THE EFFECT OF ELECTROMYOGRAPHY BIOFEEDBACK IN COMBINATION CONVENTIONAL PHYSIOTHERAPY TRAINING ON IMPROVING WALKING SPEED IN INDIVIDUAL WITH CHRONIC STROKE: A META-ANALYSIS

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Abstract

Background: The main important goal in rehabilitation of chronic stroke patients is improvement walking speed. EMG biofeedback training is promising treatment for improving that outcome. It offers an exceptional approach (self-control training) that does not exist in conventional physiotherapy. Based on a continuous biofeedback of EMG signal recorded in selective muscles, with the goal of modifying it. **Objectives:** Efficiency EMG biofeedback training in combination conventional physiotherapy approaches and the implementation into clinical settings to improve walking speed in individuals' chronic stroke. **Methods:** We searched English-language of randomised controlled studies (RCT) and words related EMG biofeedback (electromyography, biofeedback, visual biofeedback and auditory biofeedback) and related walking speed (gait speed, walking velocity, and gait velocity) as well as chronic stroke between 1980-2019 using MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library, ScienceDirect, and Physiotherapy Evidence Database (PEDro), Grey Literature Report, The British Library. **Results:** Eleven studies including 110 participants met the inclusion criteria but only nine checked sufficient outcome data for gait speed. For this meta-analysis, the mean effect size was statistically significant (p = 0.03) with mean 2.15 (95% CI, 0.16 [0.01, 0.30]), Z test. However, the result did not exceed Minimal Clinically Important Difference (MICD) score of walking speed improvement in chronic stroke patients. **Conclusions:** Statistically, the result indicate that EMG biofeedback training is superior to conventional physiotherapy alone for enhancing walking speed in individuals with chronic stroke. However, the meta-analysis verified lack of clinical significance for implementing EMG biofeedback training in clinical settings. *Applications/Originality/Value*: This study contributes to solving nutrition problem in adolescent female athlete and as a basis for intervention in the problem of female athlete triad.

1. Introduction

Stroke is a primary cause of disability. There are an estimated nine million Stroke survivors global each year, and this number is predicted to growth 30% between the years 1983 and 2023 (1). Nearby one-third of those alive at six months following a Stroke are functionally dependent on others (2). Moreover, The Stroke Association (2018) estimated 152,000 people in United Kingdom have a Stroke each year while 1,2 million are Stroke survivors. In addition, roughly 72% of Stroke survivors sustain lower extremities i(hemiplegic gait).

"Stroke is defined as promptly developing clinical signs of focal (or global in case of coma) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than a vascular origin" (3).

Six months after Stroke (chronic phase), patient needs goal-specific training to enhance quality of life. For the aims of this review, only studies on chronic Stroke will be selected, because long-term studies have recognised that Stroke patients require advance rehabilitation from professional health practitioners to recover their activities as walking speed as crucial component (4, 5).

The stroke survivors can experience some functional disability with locomotive ability being main issues (6), around 75 to 85 % are eventually discharged home (7, 8). Statistically, even though 65% to 85% of stroke survivors learn to walk by six months post stroke (9). Additionally, patients with paretic walk one third as fast 40% the distance of age-matched healthy people (10). Therefore, hemiparesis walking demonstrates lack of ability to provide a proper dynamic and voluntary activation between ankle plantar and dorsi flexion, reducing walking speed (11, 12).

The effect of Stroke changes in locomotor performance which decreasing walking speed as the problem. Due to this problem, stroke patients spend more of their rehabilitation time for walking rehabilitation compared to all other activities (13). Bohannon, Andrews (4) shown that enhanced walking ability is one of the most often stated goals by patient undergoing rehabilitation.

Numerous optional conventional physiotherapy approaches were offered to enhance walking ability during rehabilitation setting. There have since been frequent experimental studies as well as systematic reviews revealed that conventional physiotherapy approach (neurodevelopmental technique, bobath concept, motor relearning program and treadmill training) had no significant effect in enhancing walking speed as alone treatments in chronic stroke patients (14-17).

According to Clinical Guideline for Physical Therapy after Stroke from Physical Therapy from The Royal Dutch Society offered overground gait training with external auditory rhythms are suggested physiotherapy approaches for individual with chronic stroke (18). As well as, the National Clinical Guideline for Stroke Royal College Physicians suggested task-specific, overground walking, and strengthening exercise for the lower limb as convenient approaches for improving walking ability (19). Regardless of not mentioned EMGBF explicitly in those clinical guidelines, concept of intervention and doses that require precise exercises correspond with fundamental concept of EMG biofeedback training. Moreover, EMG Biofeedback training offers real-time communication for chronic stroke patient during training. Wherease, Cho, Shin (20) found that walking rehabilitation training with real-time communication approach induces cortical reorganisation (measured by functional MRI) in stroke patients. Furthermore, Schauer, Seel (21) believed the terminal phase of rehabilitation would greatly benefit from to have real-time biofeedback on muscle activity, such as during walking.

