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Review Article

The Characteristics of the Pelvic Floor Muscle Training Programs Used in Experimental Studies with Surface Electromyography in Non-Pregnant Women: A Systematic Review

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Abstract

Background: We aimed to characterize the pelvic floor muscle training (PFMT) programs for non-pregnant women used in the experimental studies with surface electromyography, based on the four training components: the frequency, intensity, time and type of exercises. Then, to characterize the study groups in which the PFMT programs were applied and the effectiveness of these programs.

Methods: This is a review of 29 papers published in the years 1986-2019, available in PubMed, MEDLINE and SPORTDiscus with Full Text databases. We used keywords: "pelvic floor", "muscle training" and "EMG or electromyography".

Results: Only in six articles all training components were characterized. The frequency was given in 17 papers, and on average, it was 4 ± 2 (M ± SD) times a week. The intensity was described in nine reports, most often the maximal contraction of the pelvic floor muscles was recommended. Researchers conducted their interventions on average for 10 ± 5 weeks. The exercise sessions lasted 25' ± 10.49'. Type of exercises was specified in eleven papers and most often quick flicks were performed. In 90% of the studies, the training programs were applied in women with pelvic floor muscle dysfunctions. In most works, positive effects of PFMT were observed. No adverse outcomes of the use of electromyography were reported.

Conclusion: The full training description should be presented in any scientific work, providing information on applied intensity, frequency, volume and type of pelvic floor muscle exercises to enable their replication and comparability between various interventions. It is important to pay more attention to preventive approach and the implementation of PFMT programs in healthy women. It is justified to use surface electromyography to support PFMT, regardless of health condition.

Keywords: Pelvic floor; Muscle training; Electromyography; Exercise

Introduction

The muscles of the pelvic floor play a key role in the proper functioning of the pelvic and abdominal organs. They must be strong enough to support the bladder, rectum, vagina, uterus and internal organs of the abdominal cavity (1, 2). Relaxation of the pelvic floor muscles is required

during urination and defecation as well as during delivery (3-5). Correct muscle tone of this muscle group ensures urinary continence during sleep and during activities increasing intra-abdominal pressure, e.g. during coughing, sneezing, lifting heavy objects, running and jumping (1, 2, 6-8).
The regular pelvic floor muscles training is essential for the prevention of urinary incontinence and other pelvic floor muscle dysfunctions at any age (2, 4-6, 9-11). Unfortunately, most of the pelvic floor muscle training programs are directed at pregnant or incontinent women. More and more scientific papers prove the positive effects of various training programs conditioning this muscle group. In order to be able to compare and effectively implement these programs, information about frequency, intensity, time and type of exercise is necessary in accordance with the FITT principle (12, 13). The training frequency is usually given in the number of training units during the week. The intensity in pelvic floor muscle training is most often expressed in relation to the maximum contraction of these muscles. The training time refers to the duration of a single exercise session (usually expressed in minutes) or the overall duration of the training program (most often expressed in the number of weeks, so called total training time). The training type should include a description of each exercise, for example including exercise positions and the exercise technique (12).
To increase the efficiency of pelvic floor muscle training and its assessment, specialized equipment is increasingly used. One of the more popular methods that allows both non-invasive assessment of pelvic floor muscle function before and after training, and visualization of the correctness of the exercises performed is surface electromyography (sEMG) (14). Electromyography is widely used both in scientific research and in practice, allowing the observation of the neuromuscular activity of pelvic floor muscles, among others owing to the use of the vaginal probes (15). Therefore, our research has focused on it. In this review study, we set two research goals. First, we aimed at characterizing the pelvic floor muscle training programs for non-pregnant women used in the experimental studies with surface electromyography, based on the four training components: the frequency, intensity, time and type of the pelvic floor muscle exercises. Second, we intended to characterize the study groups in which the PFMT programs were applied and the effectiveness of these programs.

Methods

The review of the literature was carried out from May 2017 to February 2019 in databases: PubMed, MEDLINE and SPORTDiscus with Full Text, using keywords: "pelvic floor", "muscle training" and "EMG or electromyography". We found 147 articles published in 1986-2019. The criteria for including papers in the analysis were: publication in English, conducting experimental research using pelvic floor muscle training in non-pregnant women, and characterizing at least one training component for the applied training intervention (frequency, intensity, volume and / or type of exercise). The above procedure was repeated by two independent researchers. Overall, 29 articles were qualified for the analysis. Fig. 1 presents the process of qualifying articles for analysis.

