



# Celebrating 50 years of Independence of Bangladesh

**SPECIAL ISSUE  
PUBLICATION**



**Special Issue**

**Section I**

**Systematic**

**Review**

**Articles**



## Commemorating 50<sup>th</sup> year of Independence of Bangladesh - Scholarly Research Investigations

With utmost respect from the core of our hearts, we intend to commemorate the 50th year of Independence of the Great Nation of the People's Republic of Bangladesh by acknowledging the ground-breaking research calibre of the Bangladeshi Research Scientists and Scholars, who kept on delivering with outstandingly innovative experimentations throughout the world. We conceived this special issue to provide a platform to disseminate outcomes of multidimensional research investigations, which have been conducted mostly in universities and research institutes in Bangladesh and neighbouring nations. These highly skilled research scientists of Bangladesh have employed cutting-edge technologies to investigate the complex and yet unexplored aspects associated with diverse areas of life ranging from medical and health issues, cognitive neuroscience, rehabilitation sciences, issues pertaining to motor control, enhancement in sports performance, motor skill limitations influencing overall development among Specially Able Children and factors associated with management of health risk as well.

In this Special issue in Section I, we have included the meta-analytic systematic review studies. These studies have examined impacts of lifestyle on PCO; effectiveness of proprioceptive training on OA limitations; efficacy of differential coordination training regimes on motor deficiencies; and benefits of VMBr and Biofeedback techniques on the performance of athletic skills. Here, the noteworthy fact is that all those meta-analytic investigations have been conducted including almost every of the previously carried out valid and authentic RCTs following rigorous methodology.

Health Science topics in Section - II have encompassed extensive research on exclusively vital current issues associated with the awareness and behavioural manifestations pertaining to the outbreak of COVID19 from a Bangladeshi perspective. Further to that, studies on the impacts of exercise interventions in enhancing health status as well as cognitive functions as the precursor for effective management of Type 2 DM among Bangladeshi individuals and cost-effectiveness of those interventions, are breakthrough investigations that are already universally acknowledged as apex research outcomes. Section III, however, has included studies on cognitive neuroscience aspects associated with neural processing of auditory attention characteristics in dyslexic children, and visual attention and language processing investigated among pregnant women. These studies have been carried out incorporating sophisticated gazettes for the assessment of topographic cortical activation based on ERP and fMRI evaluations. In this section experiments on the rehabilitation sciences are also disseminated. While one case study has reported on the utilization of unique techniques for prosthetic rehabilitation, the other study has been conducted introducing EMG biofeedback and modified isokinetic intervention techniques following rigorous methodology to minimize feelings of pain and perceived stiffness among elderly osteoarthritic patients. Finally, Section - IV has been considered to include investigations on the effectiveness of VMBr and Biofeedback intervention techniques on athletic performance excellence; the impact of motor skill training on complex reaction ability in young-adult individuals having partial dyspraxia. Apart from all those, this section has also included outcomes of an extensive study on Specially Able Children, in which facilitative impact of young athlete (motor skill-oriented) training on tandem walking ability has been thoroughly investigated.

We have critically reviewed (double-blind review) and evaluated all the manuscripts submitted for publication in this issue. The final reviewer has adequately ensured that as per the suggestions of the reviewers, original research submissions have been optimally modified. Thereafter, all the Section Guest-editors of this issue, upholding the core academic and research integrity, have endeavoured to leave no stone unturned to warrant the quality and validity of the research documents accepted for publication. In every section content of the articles are linked with the cited references, which may provide optimal opportunity to the learned researchers. Apart from that, we have also provided back-and-forth links of cited documents, so that the readers can easily check the citations in the list of references and can promptly go back to the area of discussion. We can vouchsafe that we have aspired only to invigorate the academic and research milieu of Bangladesh. This country on the brink of achieving hard-earned independence was proclaimed as the “bottomless basket”. I am sure I am not the only one who strives hard to showcase the development of the Nation of Bangladesh, the country having full of enthusiasm. Here I am being the Lead Guest-Editor would like to acknowledge the dedication of all the Guest -Editors and Reviewers for their sincere contributions. I would most sincerely like to thank all of them, who relentlessly took care of their responsibilities to ensure the validity of the research articles and the high academic standard of this issue.

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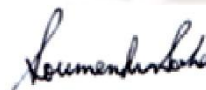
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## SECTION I – Systematic Review Articles

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Manuscript No.	Title	Authors	Page no.
<a href="#">MS-BD50 Lit-Rev. - 1</a>	MANAGEMENT OF POLYCYSTIC OVARY SYNDROME THROUGH LIFESTYLE MODIFICATION: A META-ANALYTIC REVIEW	Konica Das and Rajib Lochan Das	1 - 5
<a href="#">MS-BD50 Lit-Rev. - 2</a>	BENEFICIAL IMPACTS OF VISUOMOTOR BEHAVIOUR REHEARSAL ON PERFORMANCE OF ATHLETIC SKILLS: A META-ANALYTIC REVIEW	Soumendra Saha, Foujia Huda, Hairul Anuar Hashim and Srilekha Saha	6 - 10
<a href="#">MS-BD50 Lit-Rev. -3</a>	PROPRIOCEPTION TRAINING AND OSTEOARTHRITIS OF KNEE: A META-ANALYTIC SYSTEMATIC REVIEW	Naresh Bhaskar Raj, Srilekha Saha and Soumendra Saha	11 - 16
<a href="#">MS-BD50 Lit-Rev. - 4</a>	CONVENTIONAL COORDINATION TRAINING INTERVENTION REGIMES ON MOTOR COORDINATION DEFICIENCIES: A META-ANALYTIC SYSTEMATIC REVIEW	Maruf Ahmed, Srilekha Saha, Faria Sultana, Selina Nargis and Soumendra Saha	17 - 22
<a href="#">MS-BD50 Lit-Rev. - 5</a>	EFFECTIVENESS OF DIFFERENTIAL BIOFEEDBACK INTERVENTION REGIMES ON ATHLETIC PERFORMANCE: A META-ANALYTIC SYSTEMATIC REVIEW	Srilekha Saha, Hairul Anuar Hashim, Foujia Huda and Soumendra Saha	23 - 27

**Process of Acceptance for SECTION I articles (Systematic Review Articles)**  
[Information on Reviewers and Section Guest Editors](#)





# Management of Polycystic Ovary Syndrome through Lifestyle Modification: A Meta-Analytic Review

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## OPEN ACCESS

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BMI, Health, Lifestyle modification, PCOS,  
Metabolism.

## ABSTRACT

**Background:** Polycystic ovary syndrome (PCOS) is a common endocrine disorder among women of reproductive age. In recent years, the issue has become more prevalent in all societies. Young women are more vulnerable due to lifestyle practices in the current industrial era. The common phenomena are the lifestyles that include food intake habit, diet choice, sedentary activities, etc.

