Segmented-Beat Modulation Method-Based Procedure for Extraction of Electrocardiogram-Derived Respiration from Data Acquired by Wearable Sensors During High-Altitude Activity

Agnese Sbrollini[1], Danilo Bondi[2], Sofia Romagnoli[1], Micaela Morettini[1], Ilaria Marcantoni[1],Tiziana Pietrangelo[2], Vittore Verratti[2], Laura Burattini[1]

[1]Università Politecnica delle Marche, Ancona, Italy
[2]Università degli Studi “G. d’Annunzio” di Chieti – Pescara, Chieti, Italy

High-altitude sports are affected by hypoxic stress-related alterations, and, consequently, may trigger severe events such as sport-related sudden death. Lack of oxygen requires higher respiratory activity, reflecting into an increase of respiratory and cardiac rhythms; thus, into-the-field monitoring of respiration is essential. Athletes are used to use wearable sensors to monitor their activity, thus, this devices may be valid tool to support athletes’ monitoring. The novel Segmented-Beat Modulation Method (SBMM)-based procedure was proposed to extract electrocardiogram-derived respiration (EDR) from electrocardiogram (ECG); thus, the aim of the study is to assess SBMM-based procedure for EDR extraction in data acquired by wearable sensors during high-altitude physical activities. Breathing rate series (BRS), respiration signal (RES) and ECG were recorded using BioHarness 3.0 by Zephyr from 3 expeditioners, while performing a trek up to 4,556m of altitude. EDR was extracted from ECG by SBMM-based procedure. BRS, RES and EDR were segmented into 60-second windows and characterized in terms of breathing rate (BR_{BRS}, BR_{RES}, BR_{EDR}, respectively). BR_{BRS}, BR_{RES}, BR_{EDR} were compared by absolute difference, concordance correlation coefficient (CCC) and linear regression analysis. BR_{BRS} values (Table) are lower than values of BR_{RES} and BR_{EDR} (Table), which instead are similar. Difference between BR_{EDR} and BR_{RES} (2[1;4]cpm) is lower than those computed between BR_{BRS} and BR_{RES} (8[3;14]cpm), and between BR_{BRS} and BR_{EDR} (7[3;13]cpm). Moreover, a good agreement between BR_{EDR} and BR_{RES} is confirmed by CCC (0.62, $P<0.05$) and regression line ($BR_{RES}=0.91 \cdot BR_{EDR}+4.47$cpm), differently from results obtained for BR_{BRS} and BR_{RES} comparison (CCC=0.27, $P<0.05$; regression line: $BR_{RES}=0.29 \cdot BR_{BRS}+29.15$cpm) and for BR_{BRS} and BR_{EDR} comparison (CCC=0.20, $P<0.05$; regression line: $BR_{EDR}=0.18 \cdot BR_{BRS}+31.05$cpm). In conclusion, SBMM-based procedure is a good method to extract EDR from data acquired by wearable sensors during high-altitude physical activities.

Table. Distributions of BR_{BRS}, BR_{RES} and BR_{EDR}.

BR_{BRS} (cpm)	29[21;37]
BR_{RES} (cpm)	38 [34;41]
BR_{EDR} (cpm)	37 [34;39]