University of Verona,
School of Exercise and Sport Science,
Laurea magistrale in Scienze motorie preventive ed adattate

Metodologia delle misure delle attività sportive

Wednesday 16/12/2015 h. 8:30÷10

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A class within a six classes module

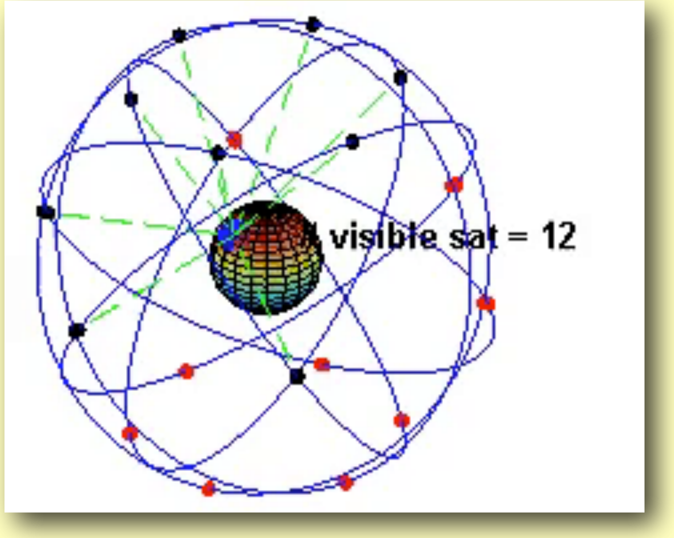
Global Positioning System

- Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites;
- provides critical capabilities to also commercial users around the world;
- is maintained by the USA government and is freely accessible to anyone with a GPS receiver;

Global Positioning System

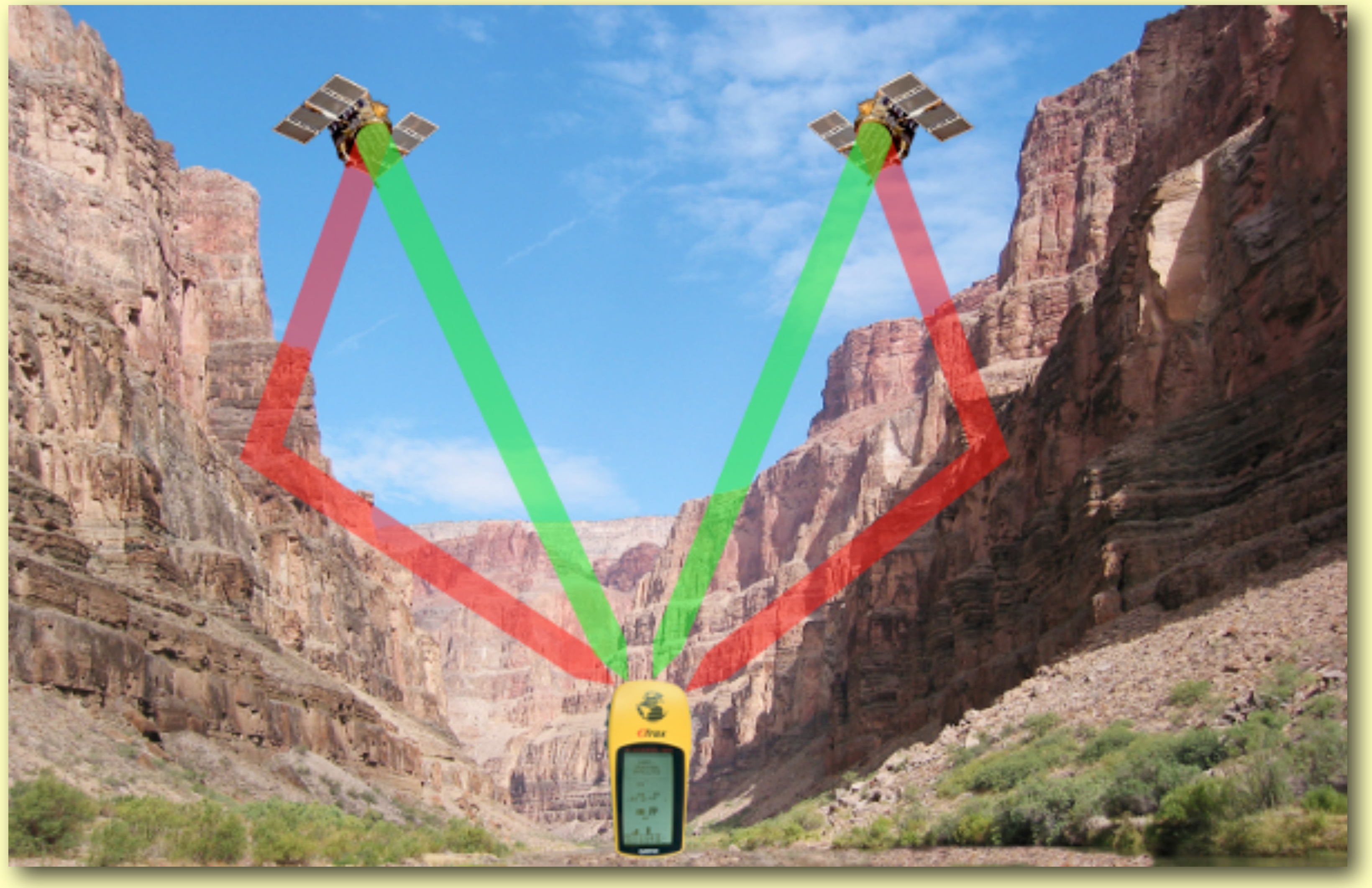
- GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include:
  . time the message was transmitted;
  . satellite position at time of message transmission;
- receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite using the speed of light;
- each of these distances and satellites' locations define a sphere. The receiver is on the surface of each of these spheres when the distances and the satellites' locations are correct;

