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Case study

Whole-Body Electrical Muscle Stimulation As a Way To Increasing a Comfort of Life for Patient with Frozen Shoulder History

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Purpose: This research aims to present the effects of a whole-body electrical muscle stimulation (WB-EMS) physical training program on body composition and subjective pain experience for the 50 years old man A 71-day program was designed for the patient who completed 6 months of physiotherapy and rehabilitation phase after arthroscopy of a frozen shoulder, as an alternative way to complete recovery and increase comfort of life.
Methods: A WB-EMS trainer supervised a subject as he worked out, following a detailed physical training program displayed on a projector screen. The subject exercised by imitating the movements shown in a previously recorded video, while the trainer carefully observed the subject. All data was collected (body composition and circumference, quality of life, subjective shoulder pain and perceived exertion questionnaire)and exercises performed based on programmed training were made in the laboratory with access to appropriate equipment.
Results: Comparing day 0 (before training) and day 71, an upward trend was observed for muscle mass +5.82 kg (+19%) and segmental body composition data for lean mass +6.38 kg (+13%) in total. A downward trend was observed for segmental body composition data for fat mass –5.60 kg (-24%) in total. Body circumference data decreased for the hip, waist, and thigh -4.4cm (-2%) in total. Body circumference data increased for the arm, calf, and chest +8.7cm (+4%) in total. Our results indicated that WB-EMS physical training program can reduce fat (especially hip and waist area) and obtain gain mass, especially muscle mass for older subjects without pain. Quality of life index increase from 115 points (67%) to 152 points 89%.
Conclusions: The WB-EMS physical training program was a joint shoulder-friendly form of physical exercise during which the patient reported no pain. Subject achieved the training goal: reducing fat mass and gaining muscle mass which will increase his comfort of life and perhaps prevents other age-related diseases 50+. Because of the study's-controlled environment, this training could likely be adapted for successful home use with careful attention to detail, especially having the trainer's guidance readily accessible.

Keywords: electrical muscle stimulation, WB-EMS, fat mass reduction, body composition, frozen shoulder

Introduction

Frequency distribution of ages adhesive capsulitis has a higher average incidence rate over age 50.[1,2] Adhesive capsulitis, also known as a frozen shoulder [3] can lead to severe shoulder pain, significant difficulties at work, and a diminished quality of life [4] and limits a range of motion.[5,6] Follow-up investigations after arthroscopy have shown that for 50 years of patients, a convalescence period is limited to a maximum of 6 months in almost half the cases and to a maximum of 12 months in 86% of cases.[7] Physiotherapy is preferred within 6 to 12 months of arthroscopy, and after this period patients can physically exercise without pain.[7] Various methods of physiotherapy are used, [8] but combining shoulder exercises with either electroacupuncture or interferential electrotherapy can effectively treat frozen shoulder.[9] Interferential electrotherapy is a popular physiotherapy treatment in Asia, that utilizes a high carrier frequency (around 4000 Hz), to accelerate frozen shoulder treatment.[9] The impact of electrical muscle stimulation is very promising on muscle stiffness problems and musculoskeletal pain.[10]

For more than 50 years an electrical muscle stimulation (EMS) was used during training of human muscles.[11] EMS was used on individual muscle groups, but rarely on more than three at the same time.[12,13] Only in the last decade has EMS technology made it possible to use the system for full body training and also guidelines regarding the safety of EMS training have begun to appear.[14,15] A training method that is gaining popularity is whole-body EMS (WB-EMS), which can stimulate several muscle groups at once with intensity that is targeted to specific regional areas. Although many different protocols could be used, WB-EMS typically uses brief impulse phases (4-6 s) interspersed with short rest phases (4 s), with moderate to high impulse intensity, lasting roughly 20 minutes. Although the majority of procedures employ comparable impulse settings (such as bipolar, 80–85 Hz, 300–400 s, intermitted), two fundamentally distinct WB–EMS concepts have emerged and should be taken into account when categorizing WB–EMS. One technique prescribes high voluntary loads superimposed by WB-EMS with an impulse intensity that only permits the proper application of the target exercise (e.g., weighted squats, jumps), and combines

several stimulation parameters (i.e., frequencies, pulse width, and current cycles).[16,17] Contrarily, the more widely used WB-EMS approach, almost exclusively used by commercial WB-EMS suppliers, focuses on negligible to low effort voluntary workload by gentle movements and moderate-high impulse intensities.[14-16] WB-EMS can be categorized primarily as a resistance type workout, regardless of this element. Resistance training is an important component of exercise protocols, mostly used to enhance muscle strength and hypertrophy. Additionally, resistance training can influence resting energy expenditure and fat metabolism, assisting in weight loss procedures.[18] Resistance training like EMS type of workout, can be combined with interval training to enhance muscle strength, improve endurance strength performance, and lean body mass.[19]

