Poincaré/Lorenz/Scatter Plot HRV in freedivers regarding the Hypoxia-Insulin-Hypothesis – and its implication as an inexpensive tool for every Sportsman and also its medical relevance

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Intruduction:

The Lorenz plot HRV, also often named Poincaré or Scatter Plot HRV, is a graph in which each RR-interval is plotted against his next RR-interval. Heart rate variability (HRV) is the measurement of the variation in the beat to beat interval of the heart. The variation is the length between to correspondend R-R peaks. For the sake of simplicity R-peak is the highest point in the QRS-complex of the electrocardiogram (ECG). The QRS-complex characterizes the depolarisation of the right and left ventricle of the heart and the contraction of the large ventriclar muscles. HRV is the dimension, in which the ability of autonomic nervsystem to adapt to different stressors is measured. During stress the HRV diminish[1].

In 2016 I did a pretest regarding my Hypoxia-Insulin-Hypothesis [2]. As insulin provides the absorption of glucose to the muscle it is set in the center of interest in hypoxic conditions, as the organism needs more glucose in anerobic situations. In the anaerobic glycolytic pathway 2ATP/glucose molecule are build in contrast to the aerobic pentose phosphate where 36 ATP/glucose molecule are genereted. Figure 1 will give a new updated overview of the Hypoxia-Insulin-Hypothesis. For the pre-test static breath-holding was used. Blood samples were taken at the end of different phases while a beat-beat measurement was continuously run via Polar RS800CX. The phases were divivded in six phases - basline, preparation (often charactarized by minimal hyperventilation and/or short terms of breath-holding), easy phase (breath-holding without contractions of the diaphragm – estimated = 35% of the average of the normal trainings apnea), struggle phase (with contractions of the diaphragm - estimated = 70% of the average of the normal trainings apnea), recovery phase after 15-20min and one after 90min(last RR-interval) and 120min (last blood sample). Fom each phase a 75sec long unit of the Polar recorded RR-interval was taken in order to determine the HRV data, esp. the Lorenz plot. It was multiple shown, that esp. Lorenz plot value SD1 could be adequately computed by small data size (60–100 R peaks)[3].

The pictures show the Lorenz plot from the Kubios software (Kubios Oy, Business ID 2740217-3, Kuopio, FINLAND) of test person 1 (P1) (Figure 2) and the diagrams of both test persons (Figure 4).

To enlighten the Lorenz plot the data from the struggle phase from P1 is plotted via my protocol, programmed in Octave (Figure 3).

The Lorenz plot can be analyzed by fitting an ellipse to the plotted points and derivate three non-linear measurements, S, SD1, and SD2. S is the area of the ellipse and represents the total HRV and correlates with baroreflex sensitivity (BRS), low frequency (LF) and high frequency (HF) power, and the root mean square of successive differences between normal heartbeats (RMSSD). SD1 stands for standard deviation of each point from the y-axis = x-axis and shows the width of the ellipses. SD1 matches the short-term HRV in ms and correlates with baroreflex sensitivity (BRS). BRS is the change in interbeat interval (IBI) duration per unit change in blood pressure (BP), and HF power. HF predicts the respiratory sinus arrythmia and is a marker for parasympathetic activity. The non-linear metric SD1 is identical to RMSSD. Just a note - “lower RMSSD values are correlated with higher scores on a risk inventory of sudden unexplained death in epilepsy”[4]. SD1 can forecast the diastolic BP and heart rate (HR) Max − HR Min, as well as pNN50 (Percentage of successive RR intervals that differ by more than 50 ms), SDNN (Standard deviation of NN intervals, and power in the LF and HF bands, and total power during 5 min recordings. SD2 stands for the standard deviation of each point from the y-axis = x-axis + average R–R interval and shows the length of the ellipses. SD2 matches the short- and long-term HRV in ms and correlates with LF power and BRS. LF is a marker for mainly sympathetic, but also for parasympathetic activity. Because when respiration rates are below 8.5 bpm or 7 s periods or when taking a deep breath vagal activity can generate oscillations in the heart rhythms that influences the LF band.