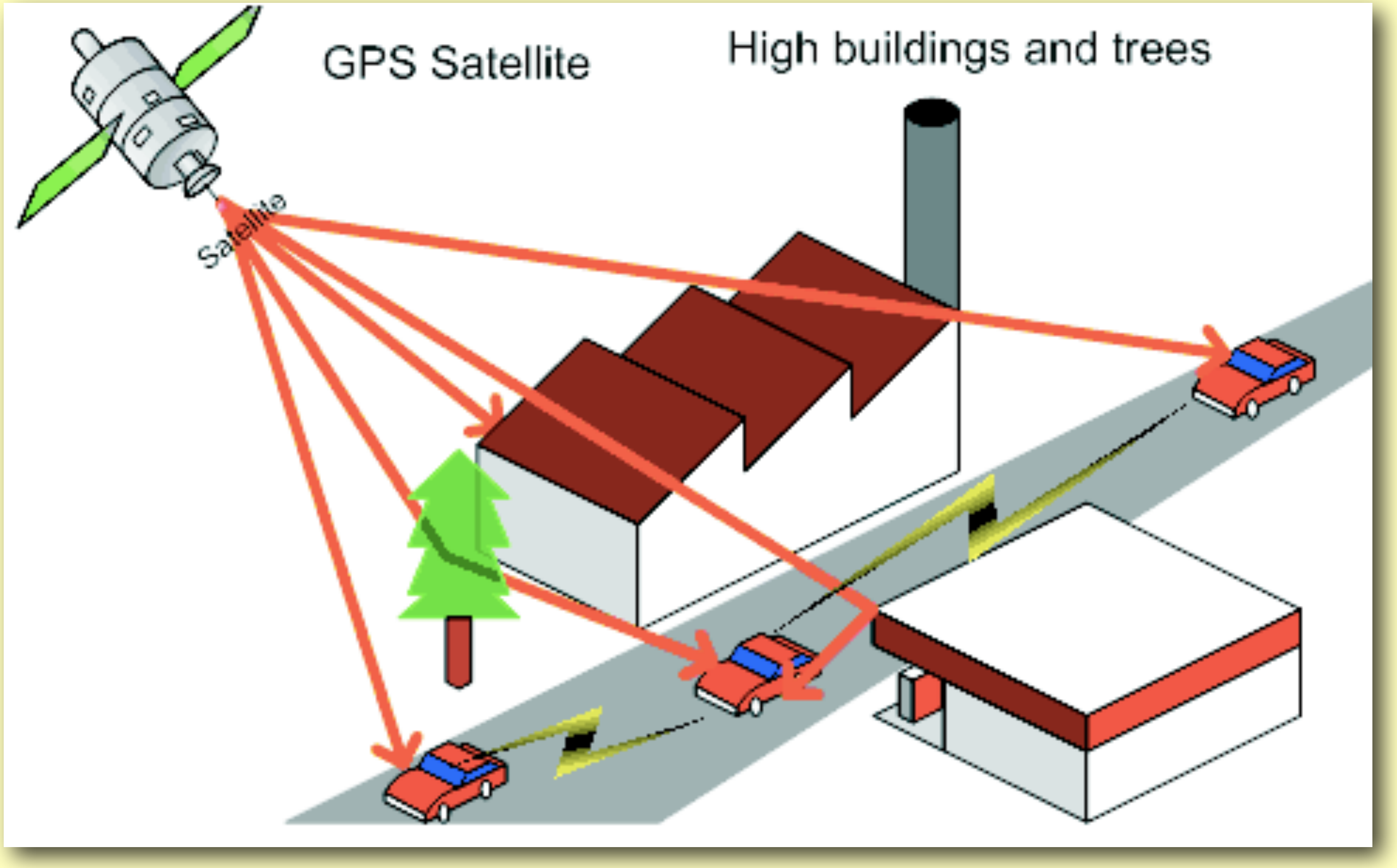
Global Positioning System



- using only three satellites -> latitude and longitude (+ current time);
- using at least four satellites -> latitude, longitude, elevation (based on a predefined geoid) (+ current time);
- three segments: space (<- US Air Force, 24÷31 satellites), control (<- US Air Force, master control station, alternate, four ground antennas, six monitor stations), user (i.e., hundreds of thousands of military, tens of millions of civil GPS receivers);

Global Positioning System





Global Positioning System

measures

– other current, future satellites systems

Global Positioning System

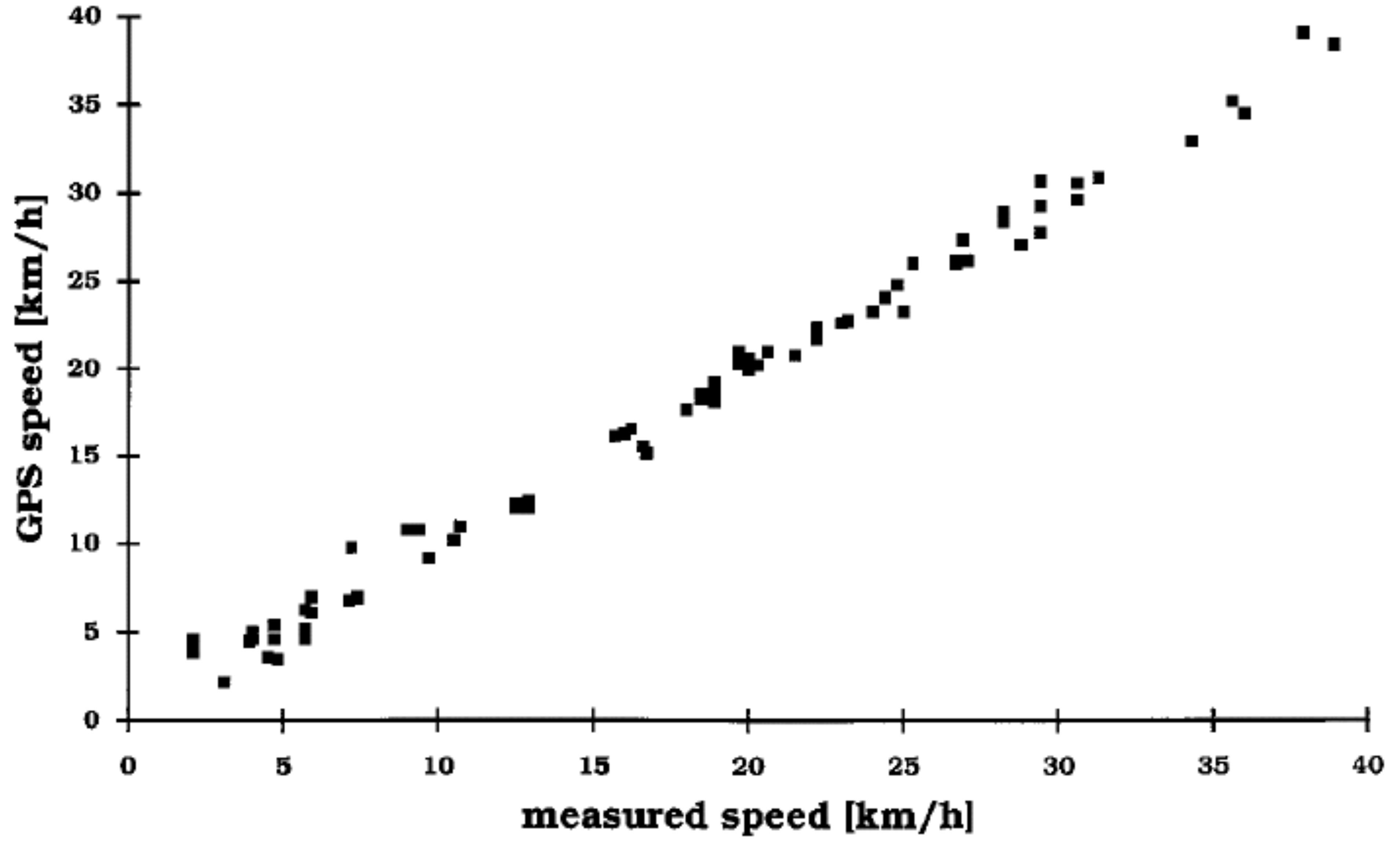


Figure 1 Relationship between the speed of displacement (walking, running and cycling) assessed by GPS ($n = 76$) and that determined by direct measurement by means of chronometry in one male subject ($r = 0.99$, $P < 0.0001$). The linear regression equation was: $speed_{GPS} = 0.42 + 0.974\ speed_{chrono}$.