Accordingly, the majority of studies examined the impact of WB-EMS on lean body mass, muscle mass as well as body fat mass.[20] Effective WB-EMS training requires careful consideration of several key parameters. These include impulse duration and rest intervals, impulse width, number of training units per week, regeneration times, fatigue levels, and the type of exercises (dynamic or static).[21] For fat mass loss to occur, the duration of the training program should last from 16 to 26 weeks, and the training itself should last from 30 to 40 minutes.[21,22] In middle-aged sedentary subjects with metabolic syndrome, WB-EMS combined with caloric restriction for 26 weeks can improve insulin resistance and lipid profile compared to diet alone.[22] Subjects trained with WB-EMS had significant improvement in systolic pressure and no one discontinued training. WB-EMS is an effective, good for joint, and widely customizable training program for maintaining muscle mass during energy restriction and can thus be considered as an alternative to more demanding resistance exercise protocols.[22]

Using WB-EMS no adverse events occurred and a positive long-term impact was known, but still, knowledge about WB-EMS is still not enough and requires further research.[23] For the effects of WB-EMS training to be only positive, training guidelines must be followed so that rhabdomyolysis does not occur. First of all, the intensity of exercise at the beginning of the program cannot reach exhaustion.[14] Secondly, safe and effective WB-EMS training must be advised and accompanied by a trained and licensed WB-EMS trainer or scientifically trained personnel.[14] Due to the potential risks of improper WB-EMS use at home, it's important to establish safe and effective exercise routines in a lab setting for future home adaptation, also for patient recovering from frozen shoulder. Proper WB-EMS application is complex, and without expert guidance, there's a high potential for injury and negative outcomes.[26] A 2020 study [26] found that 228 people out of 1902 surveyed suffered musculoskeletal injuries during home training. The authors blame this trend on overly intense/frequent workouts and a lack of personalized training programs, particularly those promoted by social media influencers. The uncertainty caused by adults searching for information on the Internet about their diagnosis [27] it's crucial to prioritize the development of knowledge about WB-EMS training that promotes safe and individualized training via case studies for public health.

The main contribution of our work is that a WB-EMS physical training program will be a successful continuation after the physiotherapy phase for patient with a history of diagnosis of frozen shoulder. The goal of the program is without feeling shoulder pain change body composition and circumference to increase the comfort of life for 50-year-old man.

Methods

Participants

A 50-year-old man participated in an interval EMS training program lasting 71 days in 6-month period, with the frequency of training gradually increasing.

Inclusion criteria were: 1) man in age 50-55, 2) normal range of ROM achieved after physiotherapy phase for frozen shoulder (flexion from 160° to 180°, extension from 40° to 60°; abduction from 160° to 180°; internal rotation from 80° to 90° and external rotation from 80° to 90° passively measured), 3) clothes size between European small and large, 4) no treatments or specialized diets 5) not taking slimming and/or protein supplements.

Exclusion criteria were: 1) person, who has contraindications to whole body EMS training (medical implants, liver disease, and neurological disorders), 2) those who refused electrical stimulation, 3) those who were under treatment for diseases during the study period.[28]

Case description

A medical history was obtained from the patient (trauma and orthopedic surgery clinic in Poland). A 50-year-old, right-handed man presented with a diagnosis of was frozen shoulder, and he received a corticosteroid injection. After worsening pain, he got arthroscopy followed by intensive physical therapy. After 6 months he discontinued physiotherapy and achieved full ROM in his right shoulder. For 2 years after diagnosis, the patient did not exercise physically and avoided loading his arm with resistance exercises, which he had previously practiced three times a week. Before diagnosis, the patient was physically active with high-intensity exercise and strength training using free weights. The time frame from diagnosis to undertaking WB-EMS physical training is shown in Figure 1.

