Analysis of the pre-Olympic test competition: the 2015 Rio de Janeiro ITU World Paratriathlon Event

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Introduction

In preparation for paratriathlon's debut next summer at the 2016 Rio de Janeiro Paralympic Games, in August 2015 it was offered to paratriathletes the opportunity of a competitive analysis of next year's original Olympic course. The pre-Olympic test competition was organized as a World Paratriathlon Event (WPE) race: the paratriathlon sport classes have been contested at the Rio de Janeiro WPE held on Saturday, August 1, 2015. Only selected sport classes will be conducted at the 2016 Paralympic Games, which will be men's PT1, PT2 and PT4 and women's PT2, PT4 and PT5. For the Italian Paratriathlon team, the athlete Giovanni Achenza competed in the men's PT1 class and the athlete Giorgio Vanerio competed in the men's PT2 class. The results of the analysis of the pre-Olympic test event are designed to provide to the Italian Paratriathlon team an aid in the training process in preparation for the Paralympic Games in Rio de Janeiro in 2016.

Characteristics of the race course

Swim

The swim course of the Paralympic competition comprises one single lap anti-clockwise of 750 meters in the open waters of the sea close to Fort Copacabana. The top view of the swim course shown by Google Earth is illustrated in Figure 1.

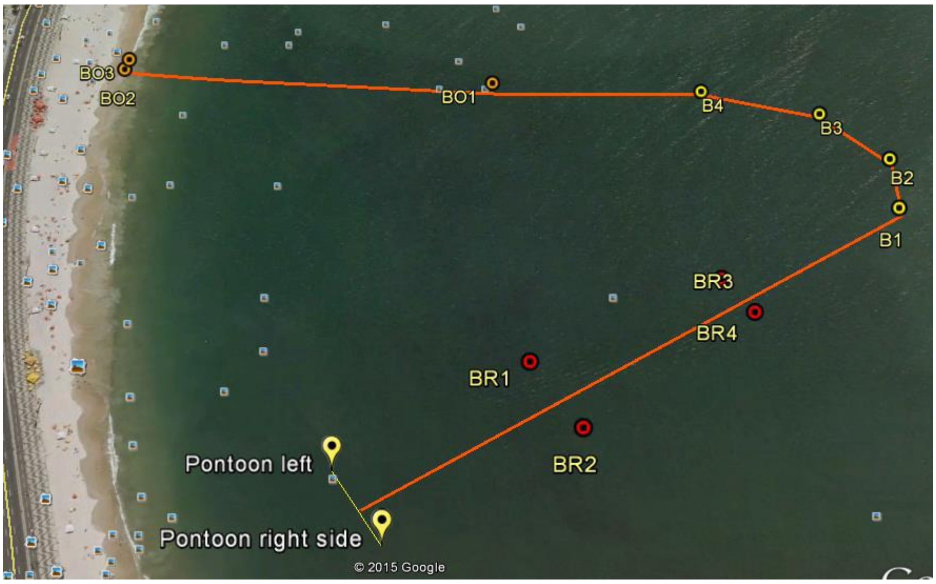

Figure 1: the swim course of the 2015 Rio de Janeiro WPE in Google Earth

Swim start

The swim start is given is in deep water, at a distance of 10 meters from a floating pontoon. Athletes are transferred to the start pontoon by boats. Athletes are allowed to swim to the start pontoon if they wish, but only through a designated swim lane. The location of the embarkation point respect to the start pontoon is highlighted in Figure 2. Tents are available on the start pontoon. Medical and swim exit handlers are located on the start pontoon as well. The location of start line and tents on the pontoon is illustrated in Figure 3. The allowed equipment for the swim course is a wetsuits up to 5mm thickness.

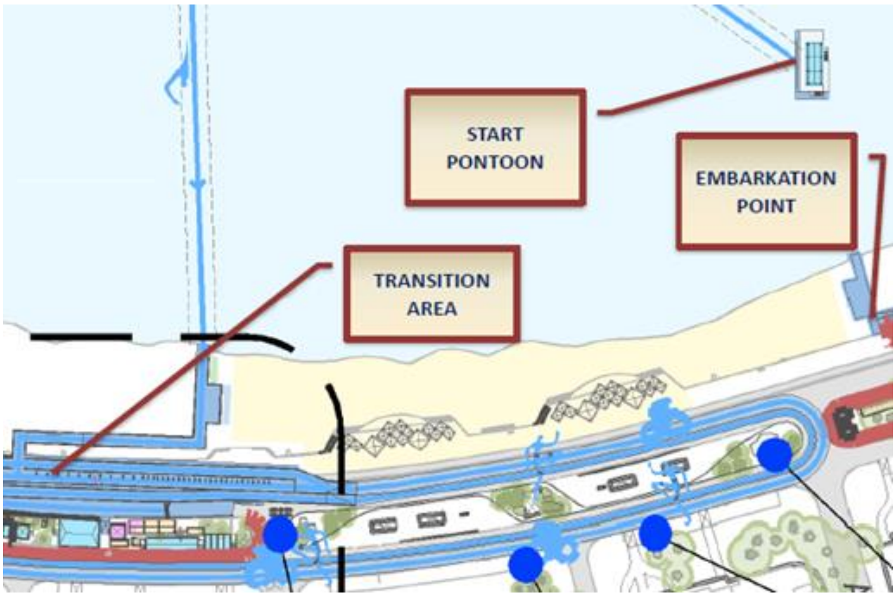

Figure 2: location of embarkation point and start pontoon (source: Aquece Rio)

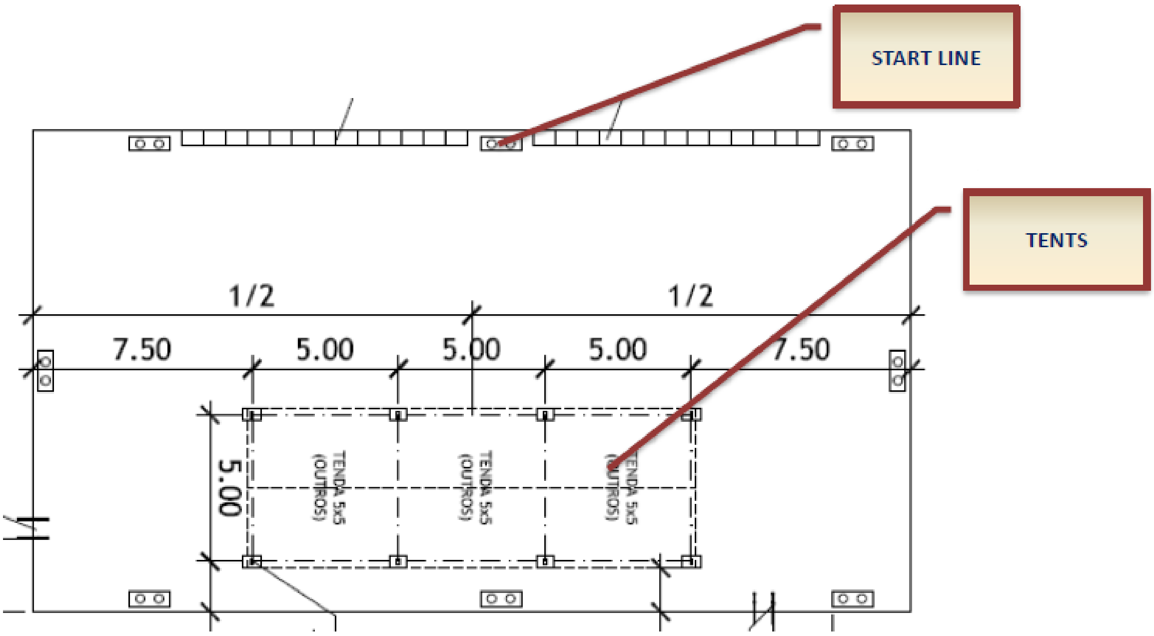

Figure 3: location of start line and tents on the pontoon (source: Aquece Rio)

Swim course

A shown in Figure 1, the swim course is one single lap with total distance of 750 meters, anti-clockwise. After two gates delimitated by a couple of red buoys (BR1, BR2, BR3 and BR4), the first yellow turn buoy (B1) is located 350 meters far from the start pontoon. The yellow buoys B1, B2, B3, B4 must be passed on left shoulder and the orange buoy BO1 on right shoulder. The last couple of orange buoys BO2 and BO3 are the exit gate.

The swim course can be divided into 3 main segments:

1. the 1st segment is 350 meters long and goes from the start pontoon to the first yellow turn buoy B1, with an average direction pointing towards the north-east (NE)
2. the 2nd segment is 50 meters long and goes from the first yellow buoy B1 to the last yellow buoy B4, with an average direction pointing towards the north-west (NW)
3. the 3rd segment is 350 meters long and goes from the last yellow buoy B4 to the exit gate, with an average direction pointing towards the west (W)

The way back (2nd and 3rd segments) is longer than the way forward (1st segment). Each swim segment can be positively or negatively affected by external factors such as tides, waves, wind and water flows. Knowing these environmental variables at the day and time of the race is important in order to foresee their effects on the athletes' swim performance. These factors are of particular interest for triathletes because Rio de Janeiro is also well known as a surfing location, and Copacabana beach is popular with surfers as well. During the winter season the winds are at their strongest and the waves are at their wildest, while the 2016 Olympic Games will be held in summer. The waves can generally range from as small as 1 meter to as high as 3 meters.

There are several online services that offer complete information on the environmental variables which are interesting to be monitored for time of the race. The following are three examples of online weather monitoring services:

- **WindFinder** (website www.windfinder.com/forecast/copacabana_rio_de_janeiro). For the wind, it provides direction, speed and gusts. For waves, it provides direction, height and period.
- **Tide-Forecast** (website www.tide-forecast.com/locations/Rio-de-Janeiro-Brazil/tides/latest). For the tide, it provides data on high and low tides (time of day and height).
- **Surfline** is a popular site for surfers (website www.surfline.com/surf-report/copacabana-southeast-brazil_7013/). It is very complete, containing all the data for the wind, waves and tides, as well as temperature of air and water and the webcam on the Copacabana beach.

Swim exit

Swim exit and pre-transition area are shown in Figure 4 and Figure 5. Swim exit handling can be performed only by the local handlers, who will provide support to all athletes according to their swim cap color. No personal handlers are allowed to assist athletes at swim exit.

In the pre-transition area all the athletes' registered equipment such as prosthesis, crutches and day chairs are located. Folding chairs are provided for wetsuit removal. Only PT1 handlers are allowed in this area. Personal handlers are allowed to push their athletes on the following ramp.

