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HISTORICAL APPROACH OF HEART RATE AND PERIPHERAL PULSE RECORDING (A DIACHRONIC APPROACH FROM THE FIRST NOTES TO THE TECHNOLOGY OF 2013)

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ABSTRACT. For thousands of years people are concerned to understand the operation of the most complex "machine" that exists on earth. For hundreds of years physiologists monitor heart sounds and interpret them to understand and anticipate the best influences that "the engine" has upon each organ of the human body, both individually and to the whole. A good anticipation of heart function is useful for everyday life, especially for applications required in physical activities. Heart rate is the parameter that we are interested primarily in physical activities because it changes directly proportional to level of effort (Derevenco, 1998), being the most rapid adjustment mechanism to the level of effort (Pufulete, 2002, p. 105).The first historical reference related with the working frequency of the heart is connected with the name of a doctor, who lived in the age of pyramids, Imhotep (Fig. 1) (roughly around 2600 BC) (Zăgrean, 1993, p. 15). After a trip through history heart rate recording we arrive to 2013. Now-a-days heart rate recording is performed with a wide range of instruments with a high accuracy for recorded data. I use a system consisting of heart rate monitor synchronized with specific software installed on my phone. After training is complete, the file containing the data taken during the session will be synchronized with your personal account on Sports Tracker site. From this account data will be exported into a file ending in '.gpx' which contains the heart rate profile during exercise session. The file '.gpx' will be imported into SportTracks program and will be processed with the tools offered by this software.

Key words: heart rate, pulse, history, record, technology.

REZUMAT. Istoricul înregistrării frecvenței cardiace și a pulsului periferic (o abordare diacronică de la primele însemnări până la tehnologia anului 2013). De mii de ani oamenii sunt preocupaţi să înţeleagă funcţionarea celei mai complexe „maşini” care există pe pământ. De sute de ani fiziologicii monitorizează sunetele inimii şi le interpretează pentru a înţelege şi a anticipa cât mai bine

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influenţele pe care le are „motoraşul” corpului uman atât asupra fiecărui organ în parte, cât şi asupra întregului. O anticipare cât mai bună a funcţiilor inimii este de real folos pentru viaţa de zi cu zi, dar mai ales pentru aplicaţiile atât de necesare în domeniul activităţilor fizice. Frecvenţa cardiacă este parametrul care ne interesează, în primul rând, în cadrul activităţilor fizice deoarece ea se modifică direct proporţional cu mărimea efortului (Derevenco, 1998), fiind cel mai rapid mecanism de adaptare la efort (Pufulete, 2002, p. 105). Prima referinţă care apare în istorie cu privire la frecvenţa cu care inima funcţionează este legată de numele unui medic care a trăit în epoca piramidelor, Imhotep (aproximativ în jurul anului 2600 î.e.n.) (Zăgrean, 1993). După o incursiune prin istoricul înregistrării frecvenţei cardiace ajungem în 2013. În această perioadă înregistrarea frecvenţei cardiace se realizează cu o gamă foarte variată de aparate care au o precizie mare privind fidelitatea datelor înregistrate. Eu folosesc un sistem format dintr-un monitor de frecvenţă cardiacă sincronizat cu un program instalat pe telefon. După ce se încheie antrenamentul, fişierul care conţine datele prelevate în timpul sesiunii de lucru va fi sincronizat cu contul personal de pe site-ul sports-tracker. Din acest cont datele vor fi exportate într-un fişier cu terminaţia '.gpx' care conţine şi profilul frecvenţei cardiace din timpul antrenamentului. Fişierul '.gpx' va fi importat în programul SportTracks şi va fi prelucrat cu instrumentele oferite de acesta.

Cuvinte cheie: frecvenţă cardiacă, puls, istoric, înregistrare, tehnologie.

For thousands of years people are concerned to understand the operation of the most complex "machine" that exists on earth. For hundreds of years physiologists monitor heart sounds and interpret them to understand and anticipate the best influences that "the engine" has upon each organ of the human body, both individually and to the whole. A good anticipation of heart function is useful for everyday life, especially for applications required in physical activities.