Figure 1. The graphical time frame from diagnosis to undertaking WB-EMS physical training

Bioelectrical impedance analysis (BIA)

To obtain muscle mass (kg), segmental lean (kg) and fat (kg) a multi-frequency BIA device InBody 170 (InBody, Eschborn, Germany) were used. This method is used by researchers in the field of WB-EMS.[23] The subject was instructed to abstain from food and drink, except a small amount of water, for a minimum of 3 hours prior to data collection, because the regular increase in water consumption has any significant effects on measurements of body composition using BIA.[24] The time 6 months is divided into 3 stages including 26 weeks with different frequencies of: measurement (1 or 2 days in stage) training (2 or 3 days in one week) and rest days (1 or 2 days in one week). The sum of the total training days is 71. The subject was measured on training days: 0, 14, 35, 56, 71. A graphical diagram of a training program containing the number of measurements, training, and rest days in appropriate weeks is in Figure no. 2.

Body circumference

Body circumference measurements were measured with a flexible, tension-sensitive, non-elastic vinyl tape measure. The subject was measured on days as above.

Whole body electrical muscle stimulation (WB-EMS)

The set of WB-EMS [29] (Personal roll, Zgierz, Poland) consists of five parts: training underwear, vest, shoulder and leg pads, and elastic belt. Figure 3 show the WB-EMS set. Everything was controlled by an Android control panel. The equipment provides freedom to moved thanks to the use of a wireless Bluetooth system. The whole set send an impulse to the electrodes placed in the vest, shoulders, and leg pads, which give an electric impulse, stimulating individual muscle groups, located on the arms, back, chest, buttocks, thighs and calves.

The EMS set was worn during training, and the impulse intensity was adjusted individually. Two types of impulse were used: fitness and relaxation. The duration of the fitness impulse was 27 minutes (used in the warm-up and the main part), for the relaxation impulse was 6 minutes (1 second impulse, 1 second break, used in the calming down part).

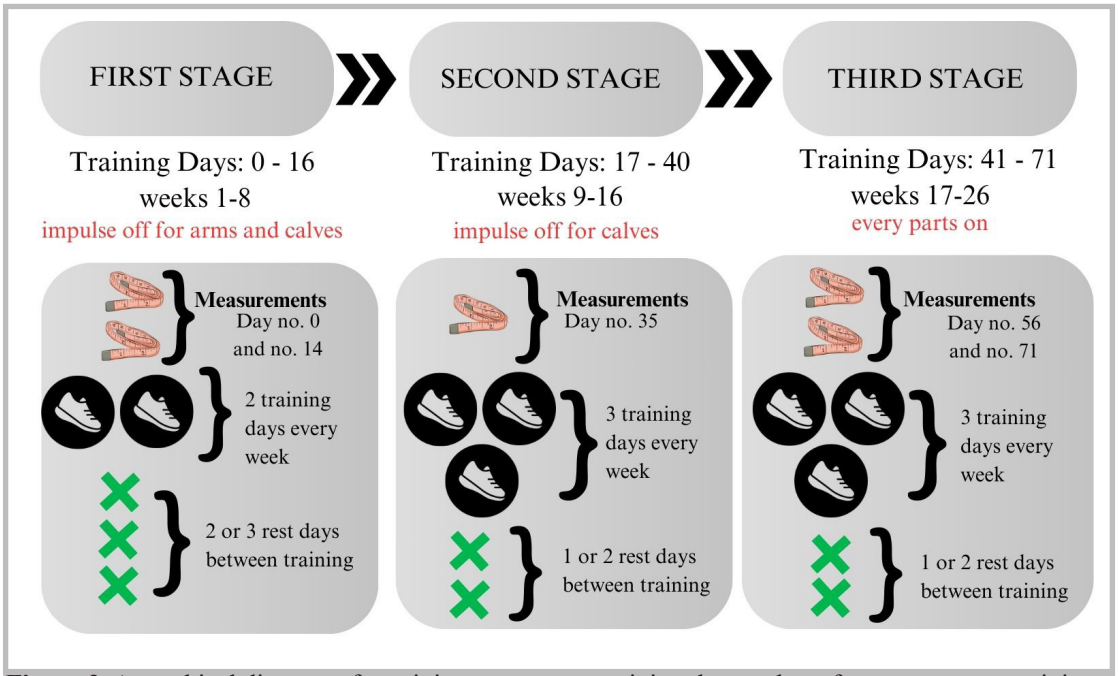

Figure 2. A graphical diagram of a training program containing the number of measurements, trainings, and rest days in appropriate weeks

