

## The comparison of Holux and Qstarz GPS receivers in free living conditions: Dynamic accuracy in different active transport modes

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**Background:** Physical activity (PA) is one of the major factors influencing human health. An important group of determinants are elements forming the built environment. For a proper understanding of relationships between the built environment and PA, we need to measure PA in space. **Objective:** This study aims to verify the accuracy of the Holux RCV-3000 GPS logger, which has not yet been validated in relation with PA. **Methods:** Two GPS receivers (Holux RCV-3000 and already validated Qstarz BT-Q1000XT) were tested during walking, running and cycling. A total of 1,908 GPS points were recorded by each device. For each trip, we calculated the percentage of points that fell within 1, 2.5, 5, and 10 m buffers, as well as the mean and median error. **Results:** Our results showed that 53.1% of all Holux and 45.1% of Qstarz GPS points fell within 2.5 m of the expected location, 90% (Holux) and 80% (Qstarz) fell within 10 m and the median error was 2.33 m and 3.15 m, respectively. **Conclusions:** The dynamic spatial accuracy of the tested Holux RCV-3000 was better than more expensive Qstarz device and can be considered as a valid instrument for assessing the spatial location of PA in future work.

**Keywords:** Global Positioning System, travel mode, validation study, dynamic accuracy, Holux RCV-3000

### Introduction

Physical activity (PA) plays an important role in the physical and mental health of youth (Bouchard, Blair, & Haskell, 2012; Janssen & LeBlanc, 2010; Reiner, Niermann, Jekauc, & Woll, 2013). Lack of PA is associated with numerous health problems and complications (Janssen & LeBlanc, 2010; World Health Organization, 2010) and its worldwide decline is well documented (Hallal et al., 2012; Knuth & Hallal, 2009). The ecological model of health behavior suggests that environmental and policy variables are determinants of PA and behavior change (Sallis & Owen, 2015). The built environment has been identified in many studies across the globe as a significant factor influencing PA (Sallis et al., 2016).

Objectively monitoring PA behavior using accelerometers is common (Cain, Sallis, Conway, Van Dyck,

& Calhoun, 2013; Hills, Mokhtar, & Byrne, 2014; Van Hoya, Nicaise, & Sarrazin, 2014), but accelerometers alone are unable to link PA to specific environments. For that reason, recent studies have concurrently assessed spatial location (McCrorie, Fenton, & Ellaway, 2014) using Global Navigation Satellite System (GNSS) – most commonly using Global Positioning System (GPS) devices. These record time-stamped position and can accurately show the route and the speed of a person (James et al., 2016). Novel approaches to process and combine these data with geographic information systems (GIS) allow for spatial analysis and visualization of PA within specific environments (Demant Klinker, Schipperijn, Toftager, Kerr, & Troelsen, 2015). However, using GPS devices also presents several issues, such as differences in accuracy and precision for different devices, unstable signal acquisition in more dense urban areas, and difficulties with data processing (Meseck et al., 2016; Shen & Stopher, 2014).

When using GPS devices in scientific research, it is important to have knowledge on the accuracy and precision of the data obtained. Early work tested devices in a static position (i.e., not moving), where the spatial

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inaccuracy ranged from 1.5 to 10 m (Townshend, Worringham, & Stewart, 2008). A more significant measurement error (40–50 m) occurred in an environment where the signal between the satellites and the instrument was obstructed (Duncan et al., 2013). This obstruction can be caused by so-called urban canyons – high-rise buildings on both sides of the street. Another study (Rodriguez, Brown, & Troped, 2005) determined a spatial inaccuracy of  $0.90 \pm 0.74$  m in conditions without signal obstruction. Wu et al. (2010) tested the dynamic accuracy (when the device is moving) of five GPS receivers (GlobalSat DG-100 and BT-335, Wintec WBT-201, Visiontac VGPS-900, Qstarz BT-Q1000X) and found that most of the GPS devices performed well on unobstructed freeways, but the performance was significantly reduced in highly urbanized areas.

The availability of GPS devices suitable for research is constantly changing and the cost per device is another important factor for researchers, especially for larger studies. One of the newer devices on the market, the Holux RCV-3000, is cheaper (70 USD) than the typical price of the frequently used Qstarz BT-Q1000XT (100 USD). The accuracy of the Holux RCV-3000 GPS logger is rated as  $\pm 3$  m by the manufacturer. The technical parameters, a low-energy 66 channel MTK chipset and sensitivity up to  $-165$  dBm, coincide with the Qstarz BT-Q1000XT, which is widely used among international researchers for measuring the location of PA (Andersen et al., 2017; Carlson et al., 2015; Pizarro et al., 2017; Schipperijn et al., 2014; Stewart, Schipperijn, Snizek, & Duncan, 2017). This is because the static accuracy (Duncan et al., 2013) and dynamic accuracy (Schipperijn et al., 2014) of this device have been successfully tested. The median dynamic positional error was 2.9 m and 78.7% of all recorded GPS points fell within 10 m of the true location (Schipperijn et al., 2014). However, the dynamic accuracy of the cheaper Holux has not been tested nor compared to the widely used Qstarz device.