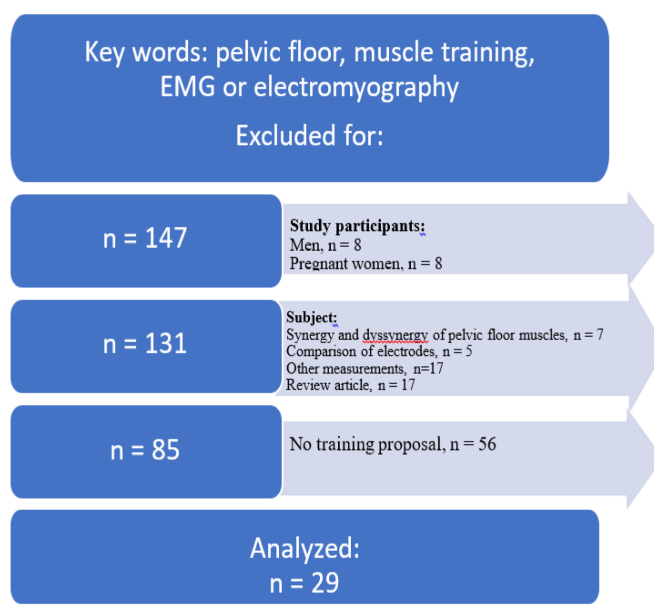

Fig. 1: The process of classification of the studies for analysis

Results

A total of 1721 women participated in 29 studies qualified for the analysis. The training components for pelvic floor muscle training presented by the authors are summarized in Table 1. Only in six articles the researchers characterized all the training components (16-21).

As for the training frequency, the number of training sessions during the week was given in 17 papers, and on average it was 4 ± 2 (M ± SD) times a week (16-32). We found information about training intensity in eleven articles. In ten of them, maximal contraction of the pelvic floor muscles was recommended (16-18, 20, 21, 23, 24, 30, 31, 33), while in one study it was the intensity of 60-80% of the maximum contraction (19).

Table 1: Proposed PFMT with the division into the training components described

Author, year			***Training program***		
	Type (description exercise)	Intensity	Frequency (n times w week)	Time (minutes/ repetitions)	Number of weeks/ sessions
Heidler, 1986 (41)	-	-	-	-	4 weeks
Hirsch et al. 1999 (25)	-	-	7	20'	26 weeks
Aukee et al. 2002 (16)	Quick flicks (5s.)	Maximum contraction	5	20'	12 weeks
Wang et al. 2004 (34)	Quick flicks	--	-	-	12 weeks
Dannecker et al. 2005 (36)	-	-	-	-	9 sessions
Capelini et al. 2006 (39)	Contraction (15 s.) Rest (15 s.)	-	-	1 set of 6-8 repetitions	8 weeks
Di gangi herms et al. 2006 (35)	-	-	-	-	12 weeks
Terra et al. 2006 (37)	-	-	-	-	9 sessions
Mcclurg et al. 2006 (42)	-	-	-	-	9 weeks
Mcclurg et al. 2008 (43)	-	-	-	-	9 weeks
Eyjólfsdóttir et al. 2009 (26)	-	-	7 (twice a day)	15'	9 weeks
Lee-bognar, 2009 (27)	-	-	7	-	9 weeks
Piassarolli et al. 2010 (38)	-	-	-	-	10 sessions
Huebner et al. 2011 (17)	Contraction (8 s.) Rest (15 s.)	Maximum contraction	7 (twice a day)	15'	12 weeks
Stüpp et al. 2011 (44)	-	-	-	-	14 weeks
Resende et al. 2012 (33)	-	Maximum contraction	-	-	14 weeks
Pereira et al. 2013 (31)	Quick flicks	Maximum contraction	2	-	6 weeks
Lúcio et al. 2014 (23)	-	Maximum contraction	2	30'	12 weeks
Alves et al. 2015 (28)	-		2	30'	6 weeks
Botelho et al. 2015 (20)	Virtual game	Maximum contraction	2	30'	10 sessions
Luginbuehl et al. 2015 (18)	Quick flicks, static hold	Maximum contraction	3 (three times a day) 3	15' 15'	1-5 weeks 6-16 weeks
Özengin et al. 2015 (22)	Contraction (10 s.) Rest (10 s.)	-	3	5-30 sets	8 weeks
shin et al. 2016 (29)	-	-	3	50'	6 weeks
Lúcio et al. 2016 (24)	-	Maximum contraction	2	30'	12 weeks
Chmielewska et al. 2016 (19)	Quick flicks	60-80% Maximum contraction	3 3	3 sets of 10 repetitions 4 sets of 15 repetitions	1-3 weeks 4-6 weeks
Bertotto et al. 2017 (30)	-	Maximum contraction	2	20'	4 weeks
Liu et al. 2018 (40)	Quick flicks	-	-	-	8 weeks
Elmelund et al. 2018 (32)	-	-	7	-	12 weeks
Pereira-baldon et al. 2019 (21)	Contraction	Maximum contraction	7	8-12 sets	8 weeks