EMG biofeedback is recommended for the treatment of numerous conditions after stroke (22). This intervention utilise an electronic instrument to detect and feedback the electric signal from muscles to make patient more aware of muscle activity and aiding to control the level of muscle contraction applied (23, 24). Moreover, EMG biofeedback training offers self-control training providing uninterrupted flow information through vision, hearing, and proprioception to a central nervous system which is essential for appropriate control of voluntary motor such as walking (25, 26). Therefore, Cameron and Sutkus (24) stated visual or auditory EMG biofeedback training involve patient to interact and participate for reaching their goal treatment during rehabilitation. In this case, the patient will be instructed to reach the myoelectrical activities threshold. However, operational standard to determine the threshold is not yet used by all researchers or clinicians.

Over the past decade, a number of studies have investigated the benefits of EMG biofeedback training in chronic stroke patient in comparison to conventional physiotherapy alone. These studies showed that EMG biofeedback in combination conventional physiotherapy was either inferior (27, 28), equal (15, 29, 30) or superior (31-33) to conventional physiotherapy alone in terms of improvement in walking speed, but further conclusion research is needed in meta-analysis framework. Despite two systematic reviews were exist to discuss the effectiveness EMG biofeedback for improving lower extremity ability, the reviews have several limitations in methodological and protocol (34, 35). Thus, it is difficult to fully determine which aspect of lower extremity function recovery it may improve and who may benefit the most from EMG biofeedback training. Therefore, this meta-analysis addresses the following two questions: (1) is EMG biofeedback training more efficacious for improving walking speed than conventional physiotherapy alone in individuals with chronic stroke? (2) How clinically important the effect of EMG biofeedback training in combination conventional physiotherapy.

2. Methods

Search Strategy and Protocol

This study was accomplished following the Preferred Reporting Item for Systematic Review and Meta-Analyses (**Error! Reference source not**

found.) for systematic reviews of intervention for establish research question, search strategies and to assume the meta-analysis

On July 02, 2019, this study performed comprehensive search of the following database (1980-2019): MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library, ScienceDirect, and Physiotherapy Evidence Database (PEDro), Grey Literature Report, The British Library. Alternative terms linking for each keyword are recognised which are then used as keywords and searches exhausted for individual keyword based on P.I.C.O.S (Population, Intervention, Comparison, Outcome, Study Design) strategy (

Table 2). Medical Subject Headings (MeSH) are used to enlarge the linked and increase the evoke of the study question. Terms linked to each keyword are combined using the Boolean strategy 'OR'. Following this, all of the selection criteria are combined using the Boolean strategy 'AND' and no limits are applied for a publication date to reach sufficiently of related articles.

Study Selection

Table 1. *Study Selection*

Study Selection Criteria
assessed the efficacy of EMG biofeedback training combined with conventional physiotherapy approaches
an outcome relating walking speed was measured
participant were individuals with chronic stroke
control group performed conventional physiotherapy treatment
the study was a RCT design
the study only published in English

Data Extraction

The involved studies were reviewed by single researcher (S.S.P) to extract data concerning the study sample (age, sex, and time after stroke), intervention (intervention length, EMG biofeedback intervention, control intervention), outcome measure finding of walking speed. The outcome data (walking speed) were extracted as the mean (SD) of experimental and control group after intervention and then was compared between groups to determine main differences score of each RCT (**Error! Reference source not found.**)

Table 2. *Key words strategy*

Key terms	Term Used	Alternative Term	MeSH	Recall
Population	Chronic Stroke	1. Chronic AND 2. Stroke AND 3. Cerebrovascular Accident 4. Drop Foot	Hemiplegic Paretic	Exploded
Intervention	Electromyography Biofeedback Training	1. Gait Rehabilitation 2. Visual EMG Biofeedback 3. Auditory EMG Biofeedback 4. Tibialis Anterior Muscle 5. Gastrocnemius Lateral Muscle	Feedback Neurofeedback Rehabilitation	Exploded
Comparison	Conventional Physiotherapy	1. Bobath Technique 2. Brunnstrom Technique 3. Neurodevelopmental Technique 4. Task-oriented Training 5. Motor Relearning Program Training 6. Task-oriented Training 7. Task-specific Training	Standard Physiotherapy Recommended Physiotherapy	Exploded
Outcome	Walking Speed	1. GAITRite motion system 2. 10 meters walking test 3. Camera motion 4. Capture system 5. ELITE computerised system	Gait Velocity AND Gait Speed AND Walking Velocity	Exploded
Study Design	Experimental Study	1. Randomised Controlled Trial 2. Double-Blind Method 3. Single-Blind Method	Controlled Clinical Trial Control Trials Clinical Trials	Exploded

Quality Assessment

This study also evaluated study quality and risk of bias for each RCT using Cochrane Collaboration's Tool for Assessing Risk of Bias (36). The type of risk assessed using this instrument consist of selection bias (randomisation and allocation concealment), performance bias (subject, therapist, and assessor blinding), attrition bias (incomplete outcome data) reporting bias (selective outcome reporting), and other possible biases specific to individually study. This method has been recommended for quality assessment (37, 38), as providing a summary score consistently weight all error and may possibly result a noticeable methodological error being ignored if only high summary score is presented.