The recognized heart functional parameters are cardiac output, systolic flow and heart rate (Derevenco, 1998). "Heart rate is the number of heart beats per minute" (Derevenco, 1998, p. 40). Peripheral pulse is a pulsatile wave propagated from the heart to the periphery. "Pulsating wave is an energy wave that propagates through the vascular wall, step by step, generated by pressure oscillations that occur as a result of the force developed by contractions of the heart" (Gusti, 1989, p. 128).

Heart rate is the parameter that we are interested primarily in physical activities because it changes directly proportional to level of effort (Derevenco, 1998), being the most rapid adjustment mechanism to the level of effort (Pufulete, 2002, p. 105).

The first historical reference related with the working frequency of the heart is connected with the name of a doctor, who lived in the age of pyramids, Imhotep (Fig. 1) (roughly around 2600 BC). He admitted "the peripheral pulse as a result of heart force" and recommended techniques of examination for this peripheral pulse (Zăgrean, 1993, p. 15).

Fig. 1. Statue of Imhotep in the Louvre (Wikipedia, 2013)

History does not specify such other notes until Aristotle who, in turn, acknowledged that "pulse was the result of the continuous beating of the heart" (Bârsu, 2007, p. 13). Aristotle (384-322 BC) made observations on changes in heart rate in different states of the body, such as: fear, hope, agony (Bârsu, 2007).

Roughly between 335-280 BC was made the first pulse recording of the human heart. It belongs to Herophilos, Greek scientist who observed that the arteries pulsate rhythmically (Billman, 2011). He analyzed the pulse rate using a water clepsydra (Bedford, 1951; Bay & Bay, 2010, quoted by Billman, 2011, p. 2). Herophilos listed many pulse features: "amplitude, speed, strength and rhythm" (Bârsu, 2007, p. 15).

In our era, Archigenes, in the first century, was the first to describe the regularity and irregularity of pulse, noting eight features for it (Bedford, 1951 quoted by Billman, 2011, p. 2). Also Archigenes stated as being dangerous a powerful and frequent pulse (Ionescu, 1987).

In the second century AD, Rufus of Ephesus was first to argue that the pulse is caused by the contraction and relaxation of the heart (Bedford, 1951 quoted by Billman, 2011, p. 2). In India, in the same century, Charaka wrote about synchronicity between pulse and heartbeat (Zăgrean, 1993). He said that "pulse disappears when death comes" (Zăgrean, 1993, p. 114).

Fig. 2. Galen of Pergamon (Wikipedia, 2013)

The most famous ancient Greek scientist was the doctor Galen of Pergamon (he lived between 131-200 AD) who wrote at least 18 books on pulse (Billman, 2011). Greek doctor said that the arteries are filled with blood when the heart contracts and marks its dilatation by beatings (Ionescu, 1987), and "arterial pulsation is due to a contraction property of a structure found in the arterial wall" (Bârsu, 2007, p. 17).

To analyze movements pressure, Galen introduced a tube into an artery and concluded that the pulsations come from the heart (Ionescu, 1987).

Regarding the measurement of pulse, Greek physician recommended that this has to be done by counting at least 100 beats (Zăgrean, 1993). Galen also explained that the pulse undergoes qualitative changes with age (Zăgrean, 1993).

The Greek physician was the first one to observe and note the effects of exercise on the heart in the book "The Pulse for Beginners" (Billman, 2011, p. 2). He advocated the usefulness of exercise, including the therapeutic process based on exercise (Derevenco, 1998).

In 1450 was presented the first method of counting the pulse by a Catholic monk, his name Nicholas Krebs (Zăgrean, 1993).

Sanctorius (1561-1636) recorded pulse variations that has been done with a tool made by him and named pulsilogium (Bârsu, 2007).

John Floyer (1649-1737) "determined heart rate per time unit and he built a special watch for this" (Bârsu, 2007, p. 58). This watch that help to measure pulse was first of its kind (Floyer, 1707 quoted by Billman, 2011, p. 3). With this watch it has been recorded both pulse and respiration in different circumstances (Billman, 2011).

Floyer analyzed pulse behavior in various circumstances, including those where the body is subjected to effort and he established normal heart rate to 100 beats / minute, describing several characteristics of pulse (Zăgrean, 1993).