Schultz et al., 1997

Global Positioning System

- publicly available speed, gradient GPS data -> literature-led metabolic cost estimate equations -> daily ME;

ning) that describe the metabolic cost of walking (C_w) and running (C_r) as a function of speed (v ($m \cdot s^{-1}$)) and incline (i):

[1] $$C_w = 1.87\ a\ v^2 - 3.77\ b\ v + c + 4.46$$

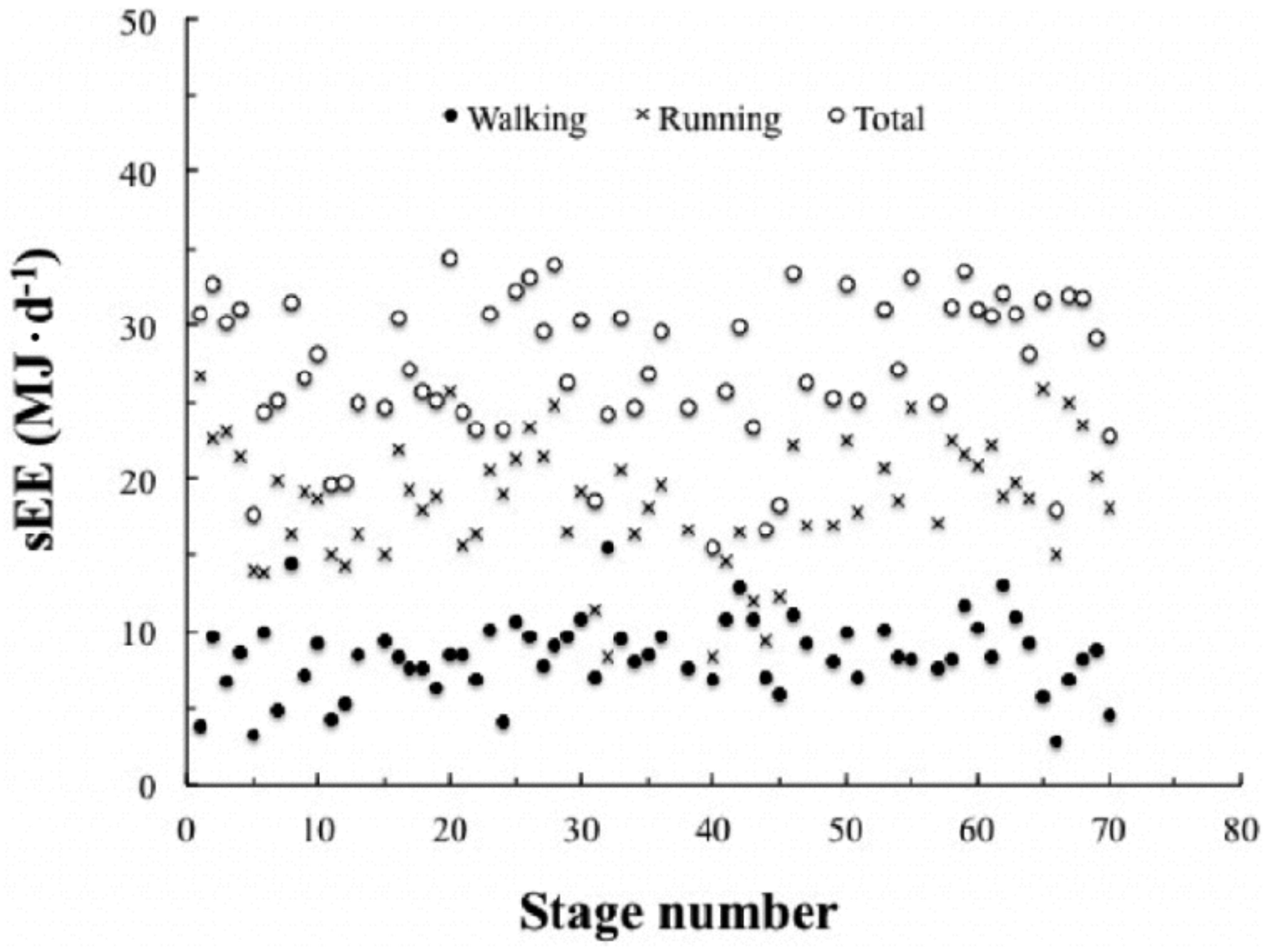
for walking, where $a = e^{4.91\ i}$, $b = e^{3.42\ i}$, and $c = 45.72\ i^2 + 18.90\ i$, and 4.46 is an empirical constant.

For running, a form of locomotion characterized by a larger cost variability, we applied the following equation:

[2] $$C_r = 62.05\ i^2 + 17.08\ i + C_{r0}$$

where C_{r0} corresponds to the metabolic cost of level running measured in the laboratory (i.e., 5.35 $J \cdot m^{-1} \cdot kg^{-1}$, see also Results section). Afterwards, metabolic cost of each 1 m of tra-

Fig. 1. Energy expenditure during activity of each stage plotted as a function of the subsequent stages of LANY.