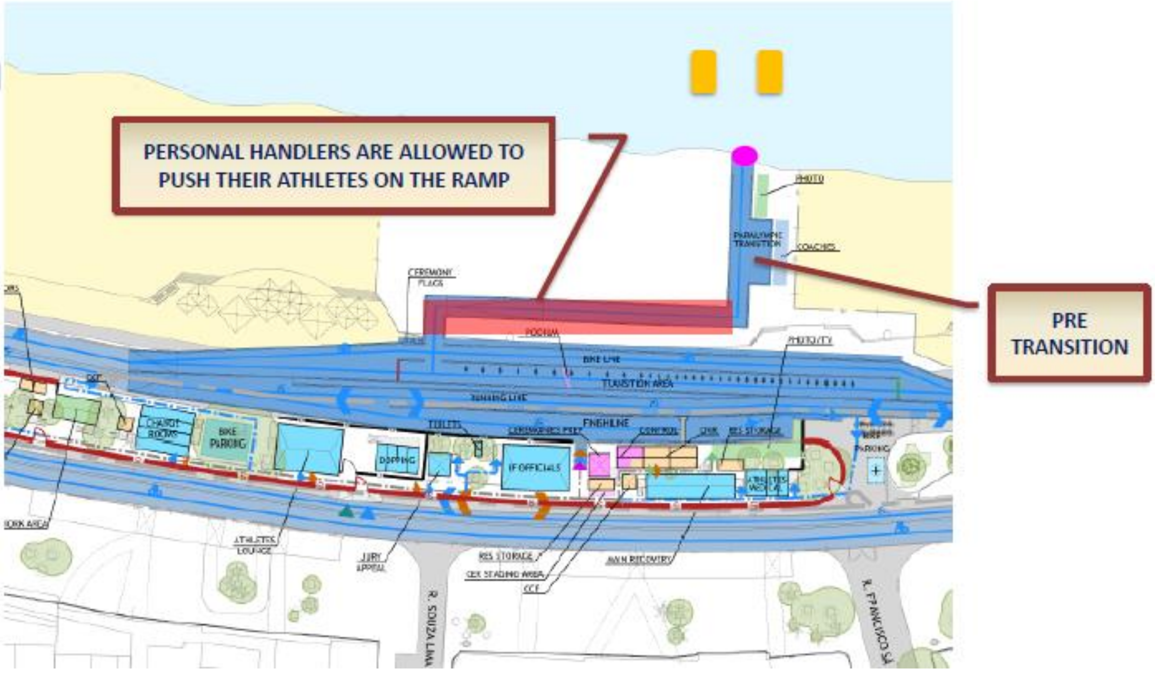

Figure 4: pre-transition area and ramp to the transition zone (source: Aquece Rio)

Figure 5: swim exit and pre-transition area with registered equipment. Photo: Simone Biava

Transition 1 to bike course

The map of the transition area is shown in Figure 6. In the transition area individual bike racks are set, with athletes' name, number, country code and flag. The transition area, as well as the start/finish area, is covered by a blue carpet. The transition area is shown in Figure 7. The bike mount line is set at the end of the transition area, indicated by a green line.

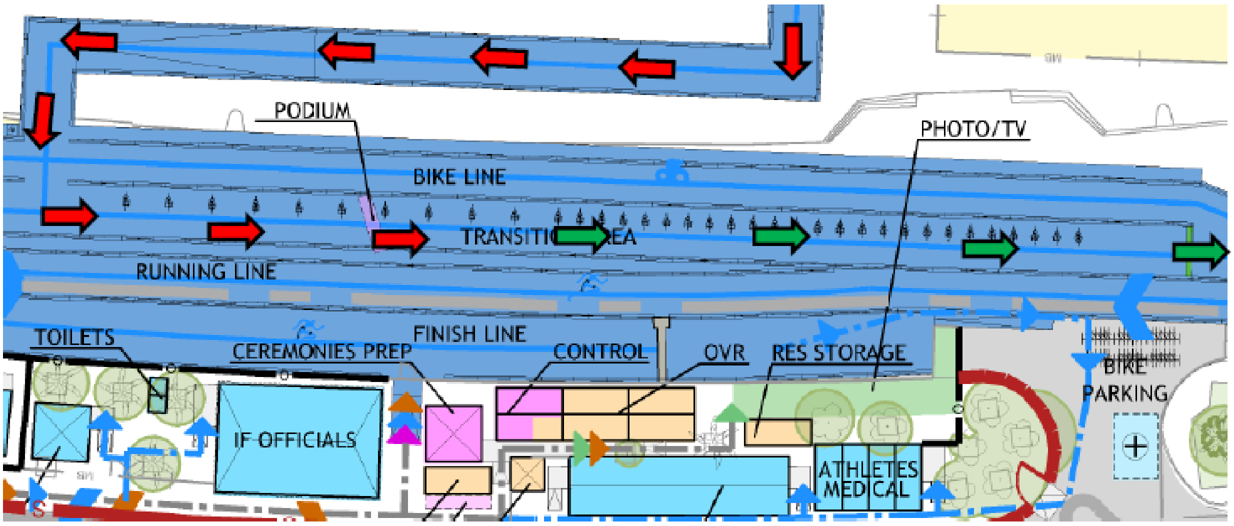

Figure 6: transition 1 to bike course (source: Aquece Rio)

Figure 7: bike racks in the transition area. Photo: Simone Biava

Bike course

The paratriathlon bike course takes place along the Avenida Atlantica, as shown in the map in Figure 8. Athletes have to ride 3 laps of 6.88 kilometers each, for a total distance of 20.64 kilometers. Each lap is completely flat and has 4 U-turns. Drafting is illegal.

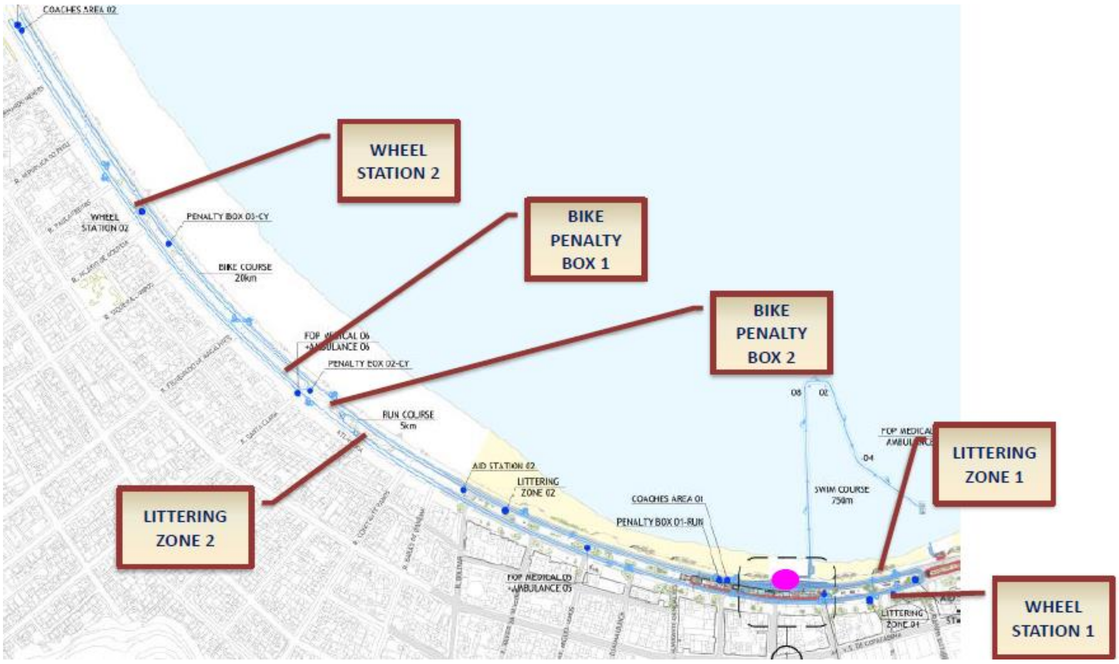

Figure 8: map of the bike course (source: Aquece Rio)

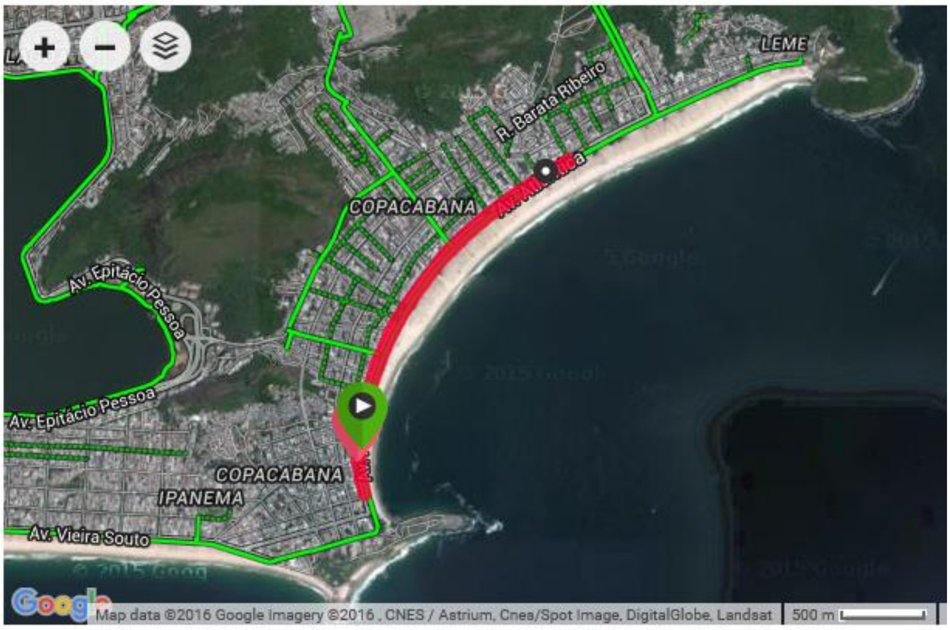

Figure 9: the bike course of the 2015 Rio de Janeiro WPE in Google Maps, with satellite view

The analysis of the bike course in Google Maps, as shown in Figure 9, put in evidence that athletes have to ride along Avenida Atlantica along two principal directions:

1. the way forward of each lap has an average direction pointing towards the north-east (NE)
2. the way back of each lap has an average direction pointing towards the south-west (SW)

Each bike segment can be positively or negatively affected by environmental variables such as wind direction, speed and gusts. Knowing these environmental variables at the day and time of the race is important in order to foresee their effects on the athletes' bike performance. **WindFinder** (website www.windfinder.com) can be used as online weather monitoring service providing complete information of the wind blowing on the Copacabana beach.

Transition 2 to run course

After the bike fraction, athletes re-enter the transition area as shown by the map in Figure 10. The bike dismount line is set at the beginning of the transition area and indicated by a red line.