The most often described component was the total training time. Researchers applied their pelvic floor muscle trainings for a period of 4 to 26 weeks, on average 10 ± 5 weeks. Most researchers implemented 12 weeks of training between the pre and post-intervention assessments (n = 7) (16, 17, 23, 24, 32, 34, 35). In four articles, the authors gave only the number of conducted training sessions, without specifying the time period in which they were performed (20, 36-38). The characteristics of the training unit in eleven articles were given in minutes: on average 25' ± 10.49' (16-18, 20, 23-26, 28-30). In four works, the number of repetitions was provided (19, 21, 22, 39). Type of pelvic floor muscle exercises was specified in eleven studies (16-22, 32, 34, 40). So called quick flicks were performed in five studies (16, 19, 31, 34, 40), the quick flicks and static holds – in one study (18) and 15-second relaxations followed by 8-10 seconds contractions also in four studies (17, 21, 22, 39).

In Table 2 we presented a summary of the analyzed articles, including the study groups and the obtained training effects regarding the pelvic floor muscle function.

Table 2: Characteristics of the analyzed articles

Author, year	***Characteristics of the study***	***Training effectiveness***
Heidler, 1986 (41)	Dysfunction of the urinary system, n = 22 G1 - sui	73% - significant improvement
Hirsch et al. 1999 (25)	Dysfunction of the urinary system - overactive bladder, n = 33 g1 = sui, n = 13 g2 = mui, n = 20	85% - significant improvement
Aukee et al. 2002 (16)	Treatment of stress urinary incontinence using biofeedback emg, n = 30 g1 = pfmt + biofeedback, n = 15 g2 = pfmt, n = 15	Greater improvement in g1
Wang et al. 2004 (34)	Dysfunction of the urinary system - overactive bladder, n = 103 g1 = pfmt, n = 34 g2 = pfmt + biofeedback, n = 34 g3 = nmes, n = 35	Effectiveness: 1. Nmes 2. Pfmt+biofeedback 3. Pfmt
Dannecker et al. 2005 (36)	Stress urinary incontinence, n = 263 g1 = sui, n = 263	71% - significant improvement
Capelini et al. 2006 (39)	Stress urinary incontinence, n =10 G1= sui, n = 10	Significant improvement
Di Gangi Herms et al. 2006 (35)	Stress urinary incontinence, n = 10 g1 = (pfmt + emg biofeedback), n = 10	Significant improvement
Terra et al. 2006 (37)	Treatment of fecal incontinence, n = 252 g1 = pfmt + biofeedback + nmes, n = 252	60% - improvement 23% - no change 17% - deterioration
Mcclurg et al. 2006 (42)	Women with multiple sclerosis with symptoms of urinary incontinence, n = 30 g1 = pfta, n = 10 g2 = emg, n = 10 g3 = biofeedback + nmes, n = 10	
Mcclurg et al. 2008 (43)	Women with multiple sclerosis with symptoms of urinary incontinence, n = 74 g1 = nmes, n = 37 g2 = simulated nmes, n = 37	G1 – 47% improvement g2 – 85% improvement
Eyjólfsdóttir et al. 2009 (26)	Treatment of stress urinary incontinence using electrical stimulation, n = 24 g1 = pfmt, n = 12 g2 = pfmt + nmes, n = 12	Significant improvement, no differences between groups
Lee-Bognar, 2009 (27)	Women with multiple sclerosis with symptoms of urinary incontinence, n = 74 g1 = nmes, n = 37 g2 = simulated nmes, n = 37	Significant improvement, no differences between groups

