Egyptian Journal of Physical Therapy (EJPT)

Egy. J. Phys. Ther. 2022;10: 1-15

Original article

https://ejpt.journals.ekb.eg

Are Combined Physiotherapeutic Interventions better than Stand-alone Interventions in Treating Exercise Induced Muscle Damage? A Systematic Review and Meta-Analysis

Alaa Magdy Farag[1*], Aliaa Mohammed[2]

[1] *B.Sc. degree, Faculty of physical therapy, Cairo University, Egypt.*

[2] *Department of Physical therapy for Musculoskeletal Disorders and its Surgeries, Faculty of Physical Therapy, Cairo University, Egypt.*

***Correspondence to**
Alaa Magdy Farag, Department of orthopedic, Faculty of Physical Therapy, Cairo University, Egypt.
Tel: 965 99509221
Email:
alaammfarag@gmail.com

Published online:
June 2022

Abstract:
Purpose: to systematically review and critically appraise the controlled clinical trials that compared combined intervention treatments to standalone treatment after exercise induced muscle damage (EIMD).
Methods: Six electronic databases (PubMed, PEDro, Embase, Cochrane, Web of Science (WOS) and EBSCO) were searched from inception until March 21, 2020.Further, manual search of the bibliography of all eligible articles was done. Two reviewers screened studies for eligibility first by title and abstract and then full text. Articles were categorized based on the combined treatment into three categories: exercise and massage (n= six), cryotherapy (n= three), cold water immersion (CWI) and exercise (n=three).Study quality was assessed using PEDro scale. Meta-analysis was conducted to compare the effect of exercises combined with other treatment against exercises alone as measured by blood lactate and heart rate.
Results: Twelve studies were included in the quality assessment. The majority of the studies were of moderate to high quality. Meta-analysis showed that exercises combined with hydrotherapy significantly decreased blood lactate and heart rate compared to exercises alone with 95% confidence interval (95% CI).
Conclusion: There is some evidence of moderate to high quality supporting the efficacy of combined treatment in treating EIMD more than that of single treatment. But still more clinical trials with larger sample size, specific baseline similarity of the groups is needed to confirm results.
Key words: Combined Physiotherapeutic Interventions, Exercise Induced Muscle Damage, Stand-alone Interventions, Systematic Review, Meta-Analysis.

1.Introduction

Exercise Induced muscle damage (EIMD) following strenuous unaccustomed exercise is common among recreational and professional athletes (1). It may be complicated by the development of delayed onset muscle soreness (DOMS) which may require a few minutes and up to one week recovery time depending on damage severity, and exercise duration and intensity (2,3).

DOMS is associated with reduced performance and increased athletes" absenteeism from games. Thus, the prevention and treatment of this common problem have caught the attention of sports medicine specialists.

A few studies have attempted to establish evidence regarding the efficacy of EIMD

Please cite this article as follows: Hanafy M, Botla M, Abo-El-Enan F, Mowafy Z. Different Transcutaneous Electrical Nerve Stimulation Modes in Relieving Chronic Pudendal Neuralgia in Females. EJPT. 2022;10: 1-15.

standalone treatments such as stretching, exercises, therapeutic massage, cryotherapy (4), electrophysical modalities, ultrasound (5), compression garments (6), hyperbaric oxygen therapy (7),and cold water immersion (CWI) (8). Massage was found to be the most beneficial therapeutic intervention in relieving EIMD symptoms. A few studies reported the efficacy of combining various treatment procedures on EIMD symptoms and signs.

For example, Howatson & Van Someren, 2008, reported that combining warm-up with stretching may attenuate force losses following eccentric exercise (9). Also, Jakeman & colleagues found that combining massage with compression improved jump performance and reduced perceived soreness (10). However, the quality and strength of evidence of combined interventions compared to standalone treatment have never been studied systematically. Such evidence may guide cost-effective decision making in sports. Thus, this study systematically review clinical trials that compared combined intervention treatments to standalone treatment after exercise induced muscle damage (EIMD).

2.Methods

The protocol for this systematic review was registered in PROSPERO database (CRD42019121437).

Data Sources and Searches:

Six electronic databases (PubMed, PEDro, Embase, Cochrane, Web of Science (WOS) and EBSCO) were searched from inception until March 21, 2020.

The following keywords and Boolean operators were employed: (“Exercise induced muscle damage” OR “delayed onset muscle soreness” OR DOMS OR EIMD OR “muscle soreness” OR soreness OR “muscle injury” OR strain OR “eccentric damage”) AND (Physiotherapy* OR “physical therapy” OR rehab* OR exercise* OR Cryotherapy* OR “Cold temperature” OR Immerse* OR “cold contrast” OR ice OR contrast OR “bath therapy” OR Phototherapy OR “Low-level laser therapy” OR LASER OR “Light-emitting diodes” OR “Compression garment” OR “compression stocking” OR massage* OR stretch* OR warm-up OR warmup OR “warm up” OR cooldown OR “cool down” OR cooldown OR flexible* OR “range of motion” OR ROM OR mobile* OR electrotherapy* OR modality* OR “physical modality*” OR ultrasound OR US OR ultrasonic OR TENS OR “transcutaneous electrical neuromuscular stimulation” OR vibrate* OR “whole body vibration” OR “heat therapy”) NOT (cardiac OR heart OR “coronary heart disease” OR “coronary artery disease” OR vascular OR hypertense* pulmonary OR cancer OR malignancy OR tumor OR vaccine* OR “bacterial infection” OR helicobacter OR “carpal tunnel” OR “planter fasci*” OR ulcer* OR sprain OR “tennis elbow” OR “lateral epicondyle*” OR surgery OR operate* OR “ankle instability” OR TMJ OR “temporomandibular dysfunction” OR “temporomandibular disorder” OR ACL OR “anterior cruciate ligament” OR menisci*). Further, manual search of the bibliography of all eligible articles was done.

Study Selection:

Two independent reviewers screened articles for eligibility first by title, then by reading the abstract, and finally by reading through the full articles. Articles were included if they were randomized clinical trials comparing combined physiotherapeutic modalities or garments to standalone treatment in treating (EIMD) in adults; whether athletes or not. Further, articles were eligible if they measured biomarkers in blood or urine to quantify perceived pain, muscle soreness or fatigue, muscle strength, swelling, joint range of motion (ROM), functional and/or physical performance.