Ardigò et al., 2012

Global Positioning System

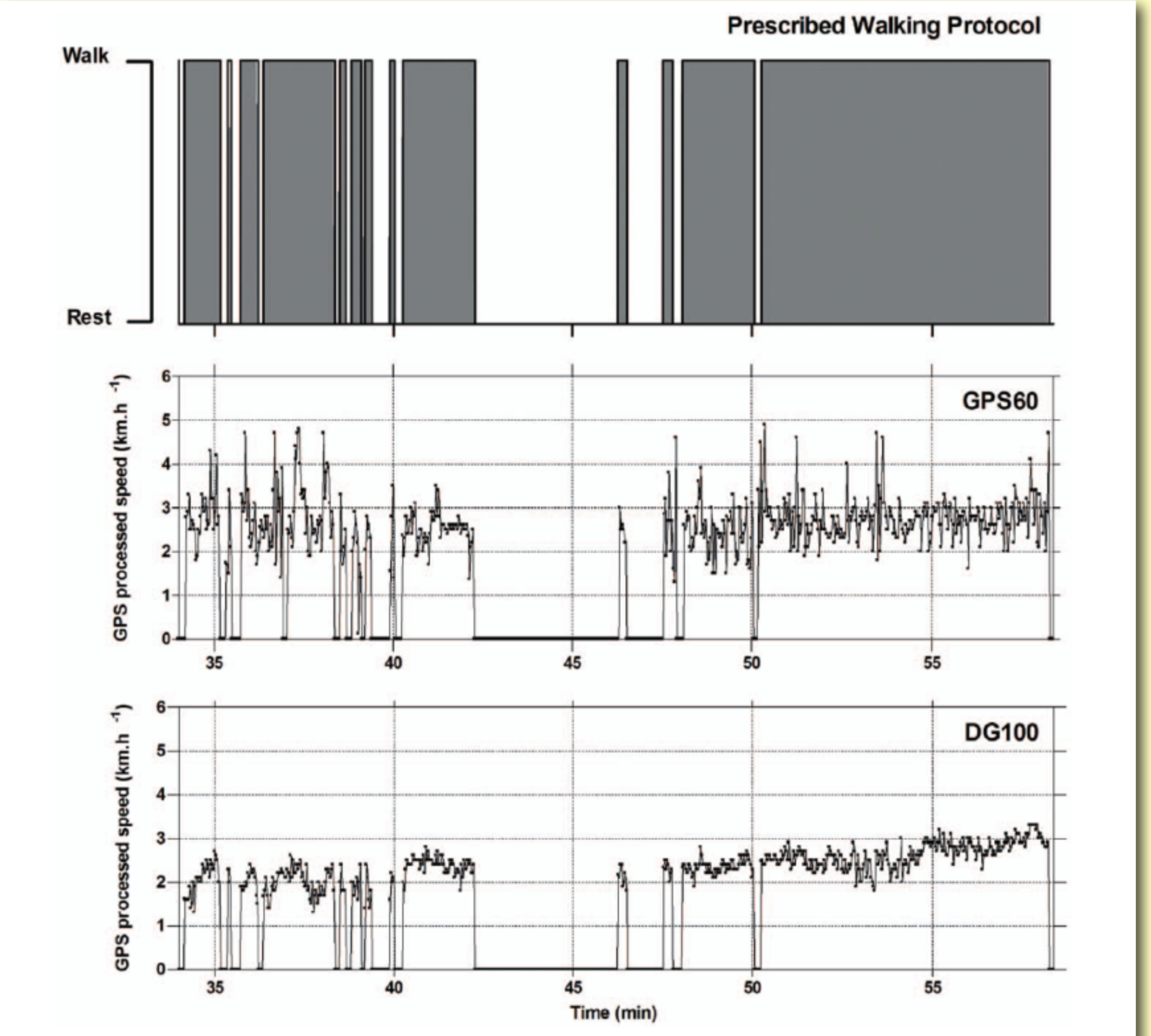


Figure 1. A typical example of GPS processed speed data obtained from a prescribed outdoor walking protocol, both for the DG100 and the GPS60. The entire PWP is not represented on the graph to simplify the figure. The period represented on the graph lasts ~24 min (from minute 34.2 to minute 58.3).
doi:10.1371/journal.pone.0023027.g001

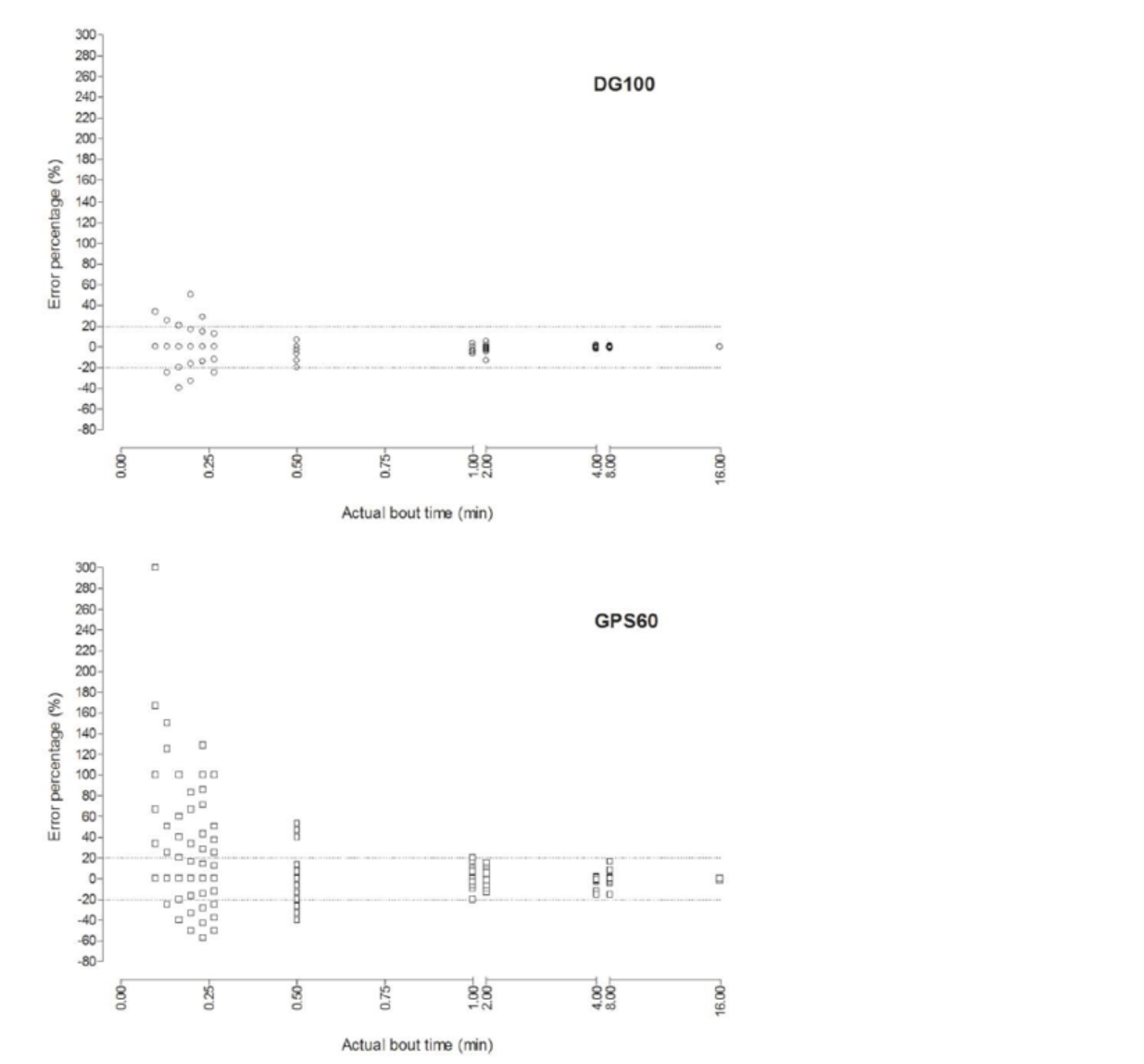


Figure 2. Graphical representation for both the DG100 and the GPS60, of the error percentage for time difference between actual and detected bouts according to actual bout time. Note: concentrations of point near 0% for the DG100 give the impression that there were fewer points, particulary for bouts less than 0.5 min. This was not the case. For instance, there were 65 and 70 bouts of 0.17 min (10 s) for the GPS60 and the DG100, respectivel.
doi:10.1371/journal.pone.0023027.g002