Piassarolli et al. 2010 (38)	Sexual dysfunctions, n = 26	69% - significant improvement
Huebner et al. 2011 (17)	Prewention of stress urinary incontinence, n = 108 g1 = emg assisted pfmt convective, n = 36 g2 = emg assisted pfmt dynamic, n = 36 g3 = emg assisted pfmt, n = 36	There was improvement in each sui prevention group, but there were no significant differences between the study groups
Stüpp et al. 2011 (44)	Treatment of pelvic organ prolapse, n = 37 g1 = intervention group, n = 21 g2 = control group, n = 16	Significant improvement in the intervention group
Resende et al. 2012 (33)	Treatment of pelvic organ prolapse, n = 58 g1- pfmt g1 - hypopressive exercises + pfmt g3 - control group	G1 i g2 – significantly better results than in the control group
Pereira et al. 2013 (31)	Postmenopausal women with stress urinary incontinence, n = 45 g1 = vc, n = 15 g2 = pfmt, n = 15 g3 = control group, n = 15	Significant improvement, no differences between groups
Lúcio et al. 2014 (23)	Women with multiple sclerosis, sexual dysfunctions and symptoms of urinary incontinence, n = 30 g1 = pfmt + biofeedback + simulated nmes, n = 10 g2 = pfmt + biofeedback + nmes, n = 10 g3 = pfmt + biofeedback + ttns, n = 10	Significant improvement, no differences between groups
Alves et al. 2015 (28)	Postmenopausal women with pelvic organ prolapse, n = 30 g1 = treatment group, n = 18 g2 = control group, n = 12	Improvement: reducing the symptoms of falling out pelvic organs in postmenopausal women
Botelho et al. 2015 (20)	Virtual game, n = 46 g1 = healthy women, n = 19 g2 = postmenopausal women with sui, n = 27	Significant improvement, no differences between groups
Luginbuehl et al. 2015 (18)	Stress urinary incontinence, n = 96 g1 = intervention group, n = 48 g2 = control group, n = 48	Significant improvement, no differences between groups
Özengin et al. 2015 (22)	Women with pelvic organ prolapse, n = 38 g1 = stabilization exercise, n = 19 g2 = pfmt, n = 19	Significant improvement, no differences between groups
Shin et al. 2016 (29)	Patients with stress urinary incontinence after a stroke, n = 31 g1 = pfmt, n = 16 g2 = control group, n = 15	Significant improvement, no differences between groups
Lúcio et al. 2016 (24)	Women with multiple sclerosis with symptoms of urinary incontinence, n = 30 g1 = pfmt +biofeedback + simulated nmes, n = 10 g2 = pfmt + biofeedback + nmes, n = 10 g3 = pfmt + biofeedback + ttns, n = 10	Significant improvement, no differences between groups
Chmielewska et al. 2016 (19)	Prewention of stress urinary incontinence, n = 21 g1 = healthy women, n = 21	Pfmt- assisted biofeedback affects the learning of correct pfm exercise techniques
Bertotto et al. 2017 (30)	Postmenopausal women with stress urinary incontinence, n = 49 g1 = control group, n = 14 g2 = pfmt, n = 15 g3 = pfmt + biofeedback, n = 16	Significant improvement in the pfmt group and pfmt with biofeedback
Liu et al. 2018 (40)	Stress urinary incontinence, n = 110	A significant improvement was noted in the second week, the effect remained until the follow-up in the eighth week
Elmelund et al. 2018 (32)	Women with spinal cord injury and urinary incontinence, n = 36 g1 = pfmt, n = 17 g2 = pfmt + ives, n = 19	Significant improvement in the g1, pfmt with ives is not superior to pfmt alone in reducing urinary incontinence
Pereira-Baldon et al. 2019 (21)	Healthy women, n = 25 g1 = training once a day, n = 13 g2 = training twice a day, n =12	Significant improvement, no differences between groups

Emg – electromyography // g – group
ives – intervaginal electrical stimulation
mui – mixed urinary incontinence // nmes - neuromuscular electrical stimulation
pfm – pelvic floor muscles // pfmt – pelvic floor muscles training
sui – stress urinary incontinence // ttns - transcutaneous tibial nerve electrostimulation
vc – vaginal cones