Data synthesis and analysis

We utilised the Review Manager software (Version 5.3; Cochrane Collaboration) to present all statistical analyses. Based on type of outcome, walking speed (continuous) that have same unit of measurement (meter/second), we stated the pooled effect as weight mean different (WMD), 95% confidence intervals (CIs), and applying the inverse variance meta-analysis method. P<0.5 was measured significant for effect estimate. According to Cohen's index (*d*), we also classified effect size as large ($d \geq 0.8$), medium ($d=0.5$) and small ($d=0.2$). (39, 40). Random effect model was utilised, as considerable heterogeneity was expected from methodological differences and clinical between studies.

I-squared (I^2) statistic was used to assess heterogeneity; which designates the percentage of variability attributable to the heterogeneity of involved studies. Ried (41) stated that if $I^2 <= 25\%$, studies are observed homogeneous and the generally used fixed effect while if $I^2 >= 75\%$ then heterogeneity is very high, this meta-analysis study could use a random effect model. The analysis was done first under fixed-effect model for assessing homogeneity; in case of heterogeneity, the random-effect model was selected. For displaying effect estimates and confidence intervals for both individual studies and meta analyses generated forest plot (42). Risk of bias publication bias was not evaluated by funnel plot because this meta-analysis study did not include 10 studies or more (43).

Results

Flow of trial through the review

Our literature search retrieved 198 unique records, which were reduced to 98 records after the title and abstract screening. After a scrupulous full-text screening, 13 studies (154 patients) were identified as qualified for our qualitative synthesis while only 9 studies (110 patients) included in our meta-analysis. **Figure 1** displays the details of screening process.

Characteristic of included trial

Quality

All included studied informed sufficiently on their methods of random sequence generation and allocation concealment, except for 1 trial for each domain (30, 31). Due to nature of the intervention, blinding participant was not possible in all included trials, excluding a study that conducted by Jonsdottir, Davide (31). Only 3 studies that reported sufficiently on their method blinding outcome measurement. In term of attrition bias, Yoo (27) demonstrated high risk of bias while other studies reported adequately method to handling incomplete outcome data. **Figure 2** summarises the risk of bias assessment result, with red, green, and yellow colors in indicating high, low, and unclear respectively.

Figure 1. *The Preferred Reporting Item for Systematic Review and Meta-Analyses (PRISMA) flow diagram of the study selection process. RCT: randomised controlled trial.*