The aim of this study was to assess the dynamic accuracy of the Holux RCV-3000 GPS device for recording spatial location under three different transportation modes (walking, running, and cycling), and compare it to the Qstarz BT-Q1000XT.

## Methods

### Procedures

Testing of the two GPS devices (worn at the same time inside the top pocket of a backpack) took place between September and November 2017 in Denmark and the research was approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University

Olomouc (2/2018). A 2-km long route (Figure 1) which included various types of environment (open, half-open, covered streets) was purposefully selected. A total of 30 trips (10 walking trips (5 km/h), 10 running trips (10 km/h) and 10 cycling trips (17 km/h)) were undertaken by one researcher along this route, following the centerline of the sidewalk or bike lane on one side of the street. The measurements were deliberately carried out under different atmospheric conditions (clear sky, cloudy, rain) and at different times of the day.

### GPS receivers

Two GPS devices were used for logging positional information (latitude and longitude) every 15 s. In total, 1,908 GPS points were collected by each GPS device. The Holux RCV-3000 (Holux Technology, Hsinchu, Taiwan) uses the highly sensitive MediaTek MT3329 chipset, which has 66 channels and is WAAS/EGNOS enabled. The size is  $62.5 \times 41 \times 17.1$  mm and weight is 53 g. The battery life is up to 28 hours in logging mode. The device was initialized using the Holux ezTour software (Version 2.3; Holux Technology, Hsinchu, Taiwan).

The Qstarz BT-Q1000XT (Qstarz International, Taipei, Taiwan) was treated as the reference device because it is widely used in the field and has shown high dynamic accuracy in varying environmental conditions and transportation modes (Schipperijn et al., 2014). This device was initialized using the QTravel software (Qstarz International Taipei, Taiwan).

### GIS analysis

Polygons for sidewalks, bike lanes and streets were digitized in ArcGIS (Version 10.5; Esri, Redlands, CA, USA) as accurately as possible based on high resolution (15 cm) aerial photos available from the Danish Geodata Agency. These polygons were then transformed to lines (function “polygon to lines”) and collapsed to one centerline (“collapse dual lines to centerline”). A one-meter buffer around the centerline was created to delineate the base lane polygon. Finally, three distance buffers (at 2.5, 5, and 10 m respectively) around the base lane polygon were created (Figure 2). For each transportation mode (walking, running, cycling) we calculated the proportion of GPS points that fell within the base lane polygon, and within the 2.5-, 5-, and 10-m buffers, respectively. For each GPS point, the distance from the edge of the base lane polygon was also calculated.

### Statistical analysis

To compare the two GPS devices, differences between proportions of points in each of the buffers were calculated using the “ $N-1$ ” Chi-squared test recommended by Campbell (2007). Differences between distances of GPS points from the edge of the base lane polygon



Figure 1. GPS points from Holux device projected on the aerial photo of Odense (Denmark).

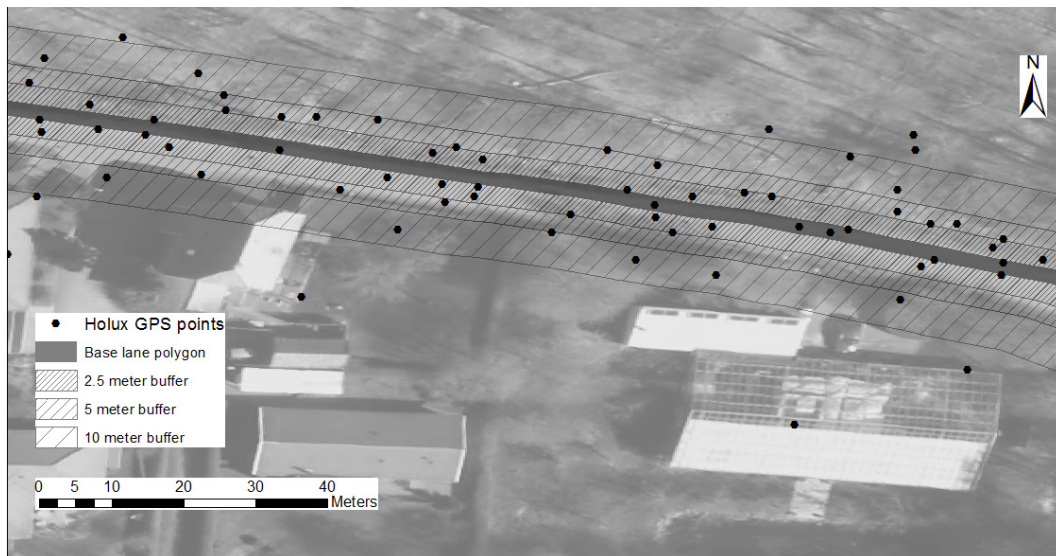


Figure 2. Buffers and Holux GPS points projected on the aerial photo of Odense (Denmark).

were calculated using a Mann-Whitney  $U$  test. All statistical analyses were performed using the software IBM SPSS (Version 22; IBM, Armonk, NY, USA) with  $\alpha \leq .05$ .