Figure 3. Subject with WB-EMS suit on (A and B subject's front sides, C and D subject's back sides)

Quality of life SF-36 questionnaire

Index for health-related quality of life: measured by the Polish version of Short Form 36 (SF-36) consisting of eight sub-domains, including physical function, role limitation-physical, body pain, general health, vitality, social function, role limitation-emotional and mental health. The SF-36 is a common tool used to assess health outcomes in research, including clinical trials and health policy studies. It's valued for its reliability and validity. The quality of life index is determined in points (171 is the maximum score that can be obtained).[25]

Subjective shoulder pain questionnaire (4 questions)

1. Do you feel pain in your right shoulder today (without touching it)? YES / NO
2. Do you feel pain in your right shoulder today (when you touch it)? YES / NO
3. Do you feel pain in your right shoulder after completing a workout (without touching it)? YES / NO
4. Do you feel pain in your right shoulder after training (after touching it) YES / NO

Interventions

Subject was invited to participate in the study through personal invitations and emails. Participant provided signed informed consent. On day 0, after an inclusion criteria examination, the participant was weighed and measured, and this process were repeated on days: 14, 35, 56, 71. Then the appropriate underwear and WB-EMS set size were selected. Pictures were taken in the T-pose front position and repeated on days 35 and 71. All measurements were made in the laboratory with access to appropriate equipment.

A WB-EMS trainer supervised a subject as they worked out, following a detailed interval program displayed on a projector screen. The subject exercised by imitating the movements shown in a previously recorded video, while the trainer carefully observed the subject during the 33 minutes of every 71 interval training days. The subject used their body weight together with the weight of the WB-EMS set. All exercises performed based on WB-EMS interval programmed training were made in the laboratory with access to WB-EMS equipment. The graphical diagram of a training program is shown in Figure 2.

The training lasts 33 minutes and was divided into three parts: warm-up (6 minutes), main part (3 x 6.5 minutes) and cool-down (6 minutes). In the main part, three rounds of exercises lasting 6.5 minutes were performed, and each round was divided into 8 exercises of 30 seconds of work and 20 seconds of active break (walking with high knee raises). After first and second rounds, a 30 second rest break was taken to drink a water.

Before each training, the subject answered the first two questions of the 4 questions subjective shoulder pain questionnaire. On day 0, the individual intensity level of each pad was determined. The subject was informed to report each time (for each part of the body) a feeling of discomfort, which could be felt as tightness or not comfortable muscle squeezing.[30] To establish personal exercise limits of impulse for each body part involved informing the trainer which level was subjectively sufficient without the feeling of discomfort. A 1 point was added for each body parts (arms, low part of back, middle part of back, upper part of back, chest, buttocks, front sides of thighs, back sides of thighs, and calves) on every 3 minutes of training unless the subject indicated to stop raising the level, considering the feeling of discomfort (by hand raising).

After completing WB-EMS interval training, the subject indicated his level of effort using the self-rated Borg Rating of Perceived Exertion (6-20 points scale), where 6 represents no exertion and 20 represents maximal exertion.[31] An individual approach to a person aged around 50 is recommended to adjust the physical intensity, but care should be taken to ensure that the exercise intensity does not exceed the hard level of perceived exertion to 8 weeks of training (15-16 points of Borg Rating of Perceived Exertion).[32] Finally, the subject answered the last two questions on the shoulder pain questionnaire.

Results

At the day 71, the subject achieves a 1kg of weight according to day 0. Subject gain 5.82kg (+19%) of muscle mass and reduced fat mass about 5.60kg (-24%).

The rest of training days and results are listed in the Table 1, Figure 4 and Figure 5.