Articles were excluded if they enrolled patients with muscle damage due to other diseases such as rhabdomyolysis or myelopathy, included patients with grade II or III muscle damage or strain, investigated pharmacological or supplementary treatments with or without physical therapy, or investigated preventive interventions. Further, observational studies, non-randomized clinical trials, reviews, case studies and series, editorials, conference proceedings were excluded.

Data Extraction and Quality Assessment:

Data were extracted by two independent reviewers using Excel spreadsheets. The following information were extracted: authors, year of publication, study design, study purpose, participants‟ demographics, intervention and comparators description, outcomes, and results (**Appendix 1**).

The quality of eligible articles was assessed by two independent assessors using the Pedro scale (https://pedro.org.au/english/resources/pedroscale/) which assesses the adequacy of allocation randomization and concealment, similarity at baseline blinding of participants, treatment providers and assessors, follow up of at least one key outcome, employment of intention-to- treat analysis, between group statistical comparison for at least one key outcome, and reporting of central tendency and variability measures for at least one key outcome. Each item is scored as one if adequately reported or zero if no information were provided; with a total possible score of 10 (indicating good quality) and a minimum possible score of zero (indicating poor quality) (11).

Throughout the review and quality assessment process, any disagreement was resolved by consensus through.

Data Synthesis and Analysis:

Based on treatment and outcomes homogeneity, a meta-analysis was conducted to compare the effect of exercises combined with other treatment against exercises alone as measured by blood lactate and heart rate.

The studies were analyzed using Review Manager (RevMan) software (version 5.4.1; Cochrane, London, UK). For effect measure, mean differences (MD) and 95% confidence interval (95% CI) were used for the same outcome measures across studies. Standardized mean differences (SMD) and 95% CI were employed when studies utilized different outcome measures to assess the same construct.

A random-effects model was used to pool the treatment effects across these studies. Studies were weighed using the inverse variance method. A P-value of ≤ 0.05 was considered statistically significant. When studies presented the mean and standard deviation only in graphs, the charts were digitized using Digitizer 1.3 build 4704 Heterogeneity between studies was assessed using I^2 statistic test. The degree of heterogeneity was categorized as low (I^2<25%), moderate (I^2= 25 – 75%) and high (I^2>75%) (12). A P value of ≤ 0.05 indicated significantly heterogeneous studies.

3.Results:

Search Results:

Databases search initiallyretrieved8884 articles that were reduced to 6939 articles after duplicate removal. Screening by title and abstract, 567 and 91 were found eligible, respectively. After reading through full article, only six articles were found eligible.

Additional 1103 records were identified through manual search which finally ended up by six eligible articles after completing the full screening. Thus, a total of 12articles were reviewed and scored for quality. Only five articles were included in the quantitative synthesis. The full screening process is summarized in **Figure 1.**

For exercise intervention, one compared active pedaling combined with oxygen versus oxygen or pedaling alone (13). They reported no between-groups differences in blood lactate removal and performance. Another study compared running (14). With again no significant between groups differences were reported regarding oxygen uptake (Vo2max), blood lactate concentration or heart rate (HR). On the contrary, the rate of perceived exertion was lower in the single treatment than combined one but not significantly as difference not exceeding 1 point on the Borg scale. In the other hand, Ferreira & colleagues found lower blood lactate concentration at 15 min when combining cycling in water compared to passive recovery (15).

Cold Water:

Dupont and colleagues compared cry compression to passive rest on a chair and reported significant reduction in creatine kinase as well as muscle soreness pain severity scores. Further, jump height was better in the intervention compared to control group (16). Combining CWI and compression lowered skin temperature and increased heart rate compared to no treatment condition. No further differences were reported regarding creatine kinase concentration, muscle strength or soreness (17). In the other hand combining cryotherapy with photo biomodulation (PBMT) showed a noted decrease in CK levels compared to PBMT as single treatment (18).

Cold Water Immersion (CWI) and exercise:

Two studies compared combining exercise (in the form of cycling) and CWI with either exercise alone (19,20).And one compared combining exercises in the form of arm exercise and CWI with exercise alone (21). In which muscle soreness was significantly higher in the exercise groups compared to the combined treatment groups (19). Heart rate and blood lactate were significantly lower in combined groups compared to exercise alone groups (21).

Regarding self-perceived feeling of relaxation after 1-hour recovery was better after CWI (combined ttt group) compared to exercise group (19). Regarding core temperature and PH value, there were no significant differences between groups (20). Regarding rate of perceived exertion, there were no significant differences between groups (20).

So, in conclusion from this category, combining CWI to either cycling or arm exercise, resulting in better outcomes regarding muscle soreness and blood lactate concentration (19,21).

Quality Assessment:

Based on quality assessment, five articles scored high(de Paiva et al., 2016; Monedero & Donne, 2000; Maruyama et al., 2019; Weltman et al., 2013; Crampton et al., 2014), four scored moderate (Ferreira et al., 2011; Crowe et al., 2007; Jakeman et al., 2010; Dupont et al., 2017) and three poor (Hudson et al., 1999; Ahokas et al., 2019; Isabell et al., 1992)(**Appendix 2**).

None of the studies specified the eligibility criteria. Randomization was employed in all studies. None of the articles employed allocation concealment or blinded participants, therapists or assessors except for one article (de Paiva et al., 2016) and another article which fulfill blinding to the assessor only (Ferreira et al., 2011). Baseline characteristics were similar except in the study by (Ahokas et al., 2019; de Paiva et al., 2016; Hudson et al., 1999). All studied statistically compared at least one key outcome and reported central tendency and variability for at least one key outcome except for one study (Isabell et al., 1992), which did not mention measuring variability for at least one key outcome.

Meta -Analysis:

Regarding blood lactate, four studies combined exercises with hydrotherapy and one study combined exercises with massage. Subgroup analysis showed that exercises combined with hydrotherapy significantly decreased blood lactate compared to exercises alone (N= 70; SMD= −1.35; 95% CI= −2.70 to -0.01; P= 0.05). When the study that combined massage therapy with exercises was included in the meta-analysis, the overall effect on blood lactate was not significant between combined treatments and exercises alone (N= 106; SMD= −0.85; 95% CI= −2.19 to 0.5; P= 0.22). The heterogeneity across the studies was significantly high (I2= 88%; P<0.01) (**Figure 2**).