**Aim:** The aim of this study is to investigate if the guided lifestyle modifications will help women with PCOS. This study is a meta-analytic review of relevant research articles selected based on specific criteria.

**Method:** Articles published from 2010 to 2019 and available in online databases such as Web of Science, EMBASE, ProQuest, PubMed, MEDLINE, Ebscohost and CINAHL were investigated for this analysis. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is used for selecting the articles and Physiotherapy Evidence Database scale (PEDro) is used for investigating the methodology quality. Review Manager is used for the effect size analysis of the Body Mass Index (BMI) data.

**Results:** From the mean data and standard deviation in the selected articles, the heterogeneity indicator was found as ( $I^2$ ) 0.98 with high confidence level ( $p < 0.00001$ ) ensuring that the articles were largely heterogeneous. Random impact effect size analysis was done with the BMI data from the selected articles. The standardized mean difference was found as 0.79.

**Conclusion:** Physicians and young women victims with PCOS may benefit from this review study. It concludes that a planned and synchronized combination of lifestyle modification has a significant positive impact on treating PCOS in especially the women of young age. A wider scope of this study could have formulated better discussion comments.

## 1. INTRODUCTION

Polycystic ovary syndrome (PCOS) is a common endocrine disorder among women manifested with infertility, irregular menstruation, and clinical or biochemical signs of hyperandrogenism<sup>1</sup>. This increasing disorder is affecting 5 to 10% of women of reproductive age<sup>2</sup>. There may be many factors effecting PCOS in women. One significant factor is weight. Among women with PCOS, up to 80% are with overweight or obesity<sup>3</sup>.

World Health Organization (WHO) defines obesity as the excessive storage of body fat and diagnosed mainly according to the Body Mass Index (BMI) criteria. A woman is diagnosed as obese when BMI is  $\geq 30$  Kg/m<sup>2</sup> and overweight when BMI is between 25 and 29.9 Kg/m<sup>2</sup>. Obesity is positively correlated to PCOS while 38 to 88% of women with this syndrome are reported as obese<sup>4</sup>. Another important pathophysiological feature of PCOS is insulin resistance<sup>5</sup>. Central obesity is the common important contributory factor of PCOS. Insulin resistance and hyperinsulinemia are responsible to increase the gonadal androgen production. Obesity contributes to not only PCOS, but also type 2 diabetes, cardiovascular disease and endometrial hyperplasia<sup>6</sup>. As a reason, PCOS is often associated with dyslipidemia and glucose intolerance<sup>7</sup>. The increasing rates of obesity are influenced by the phenomena of industrial life, which are attributed to lifestyle

including unhealthy dietary habits like consuming fast-food coupled with sedentary lifestyle, food pattern and behaviour<sup>8</sup>.

Lifestyle modification is a primary treatment of PCOS. It involves an altering long-term habit typically of eating or physical activities and maintaining new behaviour for months or years. Lifestyle modification treats a range of diseases including obesity<sup>9</sup>. Therapeutic lifestyle changes comprise diet, weight management and physical activity. Healthy lifestyle includes diet and exercise shown to prevent or delay the onset of type 2 diabetes mellitus and its complications<sup>10</sup>.

As lifestyle characteristics such as, inappropriate food patterns and behaviours are formed in adolescence and continue into adulthood those may result in obesity<sup>11</sup>. In the contrary, a balanced diet includes food such as vegetables, fruits, low fat dairy products, lean meat and other sources of proteins and whole grains. High fibre diet reduces oestrogen serum concentration in premenopausal women, and it is supposed that a low fibre high lipid diet may increase circulating oestrogen and androgen concentration with a consequence in both oestrogen and androgen availabilities to target tissues<sup>12</sup>. Combination of balanced diet and food habit is only a proponent of lifestyle modification, which is followed by physical exercise. Participating in physical activities in shorter intervals is equally important like dietary habit for treating women with PCOS<sup>13</sup>.

This study is intended to compare the research articles selected based on pre-planned criteria and finally find a combined solution for treating PCOS from the findings and discussions of the selected articles.

## 2. MATERIALS AND METHODS

A meta-analysis had been carried out to assess the impact of lifestyle modification by changing dietary habits and incorporating physical exercises in young women with PCOS. The systematic process and explanations on the meta-analysis are discussed with the following sections.

### 2.1 Searching strategy

Relevant literature published, from 2010 to 2019, in various online sources of databases such as Web of Science, EMBASE, ProQuest, PubMed, MEDLINE, Ebscohost and CINAHL were thoroughly searched for this analysis. The terms used for searching the articles were 'polycystic ovary syndrome', 'PCOS', 'lifestyle modification', 'dietary habit', 'diet control', 'exercise', 'aerobics', 'women with PCOS', 'young women with PCOS'. Cross-referencing was also used for finding the articles with related or connected study areas.

### 2.2 Selection process

Selection process of the articles is presented with the following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram<sup>14</sup>.