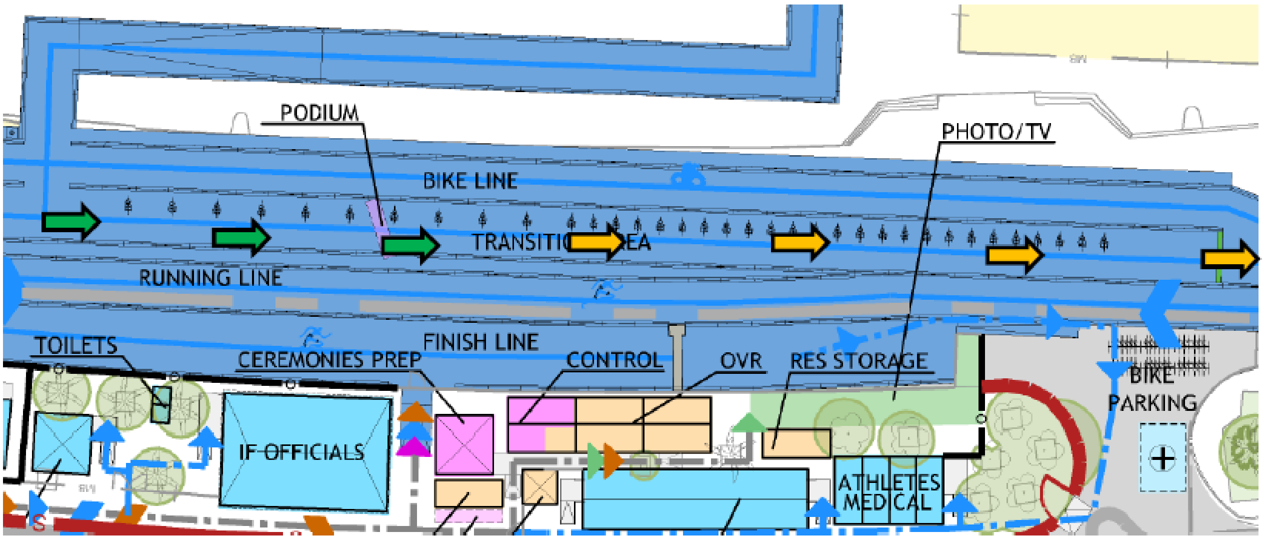

Figure 10: transition 2 to run course (source: Aquece Rio)

Run course

The run course takes place along the same flat course of the bike segment, in Avenida Atlantica, as shown in Figure 11. Athletes have to run 2 laps of 2.50 kilometers each, for a total distance of 5 kilometers. Each lap is completely flat and has 2 U-turns.

Like the bike course, the run course has a way forward with an average direction pointing towards the north-east (NE), and a way back with an average direction pointing towards the south-west (SW). Each run segment can be positively or negatively affected by wind direction, speed and gusts, although with less influence respect to the bike course.

The blue carpet covering the transition area and the start/finish area has better damping properties than asphalt, so that the energy loss (from surface deformation to heat generation) is higher while running on the carpet than when running on asphalt.

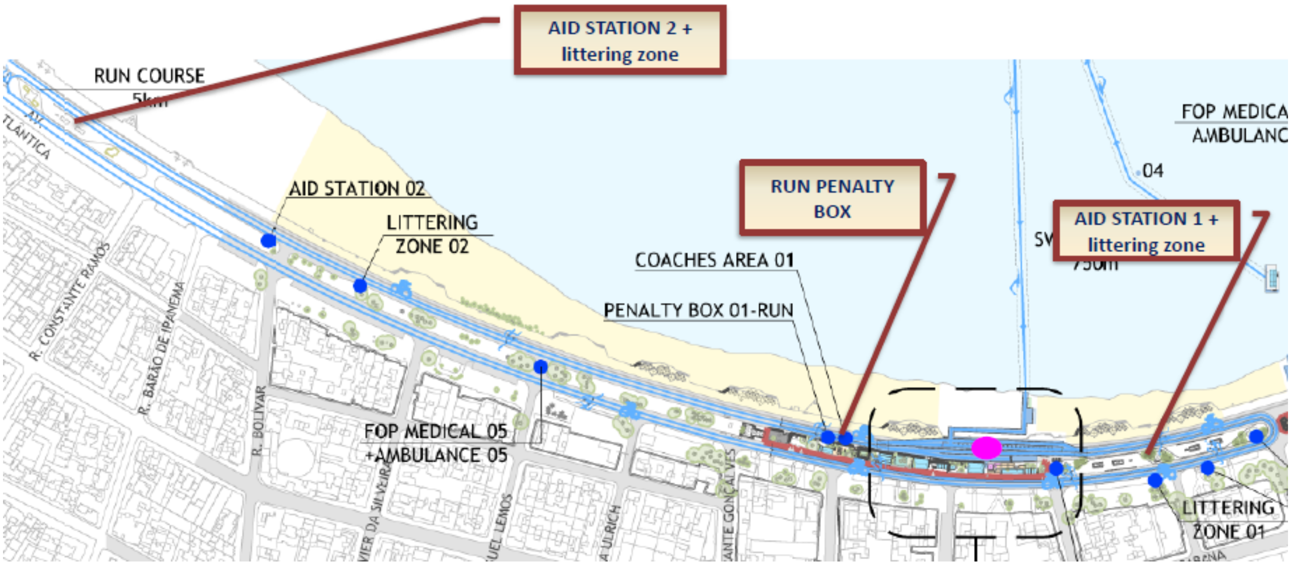

Figure 11: map of the run course (source: Aquece Rio)

Analysis of the pre-Olympic test competition

The Italian paratriathlon team

The Italian delegation, headed by the technical director Simone Biava and accompanied by the project manager Neil McLeod, convened two athletes for the Rio de Janeiro World Paratriathlon Event: Giovanni Achenza (*Sport Abili Alba* team), competing in the category PT1, and Giorgio Vanerio (*Oxygen* team) competing in the category PT2. The start time for the PT2 group was given at 9:30 am, local time, while the start time for the PT1 group was given at 12:45 pm, local time.

Materials and methods for PT2

For the quantitative analysis of the pre-Olympic test competition, the athlete Giorgio Vanerio, competing in the PT2 sport class, was equipped with the following technical instrumentation:

1. Garmin Forerunner 920XT multisport watch
2. Garmin Edge 1000 bike computer
3. Power2max cycle power meter

The Garmin Forerunner 920XT multisport watch was used for the analysis of the entire competition, with a particular attention to the swim fraction, the transitions and the run fraction. The bike of the athlete was equipped with the Garmin Edge 1000 bike computer paired with the Power2max cycle power meter, for a deep insight on the cycling quantitative parameters.

The Forerunner 920XT provided by Garmin® (www.garmin.com) is a GPS multisport watch that packs high-end training features into a sleek device. In addition to GPS, the Forerunner 920XT can also receive GLONASS signals for improved accuracy. During the participation in a triathlon race, the triathlon activity profile can be selected in the multisport watch, for quick transitions to each sport segment.

For the swim fraction, the Forerunner 920XT is designed for open water and pool swimming, measuring geographical coordinates, time, distance, speed, stroke and calories burned in the workouts, together with a wetsuit-friendly design. For the run fraction, the Forerunner 920XT provides data as geographical coordinates, altitude, time, distance and speed. It can also help to train for optimal running form by reporting dynamics data as run cadence (total steps per minute). For the transitions T1 and T2, the Forerunner 920XT provides distance and time. The Forerunner 920XT sport watch is shown in Figure 12.

Figure 12: the Forerunner 920XT sport watch (source: Garmin® Forerunner 920XT owner's manual)

Recorded workouts and race activities can be uploaded from the sport watch into Garmin Connect™ (www.connect.garmin.com), a free online web community where athletes can save, plan and share their efforts. When an activity is completed using a multisport activity profile on the device, each leg and transition time is stored in one combined file for easy review and sharing. Individual tabs allow accessing detailed data for each leg. There are multiple ways to sync recorded data with Garmin Connect: the Forerunner 920XT can transfer the data through the Garmin Connect™ Mobile app on a smartphone using Bluetooth® technology; one or more Wi-Fi® hot spots can be set up as well, and the 920XT automatically syncs with Garmin Connect when in range; the Forerunner 920XT can be also synced with a desktop computer through a USB connection. The laptop view of Garmin Connect is shown in Figure 13.

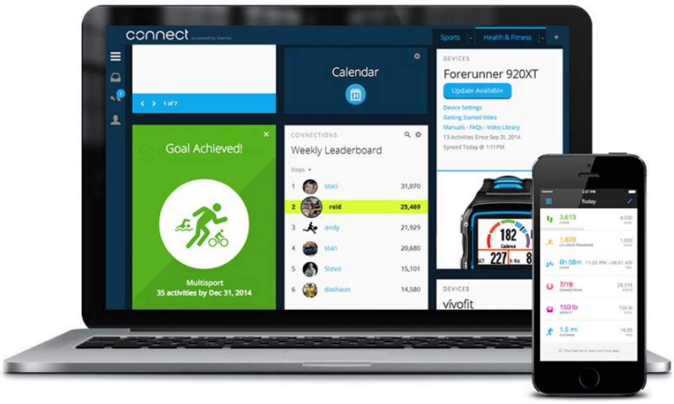

Figure 13: laptop view of Garmin Connect (source: Garmin® website)

The Edge 1000 provided by Garmin® (www.garmin.com) can be used either as a cycling computer or a cycling navigator, offering advanced bike-specific navigation and mapping capabilities. The preloaded Garmin Cycle Map includes OSM (Open Street Map) content with routable road and bike paths, elevation data, points of interest and address search. Mapping data is stored onboard the Edge, so the access to navigation and performance capabilities is not dependent on cell coverage. Map updates are free.

The Edge 1000 features a 3-inch high-resolution color touchscreen display with dual orientation. It has an ambient light sensor that automatically adjusts the screen brightness to changing light conditions to improve visibility. The display is optimized to work with gloves and in the rain. The training pages can be customized with up to 10 data fields. The Edge 1000 bike computer is shown in Figure 14. For an advanced performance analysis, the Edge 1000 is compatible with ANT+® sensors, including speed, cadence and heart rate. It can also display power metrics when paired with ANT+® power meters, including the Power2max cycle power meter.

Figure 14: the Edge 1000 bike computer (source: Garmin® Edge 1000 owner's manual)

Like the Forerunner 920XT, the data recorded by the Edge 1000 can be uploaded to Garmin Connect™ (www.connect.garmin.com) via Bluetooth® or Wi-Fi® for post-ride analysis.

The cycle power meter provided by Power2max® (www.power2max.com) is designed to offer outstanding precision and reliability whilst being very simple to use. Power2max has the AutoZero function: every time the athlete stop pedaling for 3 seconds or more, the power2max "re-zeros", keeping the zero offset value precise, with no need to re-zero manually. Power2max calculates the cadence precisely using an accelerometer, so there is no need to install a cadence magnet on the bike.

Power2max power meters deliver precise and reliable data under all environmental conditions: they are well waterproofed, and the built-in temperature compensation mechanism ensures that they stay accurate even in changing weather. The power meters achieve accuracy of ±2% (or better), including all environmental influences.