Results:

Obviously in the easy phase of breath-holding the SD1 value shrink. While in the struggle phase, where the contractions of the diaphram take place, it clearly increases (Figure2, Figure 4). The insulin value decreases at the end of the easy phase and clearly increases at the end of the struggle phase (Figure 5). Due to laboratory problems the insulin values of test person 2 were not measured.

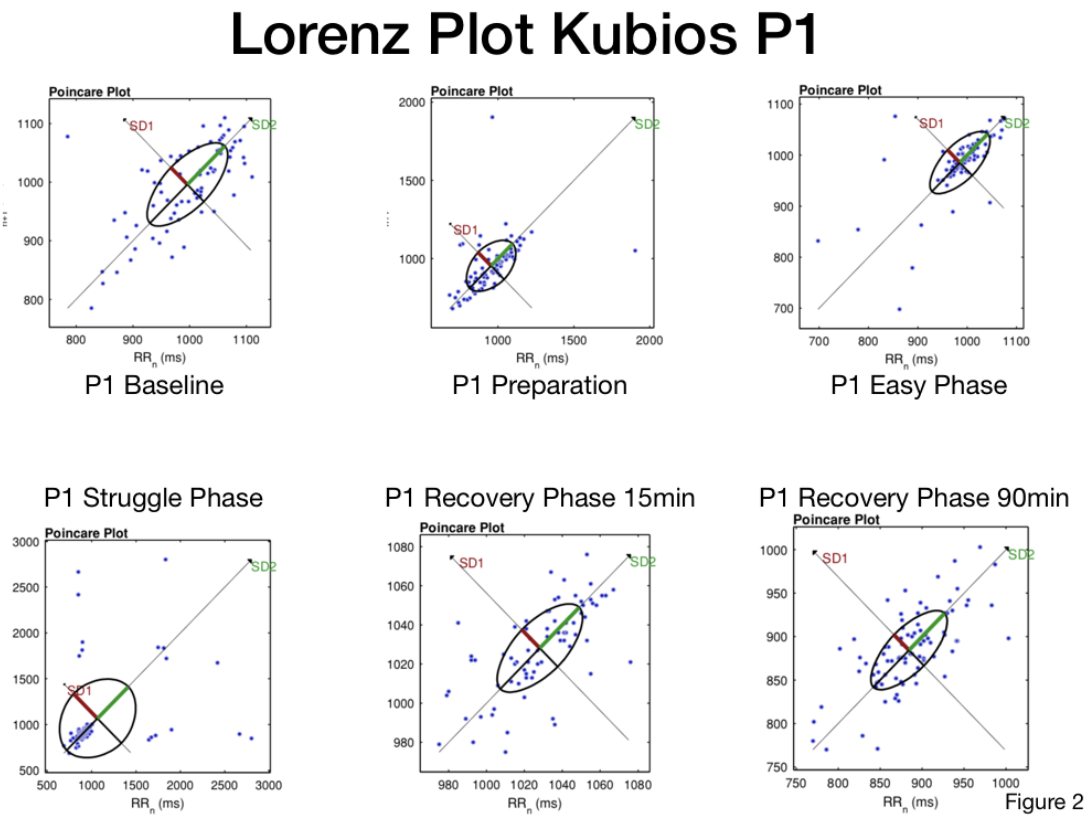
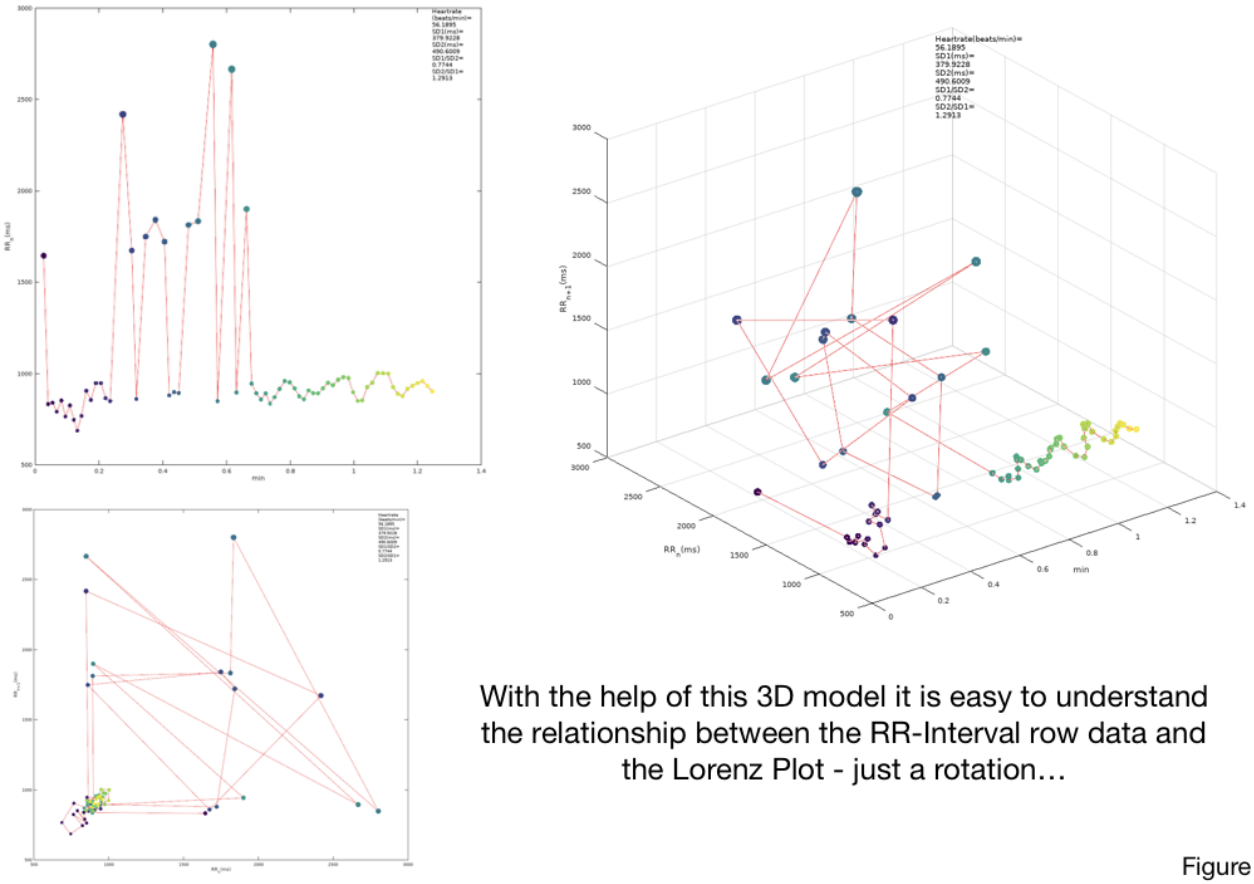