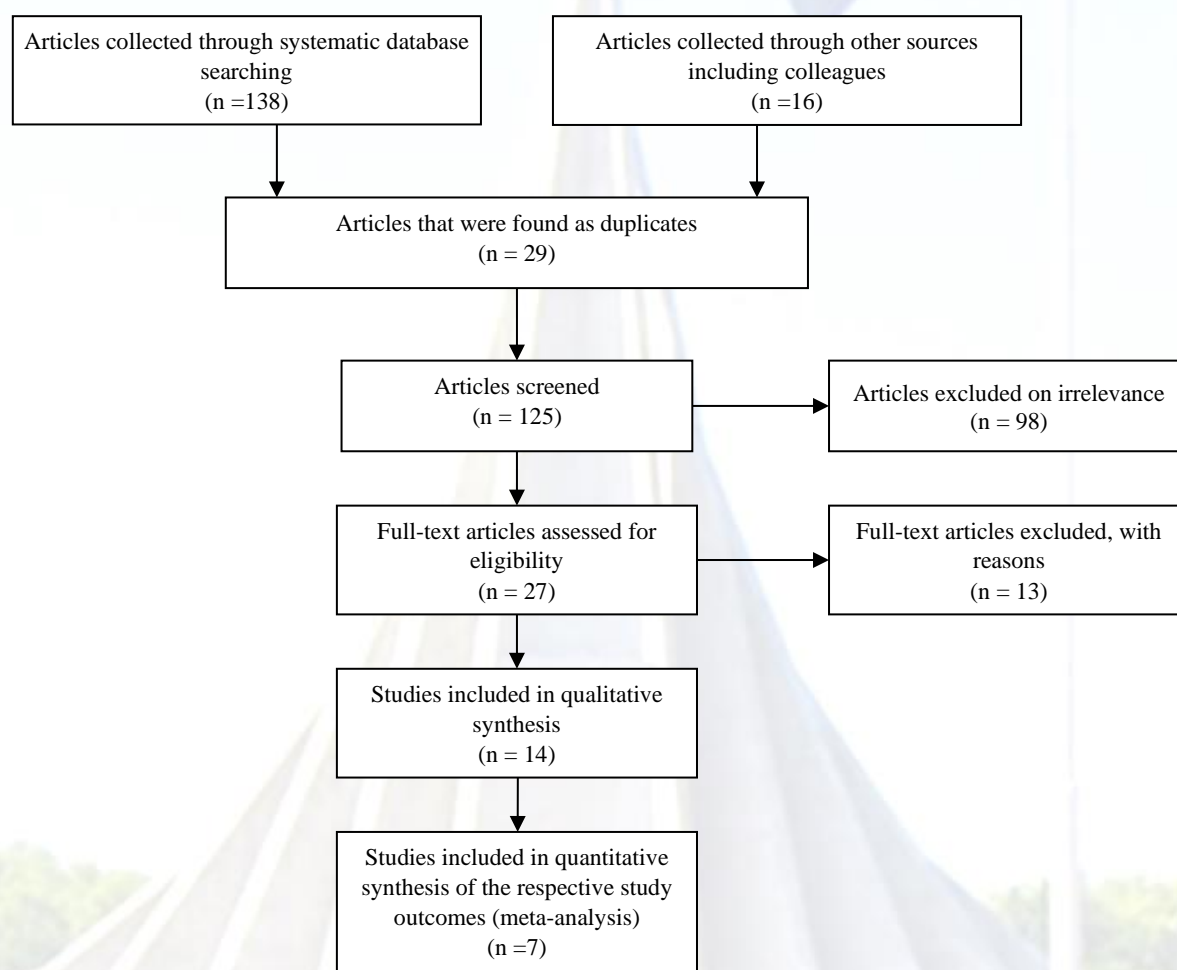


Figure 1: PRISMA flow diagram of the systematic process of article selection

The article inclusion criteria used for this review study is stated below.

- The research was conducted on women with PCOS especially the young females.
- The articles that included dietary habit and/or physical exercise and/or other commonly accepted behaviours of lifestyle modifications in the research.
- The research that was intended to find results of lifestyle modifications in the women with PCOS.

- The articles depicting quantitative results by groups, particularly by experimental and control groups.
- The articles that included sufficient demographic information of respondents along with sample size and selection.

### 2.3 Methodological quality assessment

Physiotherapy Evidence Database scale (PEDro) was used for investigating the qualities of the articles selected. This is a widely used tool with 11 checkpoints for assessing methodological quality of this review<sup>15</sup>. Table 1 shows the score of the articles selected. The average PEDro scale score of this review was 7.00.

Table 1: PEDro scale score of articles that describes the assessment quality

Study article	1. Eligibility criteria?	2. Random allocation?	3. Concealed allocation?	4. Baseline Similarity?	5. Blind participants?	6. Blinding therapists?	7. Blinding assessors?	8. Follow up?	9. Intention to treat analysis?	10. Group comparison?	11. Point and variability?	Score
Abazar et al 2015	Y	Y	N	Y	N	N	Y	N	N	Y	Y	6/11
Arslanian et al 2002	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	8/11
Carolo et al 2017	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	8/11
Eleftheriadou et al 2014	N	N	Y	Y	Y	Y	N	N	N	Y	Y	6/11
Gaeini et al 2014	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	8/11
Barr et al 2011	N	Y	Y	N	Y	N	N	N	Y	Y	Y	6/11
Lin et al 2019	Y	N	Y	N	Y	Y	N	Y	N	Y	Y	7/11
Score	5	3	6	5	5	2	2	3	4	7	7	7.00

### 2.4 Demographic characteristics

There were various levels of demographic information included in each of the articles for the respective respondents. Only the entries relevant to this study were taken into consideration and shown in Table 2. The average score >5.5

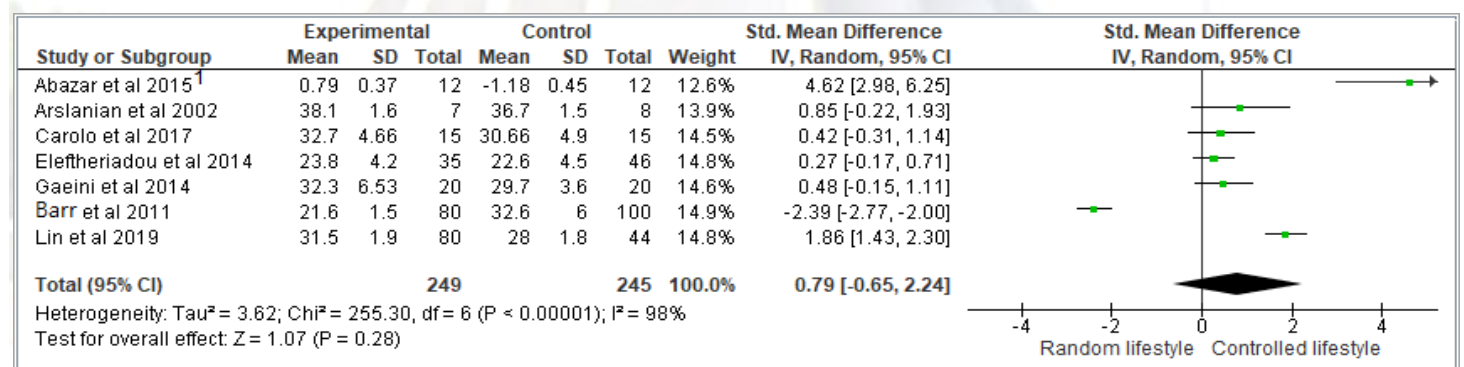
confirms the satisfactory level of methodological quality. Age range of the participants in all of the research was 13 to 35 years, which reveals that the women were young. Highest age was recorded as 29 years with only one exception in the article of Barr et al<sup>16</sup>. Among 7 selected articles, 3 were focused with physical exercise and 5 were focused with dietary habits including one common in both diet and exercise. Similar research done by Arslanian et al<sup>17</sup> also considered the impact of Metformin in treating women with PCOS.

