

Heart Rate Variability - Study
with
„Bubble“ from *CENTROPIX Global AG*

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Heart Rate Variability-Study with „Bubble“ from CENTROPIX Global AG

1. Description

As part of a heart rate variability (HRV) study, the product "Bubble" from CENTROPIX Global AG was examined for its potential influence on the HRV.

Sixteen HRV parameter of 50 person, age 4 to 72 years (30 female: age 6-72 years; 20 male: age 4-64 years) were evaluated. All participants had to stream with their smartphone the same self-selected Youtube video twice for at least 10 minutes each. At the same time, they wore (directly on their skin) either an active "bubble" or a "bubble dummy." The order of testing of the visually indistinguishable two "bubble" pendants was chosen by the participants themselves.

Note: In the case of repeating HRV measurements the temporal change of successive examinations is a very important influencing factor. I.e. is as a rule the second examination better than the first, because the person had more time to rest during the measurements. This is in turn reflected in improved HRV values. Therefore, it was important for this HRV study that the order of the "bubble" pendants used was randomized.

Another very important point is that the participants did not know whether it was an active "bubble" or a dummy, as the attitude and expectation of each person could affect the HRV.

For the analysis of the HRV data each measurement was assigned a sequential code (e.g., "M1_14_a"...). This is important to ensure an objective cleaning and processing of the recorded HRV data and the subsequent selection of 5 minutes per recording.

2. „Bubble“ - Double Blind Study

A double-blind study is a randomized controlled study in which neither the person conducting the study nor the study-participants have knowledge of the respective group membership (control group, experimental group).

This criteria was attempted to be fulfilled in this study in such a way that, on the one hand, the participants did not know which "bubble" was the active or passive one, and on the other hand, the person who evaluated the HRV did not know from which person or which measurement the data series came from.

3. HRV Parameter tested

The following HRV Parameter were examined in this study:

Mean HR (bpm) ... pulse (beats per minute).

SDNN (ms) ... standard deviation of all RR- intervals.

(The SDNN value strongly reflects the activity of the autonomous nervous system/ANS and its regulating function).

RMSSD (ms) ...root mean square of successive heartbeat interval differences. It describes the change of heart frequencies from one heart beat to the next. It is comparable to the SDNN, whereas it is better suited for short time measurements. The RMSSD reflects as the pNN50 the parasympathetic activity.

pNN50 / pNN20 / pNN10 / pNN05 (%) ... Percentage of intervals with $> 50\text{ms}$ / $> 20\text{ms}$ $>10\text{ms}$ / $>05\text{ms}$ deviation from the preceding interval.

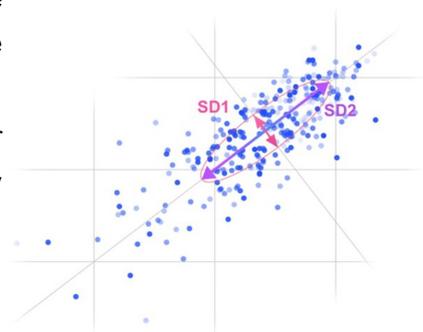
(The pNN values, especially the pNN50, are indicators of the parasympathetic activity. Decreasing values correspond to pathological changes. Often when people are very exhausted or have recently had a very stressful time, the pNN50 is very low - often even tending towards 0. However, if at the same time the measured pNN20 values are (still) $> 20\%$...it is a good indicator that this person still has a relatively good regenerative capacity. Good pNN10 / pNN05 values can be considered as deeper HRV resources).

SD1 (ms) ... indicator of short-term variability (spontaneous variability); standard deviation of the orthogonal distances of the $\text{RR}_i/\text{RR}_{i+1}$ -points to the across diameter of the ellipse width of the point cloud in the Poincaré plot.

(A high SD1 value is also an indicator of good adaptability of the body to stressful situations. In other words, it shows good physical adaptability. The SD1 value reflects as well as the pNN50 and the RMSSD the parasympathetic activity of the autonomic nervous system. It shows especially the change in the higher frequency areas).

