Reference

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Comparative Efficacy of Neuromodulation and Structured Exercise Program on Autonomic Modulation in Fibromyalgia Patients: Pilot Study

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Products

EXOPULSE Mollii Suit vs. Exercise

Aims

Irregularities in the autonomic nervous system (ANS) is common in fibromyalgia. This study aims to show the modulation effects on ANS, express through the outcomes cortical arousal, heart rate variability and blood microcirculation.

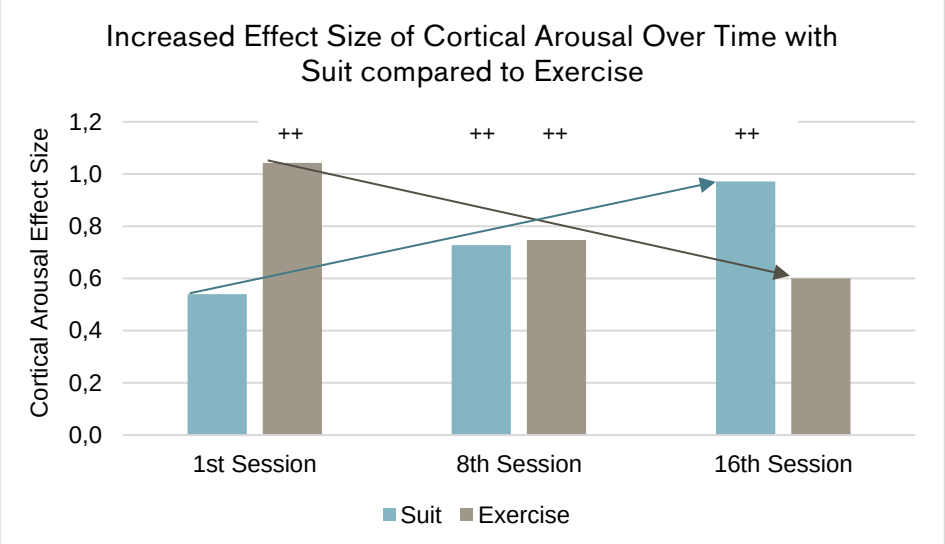
Comparison was made with EXOPULSE Mollii suit to Exercise therapy, the current gold standard in treatment of Fibromyalgia symptoms. Equivalence of results is advantageous for Suit therapy.

Major Findings

With EXOPULSE Mollii Suit compared to Exercise after 8 weeks of each intervention:

→ Improvements in cortical arousal (flicker test) with both interventions

- **Suit**: incremental increase by 0.5 Hz (1.6 %) after the 1st session, 1.1 Hz (3.5 %) after the 8th session, and 1.4 Hz (4.4 %) after the 16th session; suggesting a steady cumulative effect
- **Exercise**: more immediate but less consistent increase in cortical arousal, with values rising by 1.5 Hz (4.7 %) after the 1st session, 1.2 Hz (3.8 %) after the 8th session, and 3.8 Hz (13.2 %) after the 16th session; suggesting the benefits might not be as sustainable as the suit



++: p<0.05 for t-test comparing pre- and post-session measurement.

Cortical arousal was measured using the Critical Flicker Fusion Threshold (CFFT) technique, performed in a controlled viewing chamber (Flicker Fusion Control Unit Model 12,021; Lafayette Instrument Company, Lafayette, IN, USA). The CFFT technique entails identifying the highest frequency at which a person perceives a flickering light as continuous, reflecting the brain's processing speed and overall cortical arousal.

→ Improvements in heart rate variability (HRV) for suit intervention

- **Suit:** improved HRV, indicating enhanced parasympathetic activity and better autonomic balance
- **Exercise:** no significant changes in HRV, highlighting a potential limitation of exercise alone in addressing autonomic dysregulation in fibromyalgia

→ Improvements in microcirculation

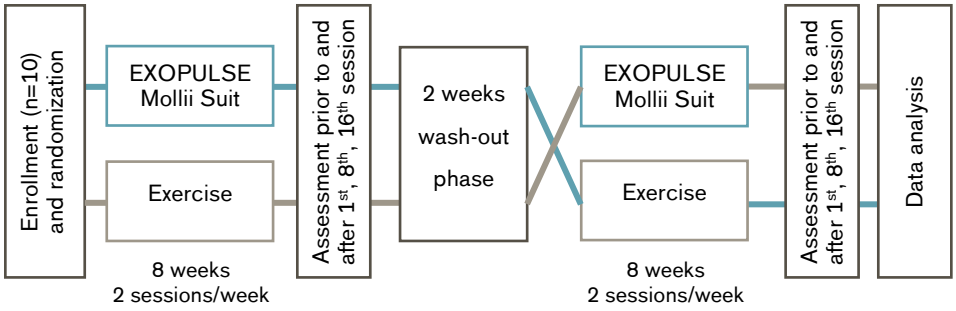
- **Suit**: shown by a progressive decrease across sessions in skin temperature at hand and index finger
- **Exercise**: shown by a consistent increase after each session at palm, back of hand, and distal and proximal index finger