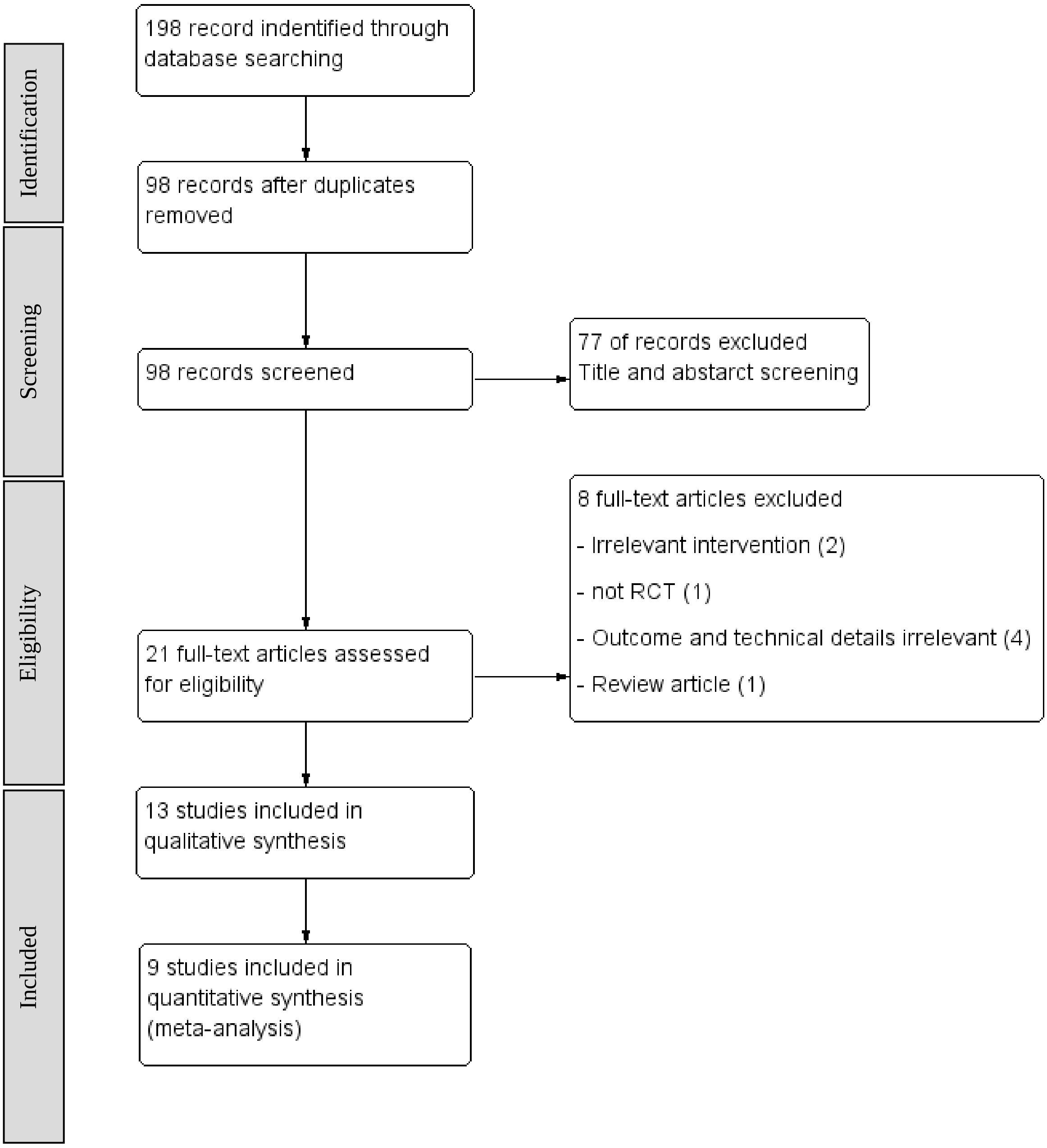
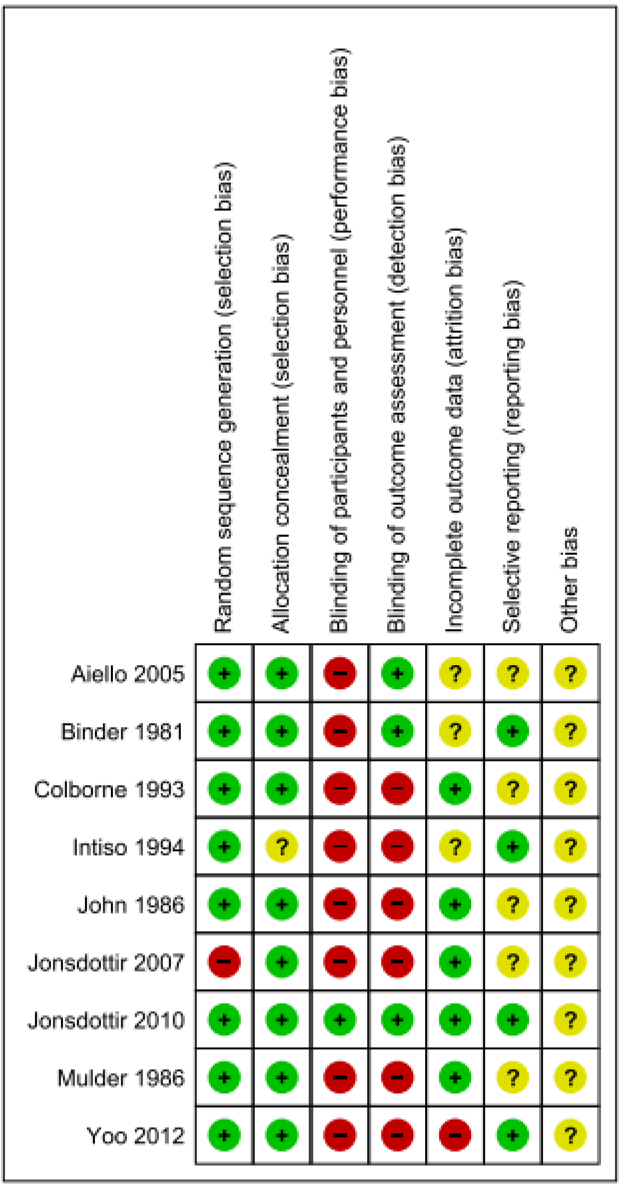


Figure 2. *Risk of bias assessment summary according to the Cochrane risk of bias tool.*