Around the same time that Floyer lived, James Keil (1673-1719) "calculated mechanical strength of the heart" (Bârsu, 2007, p. 60).

In 1733, Stephen Hales noted that variation of pulse is related with respiratory cycle (Hales, 1733 quoted by Billman, 2011, p. 3).

After he invented the smoke kymograph (mechanical device that recorded movements on a drum), German physiologist Carl Ludwig noted in 1847 that the pulse is accelerated by inspiration and it is reducing by expiration (Berntson et al., 1997).

In 1854, Karl Vierordt (1818-1884) invented a more accurate pulse recording device, called sphygmograph (Bârsu, 2007). A variant of sphygmograph was designed in 1860 by Etienne-Jules Marey, too (Bârsu, 2007).

The first scientist who recorded the electrical activity of the heart was Willem Einthoven in 1895 (Einthoven, 1895; Katz and Hellerstein, 1982; Hurst, 1998 quoted by Billman, 2011, p. 3).

In 1897, Sir James MacKenzie (1853-1925) "imagined a polygraph which simultaneously recorded arterial and venous pulse" (Fig. 3) (Bârsu, 2007, p. 95).

The nineteenth century, especially the second half, came to be defined by the invention of many methods used for recording the pulse graphic (Zăgrean, 1993).

There was, in 1961, the portable electrocardiograph for periods of time up to 24 hours, realized by Norman Holter (Holter, 1961 quoted by Billman, 2011, p. 3).

In 1983, Polar Electro invented the first wireless transmission electrocardiograph (between the ring electrode and receiver): Polar Sport tester PE 2000 (Parker, 2007).

It began, thereby, the portable heart rate monitors era. They were developed continuously, modifying their performance at a very fast pace.

Such a device consists of a belt with electrodes that is positioned on the chest. These electrodes monitor the electrical activity of the heart and transmit information by radio signal to receiver that calculates heart rate per minute. This receiver can be a device like a clock attached to the human forearm, or can be any type of device (phone, tablet) that has Bluetooth function and software designed for decoding signals received. Professional equipments have the signal between the belt and the receiver encoded to prevent interference by neighboring devices (Parker, 2007).

These devices which monitor heart rate allow the user to read real-time heart rate value. They are very useful for real-time monitoring exercise intensity levels.

The system used by me for Ph.D. research consists in one belt with Bluetooth transmitter, Polar brand, one phone (Smartphone) with Bluetooth and specific software for reception, analysis and interpretation of heart rate data.

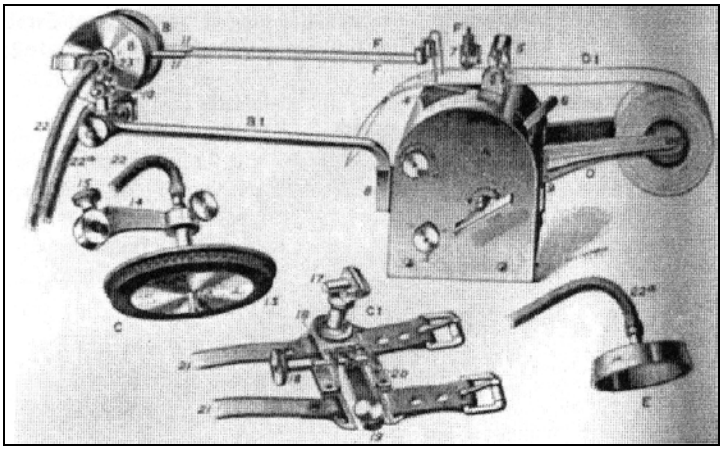

Fig. 3. The polygraph of Sir James MacKenzie (Bârsu, 2007, p. 96)

To be more specific, my system includes:

- Polar WearLink® + transmitter with Bluetooth® (Polar, 2013) (Fig. 4)
- Smartphone Samsung Xcover GT-S5690 (Samsung, 2013) (Fig. 5)
- Phone software for Android, Sports Tracker (Sports Tracking Technologies Ltd., 2013) (Fig. 6)

- PC software for Windows XP, SportTracks (Zone Five Software LLC, 2013) (Fig. 7).

