Prošireni sažetak / Extended abstract

Računalni pristup ispitivanju kardiorespiratorne sinkronizacije

Computational approach for the study of cardiorespiratory synchronization

Alberto Macerata*
Department of Physiological Sciences, Pisa, Italija
Department of Physiological Sciences, Pisa, Italy

Ritmičko ponašanje je vrlo uobičajeno kod mnogih bioloških funkcija našeg tijela, kao što je srčana frekvencija, tijekom dnevnog ciklusa hodanja i spavanja, pri otpuštanju hormona itd. Ovi ritmovi pod kontrolom različitih sustava fiziologičke interakcije mogu međudjelovati jedni s drugima, kao i s vanjskim okruženjem. Od bioloških ritmova, srčani ritam i respiracija su od posebnog interesa. Dobro je poznato da je frekvencija srca (HR) pod utjecajem respiratorne funkcije, a respiratorna sinusna aritmija (RSA) je izravan učinak respiracije na trend HR. Kod RSA HR slijedi isti trend respiratornog signala, povećavajući se tijekom inspirija i smanjujući se tijekom ekspirija. Sa stajališta frekvencije, ovo znači da možemo pronaći istu frekvenciju i u HR i vremenskim serijama respiracije. Ova interakcije nije uvijek prisutna zato što je to funkcija različitih fizioloških stanja, od kojih je najvažnije simpatetička-parasimpatetička ravnoteža autonomnog živčanog sustava (ANS). Interesantno je da se između HR i respiracije može pojaviti poseban fenomen koji se naziva fazna sinkronizacija.

Kardiorespiratorna fazna sinkronizacija (CRS) se pojavljuje kada je kod uzastopnih n respiratornih ciklusa uvijek prisutan jednak broj otkucaja u EKG zapisu, a fazna razlika između kašnjenja između početka respiracije i prethodnog ciklusa u EKG je konstantna. U ovom slučaju možemo reći da postoji sinkronizacija s omjerom frekvencije. U biti, klasična definicija "sinkronizacije" se odnosi na periodičke, samoodržive oscilatore. Kod nestacionarnih, nelinearnih oscilatora kao što su oni koji su prisutni u biološkim sustavima, definicija se mora pravilno podesiti i pojednostaviti. Dostupne su mnoge metode za identifikaciju prisutnosti sinkronizacije i izračuna omjera frekvencije. Najpopularniji je Sinkrogram koji se temelji na izračunu stroboskopskog prikaza respiratornog signala koji se dobija u vremenskim markerima koji odgovaraju svakom ciklusu u EKG zapisu. Dobija se grafička reprezentacija koja može pokazati prisutnost razdoblja sinkronizacije, njihovo vremensko trajanje i omjer frekvencije.

Što se tiče HR i respiracijskih signala, sinkronizacija nije uobičajeno stanje u svakodnevnom životu. Ustanovljeno je da je prisutnija pri mirovanju, nego kod vježbanja ili umnih aktivnosti. A tijekom mirovanja je naglašenija kod sportaša nego kod ne-sportaša. Ova ovisnost CRS o različitim uvjetima u okolini i zdravstvenom stanju ukazuje da fenomen

Rhythmic behaviors are quite common in many biological functions of our body, like in the heart beating, during the daily cycle of waking and sleeping, in the release of hormones and so on. These rhythms can interact each others, as well as with the outside environment under the control of different physiological feedback systems. Among biological rhythms, the heart rate and respiration are of special interest. It is well known that Heart Rate (HR) is influenced by the respiratory function, and the Respiratory Sinus Arrhythmia (RSA) is the direct effect of respiration on the HR trend. In the RSA the HR follows the same trend of the respiratory signal, increasing during inspiration and decreasing at expiration. From frequency point of view, this means that we find the same frequency both in the HR and in the respiration time series. This interaction is not always present because it is function of different physiological conditions, the most relevant one being the sympathetic-parasympathetic balance of the Autonomic Nervous System (ANS). What is interesting is that, between HR and respiration, a special phenomenon, named Phase Synchronization, can happen.

The Cardiorespiratory Phase Synchronization (CRS) occurs when in consecutive n respiratory cycles are always present the same number of ECG beats, and the phase difference between the delay between the onset of the respiration and the preceding ECG cycle is constant. In this case we can say that exists a synchronization with a frequency ratio. Actually the classical definition of 'synchronization' refers to periodic, self-sustained oscillators. With not stationary, non linear oscillators like those present in biological systems, the definition has to be properly adjusted and generalized. Many methods are available for identifying the presence of synchronization and computing the frequency ratio. The most popular one is the Synchrogram which is based on computing a stroboscopic view of the respiratory signal as obtained at the time markers corresponding to every ECG cycles. The output is a graphic representation able to show the presence of synchronization periods, their time length and frequency ratio.

For what concerns the HR and respiration signals, the synchronization is not a common condition in daily life. It was found that it is more present at rest than during exercise or mental tasks. And, at rest, it is more pronounced in athletes

sinkronizacije sadrži korisne informacije koje mogu poboljšati naše znanje o kardiorespiratornoj interakciji i povezanim neuralnim i kardiovaskularnim sustavima. U literaturi postoje primjeri koji naglašavaju važnost obrazaca disanja kod promoviranja sinkronizacije. Ovo je posebice točno kada okruženje pogoduje "sinkronom" disanju, kao što je tijekom izgovaranja krunice ili mantra ili recitiranja poezije.

Ključne riječi: fazna sinkronizacija, varijabilnost srčanog ritma, fiziološki ritam.

than in non-athletes. This dependence of CRS on different environmental conditions and health status suggests that the phenomenon of synchronization contains useful information that can improve our knowledge on the cardiorespiratory interaction and on related neural and cardiovascular systems. In literature, there are examples that highlight the importance of the breathing pattern in promoting synchronization. In particular, this is true when the environment favors breathing 'synchronous', as during the rosary or mantras reciting or poetry recitation.

Keywords: phase synchronization, heart rate variability, physiological rhythms.

*Corresponding author — E-mail: macerata@ifc.cnr.it

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