Participants

Table 3. Participant Details

Participant details
The mean age of participant ranged from 47 to 50 years
Male (61%); female (39%)
The mean time after stroke range from >6 months to 3 years

Intervention

Table 4. Type of Biofeedback

Type of Biofeedback EMG	Number
Visual	4 trials
Auditory	3 trials
Combination of both	2 trials

Table 5. Doses of Treatment

Time details	Doses
Session	30 minutes
Frequency	3.2 days per week
Duration	4.8 weeks

Meta-analyses

Nine studies including 110 participants met the inclusion criteria but only nine contained sufficient outcome data for gait speed. For this meta-analysis, there were six positive effect sizes, two negative effect sizes, and only one neutral effect size. The mean effect size was statistically significant (p = 0.03) with mean 2.15 (95% CI, 0.16 [0.01, 0.30]), Z test (**Error! Reference source not found.**).

Three of six positive effect sizes are considered small beneficial (0.2<ES<0.8) while only one study has potentially moderate beneficial effect (0.8<ES<1.0). Meanwhile, two negative effect size (-0.2<ES<-0.8) are small harm and three effect sizes are considered trivial (0<ES<0.2). Individual effect sizes, as well as the combined mean effect size, are shown in figure **Error! Reference source not found.** the heterogeneity is very high (I^2 = 83%).

Table 6. *Summary of included studies (n=9)*

Trials	Design	Participants	Intervention	Outcome measure used in analysis	Effect size
Binder **(44)**	**RCT**	**n = 10** Age (y) = ? (?) Gender = ? (?) **TSS = >15 months**	**Exp = EMG Biofeedback training: combination visual and auditory biofeedback** Con = only conventional physiotherapy: (?) Freq = 15 sessions, 5 weeks	**Walking speed (m/s)** Conventional measurement: timed ambulation	**0.56**
John **(28)**	RCT	**n = 12** Age (y) = 44.2 (?) Gender = 5M; 7F **TSS = 25 months**	**Exp = EMG Biofeedback training: (?)** **Con = only conventional physiotherapy: (?)** **Freq = 12-15 sessions, 3 weeks**	**Walking speed (m/s)** Conventional measurement: Ashburn scale time to walk 15 meters	**-0.20**
Mulder **(29)**	RCT	**n = 12** Age (y) = ? (34-68) Gender = ? **TSS = chronic phase**	**Exp = EMG Biofeedback training: (?)** **Con = only conventional physiotherapy: NDT approach** Freq = 15 session, 5 weeks	**Walking speed (m/s)** ?	**-0.01**
Calborne **(15)**	RCT	**n = 6** Age (y) = ? Gender = ? **TSS = 17 months**	**Exp = EMG Biofeedback training: combination visual and auditory biofeedback** **Con = only conventional physiotherapy: NDT approach and motor relearning** Freq = 8 session, 4 weeks	**Walking speed (m/s)** Laboratory settings: LOCAM camera system and gait walkway	**0.05**

Intiso **(30)**	RCT	**n = 14** Age (y) = (?) 40-85 Gender = ? **TSS = 9.8 months**	**Exp = EMG Biofeedback training: auditory biofeedback** **Con = only conventional physiotherapy: Bobath for lower extremities** Freq = 20 minutes, 2 months	**Walking speed (m/s)** Laboratory settings: ELITE computerised system	**0.05**
Aiello **(33)**	RCT	**n = 16** Age (y) = 54 (47.2-59) Gender = 14M; 2F **TSS = >24 months**	**Exp = EMG Biofeedback training: visual biofeedback** **Con = only conventional physiotherapy: regular gait training** Freq = (?)	**Walking speed (m/s)** Laboratory settings: VICON camera system	**0.25**
Jonsdottir **(32)**	RCT	**n = 10** Age (y) = 55 Gender = ? **TSS = 42 months**	**Exp = EMG Biofeedback training: auditory biofeedback** **Con = only conventional physiotherapy: (?)** Freq = 5 session, 3 time a week, 6 weeks	**Walking speed (m/s)** Laboratory settings: ELITE motion analysis system	**0.25**
Jonsdottir **(31)**	RCT	**n = 20** Age (y) = ? Gender = ? **TSS = >=6 months**	**Exp = EMG Biofeedback training: auditory biofeedback** **Con = only conventional physiotherapy: NDT approach, task-specific and task-oriented training** Freq: 20 session, 6 weeks	**Walking speed (m/s)** Conventional measurement: Time walking test	**0.30**
Yoo **(27)**	RCT	**n = 10** Age (y) = 57.2 Gender = ? **TSS = > 6 months**	**Exp = EMG Biofeedback training: visual biofeedback** **Con = only conventional physiotherapy: ?** Freq: (?)	**Walking speed (m/s)** Laboratory settings: GAITRite system analysis	**-0.17**

RCT: randomised controlled traial; **?**: unclear; **y**: year; **TSS**: time since stroke; **Exp**: experimental group; **Con**: control group; **Freq**: frequency; **m/s**: meter per second.