Figure 2

Lorenz Plot P1 Struggle Phase via Octave



With the help of this 3D model it is easy to understand the relationship between the RR-Interval row data and the Lorenz Plot - just a rotation…

Figure 3

P1 struggle Phase (Row-Data)

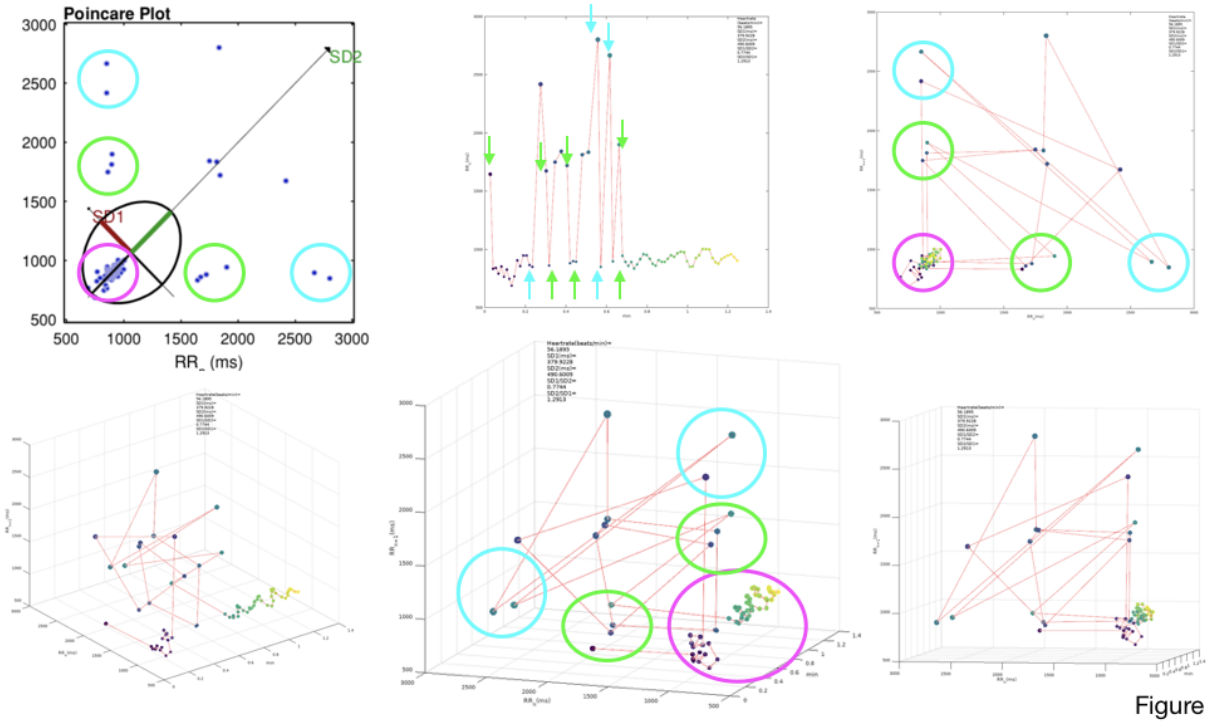


Figure 8

Diagrams P1 and P2

	W	X	Y	Z	AA	AB	AC
1	Baseline SD1	Vorbereitung SD1	Easy-Phase SD1	Struggle-Phase SD1	15min nach SD1	1.30h nach SD1	
2	41,1	121,4	35,3	380	13,4	25,2	
3	31,7	25,5	10,4	332	26,3	26,9	
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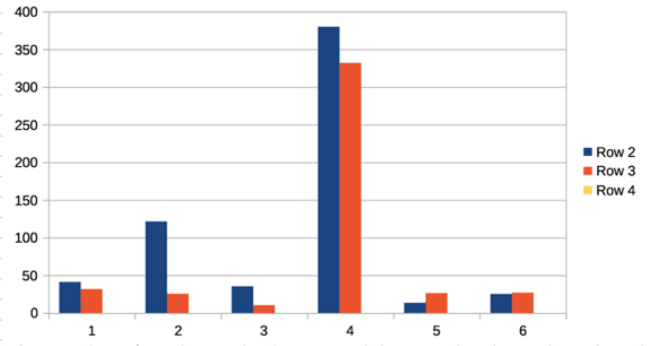


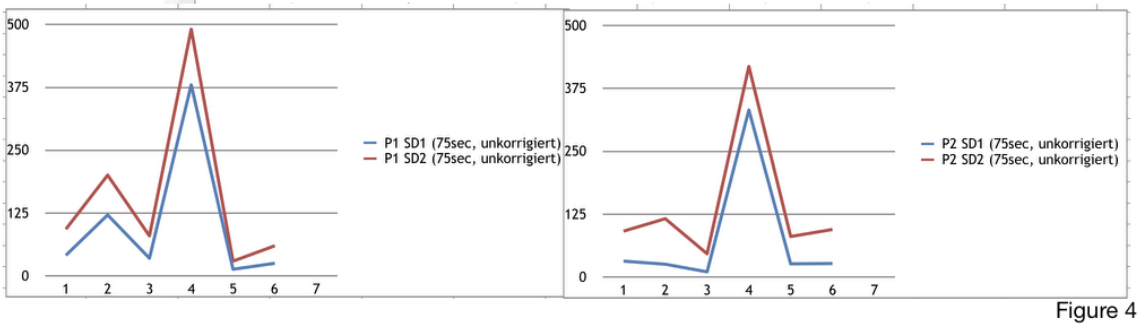
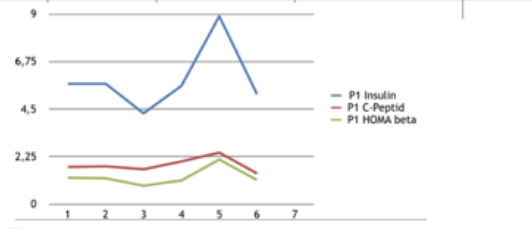