The Power2max power meter estimates the contribution of the athlete's left and right leg, offering useful additional information for the training: the right power is the downward pressure on the right plus the upward pull on the left, while the left power is the downward pressure on the left plus the upward pull on the right.

Power2max power meters use the ANT+ standard to transmit data wirelessly to the Edge 1000 bike computer. The ANT+ standard guarantees a reliable transmission. The pairing of the Edge 1000 bike computer with the Power2max power meter offers a deep insight on the ride performance. The recorded data are the following: geographical coordinates (latitude, longitude and altitude), time, distance, cadence and power.

Materials and methods for PT1

For the quantitative analysis of the pre-Olympic test competition, the athlete Giovanni Achenza, competing in the PT1 sport class, was equipped with the following technical instrumentation:

1. Garmin Edge 500 bike computer
2. SRM cycle power meter
3. Garmin VIRB Elite camera

The Garmin Edge 500 bike computer was used for the analysis of the entire road competition, for the handbike fraction as well as for the wheelchair fraction. The handbike of the athlete was equipped also with the SRM cycle power meter and the Garmin VIRB Elite camera. Both the Edge 500 bike computer and the VIRB Elite camera were paired with the SRM power meter for a deep insight on the cycling quantitative parameters.

The Edge 500 provided by Garmin® (www.garmin.com) is a lightweight GPS-based bike computer for a performance-driven analysis of the ride. Edge 500 features a high-sensitivity GPS receiver with HotFix® satellite prediction to calculate the position faster. During the ride, the Edge 500 measures speed, distance, time, calories burned, altitude, climb and descent, and records this data for further review. For extra-precise climb and descent data, the Edge 500 also incorporates a barometric altimeter to pinpoint changes in elevation.

The Edge 500 works with third-party ANT+-enabled power meters to display power output in watts. When the ride is concluded, the Edge 500 can be connected to the computer with the dedicated USB cable to analyze the performance. Recorded data can be uploaded into Garmin Connect™ (www.connect.garmin.com) for further analysis and sharing. The Edge 500 bike computer is shown in Figure 15.

Figure 15: the Edge 500 bike computer (source: Garmin® Edge 500 owner's manual)

The cycle power meter provided by SRM® (www.srm.de) is the first crank based power meter, patented in 1987. The SRM power meter utilizes a torque measuring based on strain gauge: inside each SRM power meter are four measuring bridges connecting the chain rings (drivetrain) to the crank arms (the rider), as shown in Figure 16. As the force from the rider's leg is applied to the crank arm (torque), the bridges measure the amount of force being applied. That force is multiplied by the speed of the pedal stroke (known as angular velocity) to obtain the power.

The SRM training system can be paired with third-party compatible ANT+ head units, like the Garmin Edge 500 bike computer or the Garmin VIRB Elite camera. The pairing of the Edge 500 bike computer with the SRM power meter offers a deep insight on the ride performance. The recorded data are the following: geographical coordinates (latitude, longitude and altitude), time, distance, cadence and power.

Figure 16: the SRM cycle power meter (source: SRM® website)

The VIRB Elite action camera provided by Garmin® (http://virb.garmin.com) records high definition video that lets athlete and coach relive every minute of the ride in full, high-contrast, undistorted detail. The device is shown in Figure 17. The camera is equipped with WideVü lens and with a 16 megapixel CMOS sensor for the highest quality video. Multiple HD video modes can be set: 1080p@30fps, 960p@48fps, 720p@30/60fps, 848x480@120fps.The 1.4 inches display on VIRB Elite is also the window into the menu settings. The VIRB Elite features a class-leading 2000 mAh lithium-ion battery that tested up to 3 hours recording at 1080p. Digital stabilization and lens distortion correction features work to enhance the quality of the video.

A variety of mounts let the camera be firmly locked in position. Mounts have interlocking joints that grip in place instead of relying solely on tension for a more durable, anti-vibration locking performance.

The VIRB Elite has built-in high-sensitivity GPS, accelerometer and altimeter for data stamping. It is also equipped with Wi-Fi for wireless communication to smartphone or computer: it is possible to see image preview, to adjust camera settings, and record or stop the camera, even while the camera is filming. VIRB uses ANT+® wireless connectivity so it is possible to use a compatible Garmin device, such as Edge, as remote controls. ANT+ also works with compatible external sensors, such as speed/cadence bike sensor or power meter.

VIRB Edit is the free desktop editing software that can be downloaded to computer for video editing that takes advantage of VIRB Elite's compatibility with external and built-in sensors. Powered by Garmin GPS, G-Metrix™ allows tracking and overlaying on the video quantitative parameters of the recorded activity: it can be used to add preset gauges, graphs and track shapes, automatically synched to the video and tailored for the specific activity. The recorded video can be played back to show the athlete’s speed, acceleration and other sensor data in real time. The pairing of the VIRB Elite camera with the SRM power meter offers a deep insight on the handbike performance. The data overlaid on the recorded video are time, distance, speed, cadence and power.

Figure 17: the Virb Elite camera (source: Garmin® Virb website)

Data processing

The Garmin devices used by the athletes in PT2 and PT1 sport classes (Forerunner 920XT, Edge 1000, Edge 500 and Virb Elite) have two alternative settings for data recording:

1. *Smart*: the device records key points where the athlete changes direction, pace, or heart rate. The activity file is smaller, allowing storing more activities on the device memory.
2. *Every second*: the device records points every second. It creates a very detailed record of the activity and increases the size of the file record.

All the Garmin devices involved in the analysis of the pre-Olympic test competition were set in every second data recording, in order to have a very detailed analysis of the recorded activities. The SRM and Power2max power meters paired with the Garmin devices were already set to send data at the rate of at least one sensor reading per second.

The data recorded in the PT2 pre-Olympic test competition by the Forerunner 920XT sport watch and by the Edge 1000 bike computer of Giorgio Vanerio were uploaded into the athlete's personal page in the Garmin Connect web community.

The data recorded in the PT1 pre-Olympic test competition by the Edge 500 bike computer of Giovanni Achenza were uploaded into the athlete's personal page in Garmin Connect. The video recorded by the VIRB Elite camera was downloaded to computer for video editing with the VIRB software.

For a detailed analysis of the pre-Olympic test competition, it was necessary to access the raw data recorded every second by the GPS devices, as the view shown in Garmin Connect only presents the overall performance of the recorded activity. From Garmin Connect, it was possible to export the raw data in TCX format. TCX stands for Training Center XML, where XML (Extensible Markup Language) is the markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable. TCX is a data exchange format introduced in 2007 as part of Garmin's technology and provides standards for transferring swimming, cycling and running information in the detailed track. It also provides summary data in the form of laps.

Each TCX file exported from Garmin Connect was renamed into an XML file and then imported by Microsoft Excel. In this way, each recorded activity was associated with a spreadsheet allowing data manipulation and data display as line graphs, histograms and charts. In the Excel grid of cells, the numbered rows correspond to every second acquisition, while the letter-named columns to the type of data recorded. Figure 18 summarizes the file conversion from Garmin TCX format to Microsoft Excel XLSX format.

Figure 18: file conversion from Garmin TCX to Microsoft Excel XLSX

Figure 19 shows a portion of the Excel file with the data recorded by Giorgio Vanerio's Garmin Edge 1000 during the bike leg of the pre-Olympic test competition. Each row corresponds to each progressive second of acquisition, as indicated in the column called *ns1:Time.* The GPS bike computer, paired with the Power2max power meter, measures time, distance, cadence, power and geographical coordinates at every second. It also shows the average speed in each single predefined lap and in the entire bike leg.

The advantage of using the Excel spreadsheet is that it is possible to perform a further processing on the recorded data. For example, it is possible to calculate and plot the instantaneous values of velocity ad acceleration: these parameters are useful in particular to evaluate the athletes' performance in correspondence of U-turns, which are very frequent in both the bike leg and in the run leg of the pre-Olympic test competition.

A1 Sport

	ns1:Time	ns1:DistanceMeters2	ns1:Cadence3	ns2:Watts	ns1:LatitudeDegrees	ns1:LongitudeDegrees	ns1:AltitudeMeters
16	2015-08-01T12:46:34.000Z	115,8199997	0	32	-22,98459772	-43,18951302	-50,40000153
17	2015-08-01T12:46:35.000Z	123,1500015	27	32	-22,98457442	-43,18958167	-50,40000153
18	2015-08-01T12:46:37.000Z	130,6999969	95	219	-22,9844699	-43,18955527	-50,59999847
19	2015-08-01T12:46:38.000Z	138,3899994	95	230	-22,98436244	-43,18952685	-50,59999847
20	2015-08-01T12:46:39.000Z	146,1399994	99	200	-22,98428264	-43,18954554	-50,59999847
21	2015-08-01T12:46:40.000Z	154	98	195	-22,98422104	-43,18956742	-50,59999847
22	2015-08-01T12:46:41.000Z	162,0700073	100	184	-22,98415205	-43,18959692	-50,40000153
23	2015-08-01T12:46:42.000Z	170,1999969	103	175	-22,98408592	-43,18962433	-50,20000076
24	2015-08-01T12:46:43.000Z	178,4900055	103	176	-22,98401652	-43,1896478	-50,20000076
25	2015-08-01T12:46:44.000Z	186,8099976	105	166	-22,98394779	-43,18967169	-50,20000076
26	2015-08-01T12:46:45.000Z	195,1900024	106	160	-22,9838726	-43,1896939	-50,20000076

Figure 19: Excel file with the data recorded by Giorgio Vanerio's Edge 1000 during the bike leg of the 2015 Rio de Janeiro ITU World Paratriathlon Event

Environmental variables

The start time for the men PT2 sport class was given at 9:30 am BRT (Brasilia Time, which is the local time). Figure 20 shows the event time announcer for the men PT2 competition. The start time for the men PT1 sport class was given later, at 12:45 pm BRT.

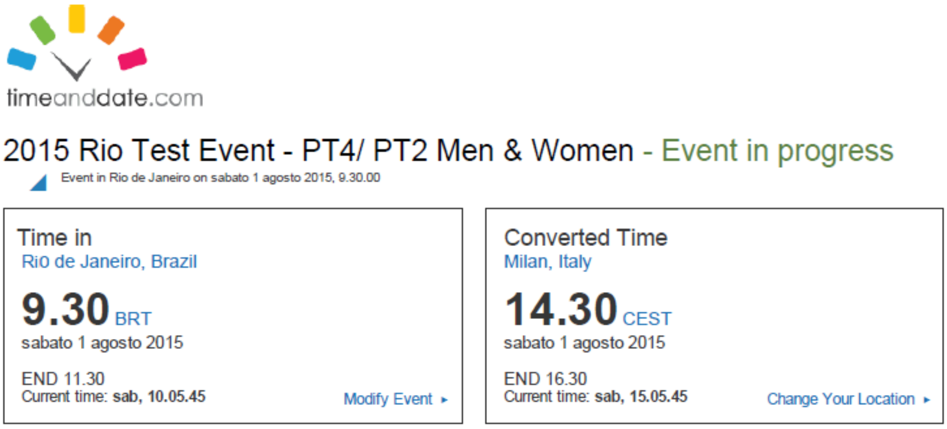

Figure 20: event time announcer for the 2015 Rio de Janeiro ITU World Paratriathlon Event, PT2 sport class competition (source: www.timeanddate.com)

Air temperature, water temperature and humidity were the environmental variables monitored by the Aquece Rio test events organization and summarized in Table 1. Figure 21 shows the official communication provided by Aquece Rio. For the heat stress illness prevention, these environmental conditions gave a high risk level on a scale of four levels (low, moderate, high and extreme).