Table 2: Demographic information of the articles' respondents

Study article	Sample size	Age range	Major Comparator	Drug/hormone
Abazar et al 2015	24	24-29 yrs	Exercise	None
Arslanian et al 2002	15	13-16 yrs	Diet, Exercise	Metformin
Carolo et al 2017	30	13-19 yrs	Diet	None
Eleftheriadou et al 2014	81	Adoles.	Diet	None
Gaeini et al 2014	40	19-28 yrs	Exercise	None
Barr et al 2011	210	23-35 yrs	Diet	None
Lin et al 2019	140	26-29 yrs	Diet	None

### 3. RESULTS

The computer program Review Manager was used for analysing the data of mean and standard deviation found the selected articles. Corresponding weights for the articles are estimated by the application. The heterogeneity indicator was ( $I^2$ ) 0.98 with a very high confidence level ( $p < 0.00001$ ), which ensures that the independency of the articles were violated and they were largely heterogeneous. Random impact effect size analysis was done with the BMI data found from the selected articles. Standardized mean difference based on the calculated average of all the studies included in this systematic evaluation was evident as 0.79. Forest plot diagram was prepared to show the individual standardized mean difference between two corresponding experimental and control groups. Position of average standardized mean difference is easily identified in the forest plot as shown in the Figure 2.



<sup>1</sup> Mean is presented as the different of BMI data between that of before and after the study period of 12 weeks.

Review Manager (RevMan) [Computer program]. Version 5.4.1, The Cochrane Collaboration, 2020.

Figure 2: Forrest Plot describing lifestyle modification in women with PCOS by BMI



#### 4. DISCUSSION

From the study with the selected research articles the overall PEDro score is 7.0 in the scale of 11, which ensures the methodology qualities of the respective studies were satisfactory. The demographic analysis of this meta-analytic study clearly shows that health hazard was common in young women of reproductive age with PCOS. Ogden et al<sup>18</sup> also found similar results by stating that PCOS had augmented in adolescent girls and the main reason behind this was the unhealthy food habits. Lin et al<sup>19</sup> found satisfactory results in the participating women, by following the US Dietary Reference guidelines as the standard diet suggested for women. As an example, item in diet, the experimental group of women exhibited marginally low intakes of dietary fibre (24 g/d) and therefore met recommended macronutrient distribution ranges<sup>19</sup>. Barr et al<sup>16</sup> found that the effects of low glycaemic index GI diets in women with PCOS specifically gave the potential benefits for glycaemic control. This was leading to a conclusion that low GI foods into everyday meals and snacks for women was prudent to incorporate in the dietary guidelines for health<sup>16</sup>. Carolo et al<sup>7</sup>, on the other hand, found adolescent girls showed a tendency to have high-protein along with low-carbohydrate/fat. A negative relationship was in between the calorie intake and the weight loss. A positive relationship was also seen between the weight loss and a high-protein, low-carbohydrate diet<sup>7</sup>. Comparing selected research findings these authors uncovered that taking balanced diet was the key point to treat PCOS.

Measurement of health condition and comparison between experimental and control groups' health were based on BMI data. The result of overall standardized mean difference on BMI data 0.79 indicates the position in favour of the controlled lifestyle with healthy dietary habits. Favourable change in BMI through improved dietary habits was the most important lifestyle modification component in the studies of the selected articles. Lifestyle modification also includes, having frequent meal and also undertaking regular exercises like aerobics, yoga, walking or swimming. On the other hand, inappropriate behaviour includes sedentary activities like working by sitting for long, watching television for hours along with eating etc. However, a similar RevMan meta-analysis was not conducted on impact of physical exercises as the necessary data were not available. Researchers of the selected articles analysed the physical activities data collected from the participants' own responses. Lin et al<sup>19</sup> wrote women with PCOS engaged in a minimum of 150 min of moderate-intensity aerobic physical activity throughout the week, as evidenced by at least 75 min of vigorous-intensity aerobic physical activity and identified by the Women's Health Initiative Study Physical Activity Questionnaire. The sport activity via reducing weight, along with other factors including insulin sensitivity, can significantly improve the menstrual condition, ovarian function in women especially overweight women with PCOS<sup>19, 20</sup>. Comparing the findings stated in the selected articles, this study found that

planned employment of intensity and duration of physical exercises have a significant role to ensure positive impacts in treating women with PCOS. It is supported by Abazar et al<sup>21</sup> as the authors stated that a considerable reduction in BMI and insulin levels was observed for all the groups with diet control and exercise. There were control and experimental exercise group of participants in this study. The fat mass concentration was reduced in both of the exercise groups while the intensity and duration of aerobic exercises were increased by weeks. The authors of this study are convinced that a combination of dietary habit and physical exercise would be most effective to treat PCOS.

Habit of food intake also has a vital role in the management of PCOS in women. Eating more frequent meals per day improves the control of the food intake and the feelings of hunger that ultimately leads to satisfactory weight loss in obese women with PCOS<sup>7</sup>. Adolescent girls with PCOS in the study of Eleftheriadou et al<sup>22</sup> were willing to eat between meals, have at least one soft drink daily and happy to have meal while watching TV. In such common behaviours, girls with PCOS had at least 3% higher average daily intake of calories<sup>22</sup>. The authors are convinced that a good habit of food intake includes frequent daily meal, avoiding sedentary activities especially while eating and following guidelines of healthy diet.

Changing lifestyle in terms of food habit and physical activities has significant psychological implications especially in young women with PCOS. A research found that, in the experimental women group, there was a tendency to consume a higher amount of protein than recommended<sup>7</sup>. However, more research works need to be conducted focusing on the psychological factors associated with change in food habit on the specific group of women with PCOS. This was similarly suggested in a study, based on the findings, that future studies need to be designed specifically to investigate the relationship between eating behaviour and BMI in women with PCOS<sup>16</sup>. Therefore, a well synchronized plan of lifestyle modification including food habit and physical exercise, and a proper drug administration can be the best fit treatment solution of PCOS in young women.

#### 5. CONCLUSION

This meta-analysis is a timely study that intended to come to an agreed point of best treatment plan for the young women with PCOS during the current industrial era. Both the groups of physicians and PCOS victims may benefit from the discussion of this study. This review study could be done with more number of research works on young women from more diverse societies. In that wider scope, this study would be concluding unto a better set of findings and reliable discussion comments.

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## 7. DECLARATION

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## 8. CONTRIBUTIONS OF AUTHORS

Conceived and designed the experiments: KD, RLD

Literature search: KD, RLD

Evaluation of Quality of Literatures: RLD

Analysed the data: RLD

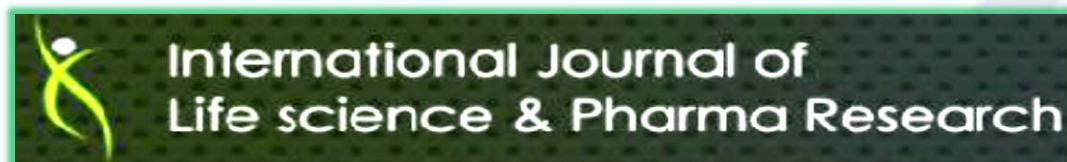
Wrote the manuscript: KD, RLD

Checked and edited the format: RLD

Final approval: KD, RLD.