SD2 (ms) ... Indicator of long-term variability, standard deviation of the orthogonal distances of the $\text{RR}_i/\text{RR}_{i+1}$ to the length diameter of the ellipse in the Poincaré plot).

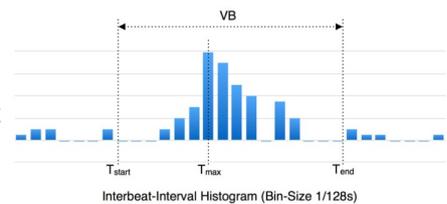
(best suitable for HRV recordings over a longer time periods. For example, in a 24h measurement, the SD2 value reflects the variability during the day with the different activities and rest periods).



VB... (Variation Broadness)

The variation broadness describes the width of the core – area of the Interbeat - Interval in the histogram.

Starting from the maximum value of the histogram (Tmax) the first interruption in the beginning (Tstart) and at the end (Tend) area determined, which takes at least 3 histogram bins.



$VB = Tend - Tstart$.

(The VB is similar to the TINN value, which is used in many HRV analysis programs. Even though the TINN value has been defined by the European Task Force does this value (based on different calculation models) vary strongly between the different HRV analysis programs. Therefore has Aquaquinta in cooperation with the FH Dornbirn/Austria established an alternative VB value).

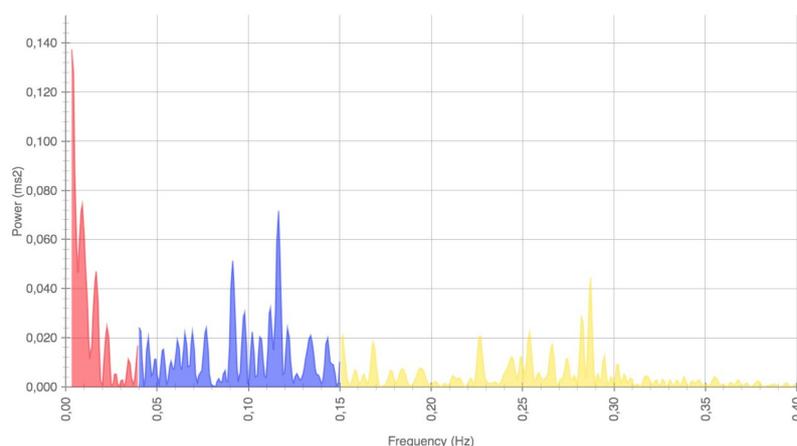
StressIndex (SI) ... "a measure of stress." Is a mathematical description of an extended histogram of the recorded RR intervals.

(Its level indicates how great the influence of the sympathetic nervous system is, and allows the assessment of the regulatory capacity of the autonomic nervous system).

CV ... "a measure of the bend-ability of HRV". Extent of dispersion of measured values around a mean value.

(The CV value is a very practical value. It is the standard deviation of RR distances related to the mean. The larger this value is, the larger the HRV).

Frequency Domain Analysis



In the frequency domain analysis, the frequency signal of the heart is divided in different frequency bandwidths. Studies show, that activities and regulation processes of the body are reflected in certain frequency areas, as for example the thermoregulation, inflammatory processes, respiration, baroreflex etc. The frequency bandwidths are divided into Very Low Frequency (VLF), Low Frequency (LF) and High Frequency (HF).

LF (0.04-0.15 Hz) ... (Low Frequency)

Low frequency, reflects both sympathetic and para-sympathetic activity. (Parasympathetic influence especially during a breathing frequency of ≤ 7 per minute).

LF is generally regarded a strong indicator of sympathetic activity. The LF is the active area of the autonomous nervous system, often referred as the fight and flight mechanism of the body. The frequency around 1Hz reflects the activity and regulation of the blood pressure/baroreflex.

The sympathetic activity leads to a decrease in the HRV.