## Results

### Holux RCV-3000

Table 1 shows the number and share of GPS points from each device that fell within each of the four polygons, for the three different transportation modes. For walking and running, 14% of the GPS points were within the base lane polygon. For cycling, 20.1% of

GPS points were within the base lane polygon. For all travel modes, about half of all recorded GPS points were located within 2.5 m from the base lane polygon (51.5% walking, 44.6% running, and 63.3% cycling). The proportion of points that fell within the 10-m buffer around the base lane polygon was 91.5% for walking, 88.3% for running, and 92.2% for cycling.

### Qstarz BT-Q1000XT

The results for the Qstarz were similar across the three modes of transportation. The base lane polygon contained 15.7% of measured points (16.3% for walking, and 15.4% for running and cycling). The 2.5- and 5-m buffers contained 45.1% and 64.4% of all logged GPS



Table 2  
Mean and median distance of GPS points from the edge of the base lane polygon in metres

Mode of transport	Holux		Qstarz		Z	p
	Mean $\pm$ SD	Median (IQR)	Mean $\pm$ SD	Median (IQR)		
Walking	3.95 $\pm$ 4.77	2.33 (4.92)	6.43 $\pm$ 9.95	3.22 (6.72)	3.44	.001
Running	4.26 $\pm$ 4.46	2.92 (5.60)	6.68 $\pm$ 11.01	3.21 (6.83)	1.15	.249
Cycling	3.24 $\pm$ 5.03	1.55 (3.53)	8.60 $\pm$ 13.87	2.98 (7.33)	5.08	< .001
All	3.92 $\pm$ 4.74	2.33 (4.93)	6.86 $\pm$ 11.02	3.15 (6.85)	5.28	< .001

Note. IQR = interquartile range; Z = standardized score of Mann-Whitney U test.

base polygon. However, within the 2.5-m buffer, Schipperijn et al. (2014) observed 40% (walking) and 55.1% (cycling) of all GPS points, while we observed 51.5% (walking) and 63.3% (cycling) using the Holux. Inside the 10 m buffer, Schipperijn et al. (2014) measured 73.5% and 86.8% of points for walking and cycling, respectively. Our Holux results show 91.5% (walking) and 92.2% (cycling) within this buffer. Overall, Schipperijn et al. (2014) reported a median error of 3.9 m for walking and 2.0 m for cycling. Our results from the Holux show a median error 2.33 m for walking and 1.55 m for cycling.

It is unclear why the Holux performed better than the Qstarz in our study. Both devices are based on same low-energy 66 channel MTK chipset with a sensitivity of up to -165 dBm. Both devices have a L1 (1575.42 MHz) receiver with C/A code (1.023 million bits per second) and the same accuracy < 3 m CEP (circular error probability) without SA (intentional degradation of public GPS signals implemented for national security reasons), and WAAS/EGNOS is supported. Both devices have an LED (indicates different statuses) and a built-in antenna. However, other specifications differ between devices: the Qstarz has longer battery life (up to 42 hours compared to 28 hours), the best on the market among other GPS devices (Wu et al., 2010), and higher memory capacity (up to 400,000 points compared to 250,000 points). On the other hand, the Holux GPS logger is slightly smaller and lighter, and is also less expensive.

Despite these promising findings, our study had several limitations. Firstly, despite comparing 30 individual trips across three travel modes, our study sample included only one participant. It is possible that different individuals may walk, cycle or run differently (e.g., intermittent speeds), which may affect device accuracy. Secondly, we tested only two GPS receivers (one of each model), so we were unable to determine the intra-model reliability of devices. Lastly, our testing route did not contain all possible environmental conditions (i.e., no urban canyons) which will likely impact results.

## Conclusions

Our results show that more than half (51.5%) of all GPS points recorded by the Holux RCV-3000 GPS device were recorded within 2.5 m of the true position, and 90.7% of all GPS points were located within 10 m. The median error was 2.33 m. The Holux device performed better than the Qstarz BT-Q1000XT GPS device we used for comparison. Given the dynamic spatial accuracy of the Holux RCV-3000 demonstrated in this study, coupled with the low purchase price, this device can be considered as a valid instrument for assessing the spatial location of physical activity in future work.

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## Conflict of interest

There were no conflicts of interest.

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