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## Beneficial Impacts of Visuomotor Behaviour Rehearsal on Performance of Athletic Skills: A Meta-Analytic Review

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VMBR, visualization, mental imagery, athletics,  
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### ABSTRACT

**Background:** Athletes continuously face with crucial challenges and multiple types of hindrances, which put deleterious effects onto their performance. Substantial amount of research investigations confirmed significance of mental skill training.

**Aim:** This present review intended to systematically review published research literatures to (i) enable the researchers in this field with pertinent information on impacts of visualization or visuomotor behaviour rehearsal or imagery training on successful performance of athletic skills, (ii) identify potential areas of problems pertaining to performance disasters and to investigate on the VMBR or visualization training regimes, which had relative contribution on athletic performance enhancement. This article also intended to examine the theoretical constructs and objective implications of the prevalent and existing literature and to recommend future course of research experimentation in this domain of interest.

**Method:** Multiple databases having articles published between 1980 and 2019, such as - PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, ProQuest, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL (National Digital Library) databases were methodically searched for articles related to impact of VMBR training on performance of athletic skills.

**Results:** Outcomes of the available dearth of literatures, however, hinted up on the possibility of combined introduction of visual imagery based physically executed simulated practice if athletic skills, as more potentially beneficial, compared to application of visualization or mental imagery alone. This review highlighted on facilitative impacts of visualization or VMBR or imagery interventions on athletic performance, and the overall effect size was evident as .89, with a confidence interval of .35, 1.43.

**Conclusions:** Authentic RCTs conducted on VMBR or visualization were included in this review which had safe score (i.e., 5.72, which is considered as low bias). These studies clarified beneficial role of interventions on athletic performance. Salient features of VMBR training were identified and potential efficacy of those aspects on performance enhancement were explained.

## 1. INTRODUCTION

Competitive and committed participation in athletic activities, such as running, jumping, and throwing etc are referred as popular athletic events. Elite athletes are always vulnerable to face with the stressful situations, and hence they always need to be efficient in coping with stressful competitive situations<sup>1-5</sup>.

Besides the all-pervasive misconception that coping with stress is a natural ability of the elite athletes<sup>1,2&6</sup>, there is false belief that, elite players are psychologically strong or mentally tough<sup>7-10</sup>, or they have hardy personality<sup>8,9,11</sup>. These misleading conceptions often instigate majority of elite-players, to ignore psychological skill training, and hence without effective stress management skills, they mostly try to apply intervention techniques on their own and succumb to failure<sup>1,2,6-10&12</sup>.

In previous research investigations, theorists attempted to evaluate limitations in athletic performance based on cognitive ability concerning motor coordination and skill<sup>13</sup> inhibitive impacts of heightened anxiety, arousal and attention relationships concerning athletic performance<sup>14</sup>. Long-time back Hull<sup>15</sup> and Spence and Spence<sup>16</sup> hypothesized on the significance of

arousal, while Hanin<sup>17</sup> later emphasized on significance of a particular level of state anxiety as individual-specific zone of optimal sport performance for the athletes. Marten and colleagues<sup>18</sup> on the other hand highlighted on differential influence of cognitive and somatic anxiety on athletes, while Porges<sup>19</sup> stressed on autonomic functions and explained heart-rate variability as the basis of emotionality among athletes. Finally, Hardy<sup>20,21</sup> specifically explained differential relations between cognitive anxiety, arousal, and performance as the valid reason behind dismal athletic performance<sup>20,21</sup>.

### 1.1 An Overview of the Study

This review study was conducted on the basis of research outcomes reported in literatures, which were critically analysed. With the intention of substantiating the research questions, only valid, authentic, and quality empirical evidence-based studies (i.e., RCTs), were included. An extensive literature search was conducted and followed by that, a PRISMA flow diagram, based on the literature search strategy was prepared. Although wide-ranging and extensive literature search was carried out, in order to maintain quality of this



study, based on the inclusion criteria, whatever research studies were available (published in authentic journals), those were appraised by the Methodological Quality Assessment, by employing the (PEDro) scale analysis, followed by meta-analytic review of literatures and Forest-plot analyses.

## 2. METHODOLOGY

### 2.1 Methods of Literature Survey

In this study, available research literatures were evaluated objectively. This was mainly done to counteract the problems associated with authenticity and relevance of the studies. Furthermore, based on quality of the research and with the evaluation of size of impacts of the interventions, those studies could be presented quantifiably as well. Next sub-sections are included to provide detailed information on step-by-step discussions on the systematic review process, which included literature search strategy, inclusion and exclusion criteria, evaluation of quality and characteristics of the studies, analysis of studies included, PRISMA Flow diagram, PEDro Scale analysis and Forest-Plot analysis.

### 2.2 Literature Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Statement guidelines<sup>22</sup>, was followed, to make the review of literature more authentic and objective based. The main purpose of considering PRISMA, as Moher et al.,<sup>22</sup> asserted, is to ensure the required extent of accuracy, completeness, transparency, and frequency of reported systematic review and meta-analysis protocols. Hence adherence to PRISMA could ensure transparency in the literature search, data extraction, and data analysis procedures, as the guidelines include four-step systematic approach of identification, screening, eligibility, and inclusion, which are rigorously followed. A meticulous search of experimental studies was conducted, principally to search for only RCTs (randomised controlled trials), investigating impacts of VMBR or Visualization on improvement in athletic skills. Research reports were obtained primarily through electronic journal searches and also manually (up to March 2020). This review utilized the archives of PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL (National Digital Library) databases. Search strategy used some relevant, authentic, and valid keywords, and terms, such as - “visuomotor behaviour rehearsal”, “VMBR”, “Visualization”, “mental imagery”, were used search for the intervention-oriented searches. In combination with those, terms for instance, “improvement in athletic skill”, “improvement in sports skill”, “improvement in athletic performance”, “improvement in sport performance”, “athletic performance improvement”, “sport performance improvement”, “performance enhancement”, were also used to search studies focussing on outcomes. This literature search was exclusively limited to studies written only in English language, and published in peer reviewed, indexed Journals. In the next sub- sections, inclusion as well as exclusion criteria of the included literatures (preferably RCTs) have been discussed, and as per the inclusion criteria and the evaluation guidelines, following the search strategies and using appropriate terms or keywords RCTs pertaining to VMBR were searched.

