Determining cardiorespiratory causal paths in elite athletes in supine position

Marcel Młyńczak, Hubert Krysztofiak, and Gerard Cybulski

Abstract— The aim was to determine causal paths affecting basic cardiac and respiratory parameters in elite athletes using Pneumonitor 2. Criteria based on generalized correlations and kernel regressions were used to establish appropriate directions and strengths of the relationships. Average activity parameters affect the diversity indicator. No strong connection between heart rate and breathing rate was discovered.

I. Introduction

Exercise scientists and sport physicians try to evaluate the state of an athlete's body during training to monitor homeostasis, maximize effect, and avoid overtraining using cardiac-related biomarkers [1]. Breathing is considered rarely, especially regarding its interdependence with heart activity.

The main aim of this work was to establish causal paths of simple cardiorespiratory parameters in athletes during rest, taking into account the type of sport that each practices.

II. Materials and Methods

A group of 100 elite athletes (32 female; aged 24.6 ± 6.4; divided into 2 groups according to the contribution of the dynamic component to total performance during competition [2]) participated in the study during a routine periodic health evaluation and medical monitoring program at the National Centre for Sports Medicine in Warsaw.

They were asked to rest supine for about 6 minutes. We acquired impedance pneumography and single-lead ECG signals using our Pneumonitor 2 device [3]. After preprocessing, we estimated several basic cardiorespiratory parameters: (1) Heart rate (HR), (2) Root-mean-square difference of successive R–R intervals (RMSSD), (3) Respiratory rate (RR), (4) Breathing regularity (BR), and (5) Shift providing the highest correlation between the signals' phases (SCP).

Then, we determined causal paths mainly based on the analysis of generalized correlations, as well as on two methods utilizing stochastic dominance in kernel regressions (using *generalCorr* R package [4]).

III. Results

Fig. 1 presents the causal path obtained from the generalized correlations analysis (differences between directions). We included only those connections with statistically significant correlation coefficients and high bootstrap proportions of correct causal determinations (for 100 repetitions).

Marcel Młyńczak and Gerard Cybulski are with the Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, Warsaw University of Technology, Poland (e-mails: {mlynczak, cybulski}@mchtr.pw.edu.pl).

Hubert Krysztofiak is with the Department of Applied Physiology, Mossakowski Medical Research Centre, Polish Academy of Sciences, Warsaw, Poland (e-mail: hkrysztofiak@imdik.pan.pl).
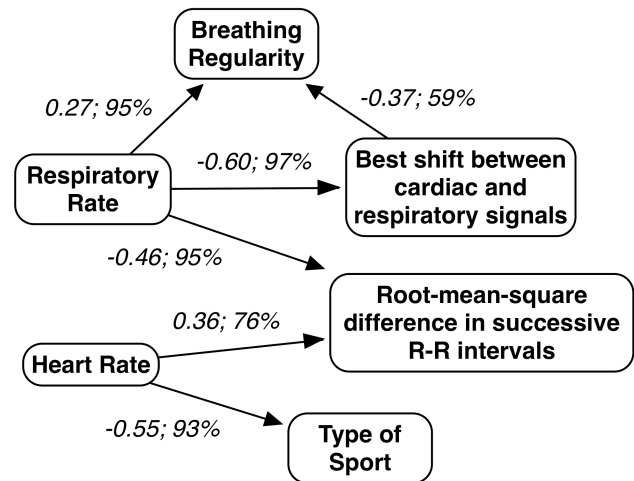

Figure 1. Causal path affecting basic cardiac and respiratory parameters, including the type of sport (1 – medium dynamic component, 2 – high); first number corresponds to generalized correlation coefficient, second is the proportion of correct causal determinations (percentage).

Interestingly, analysis of all three criteria provides slightly different inference. Particularly, the type of sport seems to be the cause of all considered parameters, and HR seems to strongly affect SCP.

IV. Discussion and Conclusions

Cardiorespiratory causal path analysis showed the expected results. The average activity rate affects the indicator responsible for diversity (effect of HR on RMSSD, or RR on BR). Interesting meaningful connections were discovered: an increase of RR seemed to cause a decrease in SCP and RMSSD parameters. However, there was no strong relationship between RR and HR, which indicates the occurrence of complex dynamics even in the most static case.

Further investigation will include more variables and positions.

References

[1] T. Wiewelhove, C. Raeder, T. Meyer, M. Kellmann, M. Pfeiffer, and A. Ferrauti, "Markers for routine assessment of fatigue and recovery in male and female team sport athletes during high-intensity interval training," *PloS One* vol. 10, no. 10, 2015, e0139801.

[2] J. H. Mitchell, W. Haskell, P. Snell, and S. P. Van Camp, "Task Force 8: Classification of sports," *Journal of the American College of Cardiology*, vol. 45, 2005, pp. 1364–1367.

[3] M. Młyńczak, M. Żyliński, W. Niewiadomski, and G. Cybulski, "Ambulatory devices measuring cardiorespiratory activity with motion," *Proc. BIOSTEC*, 2017, pp. 91–97.

[4] H. D. Vinod, "Generalized Correlation and Kernel Causality with Applications in Development Economics," *Communications in Statistics - Simulation and Computation*, vol. 46, no. 6, 2017, pp. 4513-4534.