Time	***Air temperature***	***Humidity***	***Water temperature***
08:45 am	23.6 °C	61%	22.4 °C
11:45 am	28.1 °C	66.7%	22.9 °C

Table 1: summary of the environmental variables monitored by AqueceRio on the race day, 1st august 2015

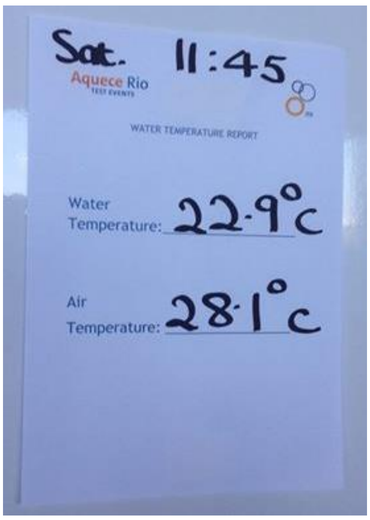

Figure 21: environmental variables monitored by AqueceRio on the race day. Photo: Simone Biava

As already mentioned, the following online services were used for monitoring other environmental variables of interest during the race time:

- **WindFinder** (website www.windfinder.com/forecast/copacabana_rio_de_janeiro), providing direction, speed and gusts for the wind and direction, height and period for the waves.
- **Tide-Forecast** (website www.tide-forecast.com/locations/Rio-de-Janeiro-Brazil/tides/latest), providing data on high and low tides (time of day and height).
- **Surfline** (website www.surfline.com/surf-report/copacabana-southeast-brazil_7013/), providing all the data for wind, waves and tides, as well as temperature of air and water and the webcam on the Copacabana beach.

WindFinder specializes in wind reports and forecasts for wind related sports like kitesurfing, windsurfing, surfing or sailing. Forecasts are available worldwide. Figures 22 and 23 show the wind forecast for Forte de Copacabana, in Rio de Janeiro, on the race day. The horizontal resolution is about 13 km. Forecasts are computed 4 times a day, at about 3:00 am, 9:00 am, 3:00 pm and 9:00 pm Brasilia Summer Time. Predictions are available in time steps of 3 hours for up to 10 days into the future. The arrows point in the direction that the wind is blowing. The default units are knots and degrees Celsius, often used by sailors, kiters, surfers or windsurfers.

Figure 22 shows the WindFinder forecast for the time interval 9 am - 12 pm, recorded at 10 am. It was of interest for the men PT2 sport class, starting at 9:30 am. In Rio de Janeiro, a light breeze wind was blowing towards the north-west direction, at a speed up to 4 knots. This very light air did not affect significantly the athletes' performances during the race.

Figure 23 shows the WindFinder forecast for the time interval 12 pm - 3 pm, recorded at 1 pm. It was of interest for the men PT1 sport class, starting at 12:45 pm. In Rio de Janeiro, a breeze wind was blowing towards the north-west direction, at a speed of 4 to 8 knots. This light air did not affect significantly the athletes' performances during the race.

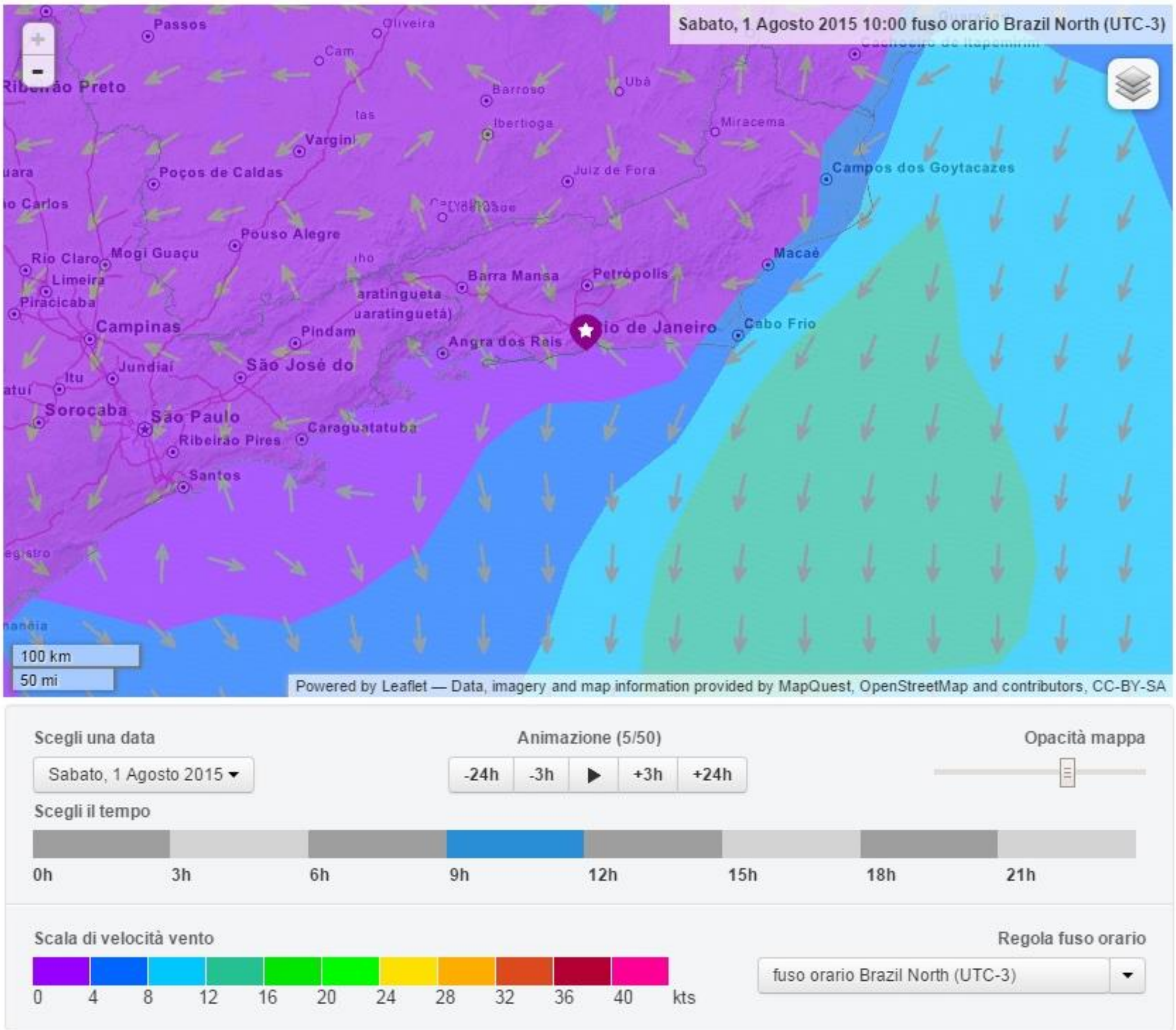

Figure 22: wind forecast for the 2015 Rio de Janeiro WPE race day, at the time 9 am - 12 pm (source: www.windfinder.com)

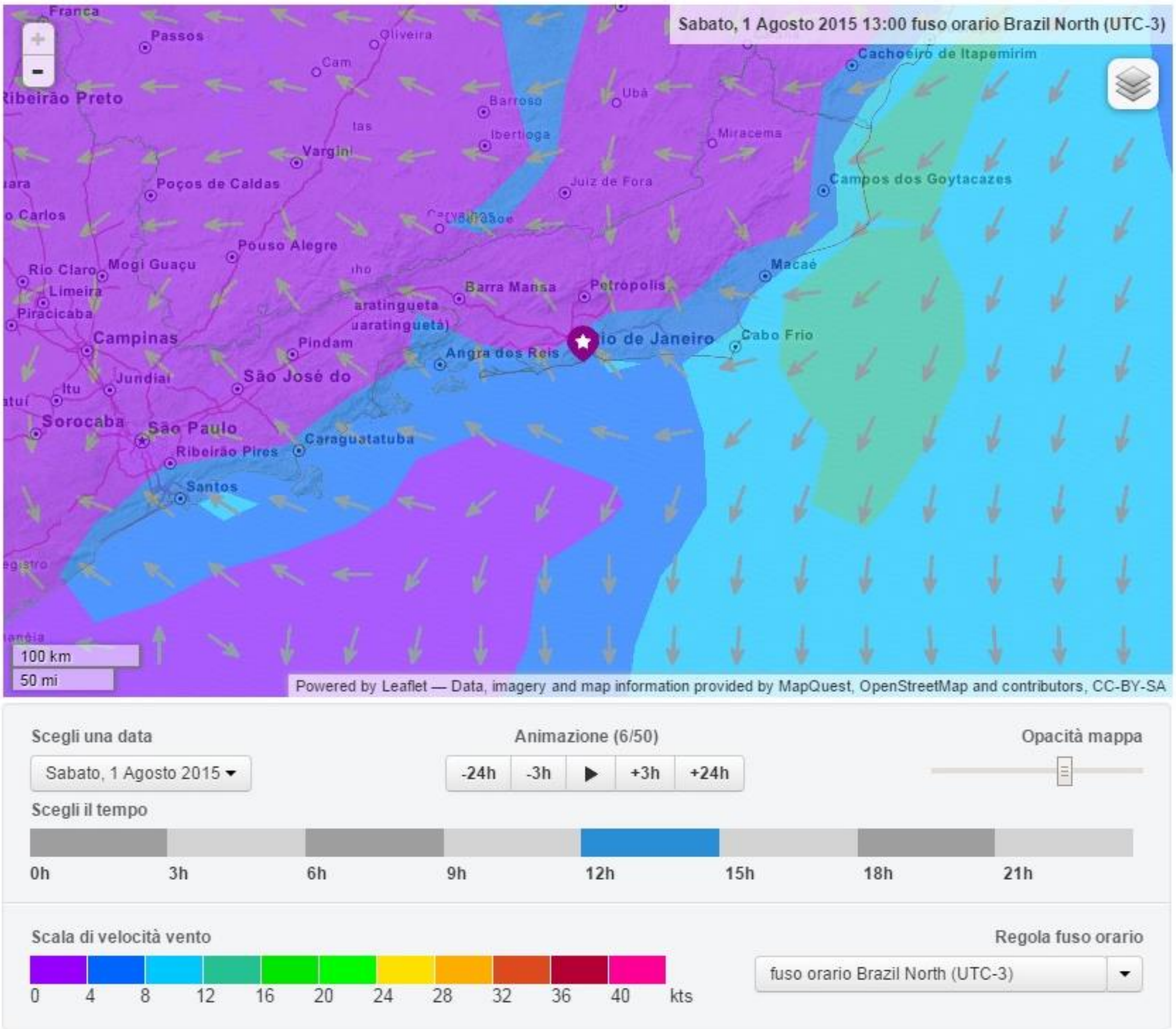

Figure 23: wind forecast for the 2015 Rio de Janeiro WPE race day, at the time 12 pm - 3 pm (source: www.windfinder.com)

Distant weather systems, where wind blows over a fetch of water, generate series of surface gravity waves that propagate along the interface between water and air. This series of mechanical waves is called swell. Swell waves have a long wavelength due to the size, strength and duration of the weather system responsible for the swell and to the size of the water body.