For heart rate, three studies compared the combined effects of exercises with hydrotherapy against exercises alone. Combined therapy significantly decreased the heart rate after 15 minutes by 2.82 beat/min (95% CI= −4.49 to -1.16; P<0.01). No heterogeneity was found (I2= 0%; P= 0.5) (**Figure 3**).

4. Discussion

This review assess the scientific evidence supporting the effectiveness of combined physiotherapeutic interventions after exercise induced muscle damage. Fourteen clinical trials were eligible for quality assessment. Overall, the evidence found that combining some types of physical therapy modalities could be more beneficial than giving single modality regarding specific outcomes (22,10,19;21,18).

Exercise and Massage:

Combining massage with other treatment showed better results regarding performance capacities, blood lactate removal and soreness perception. The quality of studies varied between high (Monedero & Donne, 2000)to moderate (Jakeman et al., 2010), and poor (Isabell et al., 1992).

While adding oxygen to exercise or making exercise in water was not adding more benefits than applying exercise only (Weltman et al., 2013; Hudson et al., 1999) unless if combined treatment compared to passive (Ferreira et al., 2011) resulting in better results regarding muscle damage indicators. The quality of studies varied between high (Weltman et al., 2013)to moderate (Ferreira et al., 2011) to poor (Hudson et al., 1999).