### 2.3 Inclusion and exclusion criteria of the Research Literatures

This review studied on internal validity of the literatures and included the following studies: (a) RCTs studies, (b) having control or no- intervention group, (c) which evaluated performance outcomes, (d) employed valid gadgets with high reliability, (e) faced with minimal experimental crisis, and (f) with healthy athletes or players having no complications were recruited as participants.

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation of quality of the studies to be included

Physiotherapy Evidence Database (PEDro) scale<sup>23</sup> was employed to appropriately evaluate the quality of the studies included this meta-analyses. PEDro analysis rates validity of research studies on a scale of 1-11 according some criteria, viz: (a) inclusion or eligibility criteria specified, (b) random allocation of participants, (c) concealed or masked allocation of participants, (d) pre-intervention similarity, (e) blinding of participants, (f) blinding of intervention trainer or therapist, (g) blinding of evaluators, (h) dropouts less than 15%, (i) treatment intention (j) statistical comparisons between-group analysis, and (k) variability of the data. Item 1 is related to external validity, and hence it is not used in the scoring.

PRISMA flow diagrams associated with the intervention regimes have been represented in the next sub-section (refer to the Figure 1). Followed by that, the list of Studies carried out employing different types of intervention techniques, viz., VMBR; Visualization; Imagery training interventions employed in enhancing sport performance (refer to table at <https://dx.doi.org/10.13140/RG.2.2.15400.70405>). RCTs included in this review study were based on PEDro analysis scores.

### 3.2 Characteristics of studies on impact of VMBR or visualization included

A considerably large number (i.e., 287) of potentially relevant studies were identified by initial literature search, from the electronic databases (viz., PubMed, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL), and by additional searches of 109 reference lists other RCTs were retrieved from other sources. Thereafter for duplication, 212 of the RCTs were excluded. Among the remaining 184 studies, only 86 studies met the criteria (as those RCTs dealt with VMBR etc. on sports population) for data extraction requirements and had sufficient information to be included in this review and the rest of the RCTs were excluded from the review process. In the next step, out of those 86 articles, only 32 were evident as meeting the criteria for impact of VMBR or visualization or imagery training, on sport performance enhancement, and hence, those 32 records were thoroughly assessed based on the eligibility criteria and out of those, only 11 studies were evident as quality RCTs (based on PEDro scale), and hence, those were selected and included in the review. Under the intervention programs, three forms of intervention regimes were studied: VMBR, visualization, imagery training or visual imagery or motor imagery training or combination of imagery training. Some of the studies were evident to include more than one form of imagery training (please refer to the Figure 1- PRISMA flow diagram).

In this systematic review, eleven studies consisting of 796 sports persons were included, out of which 379 athletes and players received VMBR or visualization or imagery training. RCTs included in this meta-analysis had good methodological quality score, with an average of 6.125, with the highest score of 8.5, and the lowest was 4, which according to PEDro scale, is considered as moderately high score for RCTs<sup>24,25</sup> (table at <https://dx.doi.org/10.13140/RG.2.2.15400.70405>).

Following the NH & MRC<sup>26</sup> (2000) criteria of demarcation; best evidence synthesis technique<sup>27</sup> and PEDro Scale<sup>24,25</sup> evaluations, out of 11 studies which were included in this meta-analytic review, 3 studies<sup>28-30</sup> were observed to have grade - III-3 level of evidence, while 2 others<sup>31,32</sup> were evident to fall under grade - III-2 level of evidence. Out of the remaining 6 studies, 5 studies<sup>33-37</sup>, however, were identified as having Grade II category of strong evidence<sup>24,25</sup>. Finally, remaining only one study<sup>38</sup>, however, was identified as having Grade I category of strong evidence<sup>24,25</sup> (Please refer to Table at DOI: <https://dx.doi.org/10.13140/RG.2.2.15400.70405>

Apart from that, three studies<sup>28-30</sup> were evident to receive PEDro Scale quality score 4 out of 11 and two other studies<sup>31,32</sup> received PEDro Scale quality score 5 and 5.5 out of 11, respectively. Hence, as per Hillier<sup>39</sup> recommendations, these studies are supposed to be considered as above



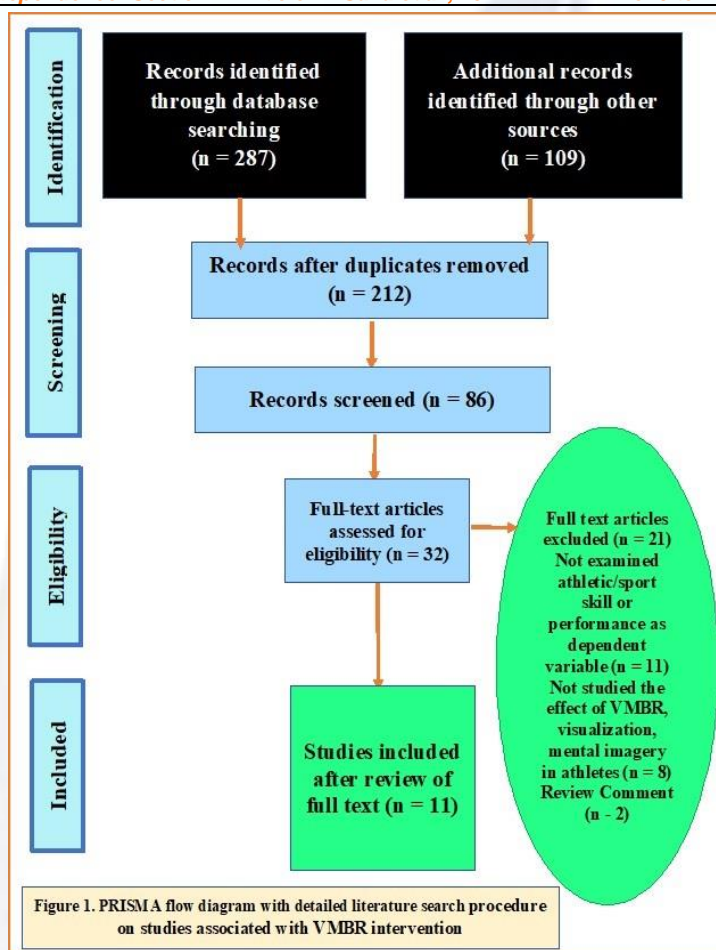
average quality studies, having high strength of evidence<sup>27</sup>. Apart from that, studies conducted by Fontani et al.,<sup>33</sup> Noel<sup>34</sup>, Zahir et al.,<sup>35-37</sup>, were observed to achieve PEDro scores within the range of 6.5 to 7.5. Thus, these studies revealed moderately high level of authentic quality of evidence. The study of Smith and colleagues<sup>38</sup> obtained a score of 8.5 out of 11, and hence, this study revealed very high level of authentic quality of evidence. Thus, to sum up, it may be postulated that the outcomes of this study indicated beneficial impact of the VMBR or visualization or imagery training regimes in improving performance among promising athletes or sport persons. Based on the data retrieved from the aforementioned RCTs Forest Plot analysis was carried out (REVMAN. Review ID: 432121012621333977).