Table 1. Segmental body composition for lean and fat mass showing minus and plus (%) data to day 0

Variables	Day 0 (week 1)	Day 14 (week 7)	Day 35 (week 14)	Day 56 (week 21)	Day 71 (week 26)
Left arm lean mass (kg)	3.35	3.38 (1)	3.53 (5)	3.55 (6)	3.77 (13)
Right arm lean mass (kg)	3.48	3.57 (3)	3.58 (3)	3.60 (4)	3.81 (6)
Left leg lean mass (kg)	8.94	8.99 (1)	9.12 (2)	9.26 (4)	9.50 (6)
Right leg lean mass (kg)	9.00	9.06 (1)	9.16 (2)	9.20 (2)	9.30 (3)
Trunk lean mass (kg)	22.75	23.58 (4)	26.85 (18)	27.5 (21)	27.52 (21)
Left arm fat mass (kg)	2.30	2.10 (-9)	1.60 (-22)	1.30 (-43)	1.30 (-43)
Right arm fat mass (kg)	2.20	2.00 (-9)	1.50 (-23)	1.30 (-41)	1.20 (-45)
Left leg fat mass (kg)	3.60	3.40 (-6)	3.30 (-8)	2.9 (-19)	2.80 (-22)
Right leg fat mass (kg)	3.60	3.40 (-6)	3.30 (-8)	2.9 (-19)	2.80 (-22)
Trunk fat mass (kg)	12.00	11.80 (-2)	11.50 (-4)	10.30 (-14)	10.00 (-17)

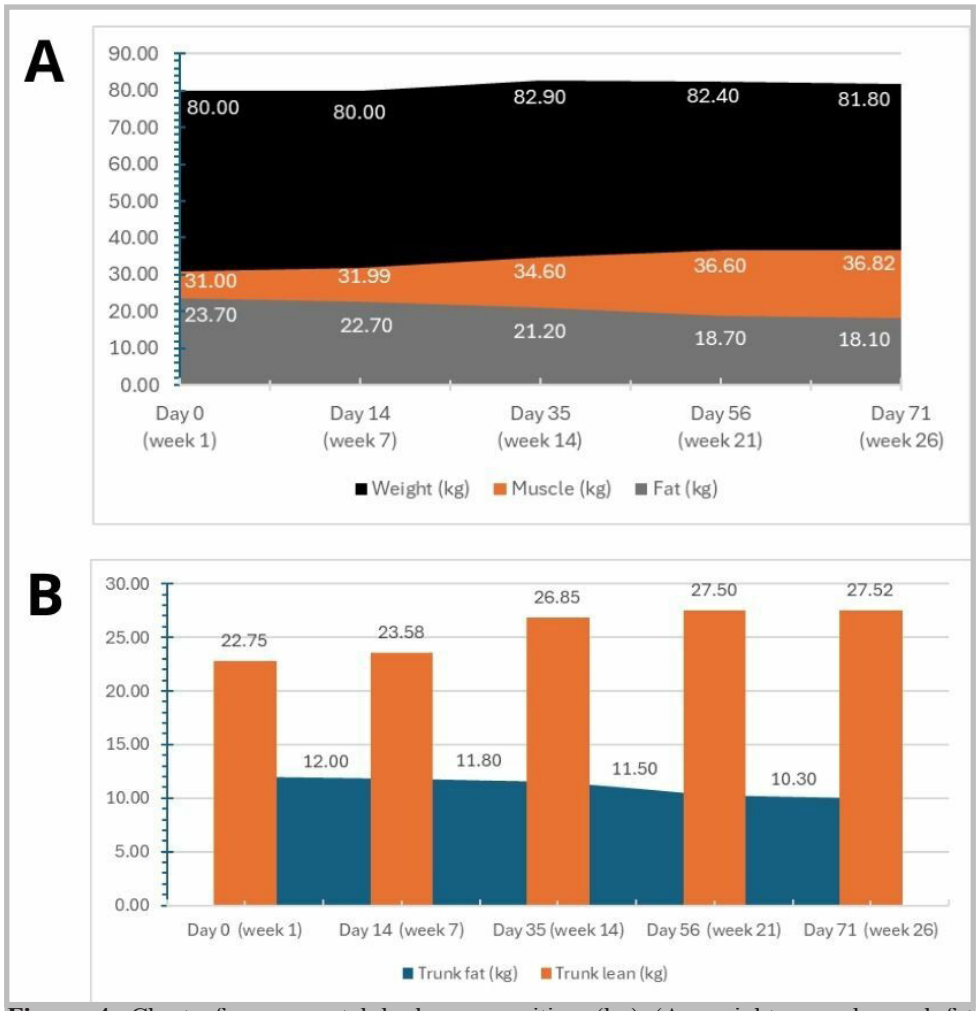

Figure 4. Charts for segmental body composition (kg) (A. weight, muscle, and fat composition B. Fat and Lean mass for trunk composition)