	Experimental			Control				Mean Difference	
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**	**Year**
Binder 1981	0.79	0.15	5	0.23	0.18	5	11.9%	0.56 [0.35, 0.77]	1981
John 1986	0.33	0.2	6	0.53	0.12	6	12.5%	-0.20 [-0.39, -0.01]	1986
Mulder 1986	0.38	0.23	6	0.39	0.3	6	9.3%	-0.01 [-0.31, 0.29]	1986
Colborne 1993	0.61	0.19	3	0.56	0.21	3	8.8%	0.05 [-0.27, 0.37]	1993
Intiso 1994	0.4	0.1	7	0.35	0.07	7	14.9%	0.05 [-0.04, 0.14]	1994
Aiello 2005	0.53	0.13	8	0.28	0.09	8	14.5%	0.25 [0.14, 0.36]	2005
Jonsdottir 2007	0.66	0.18	5	0.41	0.2	5	11.1%	0.25 [0.01, 0.49]	2007
Jonsdottir 2010	0.45	0.1	10	0.15	0.15	10	14.5%	0.30 [0.19, 0.41]	2010
Yoo 2012	0.7	0.5	5	0.87	0.8	5	2.5%	-0.17 [-1.00, 0.66]	2012
Total (95% CI)			**55**			**55**	**100.0%**	**0.16 [0.01, 0.30]**	

Heterogeneity: Tau² = 0.03; Chi² = 45.94, df = 8 (P < 0.00001); I² = 83%
Test for overall effect: Z = 2.15 (P = 0.03)

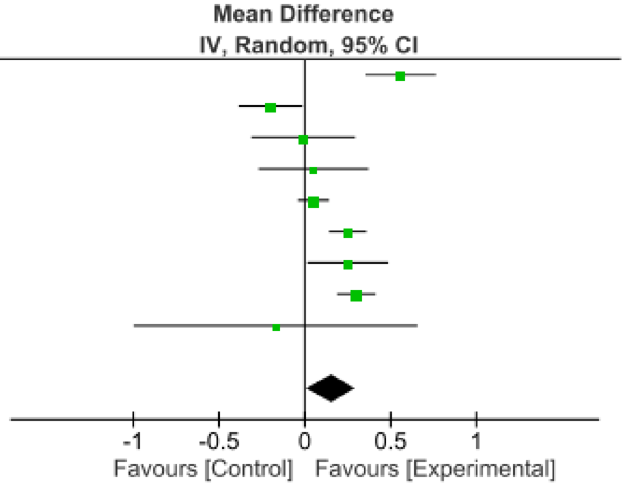


Figure 3. Forest Plot: The pooled mean difference between EMG biofeedback training in combination and control group in term of walking speed score.

Discussion

Statistically, this meta-analysis showed that patient on EMG biofeedback training achieve more improvement in walking speed than only acquire conventional physiotherapy approach in individuals with chronic stroke. This result is sustained by several EMG biofeedback studies in 1960-1990s believed that EMG biofeedback training in combination conventional physiotherapy be successful in improvement walking speed for stroke survivors (14, 17, 45). Meanwhile, EMG biofeedback as alone treatment failed to prove its effectiveness (16, 46).

The other objective of this meta-analysis is to confirm whether EMG biofeedback suitable for clinical settings. The result of this study in walking speed improvement using EMG biofeedback (0.16 m/s) is not strong enough as parameter for clinical to set a goal and interpret change in chronic stroke patients. Two studies by Bushnell, Bettger Janet (47), (48) believed that minimal clinically important difference (MCID) for walking speed in stroke survivor should be more than 0.175 m/s. To explain this issue, van Bloemendaal, van de Water (49), (50) define this issue as the ability to walk 6 months after the first physiotherapy session. This parameter evaluated in long run (approximately 6 months after the first physiotherapy session) since a shorter-term assessment may be unreliable. This statement in line with our findings that revealed all included studies evaluated the outcome (walking speed) less than 6 months (15, 27-33, 44). Moreover, we evaluated that sustainable effect of EMG biofeedback training was not demonstrated in all EMG biofeedback studies. Whereas, two studies believed walking speed plays essential aspect to enhance quality of live after stroke (51, 52). Thus, further study with long-term settings after intervention is required to confirm this issue.

Fine Wire Versus Surface Electrodes EMG

Regarding the small difference mean difference between groups that influence clinically significance. The effect of fine-wire and surface electrode in EMG biofeedback treatment is worth discussing. This is essential because two included studies in 1980s using fine wire EMG (fwEMG) device during biofeedback training tend to stated that EMG biofeedback training failed to improve walking speed (28, 29) while the rest of included studies showed promising effect in improving walking speed using sEMG.