Figure 4

Blood sample values P1

	A	B	C	D	E	F	G	H
1	Proband (P)	Baseline	Vorbereitung	Easy-Phase (35%)	Struggle-Phase (70%)	Erholung nach 20min	Erholung nach 2h	
2	P1 bereinigte LF/HF	3,785	1,595	2,815	0,741	2,496	2,171	
3	P1 bereinigte LF	0,791	0,614	1,025	0,425	0,714	0,685	
4	P1 bereinigte HF (FFT)	0,209	0,385	0,364	0,574	0,286	0,315	
5	P1 SD1 (75sec, unkorrigiert)	41,1	121,4	35,3	380	13,4	25,2	
6	P1 SD2 (75sec, unkorrigiert)	93,1	200,5	79,7	490,6	29,5	60,1	
7	P1 SD1/SD2 (75sec, unkorrigiert)	0,44	0,61	0,44	0,77	0,45	0,42	
8	P1 SD2/SD1 (75sec, unkorrigiert)	2,27	1,65	2,26	1,29	2,2	2,38	
9	P1 DFA alpha 1 (75sec, unkorrigiert)	1,393	1,027	1,002	0,956	1,228	1,324	
10	P1 DFA alpha 2 (75sec, unkorrigiert)	0,718	0,791	0,535	1,032	0,64	0,909	
11	P1 Glukose	89	87	82	81	96	89	
12	P1 Insulin	5,7	5,7	4,3	5,6	8,9	5,2	
13	P1 C-Peptid	1,76	1,79	1,65	2,02	2,44	1,45	
14	P1 HOMA beta	1,25	1,22	0,87	1,12	2,11	1,14	
15	P1 Serotonin	111,2	107,8	106,9	112,8	101,1	129,4	
16	P1 Kortisol	11,3	11,1	13,8	13	18,5	8,7	
17	P1 freies T3	2,47	2,68	2,71	2,69	2,49	2,52	
18	P1 freies T4	0,93	0,97	1,01	1,01	0,99	0,99	
19	P1 Renin aktives	10,2	6,9	6,9	8,5	5,8	10,9	
20	P1 Insulin Cortisol bereinigt	5,7	5,8	3,04	4,74	5,27	6,5	
21								