Population

Subjects:	n = 10 (all female)
Etiology:	Fibromyalgia (at least three months); no pharmacological therapies in the past month
Mean age:	51.6 ±7.2 years
Mobility:	Able to walk independently, devoid of reliance on assistive devices

Study Design

Randomized, crossover, longitudinal pilot study:



The intervention phases consisted of 2 sessions per week for 8 weeks with EXOPULSE Mollii Suit or Exercise, respectively.

EXOPULSE Mollii Suit: 60 min session with the Suit with all 58 electrodes active, participants lay on a massage table facing upwards.

Exercise: 60 min training consisting of warm up, strength training, and High-Intensity Interval Training (HIIT).

Results

Body Functions & Structure					Activity			Participation	Environment
Pain	**Spasticity**	**Physiological function**	**Psychological function**	**General Health**	**Activity**	**Mobility & Safety**	**ADLs**	**Preference, Satisfaction, QoL**	**Health Economics**

Results Table 1: Results for comparison of both interventions (over all sessions)

Category	Outcomes	Results for comparison of interventions → Suit vs. Exercise	Sig.*
General Health - Cortical arousal	Critical Flicker Fusion Threshold (CFFT) [Hz]	No significant differences between interventions	0
General Health - Thermography	Hand Temperature [°C]	*palm of hand*: Significant difference only for post 1st session	+
		back of hand: Significant difference only for post 8th session	+
		distal index finger: Significant difference for all three post sessions	+
		proximal index finger: Significant difference for all three post sessions	+
General Health - Heart Rate (HR)	Mean HR values [bpm]	Significant difference only for post 8th session	+
	Maximum and minimum HR values [bpm]	*Max*: No significant differences between both interventions	0
		Min: Significant difference for post 8th and post 16th sessions	+
General Health - Heart Rate Variability (HRV)	Root Mean Square of Successive Differences (RMSSD) [ms]	Significant difference only for post 8th session	+
	PNN50 [%] (% of successive normal sinus (R-R) intervals that differed by more than 50 ms)	Significant difference only for post 8th session	+
	Frequency-domain measures [nu]	*HF*: No significant differences between both interventions	0
		LF: No significant differences between both interventions	0
	Nonlinear domain analysis [ms]	*SD1*: Significant difference only for post 8th session	+
		SD2: No significant differences between both interventions	0

* no difference (0), trend (+), significant (++), not applicable (n.a.)
* Analysis comparing both interventions for each measurement

Results Table 2: Results for pre- and post-intervention variables for Suit and Exercise intervention

Category	Outcomes	Results for pre-intervention vs. post-intervention *(expressed as means ± SD for quantitative variables)*	Sig.*
General Health - Cortical Arousal and salivary patterns	Critical Flicker Fusion Threshold (CFFT) [Hz]	Both the Suit and Exercise significantly improved cortical arousal over the course of the study	n.a.
		Suit No significant change between 1st pre vs. 16th post session	0

session	pre	post	*Sig.*
1st	32.00 ± 2.39	32.50 ± 2.48	*0*
8th	31.10 ± 3.38	32.20 ± 2.46	*++*
16th	31.70 ± 2.91	33.10 ± 2.39	*++*

Exercise No significant change between 1st pre vs. 16th post session — 0

session	pre	post	*Sig.*
1st	32.00 ± 2.48	33.50 ± 3.17	*++*
8th	31.60 ± 2.86	32.80 ± 2.92	*++*
16th	28.80 ± 10.52	32.60 ± 2.97	*0*

General Health - Thermography — Hand Temperature [°C] measured on
- palm of hand
- back of hand
- distal index finger (finger tip)
- proximal index finger

Suit Significant (++) change between 1st pre vs. 16th only for backhand temperature — **++**

Hand

session		pre	post	*Sig.*
1st	palm	31.50 ± 4.65	30.90 ± 3.25	*0*
	back	**30.70 ± 4.56**	30.60 ± 3.41	*0*
8th	palm	33.40 ± 2.63	33.00 ± 3.19	*0*
	back	32.40 ± 3.12	32.20 ± 2.74	*0*
16th	palm	34.90 ± 1.75	33.40 ± 3.15	*0*
	back	33.90 ± 2.18	**32.90 ± 3.47**	*0*