Noury-Desvaux et al., 2011

Global Positioning System

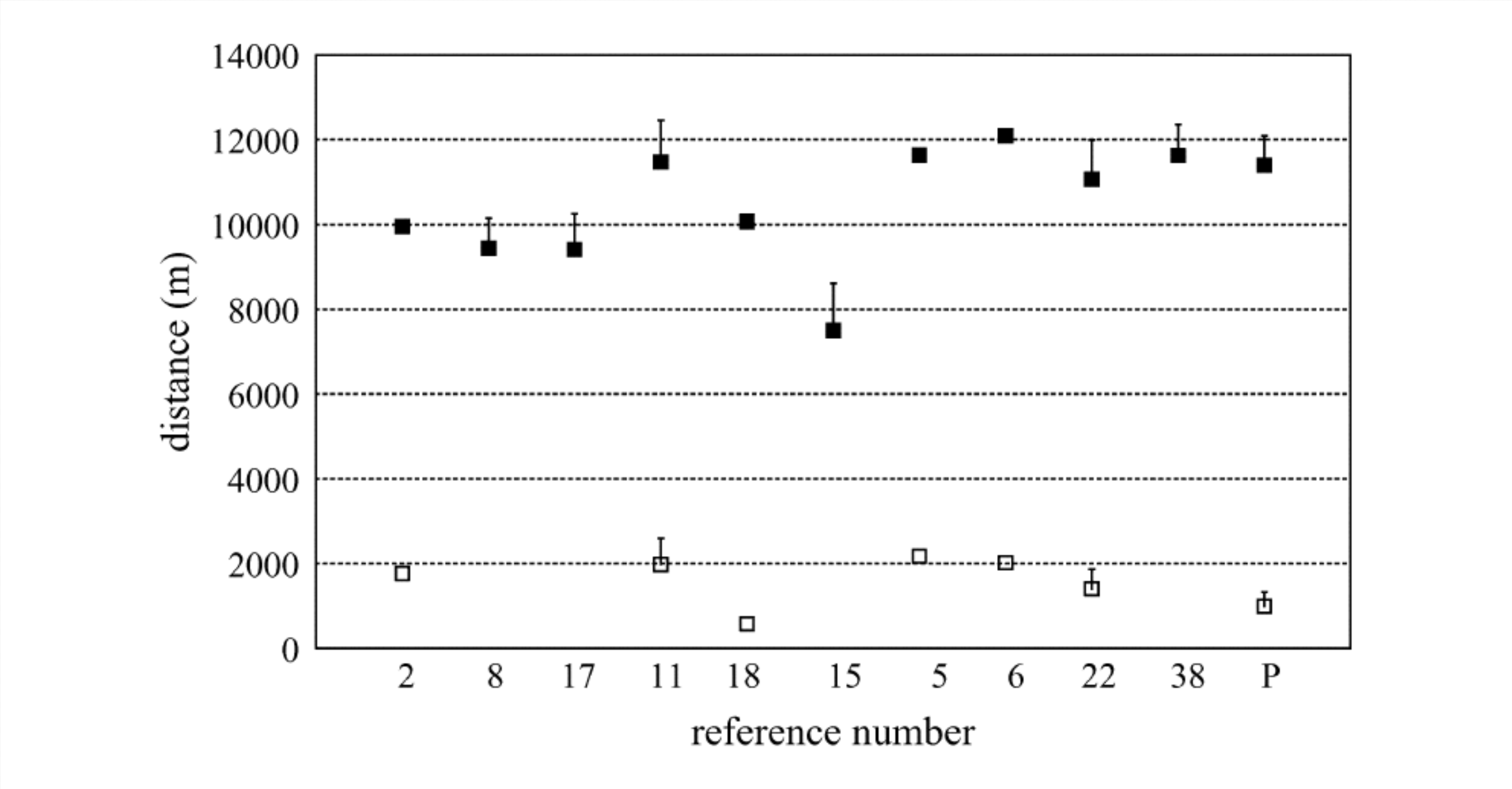


Figure 1. Referees' total match distance (black squares) and high-quality running (empty squares) from literature and present study (references in chronological order and P: present study; average + positive standard deviation [when given]; same in Figures 2, 3, and 4).

Ardigò, 2010

Geographic Information System

- Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data;
- a GIS developed for an application, jurisdiction, enterprise, or purpose may not be necessarily interoperable or compatible with a GIS that has been developed for some other application, jurisdiction, enterprise, or purpose;

Geographic Information System

Global Positioning System

Figure 1 — Combined GPS and accelerometer continuous data indicating location of sedentary, light, moderate, and vigorous minutes of physical activity (for weekdays) days).