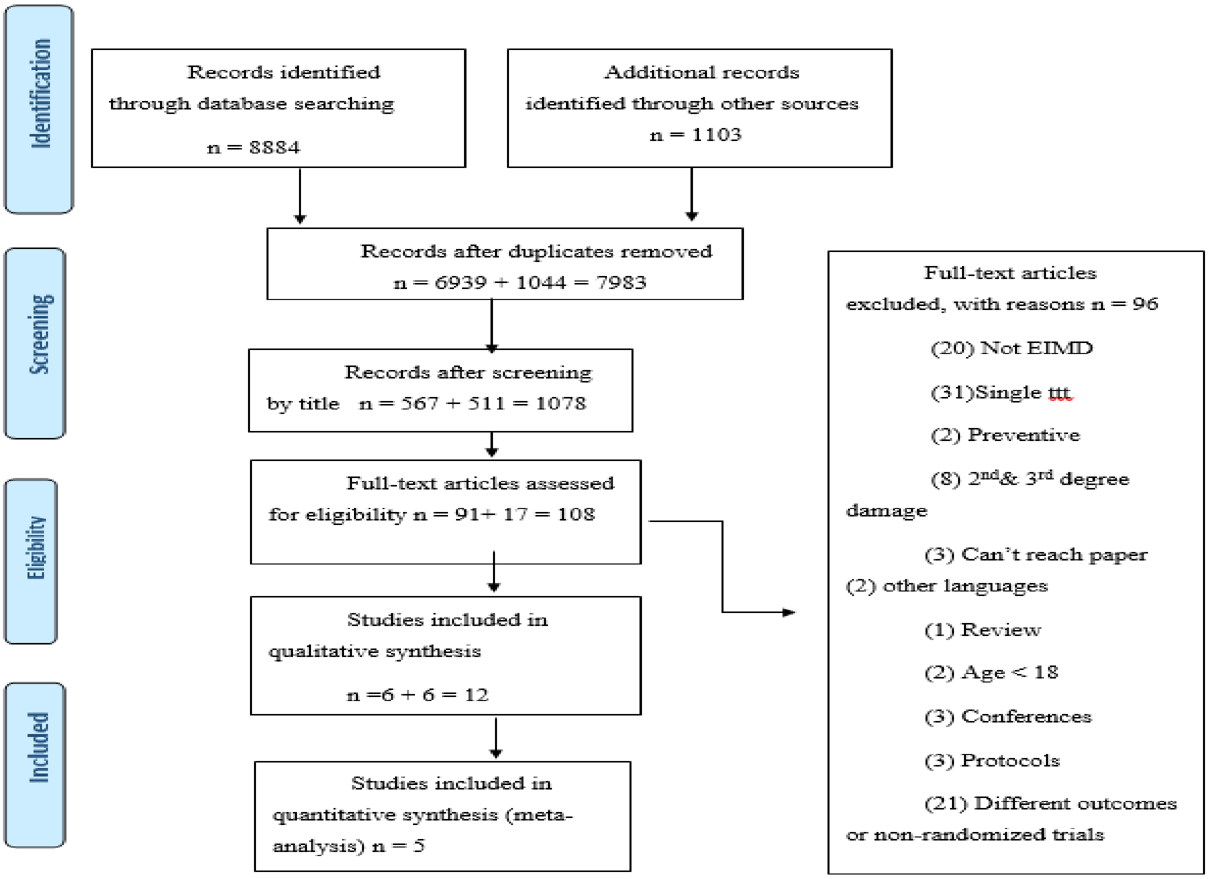

Figure 1: A flow diagram showing article selection, screening, and exclusion

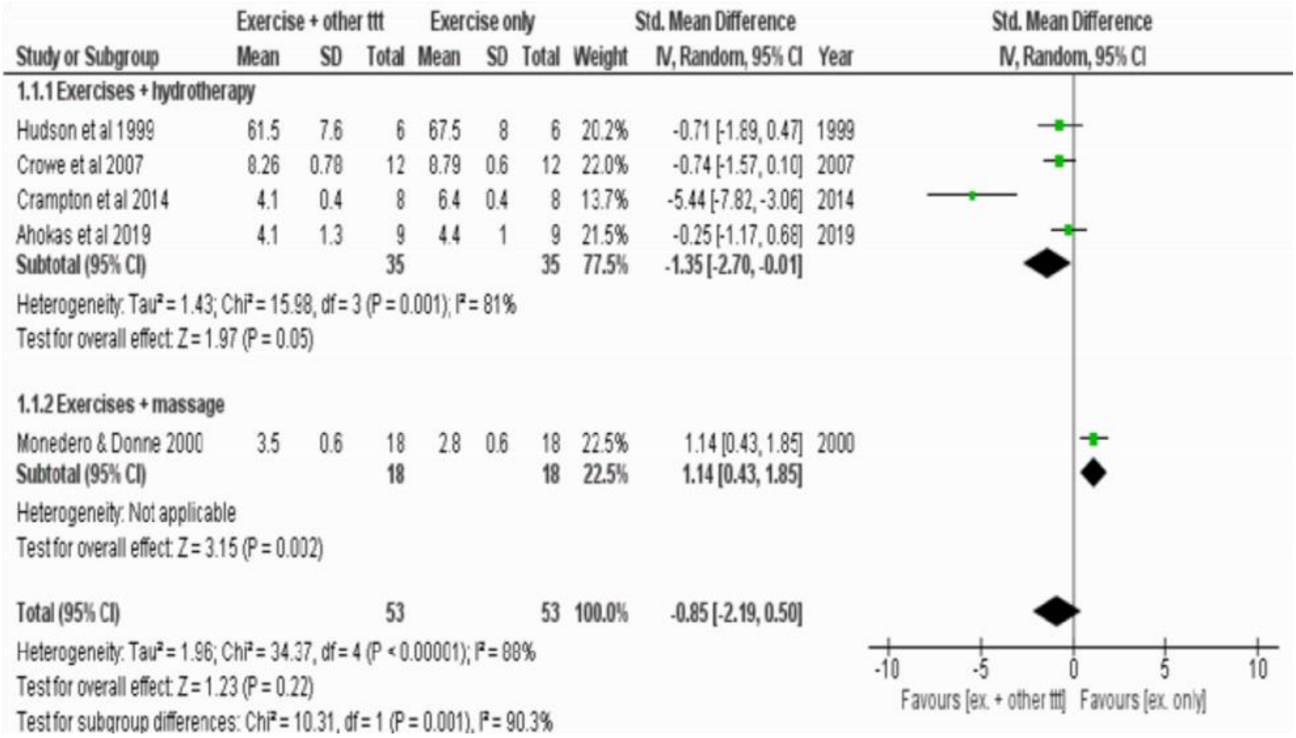

Figure 2: A forest plot of standardized (Std.) mean difference, with 95% confidence interval (95% CI) for blood lactate between combined exercises with other treatment (ttt) and exercises only. IV = inverse variance

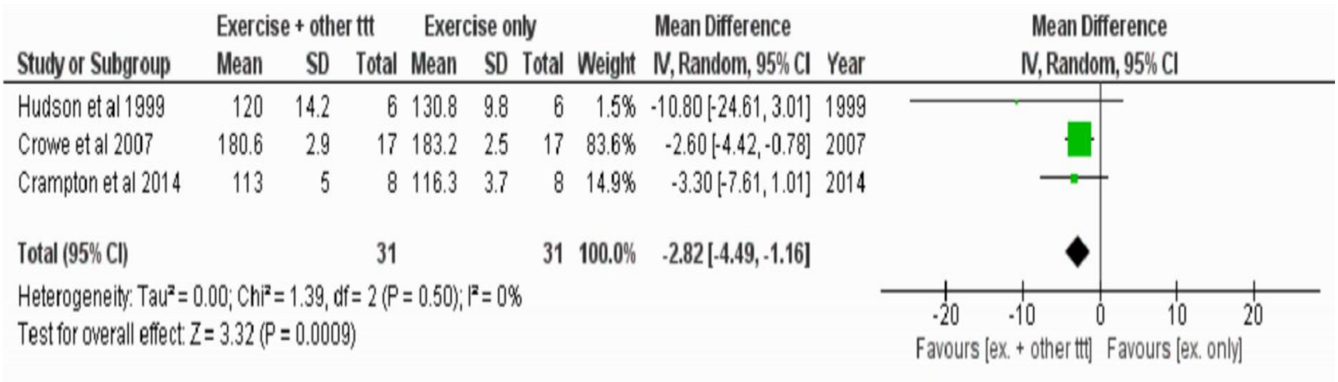

Figure 3: A forest plot of mean difference, with 95% confidence interval (95% CI) for heart rate between combined exercises with other treatment (ttt) and exercises only. IV = inverse variance.

All the participants in the studies of this group were randomly assigned into groups, the majority of the included studies are similar at base line except for one study (14), the major risk of bias in this category is that the majority of included studies did not mention that at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups except for two studies (Monedero & Donne, 2000; Weltman et al., 2013) and that there were no blinding in any study except for one study which include blinding to the assessors (Ferreira et al., 2011) but this was because it was not applicable to blind the participants from any of the treatments and in spite that no blinding to the assessors, the some outcomes are objective like that of blood sampling & questioners so this may not affect the quality of these studies regarding these points of risk of bias. The major limitations of studies included in this category is that small sample size, for future recommendations more clinical trials with larger sample size will give more accurate data.

Cold Water immersion:

Three studies, two of them of high quality, one of them assess the difference between combining cold water immersion and compression versus no treatment where the only improvement was only in skin temperature which was lower in the combined group than control group(Maruyama et al., 2019)And the other compared combining cryotherapy to PBMT resulting in positive results in decreased pain ($p < 0.05$) compared to placebo control group from 1 to 48 h and a noted decrease in CK levels compared to PBMT as single treatment(de Paiva et al., 2016).

And the other study of moderate quality (Dupont et al., 2017) who compared cry compression therapy versus passive treatment(sitting on chair), in which the combined group resulted in significant lower values of creatine kinase, muscle soreness & pain scores and greater jump height compared to control group which stay sitting on chair receiving no treatment.

The conclusion of this category is that combining cold water with compression or PBMT is beneficial than single treatment regarding muscle soreness, performance or even skin temperature.

All the studies of this category were randomly assigned into groups, the groups were similar at baseline except for one study(de Paiva et al., 2016), the majority of included studies mentioned that at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups except for one study (Dupont et al., 2017).

There were no blinding in any study except for one study (de Paiva et al., 2016) but this was because it was not applicable to blind the participants from any of the treatments and in spite that no blinding to the assessors, some outcomes are objective like pain and soreness which measured in this category through blood sampling, Questioners so this may not affect the quality of these studies regarding these points of risk of bias

.

Cold Water Immersion and exercise:

Three eligible studies, one of them of high quality (Crampton et al., 2014)scoring six stated that heart rate and blood lactate were significantly lower in combined groups compared to exercise alone groups, where he compared combing cold water immersion with arm exercise versus arm exercise or cold water immersion alone.

Another one study of moderate quality scoring four which (Crowe et al., 2007)which found that regarding core temperature, rate of perceived exertion and PH value, there were no significant differences between groups.

The last study out of the four is of poor quality scoring three (Ahokas et al., 2019), where he tested the effect of combining cold water with exercise versus exercise alone and he conclude that muscle soreness was significantly higher in the exercise groups compared to the combined treatment groups and that the self-perceived feeling of relaxation after 1-hour recovery was better after CWI compared to exercise group.