Surf forecasting is the process of using offshore swell data to predict onshore wave conditions. Onshore wave conditions were of particular interest for the 2015 Rio de Janeiro World Paratriathlon Event because they directly affected the athletes' performances during the swim leg. It is impossible to make an exact prediction of the surf, that is shape and size of breaking waves, but by knowing some key factors a good prediction can be made. In order to forecast the surf, the following swell data need to be analyzed:

1. Swell height: the height of the swell in deep water
2. Swell direction: the direction from which the swell is coming. It is measured in degrees and often referred to in general directions, such as a NNW or SW swell
3. Swell period: the measurement of time between successive waves in seconds

In Figure 24 the swell data for Rio de Janeiro on 1st august 2015 is shown. The data were recorded at 3 am, with a 4 knots breeze blowing from NW direction. According to the analysis provided by Surfline, swell had an ESE direction, a period of 8 seconds and a height varying between 0.3 and 0.6 meters.

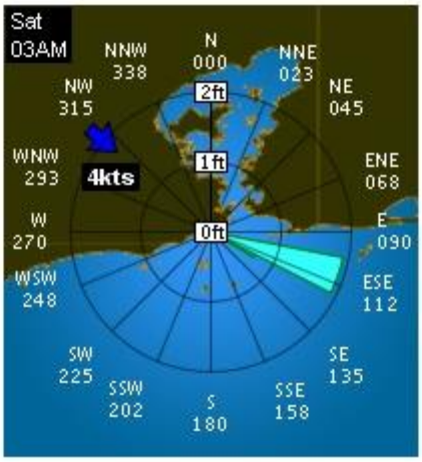

Figure 24: swell data for Rio de Janeiro on 1st august 2015 (source: www.surfline.com)

Tide levels are an extremely important factor that also impact on surf conditions. Tides, which occur from varying gravitational forces between the sun, moon, and the earth, are easy to predict far in advance. The effect of tides on wave quality differs between surf breaks: some breaks can be excellent for surfers on a low tide, but can suffer from a drop in quality during a high tide, when the water depth is too great, causing the wave face to break more slowly and with less power. Other surf breaks may experience the opposite effect and have better wave shape for surfing during high tide. Coastal geography and man-made coastal features such as seawalls, harbors, piers, and dredging all impact how a surf break will respond to tides.

Tide changes proceed via the following stages:

1. Sea level rises over several hours, covering the intertidal zone (flood tide)
2. The water rises to its highest level, reaching high tide
3. Sea level falls over several hours, revealing the intertidal zone (ebb tide)
4. The water stops falling, reaching low tide

Tides produce oscillating currents known as tidal streams. The moment that the tidal current ceases is called slack water or slack tide. The tide then reverses direction and is said to be turning.

The tide chart shown in Figure 25 shows the height and times of high tide and low tide for Rio de Janeiro as provided by Tide-Forecast. The yellow shading corresponds to daylight hours between sunrise and sunset at Rio de Janeiro. The red dot shows the tide data at the time of the recording, which was 9:30 am on 1st august 2015, corresponding to the start of the PT2 competition in the 2015 Rio de Janeiro WPE. Table 2 summarizes all the tide data provided by Tide-Forecast for Rio de Janeiro on the race day. In considering the influence of tidal streams on the athletes' performances during the swim leg of the 2015 Rio de Janeiro World Paratriathlon Event, it is important to notice that the swim leg of the men PT2 competition, starting at 9:30 am, was done in ebb tide, while the swim leg of the men PT1 competition, starting at 12:45 pm, was done in flood tide. Tidal streams affect in particular the 1st and 3rd segments of the swim course.

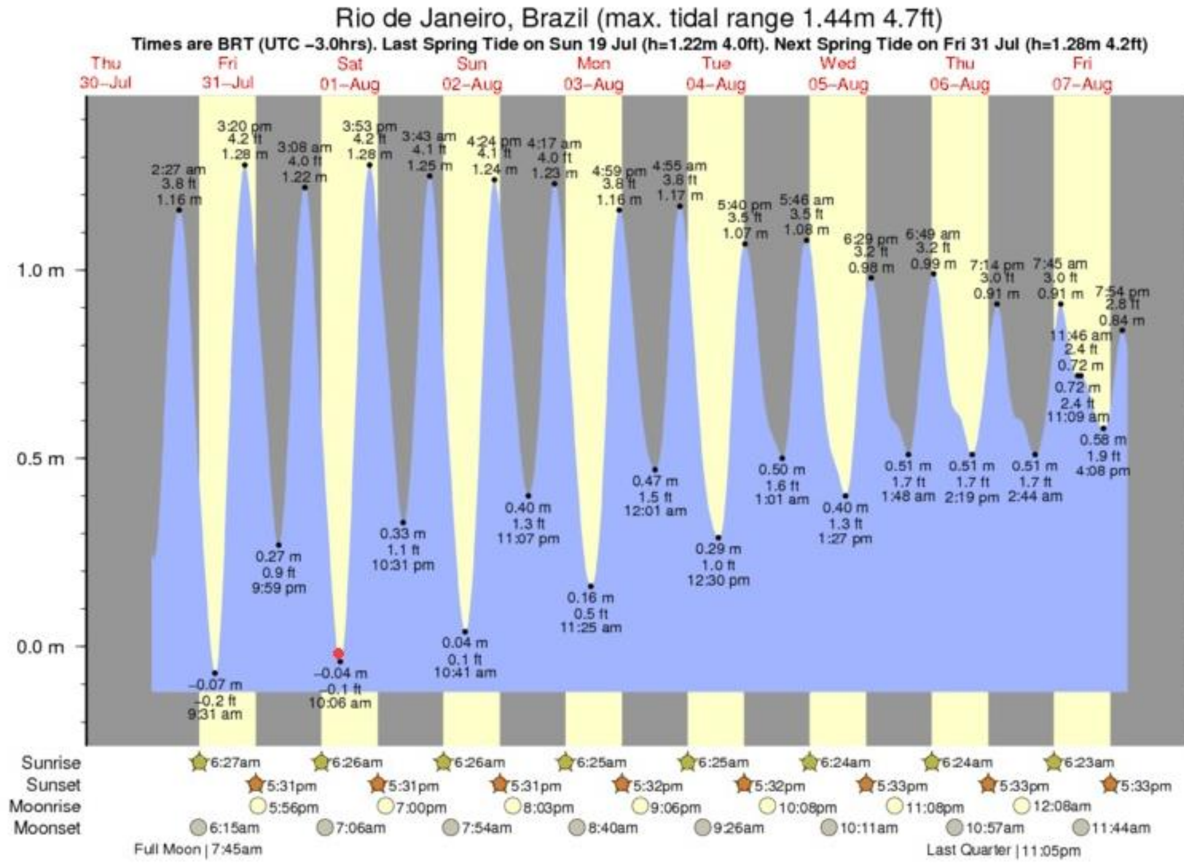

Figure 25: Rio de Janeiro tide chart (source: www.tide-forecast.com)

RIO DE JANEIRO TIDE TABLE:

Saturday 1 August	**3:08 AM**	BRT	1.22 m	(**4.01 feet**)	**High Tide**
	6:26 AM	BRT			Sunrise
	7:06 AM	BRT			Moonset
	10:06 AM	BRT	-0.04 m	(**-0.14 feet**)	**Low Tide**
	3:53 PM	BRT	1.28 m	(**4.20 feet**)	**High Tide**
	5:31 PM	BRT			Sunset
	7:00 PM	BRT			Moonrise
	10:31 PM	BRT	0.33 m	(**1.08 feet**)	**Low Tide**

Table 2: Rio de Janeiro tide table (source: www.tide-forecast.com)

Figure 26 shows the surf forecast provided by Surfline for Copacabana beach on 1st august 2015. The data include predicted surf trend and swell detail, winds, tides, as well as air and water temperature.

The surf height forecasted for the race morning is about 0.3 to 0.6 meter, therefore not critical for the swim leg of the 2015 Rio de Janeiro WPE.

The live wind recorded at 9 am is a light breeze of 3 knots blowing from the NE direction. This recorded data partially correct the forecast considering the SE direction as wind origin. This contrast between forecast and observation is not so relevant due to the very low wind intensity: the speed of the forecasted and observed breeze is only 3 to 4 knots. Anyway, for the next 2016 Rio de Janeiro Paralympic Games, it will be important to repeatedly monitor all the selected online services for knowing exactly the predicted and observed environmental variables which are interesting for their influence on the athletes' performances during the race.

Figure 27 shows the picture of Copacabana beach taken by a webcam service on 1st august 2015, at 12:30 pm BRT, during the Rio de Janeiro WPE.