An unbalanced, stressed lifestyle leads to a continuously dominant sympathetic activity. Short breath is a typical indicator for sympathetic dominance.

HF (0.15-0.4 Hz) ... (High Frequency). Mainly dominated by the parasympathetic nervous system (with vagus as the main nerve).

(The higher the values of HF in general, the better the HRV).

PowerTotal (mS2) ... also called Total Energy (Total Power). Power density spectrum or spectral density of the different frequencies (VLF, LF and HF).

(The PowerTotal is a general benchmark for the regulatory capacity of the autonomic nervous system (ANS). Low values can be equated with low SDNN from time-related HRV analysis. The PowerTotal values are also dependent on the length of the respective HRV measurement in addition to the health status. It is not uncommon for a 24h measurement to yield 10x higher values than a 5 minute measurement. As a rule, the dominant part of the measured frequency range derives in most cases from the sympathetic nervous system).

LF/HF ... Ratio of LF to HF. Expression of the vegetative balance of sympathetic and parasympathetic nervous system.

The higher the value, the more sympathetic activity. LF/HF \uparrow = sympathetic; LF/HF \downarrow = parasympathetic.

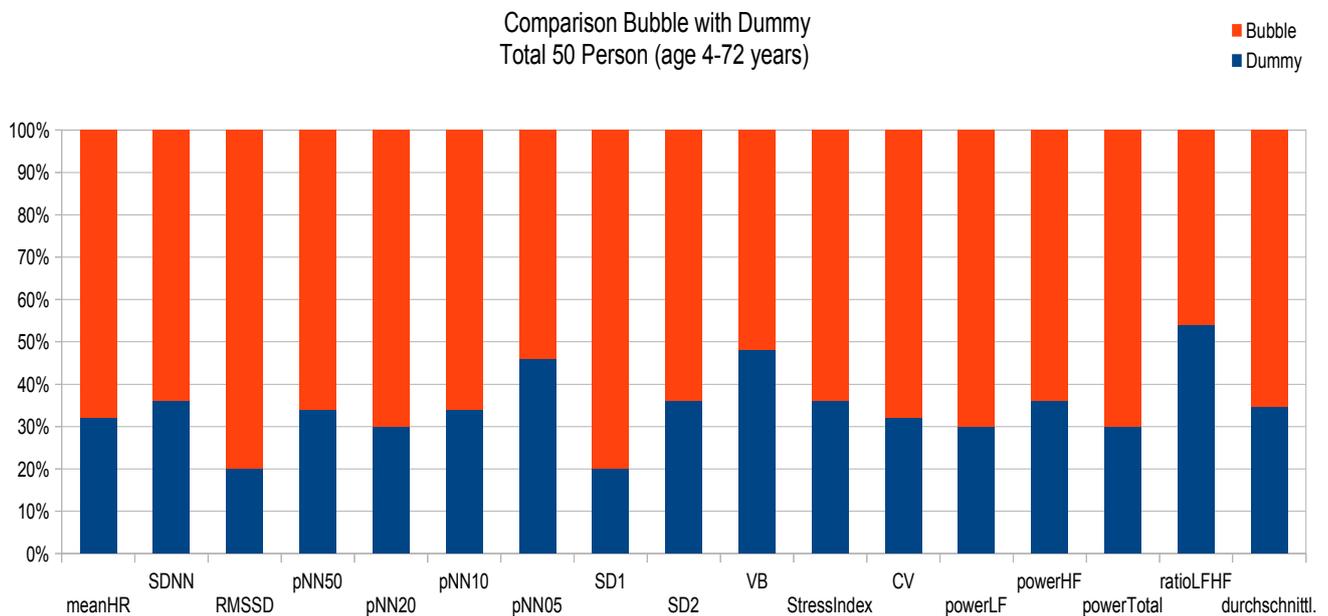
(also an indicator of existing stress level or current energy demand and consumption).