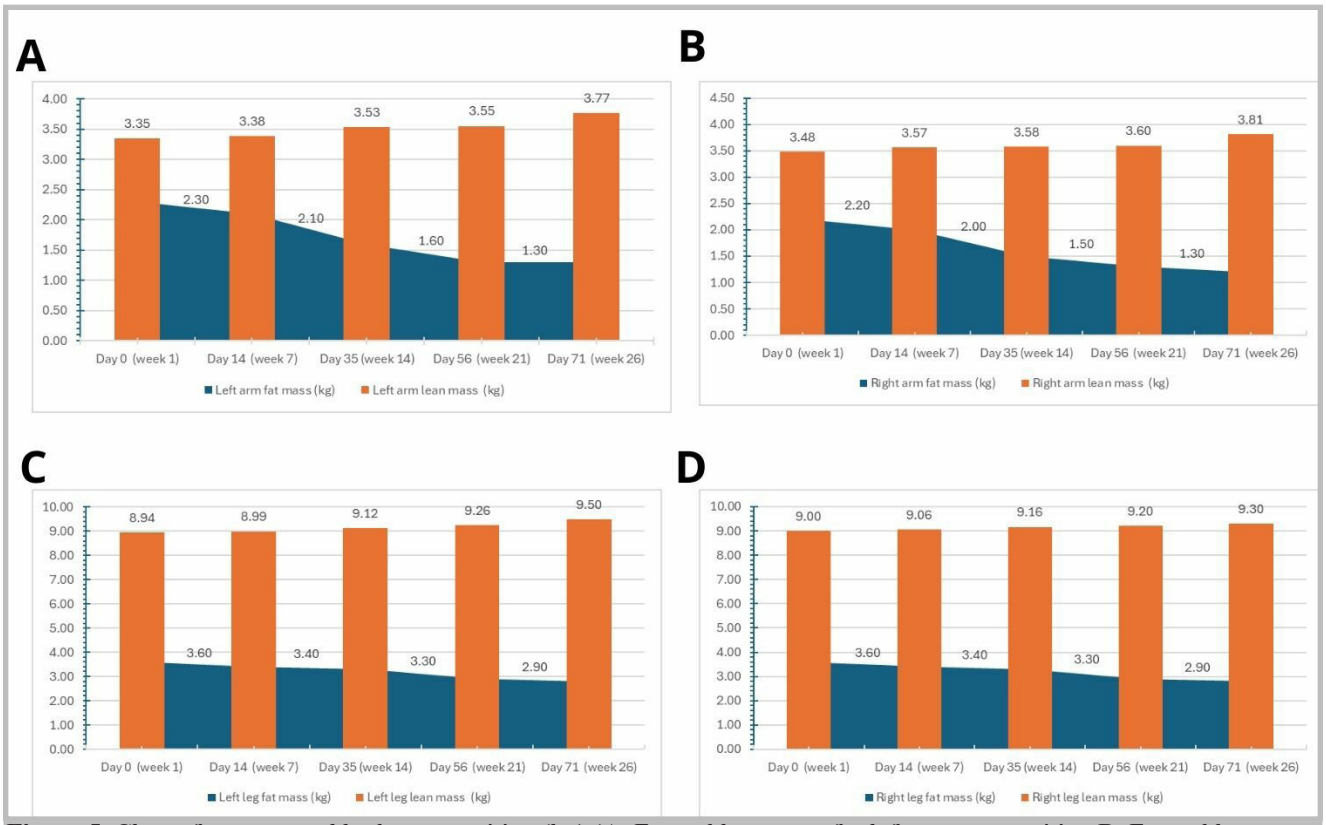

Figure 5. Charts for segmental body composition (kg) (A. Fat and lean mass for left arm composition B. Fat and lean mass for right arm composition C. Fat and lean mass for left leg composition D. Fat and lean mass for right leg composition)

At the day 71, the subject reduced body circumference for left thigh for .9cm (-2%). Right and left calf circumference increased about .6cm (+2%) and .3cm (+ .5%). Body circumference for hip was reduced about 1.8cm (-2%) and waist about 1.5cm (-1.5%). The chest measurement increased during exhalation and inhalation about 1.2cm (+1%) and 1.5cm (+1.5%), respectively. Arm circumference increased, for right arm about 3.1cm (+9%) and left arm about 3.5cm (+10%). The rest of training days and results are listed in the Table 2.