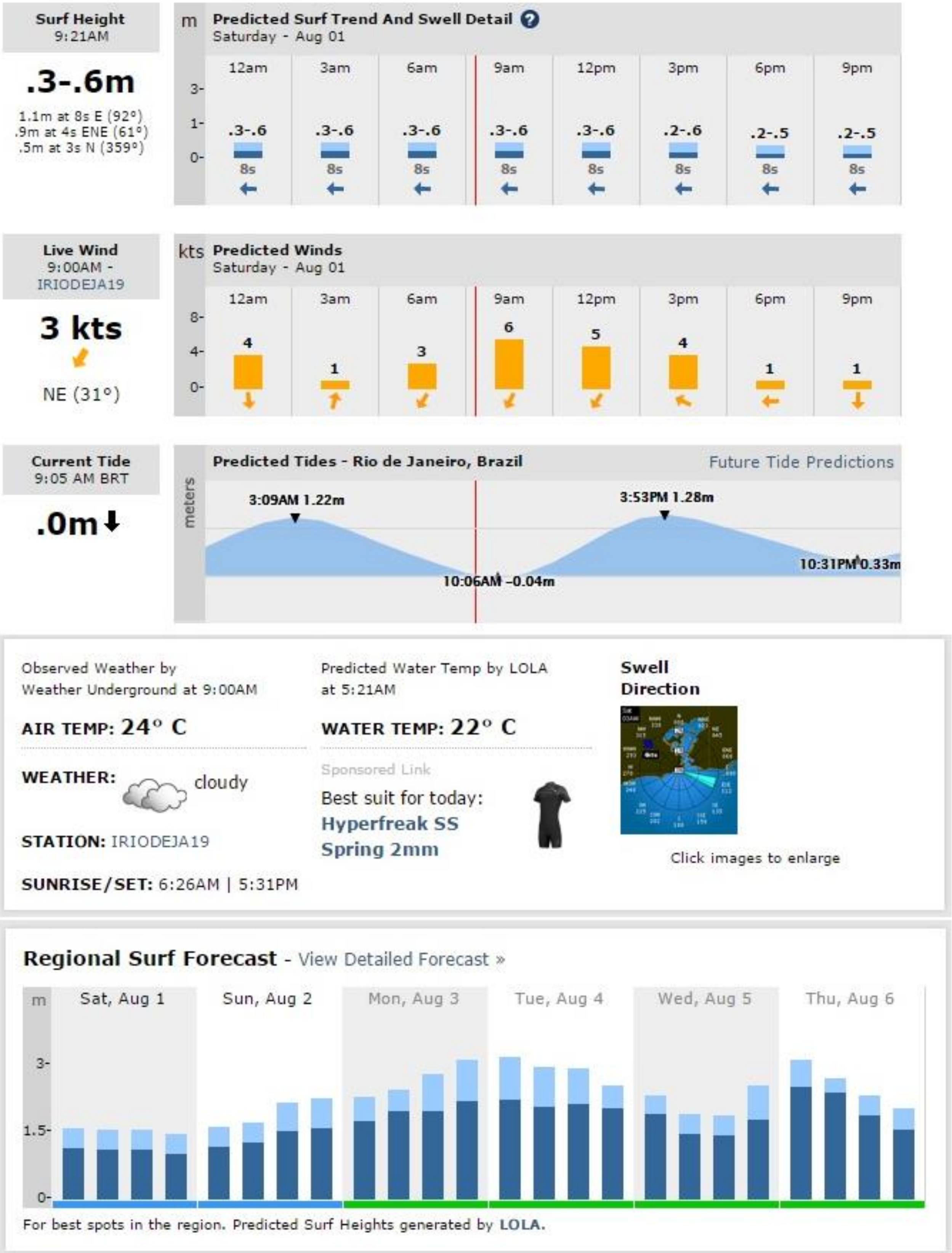

Figure 26: surf forecast for Copacabana beach on 1st august 2015 (source: www.surfline.com)

Figure 27: webcam on Copacabana beach during the 2015 Rio de Janeiro WPE (source: www.homesinrio.com)

Analysis of the swim leg

The official results for the swim leg of the athlete Giorgio Vanerio, competing in the PT2 sport class, show a time of 11 minutes and 20 seconds for the total distance of 750 meters, with a swimming speed of 1.10 meters per second.

The swim leg was also recorded by his Garmin Forerunner 920XT multisport watch, for further analysis. The data from the Forerunner 920XT show a time of 11 minutes and 33 seconds for the total distance of 731 meters, with a swimming speed of 1.05 meters per second: the data recorded by the sport watch may differ from those recorded by the official timing of the competition due to the manual action of start and stop recording that had to be performed manually by the athlete himself during the competition.

The data recorded by the Forerunner 920XT were used for analyzing the influence of the environmental variables on the swim leg. During the PT2 competition, starting at 9:30 am, the swim leg was affected by ebb tide, resulting in a positive influence in the 1st segment of the swim course and in a negative influence in the 3rd segment of the swim course. The 2nd segment could be neglected considering its shortness and direction. The influence of the surf was instead negative in the 1st segment and positive in the 3rd segment of the swim course. The first 300 meters of the swim course, comprised in the 1st segment, were performed in 4 minutes and 40 seconds, while the last 300 meters, comprised in the 3rd segment of the swim course, were performed in 4 minutes and 30 seconds. This data highlight the fact that the surf had much influence than the tidal current on the swim performance.

The official results for the swim leg of the athlete Giovanni Achenza, competing in the PT1 sport class, show a time of 11 minutes for the total distance of 750 meters, with a swimming speed of 1.13 meters per second. Figure 28 shows the athletes of the PT1 group while sitting on the floating pontoon, ready for the start of the Paralympic test event. Since the first yellow buoy was 350 meters far from the pontoon, the position of the athletes on the floating platform was not fundamentally important. During the PT1 competition, starting at 12:45 pm, the swim leg was affected by flood tide, resulting in a negative influence in the 1st segment of the swim course and in a positive influence in the 3rd segment of the swim course. The influence of the surf was the same as the tidal current in the two considered segments of the swim course.

The official transition time T1 for the PT2 athlete Giorgio Vanerio was 2 minutes and 33 seconds. The official transition time T1 for the PT1 athlete Giovanni Achenza was 1 minute and 28 seconds.

Figure 29 shows the role of the assistants in helping PT1 paratriathletes to get out of the water, while Figure 30 shows PT2 paratriathletes running along the transition zone to reach their bike.

Figure 28: athletes sit on the pontoon, ready for the start of the men's PT1 Paralympic triathlon test event in Rio de Janeiro. Photo: Associated Press

Figure 29: assistants helping PT1 athletes out of the water. Photo: Alex Ferro/Rio 2016

Figure 30: PT2 paratriathletes running along the transition zone. Photo: Alex Ferro/Rio 2016

Analysis of the bike leg

The bike of the athlete Giorgio Vanerio, competing in the PT2 sport class, was equipped with the Garmin Edge 1000 bike computer paired with the Power2max cycle power meter, for a deep insight on the cycling quantitative parameters. Giorgio Vanerio completed the 20.64 kilometers of the bike leg in

38 minutes and 35 seconds, with an average speed of 32.09 kilometers per hour. By analyzing the data recorded by the power meter, the average power developed by the PT2 athlete in the whole course was 150 watts, with a maximum peak of 356 watts. The average power in the first half of the course, namely in the first 10.32 kilometers, was 148 watts, while in the second half of the course the average power increased up to 152 watts. The average bike cadence in the whole course was 87 RPM (i.e. revolutions per minute), with a maximum peak of 111 RPM. In the first half of the course the average bike cadence was 88 RPM, decreasing to 86 RPM in the second half of the course. Table 3 summarizes the performance parameters of the athlete Giorgio Vanerio's bike leg.

Time [min:s]	38:35
Average speed [km/h]	32.09
Average power [W]	150
Average power in the 1st half of the course [W]	148
Average power in the 2nd half of the course [W]	152
Maximum power [W]	356
Average cadence [RPM]	87
Average cadence in the 1st half of the course [RPM]	88
Average cadence in the 2nd half of the course [RPM]	86
Maximum cadence [RPM]	111

Table 3: bike performance parameters of the PT2 athlete Giorgio Vanerio

The handbike of the athlete Giovanni Achenza, competing in the PT1 sport class, was equipped with the Garmin Edge 500 bike computer, the SRM cycle power meter and the Garmin VIRB Elite camera. Both the Edge 500 bike computer and the VIRB Elite camera were paired with the SRM power meter for a deep insight on the cycling quantitative parameters. Giovanni Achenza completed the 20.64 kilometers of the bike leg in 34 minutes and 17 seconds, with an average speed of 36.12 kilometers per hour. By analyzing the data recorded by the power meter, the average power developed by the PT1 athlete in the whole course was 150 watts, with a maximum peak of 342 watts. The average power in the first half of the course, namely in the first 10.32 kilometers, was 155 watts, while in the second half of the course the average power decreased down to 145 watts. The average handbike cadence in the whole course was 95 RPM, with a maximum peak of 137 RPM. In the first half of the course the average handbike cadence was 97 RPM, decreasing to 92 RPM in the second half of the course. Table 4 summarizes the performance parameters of the athlete Giovanni Achenza's bike leg.

Time [min:s]	34:17
Average speed [km/h]	36.12
Average power [W]	150
Average power in the 1^{st} half of the course [W]	155
Average power in the 2^{nd} half of the course [W]	145
Maximum power [W]	342
Average cadence [RPM]	95
Average cadence in the 1^{st} half of the course [RPM]	97
Average cadence in the 2^{nd} half of the course [RPM]	92
Maximum cadence [RPM]	137

Table 4: handbike performance parameters of the PT1 athlete Giovanni Achenza

Figure 31 shows the bike course as recorded by the Garmin Edge 500 bike computer mounted on the handbike of Giovanni Achenza. The pairing of the VIRB Elite camera with the SRM power meter offered a deep insight on the handbike performance. With the use of the VIRB Edit desktop editing software, G-Metrix™ allowed tracking and overlaying on the video the quantitative parameters of the recorded ride. Time, distance, speed, cadence and power were the data overlaid on the recorded video. Figure 32 shows a screenshot of the recorded and edited video: time and distance are overlaid in the upper left and right corner of the frame, respectively. In the lower left corner of the video frame, the instantaneous values of speed and cadence are shown. In the lower right corner, the instantaneous value of the power is shown.