Maddison et al., 2010

Global Positioning System

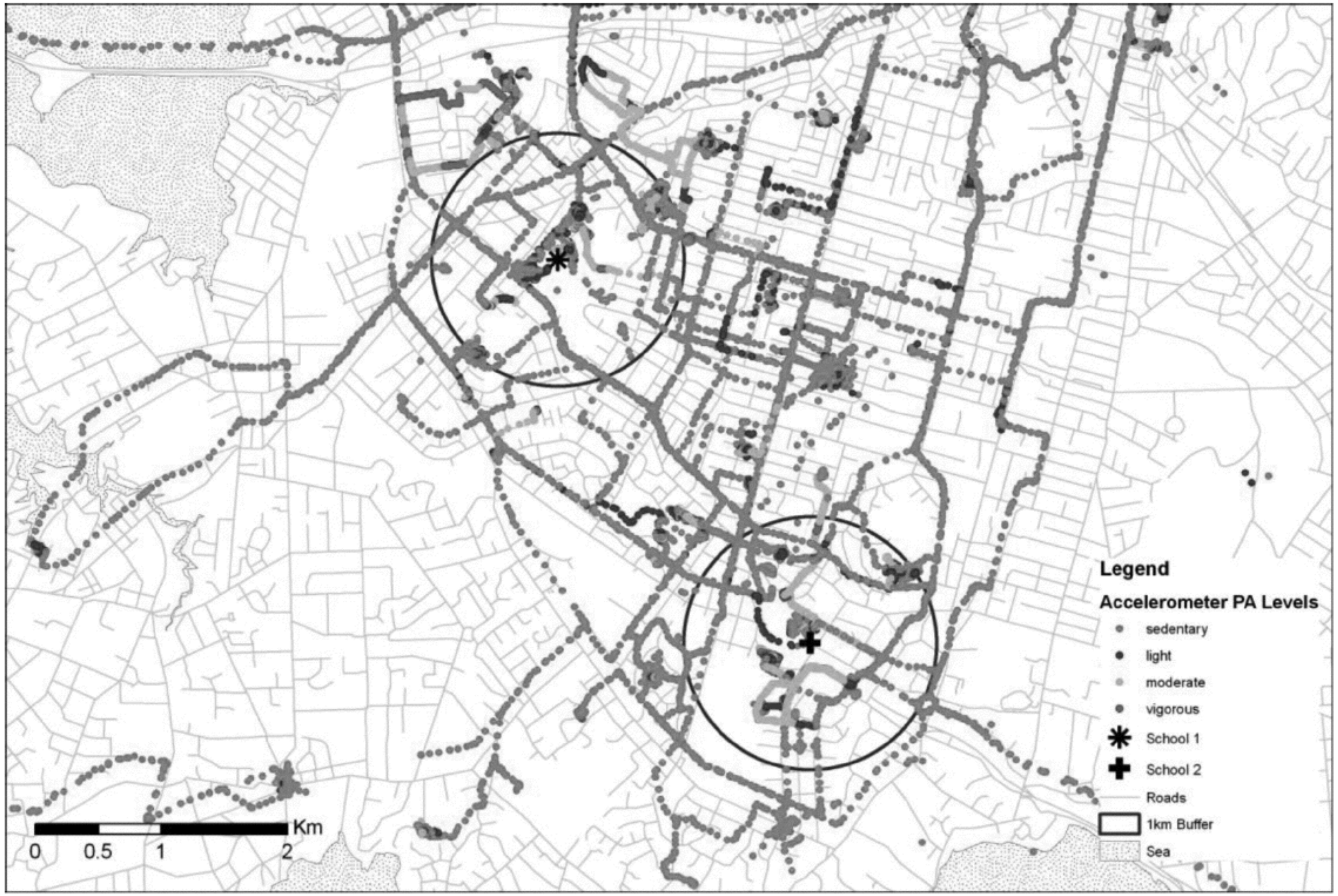


Figure 2 — Combined GPS and accelerometer continuous data indicating location of sedentary, light, moderate, and vigorous minutes of physical activity (for weekend days).

Maddison et al., 2010

Global Positioning System

Global Positioning System

Good to know... II

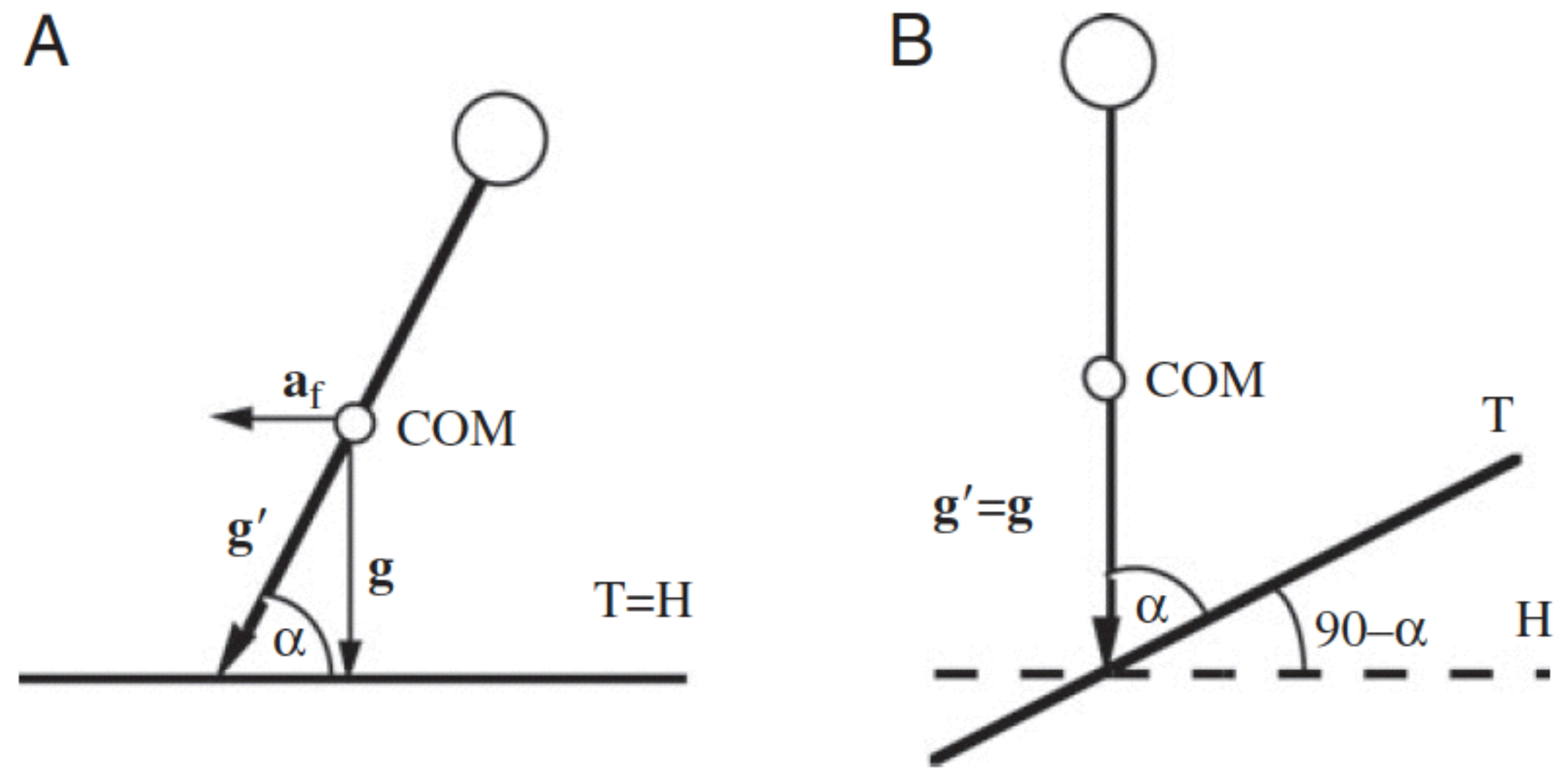


Fig. 1. Simplified view of the forces acting on a runner. The subject is accelerating forward while running on flat terrain (A) or running uphill at constant speed (B). The subject's body mass is assumed to be located at the centre of mass (COM); $\mathbf{a_f}$=forward acceleration; $\mathbf{g}$=acceleration of gravity; $\mathbf{g'}=(\mathbf{a_f}^2+\mathbf{g}^2)^{0.5}$ is the acceleration resulting from the vectorial sum of $\mathbf{a_f}$ plus $\mathbf{g}$; T=terrain; H=horizontal; α (=arctan $\mathbf{g}/\mathbf{a_f}$) is the angle between runner's body and T; the angle between T and H is α′=90–α. (Modified from di Prampero et al., 2002.)