The Forest Plot analysis (REVMAN. Review ID: 432121012621333977), however, revealed a valid meta-analytic outcome that confirmed beneficial impact of the intervention techniques employed in those RCTs. Risk of bias analysis score of 5.72, indicated the RCTs were carried out with bare minimum risk of methodological errors. Thus, the RCTs included in this systematic review were observed to carry moderately higher level of strength of evidence (based on PEDro scale score) and adequate methodological transparency. Outcomes evident in the Forest Plot analysis favoured the beneficial impacts of interventions, and the overall effect size was evident as 0.89, with a confidence interval of 0.35, 1.43. Higher extent of heterogeneity in the included studies was evident (90%). This high percentage of heterogeneity could be attributed to wide range of differences evident in RCTs, which were already detailed in the earlier section. The  $\chi^2$  value was observed as 105.16 ( $P=0.00001$ ), with degrees of freedom of 10.

The meta-analysis, however, implied that most of the RCTs clearly confirmed the improvement of athletic skills by the interventions. Out of 11 studies, only the study of Zahir et al.,<sup>37</sup> partially confirmed improvement in athletic skills, while all other studies clearly confirmed beneficial impacts of either VMBR or visualization or imagery training. In sum, it may be said that, although very limited number of RCTs investigating impacts of VMBR could be included, impact of intervention on athletic skill improvement is favourable. Observed improvement in athletic skills could be generalised, if large number of studies could be included, and if RCTs on VMBR training could be designed following rigorous methodology. Higher extent of heterogeneity evident, however, raised questions on the methodological clarity of the RCTs evaluated, and hence highlighted the need of more authentic research on this issue, following rigorous methodology.

### 3.3 Summary of the Meta-Analyses on impact of VMBR

This sub-section summarised the outcomes of the systematic review of literatures on VMBR training and pinpointed the issues of key methodological concerns and fundamental precautionary measures to be employed in conducting well-designed RCTs. Smith et al.,<sup>38</sup> carried out two studies, in which the researchers introduced PETTLEP-based imagery compared to traditional imagery interventions. The study 1 was conducted on university field hockey players, in which PETTLEP-based imagery was observed as more effective in enhancing performance. While in study 2, on female gymnasts, in comparison with active physical practice, PETTLEP-imagery intervention was not found as better effective. It was quite interesting to see that PETTLEP-based imagery intervention, which is undoubtedly one of the most organised and adequately designed imagery-based visualization training, was not found effective in improving gymnastic performance skills, which mostly require serial to discrete close skill activities, while this imagery could improve performance in field hockey requiring, which is a team game involving wide ranges of variations, from open to close skill, discrete to serial and sometimes continuous skills as well. Noel<sup>34</sup>,



engaging 14 male tennis players, observed beneficial impact of VMBR in improving Tennis service skills only among more advanced players, who could utilize the service imagery used in VMBR training and got benefitted. Noel<sup>34</sup> concluded that, less experienced and skilled players could not benefit from VMBR.

Fontani et al.<sup>33</sup>, on the other hand, introduced motor imagery training to 30 male karateka, and observed efficacy of motor imagery training, which improved muscle strength and power. Fontani et al.<sup>33</sup>, further reported that, the movement related brain macro potentials got modified, which hinted up on the modulation of motor neuronal activities as the basis of motor performance excellence.

Zahir et al.,<sup>35-37</sup> following rigorous methodology, conducted a series of experiments on 85 promising soccer players, and observed that VMBR training resulted in improvement in bidirectional motor learning skill, and improved muscle contractility, which as they hypothesized, were essential for reduction of errors in motor performance<sup>35</sup>. Following similar protocol, Zahir et al.,<sup>36</sup>, assessed motor learning ability, neuromuscular steadiness, and soccer agility, among the same group of promising players, and reported on faster recovery from muscular fatigability, modulation of autonomic stress and psychobiological adaptation were the precursor factors for modification in erroneous motor actions<sup>36</sup>. Zahir et al.,<sup>37</sup> contrarily, engaging identical sample, assessed bilateral motor coordination, Sc latency and amplitude indices and whole-body reaction ability of the players, and concluded VMBR training perhaps restructured and developed the cognitive schema for transitional development from discrete to serial motor skill. Further to that, they proposed that, VMBR along with actual action-regulation training outshines autonomic competence and improved agile reactions<sup>37</sup>.

To sum up, it could be postulated that, development of VMBR regimes were evident as crucially important. More so, appropriate introduction of the intervention training and finally the development or at least

restructuring of cognitive schema concerning psychomotor performance were evident as of vital importance. Furthermore, reinforced by optimal peripheral regulation and cognitively mediated sensorimotor engagements, along with psychobiological competence, players would excel in their performance. As Smith et al.<sup>38</sup> employing well-designed PETTLEP imagery observed, and Zahir et al.<sup>37</sup>, working on a large sample recommended, introduction of actual physical task-oriented visualization training worked optimally better than any other type of VMBR training. Following those outcomes, as postulated by the researchers of previous studies, in this study VMBR intervention was designed in combination of simulation of actual performance-oriented strategies.