4. Evaluation and results of the study

The focus of this study was to investigate the possible effect of "Bubble" on the different HRV parameter. The health aspect of the individual participants and the relationship of the different HRV parameter to each other were not considered in this study. All HRV measurement results were therefore simply scored as 0 or 1. (See Appendix for individual results). I.e., if an improvement was achieved for an HRV parameter by "Bubble", it was rated as 1. If the value remained the same or even became smaller, it was evaluated with 0. Only in the case of the Pulse, the StressIndex (SI) and the LF/HF ratio was the assessment reversed, since a decrease is generally regarded as positive. None of the participants suffered from bradycardia (slow heartbeat/dysrhythmia). A decreasing pulse could not be considered an improvement in that case. Generally could be said: The higher the HRV values, with the exception of Pulse, StressIndex (SI) and LF/HF-ratio, the better.

Results of the different HRV parameter of all 50 examinations:

	meanHR	SDNN	RMSSD	pNN50	pNN20	pNN10	pNN05	SD1	SD2	VB	SI	CV	LF	HF	Pw.Total	LF/HF	Ø
Dummy	16	18	10	17	15	17	23	10	18	24	18	16	15	18	15	27	17
Bubble	34	32	40	33	35	33	27	40	32	26	32	34	35	32	35	23	33



Based on the results, better values were achieved with "Bubble" for almost all HRV parameter. Only the LF/HF ratio, VB and pNN05 showed no or almost no improvement.

5. Binomial distribution test of the frequency of improvements of the individual HRV parameter.

	Kategorie	N	Beobachtete Wahrsch.	Testwahrsch.	Exakte Sig. (2-seitig)
MeanHR	Group 1	1,00	,34	,68	,50
	Group 2	,00	,16	,32	
	Gesamt		,50	1,00	
SDNN	Group 1	1,00	,32	,64	,50
	Group 2	,00	,18	,36	
	Gesamt		,50	1,00	
RMSSD	Group 1	1,00	,40	,80	,50
	Group 2	,00	,10	,20	
	Gesamt		,50	1,00	
pNN50	Group 1	,00	,17	,34	,50
	Group 2	1,00	,33	,66	
	Gesamt		,50	1,00	
pNN20	Group 1	1,00	,35	,70	,50
	Group 2	,00	,15	,30	
	Gesamt		,50	1,00	
pNN10	Group 1	1,00	,33	,66	,50
	Group 2	,00	,17	,34	
	Gesamt		,50	1,00	
pNN05	Group 1	1,00	,27	,54	,50
	Group 2	,00	,23	,46	
	Gesamt		,50	1,00	
SD1	Group 1	1,00	,40	,80	,50
	Group 2	,00	,10	,20	
	Gesamt		,50	1,00	
SD2	Group 1	1,00	,32	,64	,50
	Group 2	,00	,18	,36	
	Gesamt		,50	1,00	
VB	Group 1	1,00	,26	,52	,50
	Group 2	,00	,24	,48	
	Gesamt		,50	1,00	
Stressindex	Group 1	1,00	,32	,64	,50
	Group 2	,00	,18	,36	
	Gesamt		,50	1,00	
CV	Group 1	1,00	,34	,68	,50
	Group 2	,00	,16	,32	
	Gesamt		,50	1,00	
powerLF	Group 1	1,00	,35	,70	,50
	Group 2	,00	,15	,30	
	Gesamt		,50	1,00	
powerHF	Group 1	,00	,18	,36	,50
	Group 2	1,00	,32	,64	
	Gesamt		,50	1,00	
powerTotal	Group 1	1,00	,35	,70	,50
	Group 2	,00	,15	,30	
	Gesamt		,50	1,00	
ratioLFHF	Group 1	,00	,27	,54	,50
	Group 2	1,00	,23	,46	
	Gesamt		,50	1,00	