Fig. 4. Polar WearLink® + transmitter with Bluetooth® (Polar, 2013)

Fig. 5. Samsung Xcover GT-S5690 (Samsung, 2013)

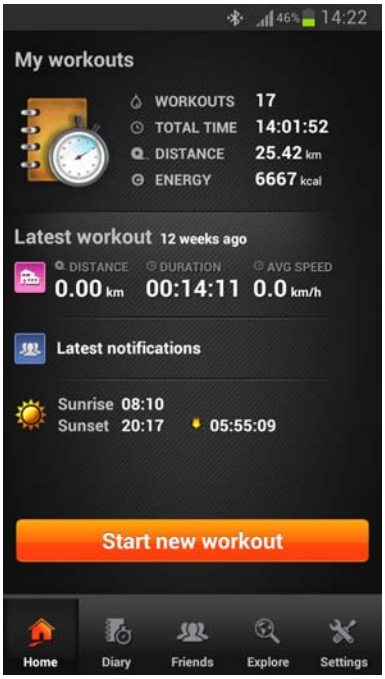

Fig. 6. Sports Tracker for Android

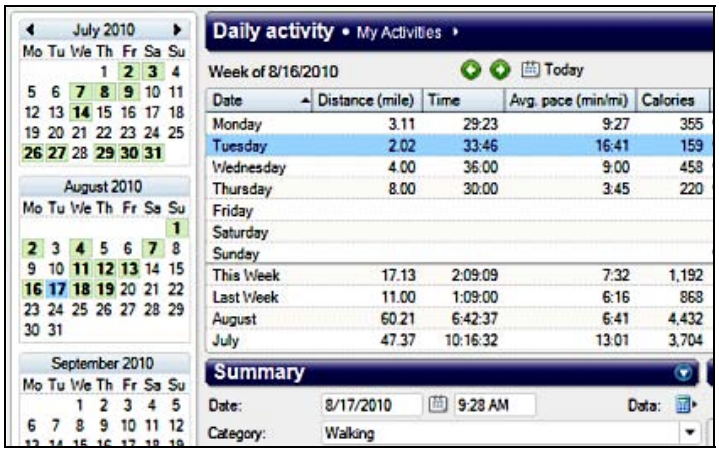

Fig. 7. SportTracks for Windows XP (Zone Five Software LLC, 2013)

Heart rate monitor records the activity of heart and sends information to receiver with which was synchronized. Synchronization is done by the software installed on the receiver and has a key consisting of '0000' (heart rate belt specific key).

The software installed on my phone analyzes information and includes it in the settings that the user has chosen. These settings are provided through the possibilities created by the software developer. The Sports Tracker for Android offers (Google, 2013):

- Track and analyze your performances, monitor your progress
- Store all training data in your personal workout diary
- Keep track of everything from calories burned to average training speed and altitude
- Use maps, time and distance calculators
- Get voice feedback during training
- Share workout data and photos with other trackers on Sports Tracker, Facebook and Twitter
- See your friends' profiles and comment their workouts and photos
- Explore the globe to discover new routes, trails and adventures worldwide

PC software for Windows XP offers (Zone Five Software LLC, 2013):

- GPS import or manual workout entry
- Show GPS routes with street, topo & satellite maps
- Chart workout trends over time

- Detail pace, elevation, and heart rate graphs
- Dynamic split time, distance and pace analysis
- User-defined workout categories and custom data
- Edit GPS routes or HR info to fix bad data
- Equipment (shoe) mileage and use tracking
- Complete control of your data, stored on your PC

After training is complete, the file containing the data taken during the session will be synchronized with your personal account on Sports Tracker site. From this account data will be exported into a file ending in '.gpx' which contains the heart rate profile during exercise session. The file '.gpx' will be imported into SportTracks program and will be processed with the tools offered by this software.

I highly recommend the use of my system because this is a system that allows high maneuverability of the recorded data. The recorded data can be processed and analyzed with high precision and multiple details. Also, this system is inexpensive and costs, depending on the cell used, less than 230 € (1000 RON).

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