Index finger

session		pre	post	*Sig.*
1st	distal	28.90 ± 5.73	28.80 ± 3.83	*0*
	prox.	30.00 ± 5.94	29.40 ± 4.07	*0*
8th	distal	29.30 ± 3.77	28.30 ± 3.37	*0*
	prox.	32.50 ± 3.45	31.30 ± 4.01	*0*
16th	distal	32.00 ± 2.15	27.80 ± 3.74	*++*
	prox.	34.00 ± 2.59	31.80 ± 4.56	*0*

Exercise Significant change between 1st pre vs. 16th post session, except for distal index finger temperature — **++**

Hand

session		pre	post	*Sig.*
1st	palm	**32.30 ± 3.17**	34.50 ± 2.16	*++*
	back	**31.80 ± 3.52**	33.70 ± 2.58	*++*
8th	palm	34.30 ± 1.99	35.70 ± 0.84	*++*
	back	33.30 ± 2.45	34.60 ± 1.08	*0*

Category	Outcomes	Results for pre-intervention vs. post-intervention *(expressed as means ± SD for quantitative variables)*				Sig.*
			16th	palm back	34.90 ± 1.83 34.60 ± 1.64	**36.20 ± 1.10** **35.40 ± 1.11**	*0* *0*

Index finger

session		pre	post	*Sig.*
1st	distal prox.	30.50 ± 5.10 **31.00 ± 4.99**	33.20 ± 3.55 34.00 ± 3.20	*0* *++*
8th	distal prox.	31.10 ± 3.73 33.80 ± 2.63	32.70 ± 2.51 35.10 ± 0.89	*0* *++*
16th	distal prox.	32.10 ± 2.50 34.50 ± 2.46	34.10 ± 2.35 **36.00 ± 1.10**	*++* *++*

General Health - Heart Rate (HR)	Mean HR values [bpm]	**Suit**	No significant change between 1st pre vs. 16th post session	0

session	pre	post	*Sig.*
1st	79.75 ± 9.99	74.12 ± 8.33	*++*
8th	77.48 ± 7.84	74.68 ± 7.44	*0*
16th	81.46 ± 7.95	84.36 ± 21.60	*0*

		Exercise	Significant change between 1st pre vs. 16th post session	**++**

session	pre	post	*Sig.*
1st	**77.53 ± 7.64**	79.61 ± 6.33	*0*
8th	76.65 ± 11.29	84.53 ± 12.10	*++*
16th	78.50 ± 5.19	**90.78 ± 10.69**	*++*

	Maximum and minimum HR values [bpm]	**Suit**	No significant change between 1st pre vs. 16th post session	0

session		pre	post	*Sig.*
1st	max min	99.71 ± 24.57 68.17 ± 8.92	92.65 ± 22.00 64.15 ± 7.94	*0* *0*
8th	max min	90.10 ± 10.43 68.70 ± 7.71	91.66 ± 16.62 65.41 ± 5.69	*0* *++*
16th	max min	100.93 ± 20.74 70.77 ± 7.57	97.25 ± 18.68 69.52 ± 11.77	*0* *0*

		Exercise	Significant change between 1st pre vs. 16th post session for both values	**++**

session		pre	post	*Sig.*
1st	max min	**91.45 ± 12.53** **69.29 ± 6.30**	95.64 ± 7.90 69.76 ± 7.08	*0* *0*
8th	max min	89.12 ± 9.55 69.52 ± 11.87	101.86 ± 13.73 74.96 ± 11.90	*++* *++*
16th	max min	97.69 ± 9.73 68.86 ± 4.65	**110.96 ± 14.09** **79.11 ± 7.75**	*++* *++*

Category	Outcomes	Results for pre-intervention vs. post-intervention *(expressed as means ± SD for quantitative variables)*		Sig.*
General Health - Heart Rate Variability (HRV)		**Suit**	Significantly improved HRV, indicating enhanced parasympathetic activity and better autonomic balance	n.a.
		Exercise	No significant changes in HRV, highlighting a potential limitation of exercise alone in addressing autonomic dysregulation in fibromyalgia	n.a.
	Root Mean Square of Successive Differences (RMSSD) [ms]	**Suit**	No significant change between 1st pre vs. 16th post session	0
		Exercise	Significant change between 1st pre vs. 16th post session	**++**
	PNN50 [%] (percentage of successive normal sinus (R-R) intervals that differed by more than 50 ms)	**Suit**	No significant change between 1st pre vs. 16th post session	0
		Exercise	No significant change between 1st pre vs. 16th post session	0
	Frequency-domain measures [nu]	**Suit**	No significant change between 1st pre vs. 16th post session	0