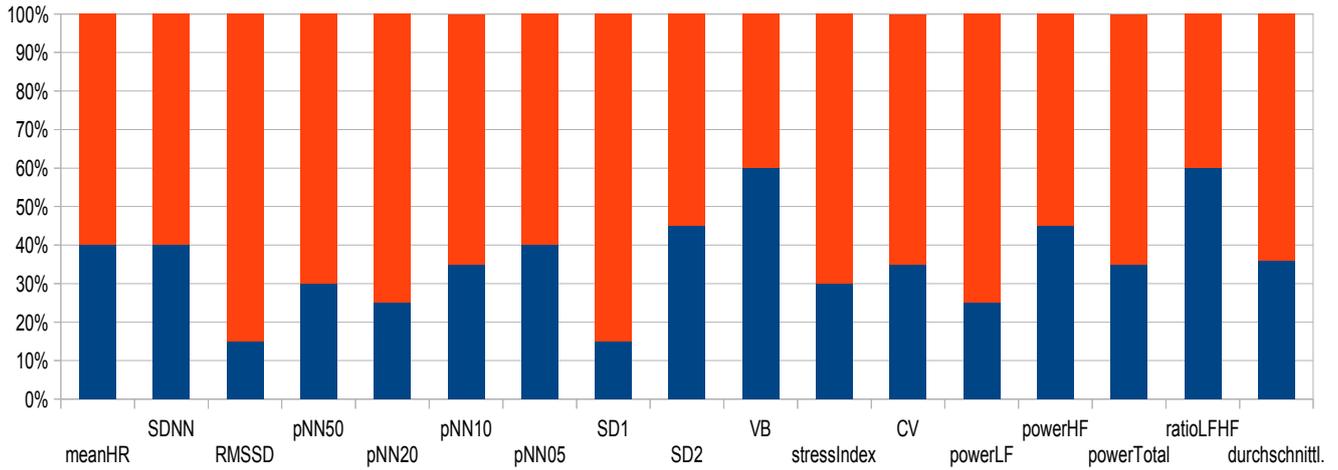
The tests showed a significant difference in favor of "Bubble" for 9 HRV parameter. For the values pNN05, VB and ratioLF/HF no significance was reached with the calculated p-values. The values of SDDN, SD2, StressIndex as well as HF are also not significantly different, but are very close to the significance level of 0.05.

6. Gender-specific test results

6.1. Results of the different HRV parameter of all 20 male examinations.

	meanHR	SDNN	RMSSD	pNN50	pNN20	pNN10	pNN05	SD1	SD2	VB	SI	CV	LF	HF	Pw.Total	LF/HF	Ø
Dummy	8	8	3	6	5	7	8	3	9	12	6	7	5	9	7	12	7
Bubble	12	12	17	14	15	13	12	17	11	8	14	13	15	11	13	8	13

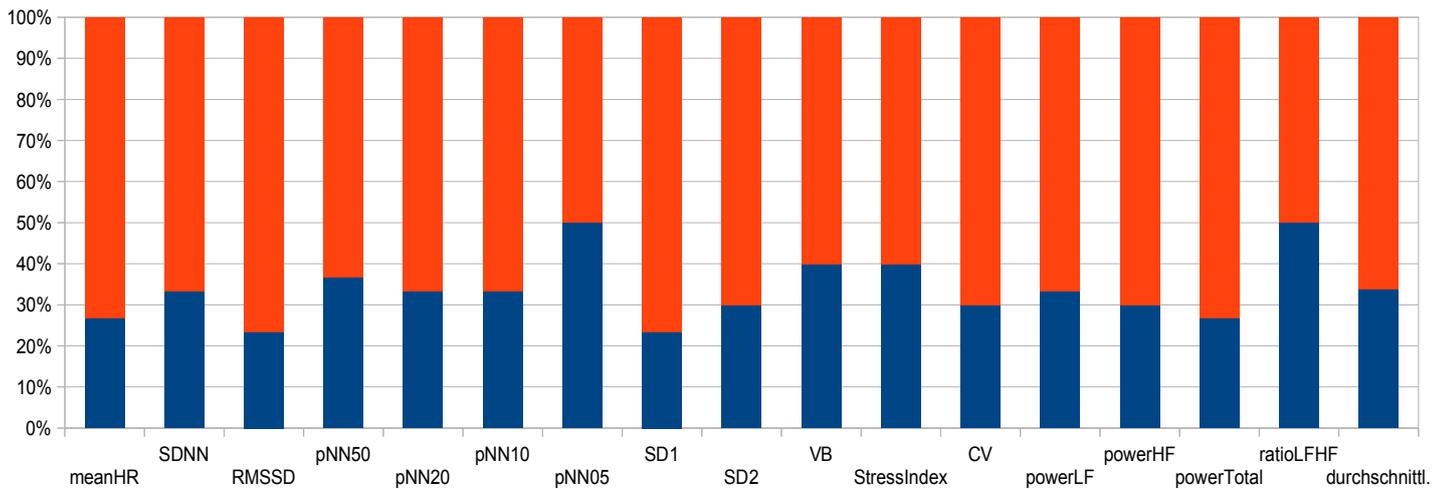
Comparison Bubble with Dummy
(20xmale, age 4-64 years)