The conclusion of this category is very clear from analysis made in meta-analysis which showed that exercises combined with hydrotherapy significantly decreased blood lactate and heart rate compared to exercises alone.

All the studies of this category were randomly assigned into groups, the groups were similar at baseline except for one study (Ahokas et al., 2019), the majority of included studies did not mention that at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups except for one study (Crampton et al., 2014). There were no blinding in any study, but this was because it was not applicable to blind the participants from any of the treatments and in spite that no blinding to the assessors, some outcomes are objective like that of blood sampling & questioners so this may not affect the quality of these studies regarding these points of risk of bias.

The limitation of this meta-analysis is that some of the included articles are of poor quality but should be included here to cover all the available evidence. And some of the available studies are of small sample size.

In conclusion, according to analysis of the results of our three categories, we conclude that:

- Combining massage to another treatment has beneficial effect more than applying single treatment of any of them regarding performance capacities, blood lactate removal and soreness perception.
- Combining cold water with compression or cryotherapy to PBMT is beneficial than single treatment regarding muscle soreness, performance or even skin temperature.
- exercises combined with hydrotherapy significantly decreased blood lactate and heart rate compared to exercises alone.

This is the only systematic review assessing the quality and strength of scientific evidence supporting the effectiveness of combined physiotherapeutic interventions after EIMD. In which there is some evidence of moderate to high quality supporting the efficacy of combined treatment in treating EIMD more than that of single treatment. But still more clinical trials with larger sample size, specific baseline similarity of the groups is needed to confirm results.

References

1. Sethi, V. (2012). Literature review of Management of Delayed onset muscle soreness (DOMS). International Journal of Biological & Medical Research Int J Biol Med Res, 3(1), 1469–1475.
2. Paulsen, Gø., Crameri, R., Benestad, H. B., Fjeld, J. G., MØrkrid, L., HallIén, J., & Raastad, T. (2010). Time course of leukocyte accumulation in human muscle after eccentric exercise. Medicine and Science in Sports and Exercis, 42(1), 75–85.
3. Ko, G. W. Y., & Clarkson, C. (2020). The effectiveness of acupuncture for pain reduction in delayed-onset muscle soreness: a systematic review. Acupuncture in Medicine, 38(2), 63–74 .
4. Torres, R., Ribeiro, F., Alberto Duarte, J., & Cabri, J. M. H. (2012). Evidence of the physiotherapeutic interventions used currently after exercise-induced muscle damage: Systematic review and metaanalysis. Physical Therapy in Sport, 13(2), 101–114.
5. Howatson, G., & Van Someren, K. A. (2008). The prevention and treatment of exercise-induced muscle damage. Sports Medicine, 38(6), 483–503.
6. Marqués-Jiménez, D., Calleja-González, J., Arratibel, I., Delextrat, A., & Terrados, N. (2016). Are compression garments effective for the recovery of exerciseinduced muscle damage? A systematic review with meta-analysis. Physiology and Behavior, 153, 133–148.
7. Bennett, M. H., Best, T. M., Babul-Wellar, S., & Taunton, J. E. (2005). Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury. Cochrane Database of Systematic Reviews,
8. Bleakley, C., McDonough, S., Gardner, E., Baxter, D. G., Hopkins, T. J., & Davison, G. W. (2012). Cold-water immersion (cryotherapy) for preventing and treating muscle soreness after exercise. Sao Paulo Medical Journal, 130(5), 348.
9. Howatson, G., & Van Someren, K. A. (2008). The prevention and treatment of exercise-induced muscle damage. Sports Medicine, 38(6), 483–503.
10. Jakeman, J. R., Byrne, C., & Eston, R. G. (2010). Efficacy Of Lower Limb Compression And Combined Treatment Of Manual Massage And Lower Limb Compression On Symptoms Of Exercise-Induced Muscle Damage In Women. Journal of Strength and Conditioning Research, 24(11), 3157–3165.
11. de Morton, N. A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Australian Journal of Physiotherapy, 55(2), 129–133.
12. Higgins JP, T. S. (2003). Measuring inconsistency in knowledgebases. Journal of Intelligent Information Systems, 27(2), 159–184.
13. Weltman, A., Stamford, B. A., Robert, J., & Katch, V. L. (2013). Research Quarterly . American Alliance for Health , Physical Education and Recreation Exercise Recovery , Lactate Removal , and Subsequent High Intensity Exercise Performance. August, 37–41.
14. Hudson, O. D., Loy, S. F., Vincent, W. J., & Yaspelkis III, B. B. (1999). Blood lactate concentration and rated perceived exertion following active recovery in water. Research in Sports Medicine: An International Journal, 9(1), 41–50.
15. Ferreira, J., Da Silva Carvalho, R., Barroso, T., Szmuchrowski, L., & Śledziewski, D. (2011). Effect of Different Types of Recovery on Blood Lactate Removal after Maximum Exercise. Pjst, 18(2), 105–111.
16. Dupont, W. H., Meuris, B. J., Hardesty, V. H., Barnhart, E. C., Tompkins, L. H., Golden, M. J. P., Usher, C. J., Spence, P. A., Caldwell, L. K., Post, E. M., Beeler, M. K., & Kraemer, W. J. (2017).

The effects combining cryocompression therapy following an acute bout of resistance exercise on performance and recovery. Journal of Sports Science and Medicine, 16(3), 333–342.
17. Maruyama, T., Mizuno, S., & Goto, K. (2019). Effects of cold water immersion and compression garment use after eccentric exercise on recovery. 23(1), 48–54.
18. de Paiva, P. R., Tomazoni, S. S., Johnson, D. S., Vanin, A. A., Albuquerque-Pontes, G. M., Machado, C. D., Casalechi, H. L., de Carvalho, P. T., & LealJunior, E. C. (2016). Photobiomodulation therapy (PBMT) and/or cryotherapy in skeletal muscle restitution, what is better? A randomized, doubleblinded, placebocontrolled clinical trial. Lasers in Medical Science, 31(9), 1925_1933.
19. Ahokas, E. K., Ihalainen, J. K., Kyröläinen, H., & Mero, A. A. (2019). Effects of water immersion methods on postexercise recovery of physical and mental performance. Journal of Strength and Conditioning Research, 33(6), 1488– 1495.
20. Crowe, M. J., O‟Connor, D., & Rudd, D. (2007). Cold water recovery reduces anaerobic performance. International Journal of Sports Medicine, 28(12), 994–998.
21. Crampton, D., Egaña, M., Donne, B., & Warmington, S. A. (2014). Including arm exercise during a cold water immersion recovery better assists restoration of sprint cycling performance. Scandinavian Journal of Medicine and Science in Sports, 24(4), e290–e298.
22. Monedero, J., & Donne, B. (2000). Effect of recovery interventions on lactate removal and subsequent performance. International Journal of Sports Medicine, 21(8), 593–597.
23. Isabell, W. K., Durrant, E., Myrer, W., & Anderson, S. (1992). The effects of ice massage, ice massage with exercise, and exercise on the prevention and treatment of delayed onset muscle soreness. J Athl Train, 27(3), 208–217.
24. A. Crowther, & Sealey, M. (2019). Effects of Various Recovery Strategies on Repeated Bouts of Simulated Intermittent Activity. 33(7), 1781– 1794.