Rajaratnam (53) believed that surface EMG (sEMG) cannot accurately represent of activation pattern of deep muscles. In addition, several studies stated that surface electrode that placed on muscles picked-up cross talk signals from neighbouring superficial muscle (54-56). Conversely, a study by Watanabe and Akima (57) refute the above statements, they stated that no significant different was observed between correlation coefficient of fwSEMG versus sEMG to evaluate global neuromuscular activation. In addition, several studies claimed that sEMG is appropriate method to obtain truthful measures of frequency, intensity, and duration of muscle contraction (58-60). Therefore, further research regarding the correlation between fine wire and surface electrode is required.

SENIAM Protocol

Utilising surface EMG closely associated to surface EMG for non-invasive assessment of muscles) SENIAM as electrode placement protocol. In spite of six included studies in this review using surface EMG as electrodes, only a half that implementing SENIAM protocol for electrode placement Jonsdottir, Davide (31), (32, 33). The results demonstrated that utilising SENIAM protocol considerably boost the effect size in those study. This is in agreement with Freriks and Hermens (61) that recommended SENIAM protocol as practical guideline for electrode placement in surface EMG. Moreover, the effect size in those studies showed superior score than meaningful clinically important change (MCID) score of walking speed in individuals with chronic stroke (48, 62). Thus, SENIAM protocol could assist the effectiveness of surface EMG biofeedback training into clinical settings, not only in statistical results.

Selective Muscles

Other findings that worth discussing is muscle selective in each EMG biofeedback studies. Contradictive approaches were presented in two studies that clearly mentioned muscle target in their studies (30, 31). A study by Intiso, Santilli (30) instructed patient to contract Anterior Tibialis muscle to obtain auditory EMG biofeedback but unclear explanation about muscle threshold. However, Jonsdottir, Davide (31) selected Gastrocnemius Lateral muscle as muscle target to be treated by auditory EMG biofeedback training.

In fact, Anterior Tibialis muscle and Gastrocnemius muscle act as agonist and antagonist muscle in different cycle gait (63). Anterior Tibialis muscle and Gastrocnemius muscle plays as an agonist and antagonist in initial contact phase respectively (63, 64). Meanwhile, Gastrocnemius muscles with Soleus muscle play essential role as agonist during midstance (63, 64). These muscles control the rate of ankle dorsi flexion, keeping its activation during terminal stance for preparing the impulse of the foot while Anterior Tibialis muscle as an antagonist (64). A study by Mayer (65) stated that the goal of walking rehabilitation in individuals with central nervous system is restoring reciprocal inhibition mechanism that influenced and affected by the quality of agonist and antagonist mechanism during walking. Therefore, further researches that selecting both Gastrocnemius muscle and Tibialis Anterior muscle in EMG study are required.

Outcome Measurements

The difference of outcome measurement settings could be interesting for discussing. Basically, this study consists two main setting of walking speed measurement: laboratory-based measurement and manual measurement. The studies before 1990 tend to use manual measurement for assessing walking speed (28, 29, 44) and the result of those studies were negative effect for improving walking speed., the studies that conducted after 1990 until 2012 using laboratory settings (15, 27, 30-32) proved the effectiveness of EMG biofeedback training for improving walking speed.

In term of psychometric properties, both manual measurement (10-meter walking test) and laboratory setting measurement (GAITRite motion system) has excellent reliability and validity for capturing walking speed changes in individuals with chronic stroke (62, 66-70). However, in responsiveness aspect 10-meter walking test demonstrated (0,05 m/s) (71) less than GAITRite motion system (0,03 m/s) (62). Therefore, we could argue that laboratory settings providing more responsive than manual measurement in capturing walking speed changes.

Conventional Physiotherapy Approaches

Another interesting finding of our study is recommended physiotherapy approach that according to national and international clinical guidelines meaningfully escalate positive effect size (31). However, two studies that did not mentioned specific conventional physiotherapy failed to prove the effectiveness of EMG biofeedback training in walking speed improvement (27, 28) while the rest included studies that utilised not-recommended physiotherapy approaches from clinical guidelines demonstrated small benefit effect of

EMG biofeedback training (15, 30, 31, 33, 44, 46). Therefore, EMG biofeedback could be a promising supplementary treatment to be combine with recommended conventional physiotherapy approaches that match the clinical guidelines.

Social Aspect

In wider context, social issues regarding utilising EMG biofeedback for walking rehabilitation in chronic stoke patients occurred in developing countries where EMG biofeedback devices would be most needed, is the lack of technological infrastructure. EMG biofeedback can only be found in laboratory settings. A cross-sectional study on 120 stroke survivors in Indonesia using real-time interaction technology approach (Microsoft Kinect XBOX 360© device) demonstrated 80-90% of patient had positive attitude toward real-time interaction approach that providing self-control training in feedback during treatment. Meanwhile, only 5% of them have experiences using that approach in stroke rehabilitation (72). Further development of EMG biofeedback network is essential to overcome this issue.