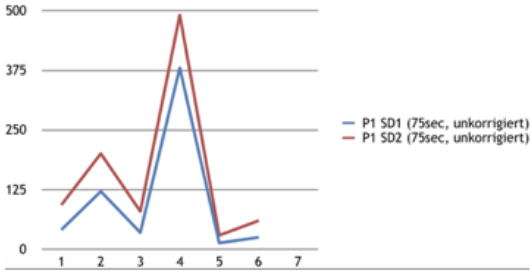


Figure 5

Discussion:
The insulin value reacts like predicted in the Hypoxia-Insulin-Hypothesis. As long as the diaphragm can be hold contracted insulin secretion seems to be diminished, as seen in the easy phase. During the struggling phase, when the diaphragm gets fatigue and the so called contractions, alternating contraction and relaxation due to muscle fatigue, start, the insulin value clearly increases. Meanwhile it was elswhere demonstrated that after breath-holding the blood insulin value increases[5].
SD1, as well as SD2, shrink in the easy breath-holding phase. This was expected, as it is a anaerobic work load and therfore stress for the body. It was proved before that SD1 and SD2 drop during exercise and that the first break-point in SD1n and SD2n curves reflect the first and the second lactat threshold[6,7]. In the struggle phase in the uncorrected (row data was used without any filter) Lorenz plot SD1 seems to dramatically increase (Figure4). But a clooser look may explain the reasons. The Lorenz plot in the struggle phase shows signs for cardiac arrhythmia[8]. Some indications for an double side lob pattern typ A, which could be a sign for premature atrial complexes (PACs) or interpolated premature ventricular complexes (PVCs) could be found[8]. But also signs for an second-degree atrioventricular (Wenckebach) block are presented, if you interpret the Lorenz plot as central ‘wedge’ pattern (Figure 8 magenta circle) with small side lobes (Figure 8 green circles) and with additional clusters (Figure 8 blue circles) (Figure 8)[9]. A distinctive clarification of the kind of arrhythmia would only be possible with ECG data. Cardiac arrhythmia are common during maximal static breath-holding performances in freedivers, esp. ectopic beats and also as recently shown, second degree AV Block [10,11]. Regarding the Hypoxia-Insulin-Hypothesis it was shown, that insulin upregulate the angiotensin II receptor typ 1 (AT1)[12]. Transgenic mice with cardiac-specific overexpression of AT1 receptor develop second-degree atrioventricular (AV) block with normal QRS duration[13]. The AT1 receptor mediates the major cardiovascular effects of angiotensin II including vasoconstriction, aldosterone synthesis and secretion. Aldosterone-Antagonists, like Spironolactone, are used to treat cardiac arrhythmias, like PVCs and also PACs[14–16]. It is important to point out, that aldosterone antagonists could also have pro-arrhythmic properties[17,18]. Multiple factors can contribute to the heart rate and arrhythmias, respectively conduction, including sympathetic and parasympathetic activity, but also hydrostatic pressure on myocardial cells, baroreceptors, blood gases, cardiovascular hormones, and pulmonary stretch receptors or pressure changes in lung volume may modify heart rate and cardiac contractility[11]. Taken this informations in consideration, it should never be forgotten, that in homeostatic systems there are different regulator mechanisms, like substrat and receptor ratio, counter regulationsystems, ect..
The Lorenz plot with filtered row-data, in this case with strong threshold artifact correction and removing of trend comonents (smooth priors) shows especially in the struggle phase different SD1 and SD2 values (Figure 6 and 7). SD1 of test-person 1 is only increasing a bit, what could be due to the so called contractions, as they could perhaps pulsative increase the vagal activity and as it was sayed before, SD1 reflects

vagal, respectively parasympathetic, activity. Important to mentioned that because of the use of strong filters the interpretation of these data is strictly limited.
During the recovery phase both SD1 as well as SD2 increases. Hence the Lorenz plot could be useful to determine individuel trainings concepts and to avoid overtraining[19]. The already mentioned software Kubios is available as a free version “Kubios HRV Standard” (https://www.kubios.com/hrv-standard/) and most fitness watches can record and export RR-data sets, which can easily imported into Kubios.