Only in three papers the trainings of pelvic floor muscles were carried out in groups of healthy women for the prevention of urinary incontinence (17, 19, 21). As many as 21 studies were performed in women with dysfunctions of: lower urinary tract (stress urinary incontinence, fecal incontinence) (16, 18, 22-27, 29, 30, 32, 34-37, 39-43) and sexual dysfunctions (38). In five of the above studies, women with multiple sclerosis were examined (23, 24, 27, 42, 43) and in one study, women after stroke (29). The other four experiments concerned female patients in the treatment of pelvic organ prolapse (22, 28, 33, 44).

A significant improvement in the function of pelvic floor muscles after training interventions was observed in 27 experiments (16-18, 20-41, 43, 44), wherein electrical stimulation was additionally used in eight of them (23, 24, 26, 27, 32, 34, 37, 43). In one work, the authors observed a positive effect of training on pelvic floor muscle function in 60% of participants, no change in 23% and its deterioration in 17% (37). In one paper, no results were reported regarding changes in pelvic floor muscle function (43).

In none of the analyzed works, any adverse outcomes of the use of surface electromyography for pelvic floor muscle assessments were reported, regardless of whether the study was performed in healthy women or in patients with various dysfunctions.

Discussion

To the best of our knowledge this is the first published study presenting the summary of pelvic floor muscle training programs used in experimental studies with the use of electromyography in non-pregnant women.

Our analysis shows that the authors usually focus on describing the results of the experiments in detail but omit information on the applied pelvic floor muscle training programs. The characteristics of training interventions are often inaccurate and do not allow their replication by other researchers, physiotherapists or exercise specialists. Only 20% of the analyzed articles contained a description of all four components: frequency, intensity, time and type of exercise. In 2016, standards for describing training programs in experimental research were developed (45). Pelvic floor muscle training programs should also be characterized in accordance with these standards and providing information on all training components.

We observed the biggest discrepancy in analyzed pelvic floor muscle training programs in the total training time. From the presented training proposals, the longest-running program of pelvic floor muscle training was proposed by Hirsch et al. in 1999 (25). The treatment of female patients with urinary system dysfunctions lasted 26 weeks, the exercises were performed seven times a week for 20 minutes. The authors did not describe the exercises performed and the applied intensity of training. 85% of patients with stress urinary incontinence and mixed urinary incontinence achieved a significant improvement in pelvic floor function. The shortest training intervention, which lasted four weeks, was presented by Heidler in 1986 (41). Information about the other components of the training applied was also not presented. Twenty-two women with diagnosed Stress Urinary Incontinence participated in this experiment. In the post-intervention assessment there was a significant improvement in pelvic floor muscle function in 73% of women. It would be worth determining the optimal time of training programs, after which women could expect significant changes in pelvic floor muscle activity. However, it should be remembered that the pelvic floor muscles, like other striated muscles, require constant training stimulus, not only during a several-week program. Therefore, pelvic floor muscle training should become a fixed element of health-enhancing physical activity.

In the vast majority of the analyzed works, the authors observed positive effects of pelvic floor muscle training, including the treatment of dysfunction of this muscle group. In a study from 2005, conducted on a group of 263 women with stress incontinence Dannecker et al. (36) noted long-term improvement in pelvic floor muscle function in 71% of respondents after nine training sessions. The study group was classified according to the severity of urinary incontinence starting from the third-degree (requiring medical intervention) to 0 degree (normal function of the pelvic floor muscles). Before the study, 60% of women were burdened with third-degree urinary incontinence; after the intervention this number decreased to 5%. This study proved the effectiveness of pelvic floor muscle exercises for patients with severe dysfunctions. It should be emphasized that the positive training effects were long-term, based on a questionnaire survey conducted over an average of 26 months (36).

In the next analyzed article (29), we also found a significant improvement in the intervention group and insufficient changes only in the controls after a six-week training program for pelvic floor muscles. In the baseline assessment, female patients with stress urinary incontinence after a stroke performed the pelvic floor muscle contraction with a maximum strength of 8.50mmHg. After a training intervention, the average strength was 17.81mmHg. The improvement also took place in the relaxation exercises; in the baseline assessment the mean value of relaxed muscle tone was 3.47mmHg and after the intervention it was 2.25mmHg. The time of the training unit was 50' and the training frequency three times a week (29). The authors did not provide information on the training intensity and type.