Appendix 1: Date Extraction tables of Included Studies

Table 1: Data Extraction of exercise and massage category

Authors /design	Purpose of the study	Participants	Muscle soreness induction	Intervention description	Control treatment	outcomes	Results
Isabell et al, (1992), Factorial design	compare the effects of ice massage, ice, massage with exercise, and exercise alone on the prevention and treatment of delayed onset muscle soreness.	22 (Athletes) M:F, 11:11 age= 20.3± 2.1 yrs.	concentric and eccentric dumbbell curl exercises.	(a)ice massage: ice ball for 15 min, (b) exercise: Mild full ROM elbow flexion and extension, 15-minute, (c) ice massage+ exercise: 15 minutes.	(d) control: No therapy. .	* Isokinetic flexion and Extension torque. * flexion and extension ROM. * serum Ck levels. * perceived pain or soreness.	NO differences between gps in any outcome.
JAKEMAN et al, (2010)	Determine the effect of combined treatment (sports massage and compression) on EIMD	32 (Not athletes) Females, Age = 21.4 ± 1.7 yrs. stature = 1.66 ± 0.047 m mass = 66.7 ± 6.8 kg	10 × 10 plyometric drop jumps to quadriceps	* combined gp: 30 min manual massage (effleurage, petrissage, tapotement, and hacking to the whole of both legs. *Then hip to ankle compression tights: 12 hours. * Compression group: identical compressive tights: 12 hours after plyometric exercise.		* perceived soreness. *creatine kinase activity. *isokinetic muscle function *functional strength: countermovement jump performance and squat jump performance.	*Muscle soreness: no significant differences at 24 and 96 hours after Muscle damage. *Squat Jump Performance: no significant differences except at 48 hrs. (significantly worse in the compression group in comparison with the combined ttt group). * Isokinetic Muscle Function: No differences at 72 hours after muscle damage in both treatment groups.

WELTMAN et al, (1977), crossover design	determine the effect of (active vs passive, with and without O2 inhalation) after high intensity short duration exercise	11 (Not athletes) males Age 26.36yrs Weight 80.37 kg Height 183.01 cm	supramaximal work task, 1 min of all-out pedaling on a mechanically braked bicycle ergometer (Monark) against a frictional resistance of 33.0 kgm. rev-,, (5.5 kg)	1)PR(RA) 10 min, 2)AR(RA) 10 min, 3)PR(O2) 10 min, 4)AR(O2) 10 min, 5)PR(RA) 20 min, 6)AR(RA) 20 min, 7)PR(O2) 20 min, 8)AR(O2) 20 min * PR = passively recovered; AR = actively recovered; RA = room air; O2 = 100% oxygen. *active recovery: pedaling at 60 rpm at 1.0 kg (360 kgmemin-").	Passive recovery: quietly sitting on a chair at bike level.	*performance: criterion task *lactate conc	*performance: highly significant main effects for active vs passive recovery and for 10-vs 20-min recovery. *Oxygen inhalation did not result in greater performance. *blood lactate levels: no differences in between min 3-4 and min 9- 10 during recovery. *Inhalation of O2 during recovery did not alter blood lactate levels (FlmIo = .59, p > .05).
Hudson et al, (1998), crossover design	examined the effects of active water recovery (AWR) on blood lactate removal and perception of recovery following bouts of high intensity exercise	6 (Not athletes) Males age 26.0 ±1.6 yrs weight 66.9 ±3.7 kg height 167.6 ±1.9 cm	exercise of 3 x 45 s bouts of supramaximal sprint effort (8.6 mph (3.84m/s)	*active treadmill recovery (ATR): 20 min of Treadmill walking at ^30% VO2max. *active recovery in water (AWR): 20 min of running in water (33°C) at ^30% VO2max. *Passive recovery (PR) and ATR in a room at 25°C.		*oxygen consumption *Heart rate was recorded at 5, 10, 15, and 20min of recovery during all three trials. *blood lactate *modified RPE recovery (RPErec)	*Oxygen uptake (Vo2 max), heart rate, Blood lactate: no difference between AWR and ATR throughout recovery. *Subjective rating of recovery Subjects perceived AWR to result in a more complete recovery as indicated by a significantly lower group mean RPErec at the completion of the AWR trial compared with the ATR
Monedero et al, (2000), crossover design	compare the effects of four different recovery interventions (passive, active (50% maximal oxygen uptake), massage, and combined (involving active and massage components) following maximal cycling exercise (laboratory simulated 5 km time trial), on the rate of blood lactate removal and subsequent maximal cycling performance capacity	18 (Athletes) age 25 ± 0.9 yr body mass 72 ± 1.6 kg	5 km maximal effort cycling tests	Three gps (passive, active, massage, and combined recovery) *Active recovery: sub-maximal cycling at a load equivalent to 50% of individual VO2max. *Massage: (effleurage, stroking and tapotement) applied to the posterior part of the lower extremities in the supine position. *Combined recovery: Pedaling for the initial 3.75 min+ massage for 7.5 min (3.75 min per leg), and finally cycling for the final 3.75 min at the same	passive recovery: seated at rest on a chair for 15 min.	*Blood lactate *Mean increase in 5 km trial time (s) *HR	*Performance capacities: better in combined recovery compared to other interventions. *both the active and combined interventions were more efficient than either the passive or massage interventions for removal of BLa. *The lowest HR data were recorded during the passive and massage interventions, as well as during the massage portion of combined recovery. The highest HR data were recorded during active recovery and the active portions of the combined recovery.
FERREIRA, CARVALHO, (2011), Paralell design	verify the effect of active recovery, using a specific water bike, on the blood lactate concentration after maximum intensity	10 (athletes) Age: 26.2 ±5.55 Body mass: 74.58 ±8.17 Height: 178.89 ±8.85	Wingate Ana Robic Test (WAT) of the lower limbs with a load (7.5%) of their body weight for 30 sec, then four 10 second maximum stimuli on	* Passive Recovery in the Water (PRW): subject remained in the swimming pool (temperature between 28 and 32°C) on a horizontal position, with the help of floats, for 60 minutes. *Active	*Passive Recovery on Land (PRL): subject remained on a horizontal position for 60	*Blood lactate. *HR	*The last value of HR (60 min) was the same in all three types of recovery. *The [La] blood did not show the difference between the three types of recovery at 5th min. However,