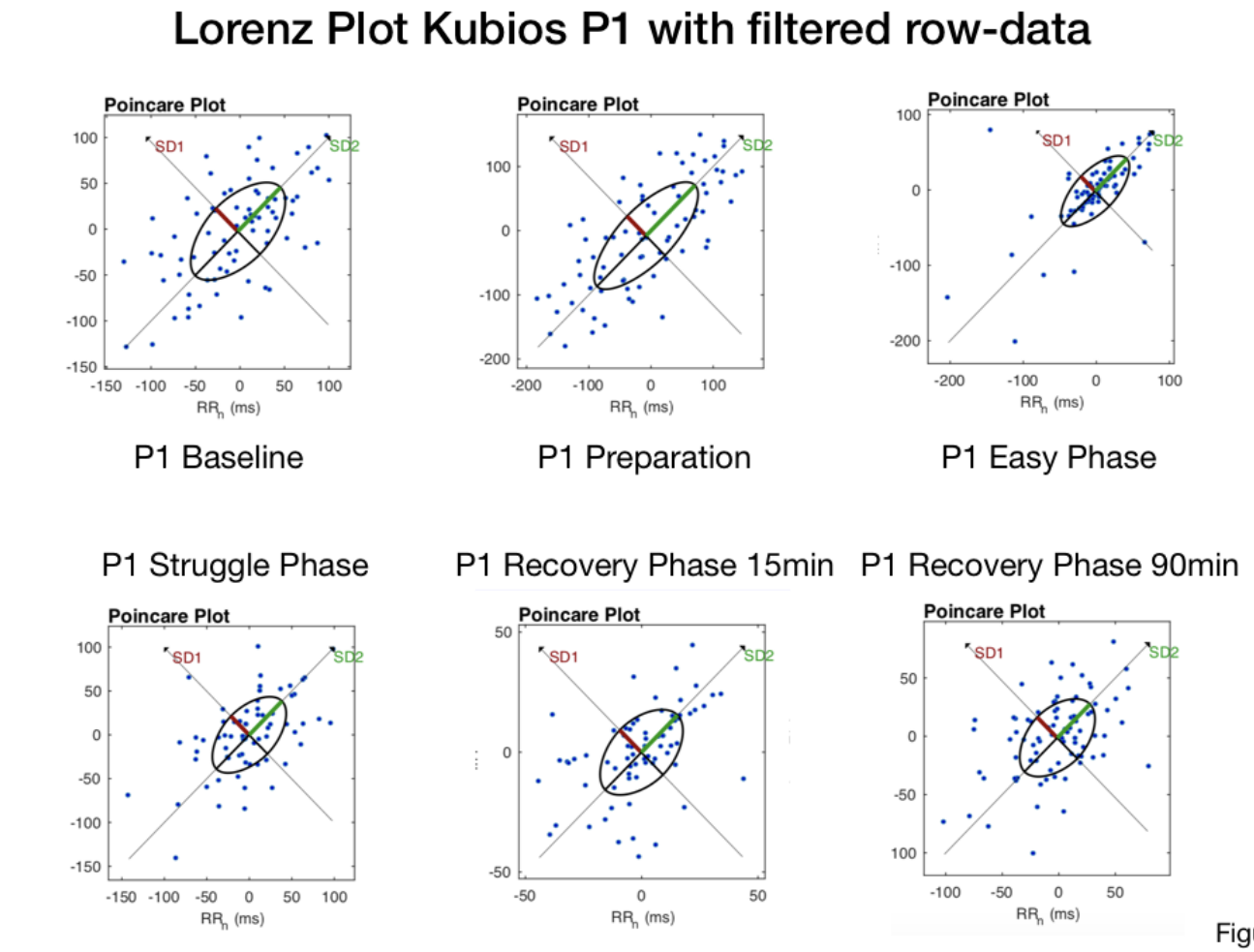


Figure 6

Diagrams P1 and P2 with filtered row-data

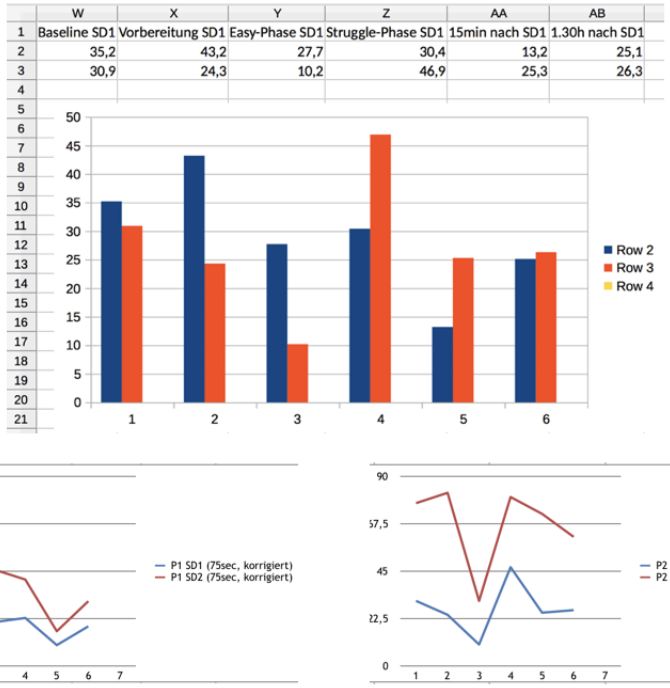