Suit — Root Mean Square of Successive Differences (RMSSD) [ms]

session	pre	post	*Sig.*
1st	17.59 ± 5.89	18.74 ± 2.89	*0*
8th	17.83 ± 4.64	19.15 ± 4.73	*0*
16th	17.06 ± 3.92	17.09 ± 3.07	*0*

Exercise — Root Mean Square of Successive Differences (RMSSD) [ms]

session	pre	post	*Sig.*
1st	**17.16 ± 4.03**	15.23 ± 5.35	*0*
8th	17.30 ± 6.11	13.51 ± 5.48	*++*
16th	15.16 ± 4.42	**12.11 ± 5.49**	*++*

Suit — PNN50 [%] (percentage of successive normal sinus (R-R) intervals that differed by more than 50 ms)

session	pre	post	*Sig.*
1st	1.71 ± 2.00	1.60 ± 1.10	*0*
8th	1.51 ± 1.49	3.96 ± 6.48	*0*
16th	0.94 ± 1.02	1.33 ± 1.14	*0*

Exercise — PNN50 [%] (percentage of successive normal sinus (R-R) intervals that differed by more than 50 ms)

session	pre	post	*Sig.*
1st	1.44 ± 1.22	0.83 ± 1.27	*0*
8th	1.35 ± 1.22	0.66 ± 0.77	*++*
16th	10.29 ± 29.12	0.75 ± 1.17	*0*

Suit — Frequency-domain measures [nu]

session		pre	post	*Sig.*
1st	HF	26.48 ± 21.14	20.91 ± 11.97	*0*
	LF	73.47 ± 21.18	79.04 ± 12.01	*0*
8th	HF	26.75 ± 16.83	23.64 ± 11.89	*0*
	LF	71.70 ± 17.63	76.31 ± 11.90	*0*
16th	HF	18.99 ± 12.69	15.99 ± 5.26	*0*
	LF	80.96 ± 12.73	83.99 ± 5.27	*0*

Category	Outcomes	Results for pre-intervention vs. post-intervention *(expressed as means ± SD for quantitative variables)*	Sig.*
		Exercise Significant change between 1st pre vs. 16th post session for both frequency components	++

session		pre	post	*Sig.*
1st	HF	25.14 ± 12.57	17.33 ± 8.39	*++*
	LF	74.81 ± 12.58	82.64 ± 8.40	*++*
8th	HF	23.87 ± 9.98	16.81 ± 10.70	*0*
	LF	76.05 ± 10.02	83.15 ± 10.71	*0*
16th	HF	14.04 ± 4.92	13.64 ± 9.01	*0*
	LF	85.92 ± 4.92	86.35 ± 9.02	*0*

	Nonlinear domain analysis [ms]	**Suit** No significant change between 1st pre vs. 16th post session	0

session		pre	post	*Sig.*
1st	SD1	12.44 ± 4.17	13.26 ± 2.05	*0*
	SD2	36.21 ± 12.07	37.86 ± 10.64	*0*
8th	SD1	12.61 ± 3.28	13.55 ± 3.35	*0*
	SD2	31.93 ± 7.43	37.69 ± 7.09	*++*
16th	SD1	12.07 ± 2.78	12.09 ± 2.18	*0*
	SD2	38.53 ± 12.84	43.14 ± 16.96	*0*

		Exercise Significant change between 1st pre vs. 16th post session for SD1	++

session		pre	post	*Sig.*
1st	SD1	**12.14 ± 2.85**	10.77 ± 3.78	*0*
	SD2	30.88 ± 5.94	33.27 ± 8.16	*0*
8th	SD1	12.24 ± 4.32	9.56 ± 3.88	*++*
	SD2	32.07 ± 9.46	28.96 ± 9.76	*0*
16th	SD1	10.80 ± 3.07	**8.57 ± 3.88**	*0*
	SD2	35.07 ± 7.43	30.86 ± 8.78	*0*

* no difference (0), trend (+), significant (++ with p<0.05), not applicable (n.a.)
* Analysis comparing all pre- and post-session measurements within suit or exercise intervention, respectively.
Analysis comparing pre- and post-session measurement for each session and intervention.

bpm= beats per minute; **ms**= milliseconds; **nu**= normalized unit; **SD1**= Poincaré plot index of short-term variability in heart rate; **SD2**= Poincaré plot index of long-term variability in heart rate

Author's Conclusion

"In conclusion, both treatments can aid in ANS [autonomic nervous system] modulation in fibromyalgia patients. The neuromodulation treatment with the EXOPULSE Mollii suit showed greater beneficial effects on cortical arousal, microcirculation, and HRV whereas the Exercise intervention only demonstrated beneficial effects on cortical arousal. However, further research is needed for both treatments to better understand their full potential and long-term impact on fibromyalgia management." (Rubio-Zarapuz *et al.*, 2024).

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