di Prampero et al., 2005

Global Positioning System

- i-Blue 747A+, TSI, Hsinchu, Taiwan;
- €71;
- one main applications: photographs' geo-tagging;
- MTK II 66 channels 5 Hz;
- cheaply measured speed (-> acceleration) GPS data -> literature-led metabolic cost estimate equation -> soccer refereeing ME;

$$C = (155.4 \cdot ES^5 - 30.4 \cdot ES^4 - 43.3 \cdot ES^3 + 46.3 \cdot ES^2 + 19.5 \cdot ES + 3.6) \cdot EM \cdot KT \qquad [1]$$

where C is in $J \cdot kg^{-1} \cdot m^{-1}$, ES is the so-called equivalent slope: ES = tan (90 – arctan g / a); g ($m \cdot s^{-2}$) = Earth's acceleration of gravity; a in $m \cdot s^{-2}$; EM is the equivalent body mass: $EM = (a^2 / g^2 + 1)^{0.5}$; 3.6 is C of constant speed running on flat terrain and on regular, compact surface; and KT (1.29) is a correction factor that corrects for the larger C elicited by running on grass surface[26].

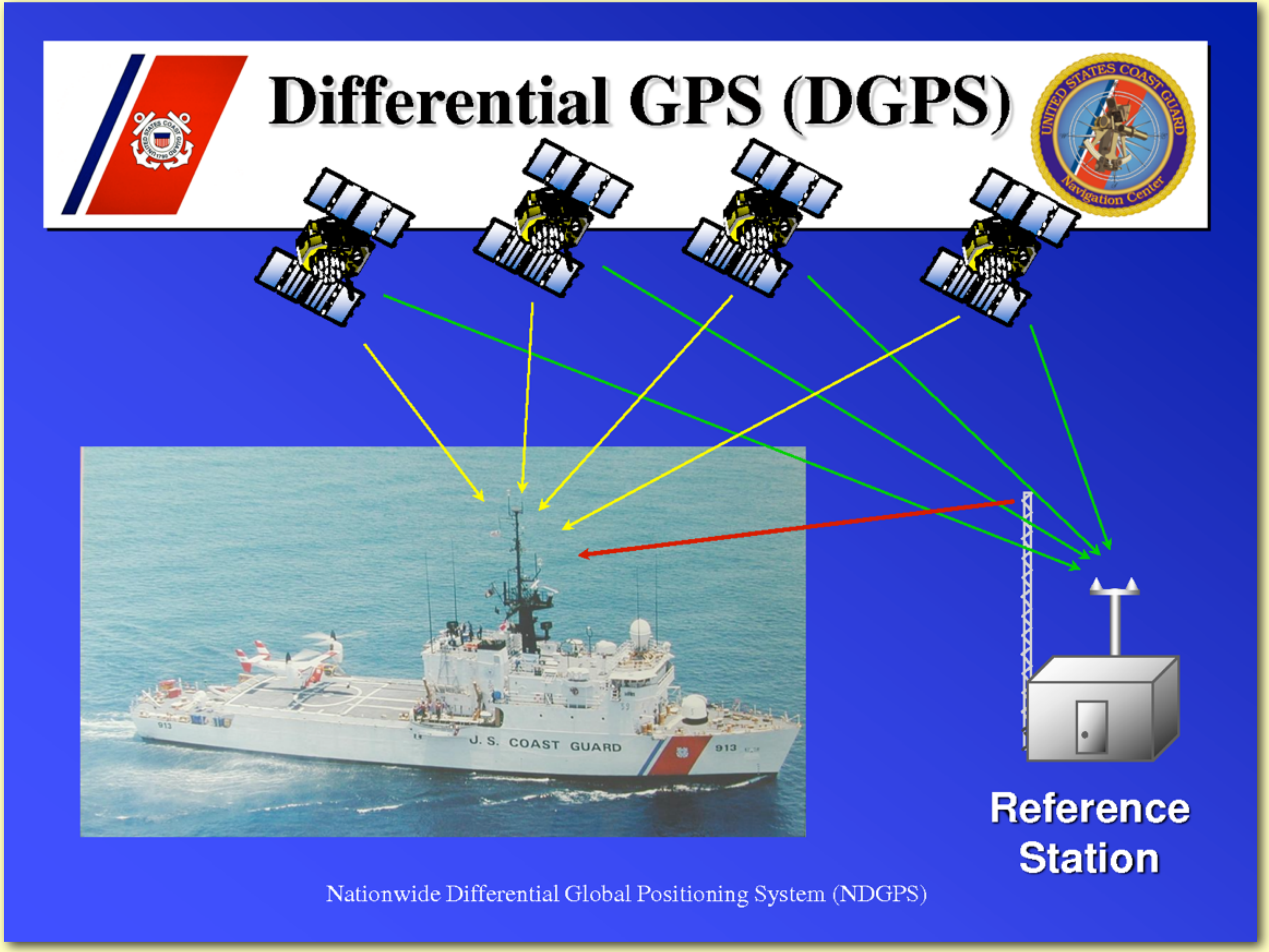
Ardigò et al., 2015

Differential Global Positioning System

- Differential Global Positioning System (DGPS) is an enhancement to GPS that provides improved location accuracy, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations;
- DGPS uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite distances and actual (internally computed) distances, and receiver stations may correct their distances by the same amount. The digital correction signal is typically broadcast locally over ground-based transmitters of shorter range