Figure 7

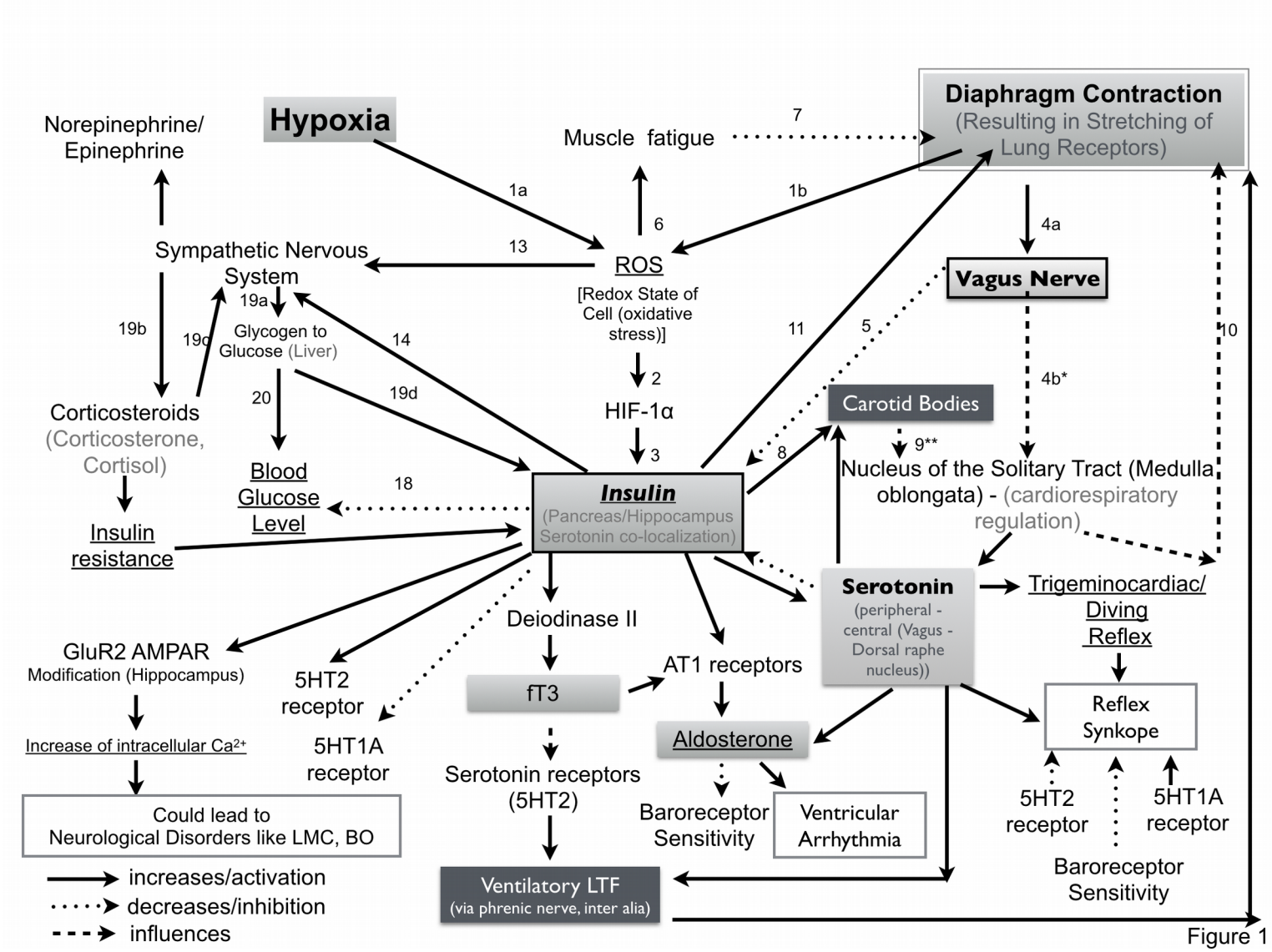


Figure 1

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