It is surprising that only three of the works analyzed (10%) concerned preventive interventions for pelvic floor muscle dysfunctions in healthy women (17, 19, 21). Due to the location of this muscle group, many people become interested in pelvic floor muscle exercises only when they feel severe discomfort. It is definitely better and more effective to undertake prophylactic training (46, 47). For preventive purposes, Huebner et al. (17) in their experiment proposed the following program: 15-second relaxation and 8-second maximal contraction of pelvic floor muscles aided by electric stimulation. Another prevention program for incontinence in healthy women was carried out by Chmielewska et al. (19) The intervention included six weeks of exercises using biofeedback. The participants performed pelvic floor muscle exercises with the intensity of 60-80% of the maximum contraction. From the first to the third week they performed 3 series of 10 repetitions and from the fourth to the sixth week - 4 sets of 15 repetitions. The training sessions were performed three times a week. The latest analyzed article describing preventive training programs were presented by Pereira et al. (21) in 2019. In the article the exercises consisted of performing individual maximum contractions each day. The training program included 25 healthy women performing the recommended exercises for a period of eight weeks. The first group exercised once a day and the second group performed the exercises twice a day. There was a significant improvement in both groups, but no differences were noticed between the groups (21).

Many other pelvic floor muscle training programs have been presented for many years, however they did not fit into our methodology for classifying the material for analysis. Pelvic floor muscle exercises were described by A. Kegel (48) for the first time in the 1940s. The Kegel's recommendations were focused on strengthening and self-control of pelvic floor muscles by performing the following exercises: maximal contraction for approx. 8-19s. and repeating this task starting from 5 and increasing to 25 times with short rests between repetitions. The pelvic floor exercises introduced by Kegel were limited only to the contractions versus relaxations. Over the years, researchers and practitioners have been modifying the, so called, Kegel's exercises, e.g. by grading the contraction, increasing the time of exercising, activation or deactivation of synergistic muscles and using additional equipment to facilitate the training. Initially, the exercises were carried out in stable positions, e.g. in a lying or standing position. Later, the contraction of the pelvic floor muscles started to be combined with the performance of various activities (49). In 2015, Botelho and others he carried out innovative research on pelvic floor muscles, including training in the form of a computer game. This protocol was designed in such a way that the participant could play a video game, sitting on the pressure platform, while directing it through pelvic movements (20). In 2010, Marques et al. (50) reviewed works on pelvic floor muscle exercises in women, summarizing the training proposals at that time. In the two studies analyzed by them, conscious suspension of the urine stream was recommended as a pelvic floor muscle exercise. However, in studies nowadays, none of the researchers offers such a form of exercise due to the potential risk of urinary system dysfunction.

It should be noted that not all proposals for pelvic floor muscle training were comprehensively composed. Some of the training programs were focused on developing one motor skill. In programs aimed at improving the function of the pelvic floor muscles based on strengthening exercises, it is also necessary to incorporate exercises that relax this muscle group (51). In the analyzed articles, we did not find a clear answer to the "gold standard" of the pelvic floor muscle training program. A practical solution would be to develop recommendations for exercise programs aimed at treatment or prevention of particular pelvic floor muscle dysfunctions.

Definitely, the influence of different training programs on particular pelvic floor muscle dysfunctions would require appropriate experimental research, using research methodology and reporting enabling their comparability. The variety of study design and the way of describing training programs in the analyzed works significantly impeded their comparison. In response to the growing interest in pelvic floor muscles and the prevention and treatment of their dysfunctions through exercises, there are more and more scientific papers on this subject (52). The limitation of our review work is that due to the adopted methodology for classifying articles for analysis, we have not presented here the full spectrum of pelvic floor muscle training programs used in current research. Nevertheless, the presented characteristics of pelvic floor muscle training interventions can certainly be a valuable reference material for other researchers.

Conclusion

The vast majority of analyzed works did not contain information on four training components for pelvic floor muscle training programs, which makes it difficult to use them by other researchers, physicians, physiotherapists and exercise specialists. It is necessary for the scientific publishers to rigorously enforce full training program descriptions to include applied intensity, frequency, volume and type of exercise.

Ethical considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors have no conflicts of interest relevant to this article.

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