Differential Global Positioning System

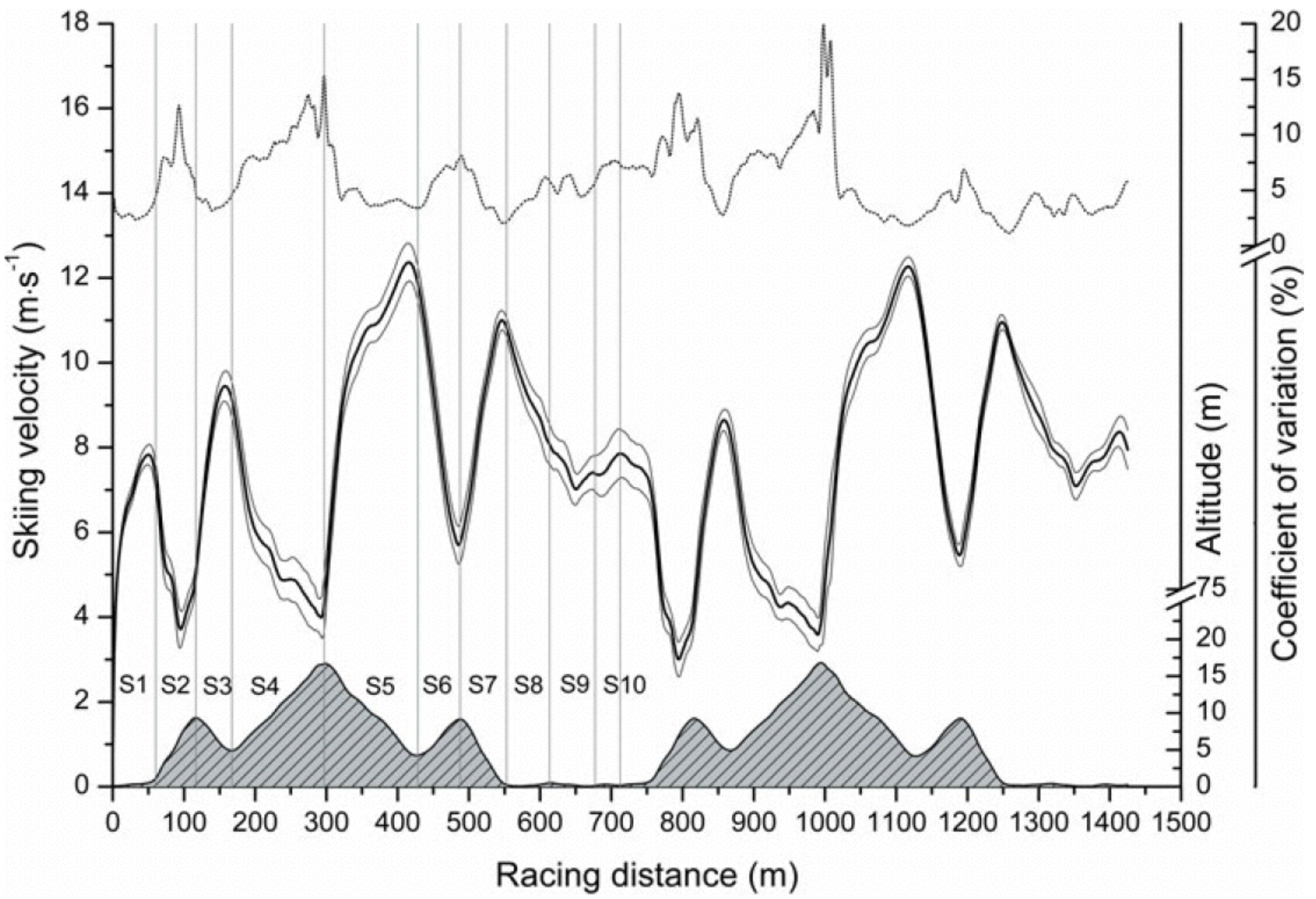
measures



Differential Global Positioning System

measures

Fig. 1 The skiing velocity (*solid line*), altitude profile (*gray area under the curve*) and coefficient of variation (*dashed line*) plotted against horizontal distance (m) for both laps. The *vertical lines* represent the 10 sections of one lap

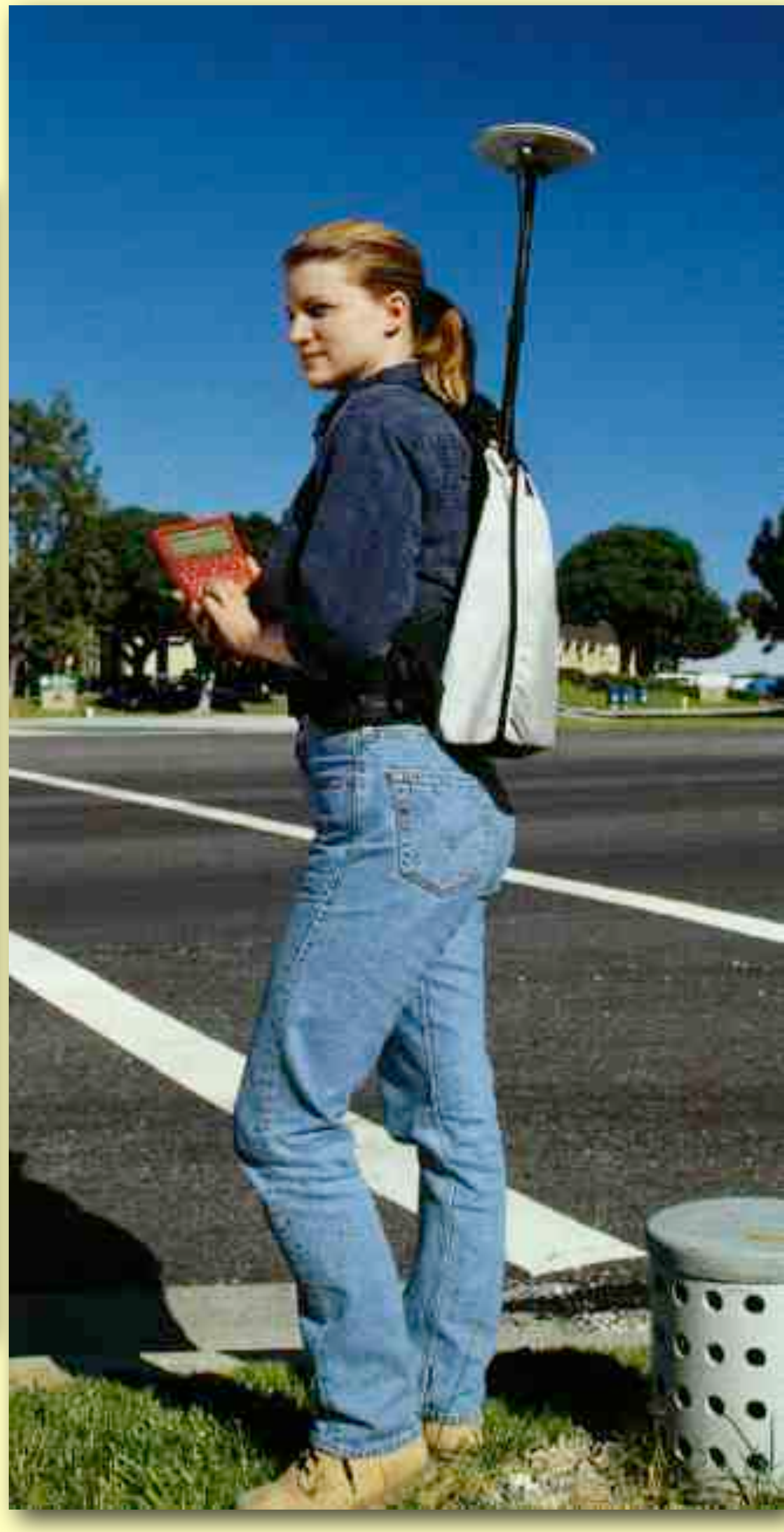


Andersson et al., 2010

Differential Global Positioning System

Figure 2. The Moven suit consisted of 16 inertial motion-tracking sensors, embedded in a lycra suit worn under the skier's skin-tight ski racing suit. The RTK GNSS receiver, data logger, and antenna are housed in a small backpack worn by the skier.

Supej, 2010



Differential Global Positioning System

Figure 1. A skier equipped with the entire measurement setup consisting of GNSS and IMU units.

Nemec et al, 2014