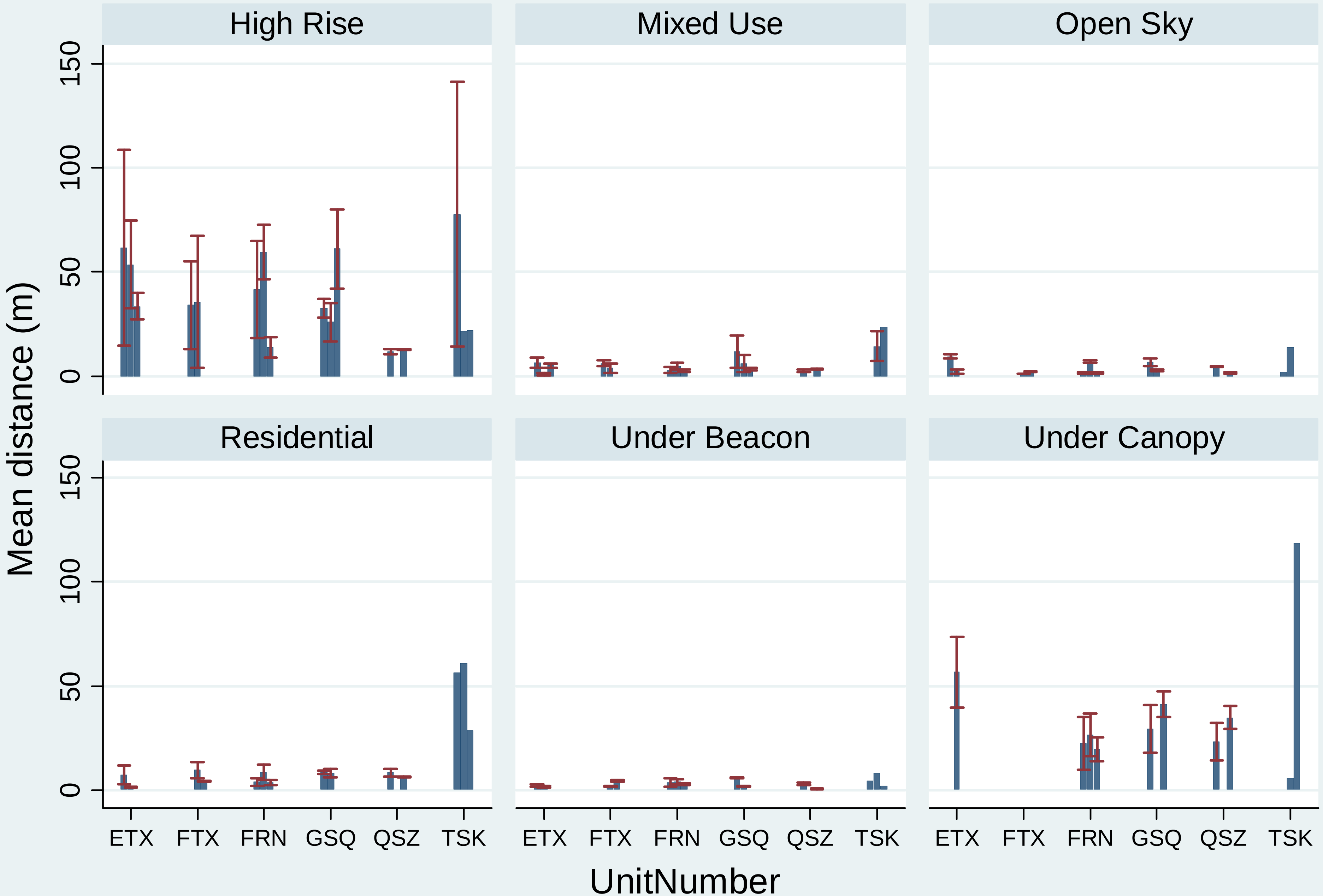
Geodetic Point 6: Urban canyon

GPS Model	N Obs	Mean	SD	Min	Max
Garmin eTrex	21977	17 m	27 m	< 1 m	256 m
Garmin Foretrex 201	17975	10 m	20 m	< 1 m	452 m
Garmin Forerunner 205	31614	13 m	18 m	0 m	121 m
GlobalSat TR-203	25215	18 m	20 m	< 1 m	175 m
QStarz BT-Q1000X	21600	9 m	11 m	< 1 m	67 m
Telespial Trackstick	19	34 m	40 m	2 m	139 m

Mean distance to geodetic points



Mean distance by unit and geodetic point



Mean distance for individual units

GPS Model	ICC	Min	Max
Garmin eTrex	0.540	0.164	0.935
Garmin Foretrex 201	0.476	0.121	0.895
Garmin Forerunner 205	0.415	0.074	0.943
GlobalSat TR-203	0.502	0.024	0.996
QStarz BT-Q1000X	0.644	0.398	0.954

Interunit reliability

Take home points

1. Advertised battery life and acquisition time of current GPS units is usually inaccurate
2. Most GPS units are accurate to within metres in unobstructed conditions and within 100s of metres in urban canyons and under canopies
3. Interunit reliability is high when unobstructed but low in obstructed conditions
4. Accuracy under dynamic conditions may be different

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The GLOBAL POSITIONING SYSTEMS in Health Research Network

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WELCOME to the GPS-HRN

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The Global Positioning Systems in Health Research Network is an international collaboration of academics and health professionals interested in GPS technology. This website is an online meeting place for members to share ideas and experiences relating to their work with GPS. GPS-HRN membership is by application only. To apply, please follow the link at the top right of this page.

Background to the GPS-HRN

Who are we?

The Global Positioning Systems in Health Research Network was launched at the 2009 International Society for Behavioural Nutrition and Physical Activity Conference in Cascais.

The aim of the GPS-HRN is to establish a communication forum that will allow GPS researchers to share ideas and experience.

The GPS-HRN administration team is based out of AUT University in New Zealand, UCL in the UK, and the University of Lausanne in Switzerland.

Lead Coordinator: Dr Scott Duncan (AUT University)
Asst Coordinator: Dr Hannah Badland (University College London)
Asst Coordinator: Dr Melody Oliver (AUT University)
Chair: Prof Yves Shutz (University of Lausanne)

The GPS-HRN is currently sponsored by AUT University; however, we will be pursuing further funding for the ongoing maintenance of the network.

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