6.2. Results of the different HRV parameter of all 30 female examinations

	meanHR	SDNN	RMSSD	pNN50	pNN20	pNN10	pNN05	SD1	SD2	VB	SI	CV	LF	HF	Pw.Total	LF/HF	Ø
Dummy	8,0	10,0	7,0	11	10	10	15	7	9	12	12	9	10	9	8	15	10
Bubble	22,0	20,0	23,0	19	20	20	15	23	21	18	18	21	20	21	22	15	20

Comparison Bubble with Dummy
(30xfemale, age 8-72 years)



6.3. Group comparison test

Examination for significant difference between male - female

(Cross table/Chi2-Test/exact Fischer Test, two-sided calculated)

All HRV parameters in the comparison male - female could not show any significant difference. (Calculations and results see Annex)

To be able to find a significant difference by gender, the same studies would possibly have to be conducted with much higher numbers of participants.

7. Discussion

The study showed that "Bubble" has a positive effect on most HRV values within a 5 minute measurement. Significant differences were found especially in HRV values which change rapidly over time, such as the RMMSD value as well as the SD1 value. Both reflect short-term changes/adjustments.

Values such as the SD2 value, which represent temporally slow changes, could not show significant differences. The pNN05 value, which can be described as the deepest basic reserve of the HRV, would certainly require much longer HRV recordings to show significant changes. Likewise, it may require longer HRV recordings for the StressIndex as well as for the Variation Broadness (VB). Both values refer to the histogram (frequency of the RR intervals distribution) which cannot be changed so quickly (especially during resting) compared to other HRV parameters.

It is interesting that the HF/LF ratio did not change significantly. This probably has to do with the fact that at low breathing rates the LF range is also strongly influenced by the parasympathetic nervous system. In this context, studies with increased respiratory frequency during physical activity would certainly be interesting here.

Long-term HRV studies/recordings of one hour and 24 hours would also be necessary to show the effect of "Bubble" on HRV parameters that do not change so quickly in time.

The SD1/SD2 ratio, which is often used in HRV examinations, was not evaluated because of the young participants in this study. This ratio, with its often occurring high SD1 values by children and adolescents is difficult for interpretation.

A differentiation in age groups was not carried out as the health status or fitness of the individual participants was not central for this study. In this study the focus was on the influence of the product "Bubble" on the HRV in general.

8. Conclusion

The HRV study shows that HRV parameter, especially those that can change rapidly for short periods of time, respond positively to "Bubble". In particular, the RMMSD and SD1 values were able to show this most clearly. "Bubble" was able to show a significant difference in 9 HRV parameter: meanHR, RMSSD, pNN50/20/10, SD1, CV, LF-at calm breathing rate, and in PowerTotal. The values of SDNN, SD2, StressIndex and HF were very close to to reach a significant difference (with a p-value of 0.065).

Therefore, based on the data, it can be concluded that the variability as well as the parasympathetic values are generally improved by wearing the "Bubble" pendant.