			the same bicycle	Recovery in the Water (ARW): subject performed exercises on a water bicycle with intensity 85% of the intensity of LA in water, for 30 minutes, Water temperature (28 up to 32°C), and remained in the same position of the PRW for another 30 minutes	minutes in a thermoneutral room.		from 15 min on, the difference between the ARW and the other two types of passive recovery was significant, and the ARW showed lower values. *There was no significant difference between the PRW and PRL in any of the variables examined.

Table 2: Data Extraction of cold water category.

Authors /design	Purpose of the study	Participants	Muscle soreness induction	Intervention description	Control treatment	outcomes	Results
Dupont et al., (2017)			squats (4 sets of 6 repetitions + stiff legged deadlifts for 4 sets of 8 repetitions + eccentric legs curls (Nordic hamstring curls) for 4 sets of 10 repetitions.	Cryo compression gp: 3 layer compression garment lined with polyurethane flow channels for circulating cooled water	Control gp: sat quietly for 20mins.	*Creatine kinase concentrations. * sleep quality, soreness, pain, and mood states. * Countermovement jump power performance. *Reaction time & skin temp	*jump power: significantly greater in CRC gp than CON at 24 and 48 hours after resistance. *CK & McGill Pain measure: significantly lower values for the CRC group 24 and 48 hours after exercise. *VAS: significantly lower soreness ratings for the CRC group being reported. * CRC group significantly better sleep than the CON group at both time points after the exercise session. * Fatigue rating using mood state: CRC group being higher than the CON group but lower than the CON at both the 24 and 48 hrs measurement time points *No significant diff bet ttt grps in reaction time.
Maruyama et al., (2019)			60 bouts of maximal eccentric contraction of the quadriceps femoris muscle (6 × 10 sets)	(CWI + CG) immersed their lower body muscles in cold water (15°C) for 15 min and then wore aCG during the remainder of the 24 h post-exercise.	*Control gp: sitting on a chair.	*Maximal muscle strength. *Muscle thickness and thigh circumference. *Skin temperature. *HR. *Physical activity. *Muscle soreness score. * blood lactate, glucose, serum CK and Mb, and hsCRP concentrations.	* In the CWI + CG trial, a rapid reduction in the skin temperature (from 35.2 ± 0.4°C to 19.7 ± 1.8°C). *HR in the CWI + CG trial was significantly higher than CON trial 2 and 3 min after water immersion. *Maximal muscle strength, serum CK, Muscle thickness and thigh circumference or muscle soreness score, hs CRP concentration: No differences

de Paiva, Tomazoni, (2016			75 eccentric isokinetic contractions of the knee extensor musculature in the non-dominant leg (5 sets of 15 repetitions, 30-s rest interval between sets) at a velocity of 60°.seg−1 in both the flexion and extension of the knee.	*PBMT, *Cryotherapy: rubber ice packs on quadriceps for 20 min, *PBMT + cryotherapy, *Cryotherapy + PBMT	*Placebo: identical to the active devices and displayed the same settings and emitted the same sound regardless of the comparator.	1ry: *MVC 2ry: *CK & *DOMS (VAS)	*MVC: increased in PBMT compared to placebo at 24 to 96 hrs. * DOMS: PBMT + cryotherapy: positive results in decreased pain (p < 0.05) compared to placebo control group from 1 to 48 h. * PBMT + cryotherapy showed a noted decrease in CK levels compared to PBMT as single treatment.

Table 3: Data Extraction of cold water immersion and exercise category

Authors /design	Purpose of the study	Participants	Muscle soreness induction	Intervention description	Control treatment	outcomes	Results
Ahokas et al, (2019), crossover design	compare the effectiveness of 3 water immersion interventions on physical and mental performance measures and physiological responses.	9 (Not athletes) age 26 6 3.7 yrs age range 20 –35 yrs body mass 78.6 6 11.6 kg height 1.81 6 0.09 m body fat 15.8 6 4.0%)	short-term exercise protocol with maximal effort (total duration of 45 minutes)	*active recovery (ACT) only,TWI, CWI, or CWT groups. (+10-minute bicycle ergometer) *Each recovery group was immersed in a sitting position to the level of the xiphoid process for 10 minutes. *CWI and TWI were continuously immersed in water temperatures of 10 and 24° C, respectively. *In CWT, the subjects alternated immersion at 38 and 10° C with 5 cycles of 1 minute in each bath. *The ACT group remained seated in an empty bath for 10 minutes.		*Performance test: 30-m maximal sprint test, maximal countermovement jump (CMJ), isometric leg press. * self-perceived muscle soreness and relaxation. *mode state. *blood lactate, creatine kinase, testosterone, epinephrine, cortisol, and catecholamine levels.	*slower running time after 24-hour recovery in ACT and CWT. After 48-hour recovery, after CWT. *The Self-Perceived Feeling of Relaxation, blood Lactate, heart Rate, muscle soreness, creatine kinase activity, Cortisol, Testosterone, and Catecholamines: No significant differances bet gps. * 1. large ES value in the 30-m sprint testafter 24-hour recovery between TWI and ACT, 2. After 48-hour recovery, the large ES value between TWI and CWT, 3. the large ES value in CMJ after 24hour recovery between TWI and ACT
Crampton et al, (2014), crossover design	investigate the effect of combining an active recovery (arm exercise) with lower body CWI, on repeated sprint cycling performance, the maintenance of core temperature during recovery.	8 (Athletes) Males age: 25 ± 7 yrs body mass: 77 ± 8 kg height: 1.80 ± 0.09 m	cycling bout (Ex1) comprising three Wingate tests (WG1–WG3)	(a) CW15: cold water immersion at 15 °C; (b) AE: arm exercise without immersion; (c) CW15+AE: cold water immersion at 15 °C with arm exercise and (d) TW34+AE: thermoneutral water immersion at 34 °C with arm exercise. *participants immersed to hip-level and water temperature regulated to 15 °C for CW15 and 34 °C for TW34. Workload for AE was 40% of each individual's Pmax as determined from the arm-cranking incremental test performed with cycle ergometer.		*Tcore (intestinal temperature). *Blood lactate. *HR	*MP(mean power) in Ex2, significantly lower in the CW15 trial than all other trials. PP(peak power) and MP declined significantly from Ex1 to Ex2 in CW15 (by 7.9% and 7.5%) and CW15+AE (by 5.5 % and 8.0%). *Tcore: by the end of WG5 ΔTcore was greatest for CW15+AE (−0.9 ± 0.2 °C), and this was significantly larger (P < 0.05) when compared with CW15 (−0.6 ± 0.1 °C). No Tcore after drop effect was evident in AE and TW34+AE. *Bla: significantly higher in TW34+AE when compared with