Hip to waist ratio before 71-days interval WB-EMS physical training program was .98. and after .97.

Borg Rating of Perceived Exertion (6-20 scale)

Completing the Borg's 6-20 points scale for rating perceived exertion by subject was 15 points for 1-8 weeks. After 8 weeks to the last training days, subject choose always 17 or 18 points, which indicated about very hard level of exertion. The study resulted in a very hard level of exercise, about 90-95% of the subject's physical effort.

Table 2. Segmental body circumference showing minus and plus data (%) to day 0

Variables	Day 0 (week 1)	Day 14 (week 7)	Day 35 (week 14)	Day 56 (week 21)	Day 71 (week 26)
Body Mass Index (kg/m²)	26.73	.0 (0)	1.0 (3.7)	.8 (3)	.6 (+2.2)
Calf – left leg (cm)	36.2	.0 (0)	.3 (.5)	.4 (1)	.3 (.5)
Calf – right leg (cm)	35.2	.0 (0)	.3 (.5)	.4 (1)	.6 (2)
Thigh – left leg (cm)	52.5	- .3 (- .5)	- .5 (- .5)	- .5 (-1)	- .9 (-2)
Thigh – right leg (cm)	51.0	- .4 (- .5)	.0 (0)	.0 (0)	- .2 (- .5)
Hip (cm)	95.0	- .2 (- .5)	- .4 (- .5)	- .7 (-1)	-1.8 (-2)
Waist (cm)	97.2	- .2 (- .5)	- .3 (- .5)	- .4 (-1)	-1.5 (-1.5)
Chest – exhale (cm)	104.5	.0 (0)	1.0 (1)	1.1 (1)	1.2 (1)
Chest – inhale (cm)	108.5	.0 (0)	1.0 (1)	1.4 (1)	1.5 (1.5)
Arm – left (cm)	34.0	.2 (.5)	.5 (1.5)	2.7 (8)	3.5 (10)
Arm – left, tension (cm)	36.5	.1 (.5)	.4 (1)	2.0 (5.5)	4.0 (11)
Arm – right (cm)	34.5	.2 (1)	.4 (1)	2.5 (7)	3.1 (9)
Arm – right, tension (cm)	37.0	.1 (.5)	.4 (1)	2.9 (8)	3.9 (10.5)

Subjective shoulder pain questionnaire (4 questions)

Subject on every day of the study, answered "NO" to every question of questionnaire.

Quality of life SF-36 questionnaire

Quality of life index increase from 115 points (67%) to 152 points 89%.

Discussion

Our single case study showed that a 71-day WB-EMS physical training program resulted in an increase in BMI of 2.2% (from 26.73 to 27.33) compared to the baseline BMI which would not be a positive effect. Taking only the BMI into account might not provide a complete picture of health, as it doesn't consider factors like body circumference and fat and muscle mass.[33] Based on the description of the own patient's history, that the patient was a gym-goer before the shoulder injury, we remain of the opinion that measuring changes based on BMI only is incorrect.[34] Looking at other parameters such as fat mass (kg) and muscle mass (kg), these values changed by -24% and +19%, respectively. Subjects were observed to gain an average of 5.82 kg of skeletal muscle mass, a significant increase particularly for older subjects with lower levels of growth hormones.[35] The hip-to-waist ratio improved, decreasing from .98 to .97. In the light of normal values for mentioned above hip-to-waist ratio as .78 to .94 for men [36] the changes were going in the correct direction. Body circumference for hip was reduced about 1.8cm (-2%) and waist about 1.5cm (-1.5%). Patients with shoulder injuries may have excessive fat mass and a lack of muscle mass which can be explained by lack of physical activity and increased BMI above 25 kg/m^2,[37] as was our case study. Recent research [37] reveals a link between overweight and obesity, measured by BMI, and the severity of rotator cuff tears, one of the causes of frozen shoulder but it's not always clear-cut.