Professional Issues

Professional issues in the competence of EMG biofeedback practitioners plays essential role to archive ethical and legal services (73)**.** There was no certification of competence to operate EMG biofeedback devises during research could be considerable raise risk for the participant. The competent practitioner in EMG biofeedback is an individual who is utilising biofeedback devices for research, teaching and performance enhancement that must have at least master's degree from accredited institution and meet training by According the Association for Applied Psychophysiology and Biofeedback (AAPB) including completion of course in biofeedback in anatomy and physiology (74). Therefore, prior to EMG biofeedback researchers and clinicians should be certificated by formal institution prior to applying EMG biofeedback as a treatment to the patients.

Trends Over Time

In term of identifying research trend, interdisciplinary collaboration is important aspect for archiving comprehensive understanding in health-care research (75, 76). In reverse, several previous studies of EMG biofeedback training were no noticeable an ideal working collaboration between physiotherapists and biomechanical engineers in researches (14, 17, 28-30, 35, 44, 46). Consequently, there is an obvious gap in translating several features and analysis system on EMG biofeedback devices into practice. For instance, lack of determining threshold value from raw data in EMG device into clinical. Therefore, interdisciplinary research between physiotherapist and biomechanical engineers would be emerging research trend in EMG biofeedback training for making easy operated system of EMG biofeedback devices.

Limitations

This meta-analysis has several limitations. The main limitation is the relatively small sample size in included studies confines the generalisability of findings. Moreover, we could not assess the risk of publication bias because according to Egger, Davey Smith (77), (78) funnel plot-based methods are not accurate for <10 included studies per outcome.

Implication for Practice

Due to no clinical guidelines supporting explicitly as well as no clinically significant change, EMG biofeedback training could not be recommended and advocated to physiotherapists in clinical practice. However, comparing with conventional physiotherapy approaches that mentioned in national and international clinical guidelines for stroke, EMG biofeedback offers several advantages that cannot be founded in conventional physiotherapy approaches, including external cues (visual or auditory) that believed can exploit motor control during contracting and relaxing muscle in gait training as well as feedback to patient in real-time interaction that enhance motivation during rehabilitation. Moreover, current clinical practises use mirrors and verbal instruction to provided biofeedback. Visual feedback from mirror presents reflected image that hard to differentiate the left and right extremities for stroke patients during treatments. Meanwhile, verbal instructions are not appropriate because of self-image and cognitive issues. As a result, the patients tend to lack of adherence to do their walking rehabilitation programs.

Unfortunately, several barriers limit the spreading of EMG biofeedback training studies; these barriers include utilising divergent treatment procedure and protocol, using electrode placement protocol, and determining threshold setting. Moreover, selecting muscles target and outcome measurements could be affected the results. It would seem reasonable for EMG biofeedback training no appear to have clinically significance. Consequently, EMG biofeedback training cannot be recommended as routine treatment.

Implication for Future

Further research on EMG biofeedback training, related outcome measures for gait ability including, muscle activation, ankle joint angle, and several gait parameters are required to gain comprehensive understanding about locomotor ability in individuals with chronic stroke. Other areas for research concern optimal frequencies and duration of treatment as well as standardised protocol training. The literature about different visual EMG biofeedback and auditory biofeedback is also an area for review and investigation.

Improving patient adherence to outpatient treatment, reducing interferences due to complexity of EMG devices, and translating into community-dwelling settings could be another interesting aspect for further research. The traditional EMG biofeedback system is accessible only in hospital or clinic settings whereas need to frequently treatment for archive rehabilitation goal.

Developing of technology could be optional for visualising the biofeedback information into mobile devices such as a smartphone or tablet can be an and it allows the patient to practice at their home environment. These would enhance an efficiency of restoration and reduce the time wasting for transport to the clinic. Due to home environment rehabilitation setting plays important role to enhance adaptive locomotor ability. Therefore, the future research should be concerned for making user-friendly and accessible EMG biofeedback devices that could be implemented in clinical practices and home environment.

Conclusion

All of subject had normal bone mineral density based on T-score. As many as 21,4% of subjects suffering menstrual cycle disorder. Menstrual cycle disorder, body fat percentage, energy intake, protein, calcium, vitamin D, magnesium, potassium, sodium intake and cBPA had no relationship with bone mineral density in adolescent female athlete, but phosphorus intake, pBPA, tBPA had relationship with bone mineral density in adolescent female athlete. The result of multivariate analysis showed that pBPA is the most influential factor of bone mineral density in adolescent female athlete.

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