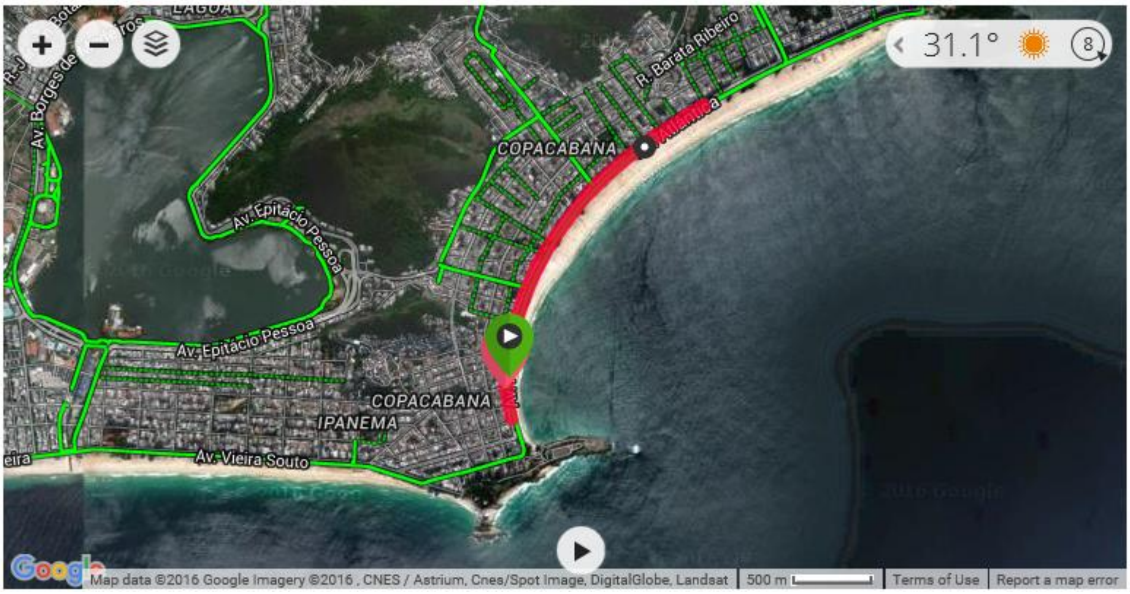

Figure 31: bike course recorded by the Garmin Edge 500 bike computer

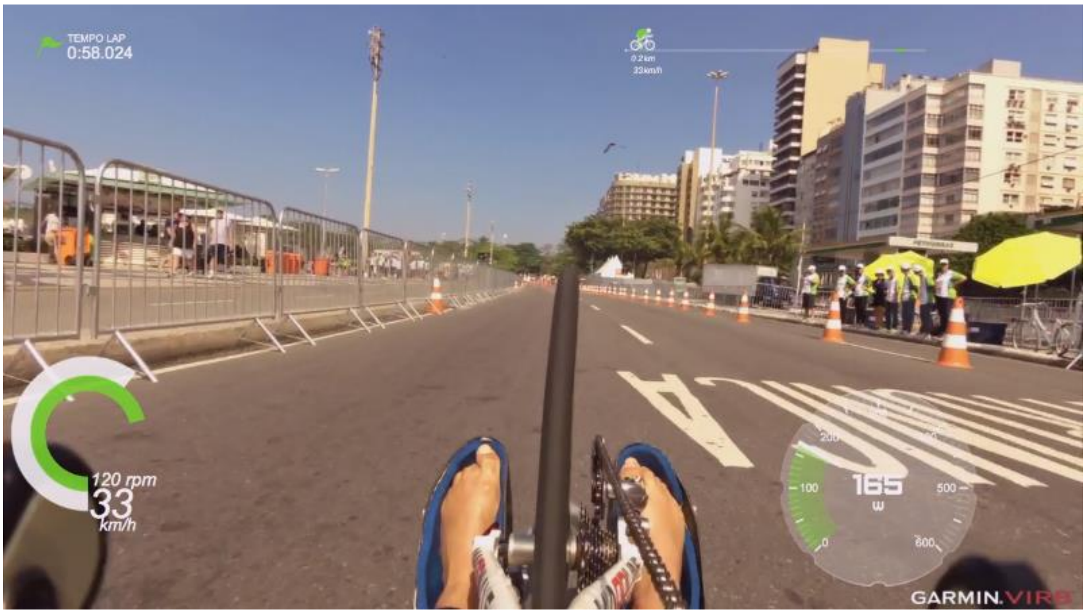

Figure 32: video recorded by the VIRB Elite camera, with quantitative cycling parameters overlaid

Analysis of the run leg

The official transition time T2 for the PT2 athlete Giorgio Vanerio was 1 minutes and 23 seconds. Giorgio Vanerio completed the 5 kilometers of the run leg in 25 minutes and 31 seconds, with an average speed of 11.74 kilometers per hour.

The official transition time T2 for the PT1 athlete Giovanni Achenza was 1 minute and 2 seconds. Giovanni Achenza completed the 5 kilometers of the wheelchair run leg in 13 minutes and 42 seconds, with an average speed of 21.90 kilometers per hour.

Conclusions

Tables 5 and 6 illustrate the ITU official results of the 2015 Rio de Janeiro World Paratriathlon Event for PT2 and PT1 sport classes, respectively.

2015 Rio de Janeiro ITU World Paratriathlon Event : Aug 01 2015 : Men's PT2 : Results

Pos	First Name	Last Name	Country		Time	Swim	T1	Bike	T2	Run
1	Vasily	Egorov	RUS		01:08:58	00:11:25	00:01:55	00:32:59	00:00:58	00:21:41
2	Mark	Barr	USA		01:10:41	00:09:11	00:02:09	00:36:07	00:01:45	00:21:29
3	Andrew	Lewis	GBR		01:10:56	00:10:32	00:02:36	00:35:55	00:01:06	00:20:47
4	Mohamed	Lahna	MAR		01:15:30	00:11:22	00:02:05	00:36:50	00:01:00	00:24:13
5	Giorgio	Vanerio	ITA		01:19:22	00:11:20	00:02:33	00:38:35	00:01:23	00:25:31
6	Andre	Barbieri	BRA		01:20:10	00:10:43	00:02:18	00:37:09	00:01:43	00:28:17
7	Tiago	Matthes	BRA		01:21:12	00:14:37	00:02:16	00:37:02	00:01:28	00:25:49
8	Juan Manuel	Geny	ARG		01:22:23	00:11:53	00:02:13	00:36:33	00:01:10	00:30:34
9	Brian	Norberg	USA		01:27:12	00:19:36	00:02:15	00:39:27	00:01:02	00:24:52

Distances: Swim 750 m (1 lap); Bike 20.640 km (3 laps); Run 5 km (2 laps) Water Temperature 22.4ºC Air temperature 23.6ºC. Wetsuit swim. Technical Delegate Thanos Nikopoulos/GRE, Race Referee Leslie Buchanan/CAN. Competition Jury Thanos Nikopoulos/GRE, Shin Otsuka/JPN Carlos Froes/BRA

Table 5: official results for PT2 in the 2015 Rio de Janeiro WPE. Source: International Triathlon Union

2015 Rio de Janeiro ITU World Paratriathlon Event : Aug 01 2015 : Men's PT1 : Results

Pos	First Name	Last Name	Country		Time	Swim	T1	Bike	T2	Run
1	Bill	Chaffey	AUS		00:59:41	00:10:58	00:01:37	00:32:53	00:00:47	00:13:26
2	Krige	Schabort	USA		00:59:57	00:11:54	00:01:01	00:33:48	00:01:03	00:12:11
3	Geert	Schipper	NED		01:00:04	00:11:40	00:01:28	00:33:48	00:00:47	00:12:21
4	Joseph	Townsend	GBR		01:01:19	00:12:34	00:01:10	00:35:00	00:00:34	00:12:01
5	Giovanni	Achenza	ITA		01:01:29	00:11:00	00:01:28	00:34:17	00:01:02	00:13:42
6	Phil	Hogg	GBR		01:02:29	00:10:53	00:01:21	00:36:03	00:00:47	00:13:25
7	Fernando	Aranha	BRA		01:03:24	00:12:12	00:01:28	00:34:57	00:00:47	00:14:00
8	Markus	Hausling	GER		01:04:38	00:10:58	00:01:39	00:36:42	00:00:50	00:14:29
9	Alexandre	Paviza	FRA		01:09:15	00:12:30	00:01:18	00:37:42	00:00:56	00:16:49
10	Junpei	Kimura	JPN		01:13:32	00:11:30	00:01:51	00:39:37	00:01:16	00:19:18
11	Anton	Swanepoel	RSA		01:13:42	00:12:09	00:02:06	00:39:42	00:01:02	00:18:43

Distances: Swim 750 m (1 lap); Bike 20.640 km (3 laps); Run 5 km (2 laps) Water Temperature 22.4ºC Air temperature 23.6ºC. Wetsuit swim. Technical Delegate Thanos Nikopoulos/GRE, Race Referee Leslie Buchanan/CAN. Competition Jury Thanos Nikopoulos/GRE, Shin Otsuka/JPN Carlos Froes/BRA

Table 6: official results for PT1 in the 2015 Rio de Janeiro WPE. Source: International Triathlon Union

The results of the analysis of the test event provide to the Italian Paratriathlon team an aid in the training process in preparation for the Paralympic Games in Rio de Janeiro in 2016, whose official logo is shown in Figure 33.

Regarding the 750 meters, single lap swim course, it was observed that the surf has much influence than the tidal current on the swim performance, so it will be important to monitor the environmental variables of interest during the race time. Since the first yellow buoy is set 350 meters far from the pontoon, the position of the athletes on the floating platform is not fundamentally important.

Figure 33: the logo of the next Rio 2016 Paralympic games

Regarding the bike course, athletes have to ride 3 laps of 6.88 kilometers each, for a total distance of 20.64 kilometers. Each lap is completely flat and has 4 U-turns, for a total of 12 U-turns in the whole bike course. The presence of several U-turns requires the athletes to be well prepared in bike or handbike acceleration practice. Each way forward and way back bike segment can be positively or negatively affected by environmental variables such as wind direction, speed and gusts. Knowing these environmental variables at the day and time of the race will be important to foresee their effects on the athletes' bike performance.

Regarding the run course, athletes have to run 2 laps of 2.50 kilometers each, for a total distance of 5 kilometers. Each lap is completely flat and has 2 U-turns, for a total of 4 U-turns in the whole run course. The presence of several U-turns requires the athletes to be well prepared in run or wheelchair acceleration practice.

Comments

Giorgio Vanerio, competing in the PT2 sport class, was 5th at the finish line, after coming out 4th from swimming, 6th from the T1 and then in the 7th place in cycling and T2. During the run leg, Vanerio moved up two positions, leaving behind the two Brazilian athletes, Barbieri and Matthes. For Giorgio Vanerio it was a great experience. Here are his words after the race: *"I am happy to have taken part in this test event, both for the beautiful location and for the high competitive level in which I measured. Swimming was below my expectations: usually I get out second and just behind Barr, but unfortunately the pain in the deltoid did not allow me to push too hard. I worked in cycling progression, then in the run Ieg I felt immediately lighter and I was concerned to point the Argentinian and the Brazilian athletes, which I was able to reach and to leave me behind."* The Technical Director of the Italian Paratriathlon team, Simone Biava, commented that it was a well-managed race, with a swim leg below expectations and a run leg in overtaking.

Giovanni Achenza, competing in the PT1 sport class, did a good swim, coming out of the water in 4th position. He was in 2nd position after T2. In handbike he remained always 2nd, but with the athletes Schabort and Schipper just behind him. In the first lap of the run leg, the two athletes passed him and went toward the 2nd and 3rd step of the podium, respectively, leaving Achenza in 4th partial position; during the last lap, the British athlete Townsend arrived, managing to overcome Achenza and to gain the 4th position, while the Italian athlete concluded his race in 5th position, just 10 seconds behind Townsend. Here his words after the race: *"I had a good swim, but I think I forced too much in handbike, I paid unfortunately in the final fraction. This test event will be very useful to review all the details of the course and the preparation for the future. I am happy and proud to have participated at this test event, it is not for everyone."* The Technical Director Simone Biava commented with these words: *"I'm satisfied of Achenza's race, it was a battle. I am convinced that, by competing with the best athletes in the world, he can still grow. He did some mistakes in the rhythm management, but that's okay for now. We come back from this test event aware to be well under way. Now we have to focus to fill the gap that divides us from more prestigious results."*

Acknowledgements

Special thanks to the Italian Triathlon Federation (FITRI, whose logo is shown in Figure 34) for the financial support in preparation for paratriathlon's debut next summer at the 2016 Rio de Janeiro Paralympic Games.

Figure 34: the logo of the Italian Triathlon Federation, FITRI

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