The shoulder joint is particularly vulnerable to injuries during resistance training, with some studies suggesting up to 36% of resistance training-related injuries occurring in this area.[38] This is partly because the shoulder, designed for mobility, is forced to bear significant weight during resistance training – a role it's not structurally optimized for.[39] Many common exercises also place the shoulder in awkward positions (like extreme outward rotation) while under heavy loads, increasing risks of both sudden and gradual injuries.[39] This combination of stress, poor positioning, and muscle imbalances makes participants susceptible to shoulder problems. Taking into account a medical history about our case study subject (50-year-old, right-handed man presented with a diagnosis of was frozen shoulder) we guessing that the condition that led to his shoulder injury was resistance training without a trainer's supervision on the gym. To prevent these issues, is important to understand high-risk training patterns. One promising option is a carefully programmed WB-EMS training

plan with trainer supervision what we implemented in the study. This type of resistance training has gained popularity in recent years.[40] In our study, a subject participated in an interval-based WB-EMS program and experienced no subjective shoulder pain during the study period, which is of course a very positive result, bear in mind that there are cases of poorly selected WB-EMS training and side-effects.[41]

There are some limitations in our case study. We must be cautious in extrapolating the results of this single case study, as such designs prioritize internal validity (understanding the specific case) over external validity (generalizability). However, they provide a starting point for creating future training programs for a similar case study. While valuable, the data does not directly indicate whether these findings apply to a larger population. Future trials with a larger sample size are warranted to validate the positive results in the present study.

Practical Applications

We recommend WB-EMS training program for patients with a history of frozen shoulder who have already completed 6 months of physiotherapy and would like to increase their quality of life after (loss of fat tissue and gain in muscle mass). The condition is to achieve a normal range of motion during physiotherapy.

For WB-EMS physical training program we suggest the following approaches:

a) Supervision: Program should be designed and monitored in collaboration with a certified personal trainer experienced in WB-EMS.
b) Intensity: Program should start with low/moderate intensity and gradually increase. Intensity should not exceed "hard" on the Borg Rating of Perceived Exertion Scale (15-16 points) for the initial 8 weeks.
c) Impulse Adjustment: Program training should include gradually increase impulses targeted at different body parts over the course of the program.
d) Frequency: Program training should include both training days and rest days. A sample schedule could be week 1-8: 2 training days per week; week 9-16: 3 training days per week; week 17-26+: 3 training days per week (adjust based on patient response).
e) Important Considerations: WB-EMS physical training should include warm-up and cool-down parts: include a gentle warm-up routine before sessions and a cool-down afterward to promote muscle recovery and flexibility. Feeling of discomfort, which could be felt as tightness or not comfortable muscle squeezing is a signal to stop training. If any shoulder pain worsens during the program, patient should immediately consult the personal trainer and consider consulting a doctor.

A program prepared in this way will increase the patient's quality of life without feeling shoulder pain during WB-EMS exercise.

Conclusions

The patient recovering from a frozen shoulder can expect to increase the quality of life, safely gain muscle mass through the implementation of WB-EMS training program and safely decrease body fat. Scheduling measurements, training days, and rest days are recommended for people who want to start WB-EMS interval training. Patients recovering from frozen shoulder can expect a WB-EMS physical training program to provide a joint-friendly form of exercise that won't worsen of shoulder pain (if any). Due to the limited research on WB-EMS, more studies are needed to draw definitive conclusions about its effects.

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Not applicable.

Ethical Committee approval

Bioethics Committee at the Karol Marcinkowski Medical University in Poznań (no. 19/23).

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Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, J.C. and J.M.; methodology, J.C; software, J.C.; validation, J.C. and J.M.; formal analysis, J.C., J.M., and A.W.; investigation, J.C.; resources, J.C. and A.W.; data curation, J.C., J.M., and A.W.; writing—original draft preparation, J.C. and A.W.; writing—review and editing, J.C., J.M. and A.W.; visualization, J.C. and A.W.; supervision, J.M.; project administration, J.C. and J.M. All authors have read and agreed to the published version of the manuscript.

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