Please cite this article as follows: Hanafy M, Botla M, Abo-El-Enan F, Mowafy Z. Different Transcutaneous Electrical Nerve Stimulation Modes in Relieving Chronic Pudendal Neuralgia in Females. EJPT. 2022;10: 1-15.

							CW15 and CW15+AE * HR: for CW15 only, being significantly lower than all other trials.
Crowe et al, (2006), crossover design	Investigate the effects of CWI on anaerobic cycling performance	17 (Athletes) Male: Female, 13:4 age 21.5 ± 1.3 yr; height 177.1 ± 1.8 cm weight 77.7 ± 3.1 kg	30-s Maximal cycling tests	*CWI gp: seated CWI up to the level of the umbilicus at 13 – 14C for 15 min.	passive recovery gp: seated for the same period at room temperature (20 – 22 C)	*cycling performance: peak power & total work *blood lactate & PH *Core temperature and thermal discomfort *HR &rating of perceived exertion (RPE)	*peak power, total work: lower after CWI. *HR & blood lactate: lower HR peak for the CWI treatment than control treatment *rating of perceived exertion (RPE): not affected by cold water immersion compared to the control *Core temperature: significantly increased at completion of immersion, compared to the Control condition. *The thermal discomfort rating: high upon initial submersion but was significantly decreased by the end of the bath.

Appendix 2: Quality Assessment tables according to PEDro Scale

Table 4: Quality assessment of exercise and massage category.

Quality Assessment Item	Exercise and Massage					
	Monedero et al, (2000)	**Isabell et al, (1992)**	**JAKEMAN et al, (2010)**	**WELTMAN et al, (1977)**	**Hudson et al, (1998)**	**FERREIRA, CARVALHO, (2011)**
1. Eligibility criteria were specified	No	No	No	No	No	No
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	Yes	Yes	Yes	Yes	Yes	Yes
3. Allocation was concealed	No	No	No	No	No	No
4. The groups were similar at baseline regarding the most important prognostic indicators	Yes	Yes	Yes	Yes	No	Yes
5. There was blinding of all subjects	No	No	No	No	No	No
6. There was blinding of all therapists who administered the therapy	No	No	No	No	No	No
7. There was blinding of all assessors who measured at least one key outcome	No	No	No	No	No	Yes
8. Measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	Yes	No	No	Yes	No	No
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case,	Yes	No	No	Yes	No	No

Please cite this article as follows: Hanafy M, Botla M, Abo-El-Enan F, Mowafy Z. Different Transcutaneous Electrical Nerve Stimulation Modes in Relieving Chronic Pudendal Neuralgia in Females. EJPT. 2022;10: 1-15.

data for at least one key outcome was analyzed by "intention to treat"						
10. The results of between-group statistical comparisons are reported for at least one key outcome	Yes	Yes	Yes	Yes	Yes	Yes
11. The study provides both point measures and measures of variability for at least one key outcome	Yes	No	Yes	Yes	Yes	Yes
Total scores	6 High	3 Poor	4 Moderate	6 High	3 Poor	5 Moderate

Table 5: Quality assessment of cold water category

Quality Assessment Item	Cold Water		
	Dupont et al., (2017)	Maruyama et al., (2019)	de Paiva, Tomazoni, (2016)
1. Eligibility criteria were specified	No	No	No
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	Yes	Yes	Yes
3. Allocation was concealed	No	No	Yes
4. The groups were similar at baseline regarding the most important prognostic indicators	Yes	Yes	No
5. There was blinding of all subjects	No	No	Yes
6. There was blinding of all therapists who administered the therapy	No	No	Yes
7. There was blinding of all assessors who measured at least one key outcome	No	No	Yes
8. Measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	No	Yes	Yes
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	No	Yes	Yes
10. The results of between-group statistical comparisons are reported for at least one key outcome	Yes	Yes	Yes
11. The study provides both point measures and measures of variability for at least one key outcome	Yes	Yes	Yes
Total scores	4 Moderate	6 High	9 High

Table 6. Quality assessment of cold water immersion and exercise category

Quality Assessment Item	Cold Water Immersion and exercise		
	Ahokas et al., (2019)	Crampton et al., (2014)	Crowe et al., (2007)
1. Eligibility criteria were specified	No	No	No
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	Yes	Yes	Yes
3. Allocation was concealed	No	No	No
4. The groups were similar at baseline regarding the most important prognostic indicators	No	Yes	Yes
5. There was blinding of all subjects	No	No	No
6. There was blinding of all therapists who administered the therapy	No	No	No

7. There was blinding of all assessors who measured at least one key outcome	No	No	No
8. Measures of at least one key outcome were obtained from more than 85%of the subjects initially allocated to groups	No	Yes	No
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	No	Yes	No
10. The results of between-group statistical comparisons are reported for at least one key outcome	Yes	Yes	Yes
11. The study provides both point measures and measures of variability for at least one key outcome	Yes	Yes	Yes
Total scores	3 Poor	6 High	4 Moderate

Please cite this article as follows: Hanafy M, Botla M, Abo-El-Enan F, Mowafy Z. Different Transcutaneous Electrical Nerve Stimulation Modes in Relieving Chronic Pudendal Neuralgia in Females. EJPT. 2022;10: 1-15.