## 4. CONCLUSION -

### Summary of the literature review

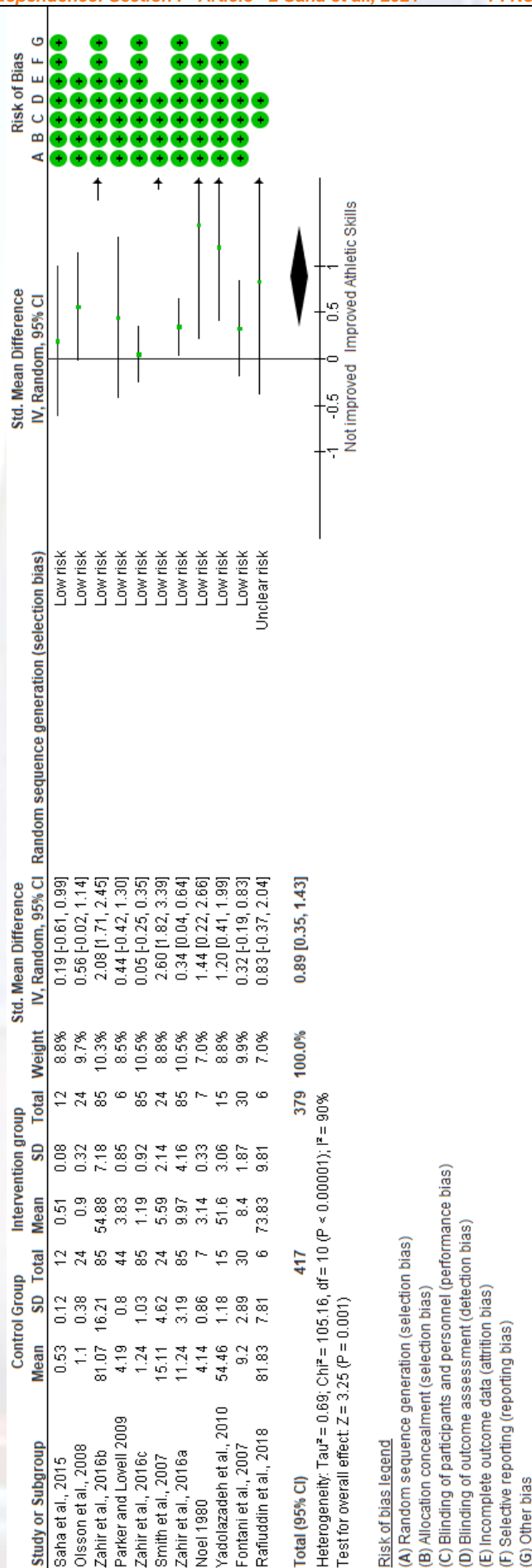
In this review study, impact of the VMBR or visualization or visual mental imagery intervention regimes on performance of athletic skills were scrutinised. RCTs conducted based on the existing theoretical considerations, revealed several limitations, and majority of the studies conducted were evident as not up to the gold standard in methodological considerations, hence outcomes were not considered as substantially valid and consistent. Available RCTs were evaluated based on PEDro Scale analysis, which were evident to carry moderately higher level of strength of evidence and those had adequate methodological transparency. Forest analysis confirmed beneficial impacts of VMBR interventions evident as the outcome of this review. Authors of this study recommend that the VMBR training protocol should be designed with simulation of actual performance-oriented strategies.

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## 6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments: SrS, HaH, FoH, SoS  
Literature search: FoH, SoS  
Evaluation of Quality of Literatures: SrS, SoS  
Analysed the data: SoS  
Wrote the manuscript: SrS, FoH, SoS  
Checked and edited the format: SrS, SoS  
Final approval: SrS, HaH, SoS

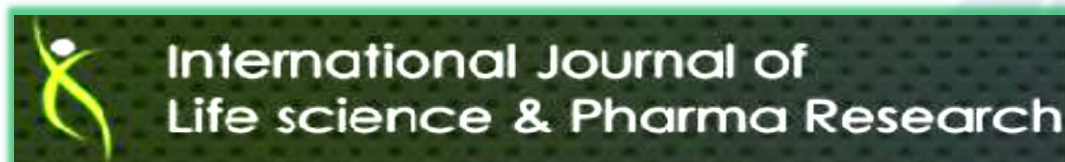




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## Proprioception Training and Osteoarthritis of Knee: A Meta-Analytic Systematic Review

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**Osteoarthritis, Knee, Proprioception, Torque,  
Bodyweight, Exercise, Strength, Weight-  
Bearing, Meta -Analysis**

### ABSTRACT

**Background:** Osteoarthritis of knee is a common degenerative joint disorder. The problems range from pain to maximal disability in movement. Proprioception in knee is commonly affected in knee osteoarthritis but has been less investigated by researchers.

**Aim:** This present review intended to systematically review published research literatures to (i) identify the research studies related to proprioceptive training on knee osteoarthritis and analyse the effect of these training, (ii) identify the effect of weight bearing and non-weight bearing exercises on proprioception in knee osteoarthritis and (iii) investigate the effect of these training on pain in knee osteoarthritis..

**Method:** Several databases such as - PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, ProQuest, Google Scholar, ScienceDirect, ResearchGate, PEDro, Academia.edu, and NDL (National Digital Library) etc were methodically searched for recently published articles on effectiveness of proprioception training and knee osteoarthritis. The methodological quality of the studies was evaluated using the PEDro scale. Seven studies were finally included for the analysis based on the inclusion and exclusion criteria.

**Results:** The average score of the studies based on the methodological quality was 6.5. different forms of proprioceptive training were used in the studies. The common duration of the proprioceptive training was 3 days per week for 8 weeks. The number of sessions was 15-24 sessions. Proprioceptive training has improved proprioception in osteoarthritis of knee SMD [95% CI] = (0.85[-1.28, -0.42], P<0.0001). There was no difference between weight bearing and non-weight bearing proprioceptive training. There was reduction in pain after proprioceptive training SMD [95% CI] = (0.45[-0.99, 0.10], P<0.0001).

**Conclusions:** The overall analysis including all the trials showed that proprioceptive training improves proprioception in knee osteoarthritis. There were no differences between weight bearing and non-weight bearing training for proprioception. Reduction of pain was evident in proprioceptive training for osteoarthritis of knee.

## 1. INTRODUCTION

Osteoarthritis (OA) is a disease that causes impairment of bones in the elderly people as it is a chronic and progressive disease accompanied by aggravated pain and resultant inevitable disability<sup>1,2</sup>. These delimiting factors prompted researchers all over the world to drastically conduct experimentations on multi-disciplinary domains concerning OA encompassing medicine, surgery, rehabilitation, biomechanics, and engineering disciplines. Researchers put their relentless efforts to innovate, modify and refine the existing repertoires of preventive measures and intervention techniques prevailing to diminish the deleterious impacts of OA. At par with these global efforts, this review is conceived to identify-1) Impact of Osteoarthritis on Human Population; 2) Relationship between Proprioception and Osteoarthritis of Knee; 3) Effects of differential modes of proprioceptive intervention training on perceived pain and disability. The review of literature identifies the parameters such as strength of the muscle and the functional outcomes of the participants to be the clinical parameters commonly investigated by most of the researchers. The description of the studies included in the review is based on chronological order starting from the latest research. The literatures that are pertinent and relevant will

be discussed in detail and those of less relevance have been omitted due to the space constraints and this does not underrate the significance of those studies.

### 1.1 Impact of Osteoarthritis on Human Population

Osteoarthritis (OA) is globally well documented as a degenerative joint disease affecting mainly the weight bearing joints of the body. Alteration in the kinetic as well as kinematic features of the knee leads to cartilage degeneration<sup>3</sup>. The entire joint structure, such as the cartilage, synovium and the bones get affected<sup>4,5</sup>. OA is prevalent among 10-60% of the people belonging to the working age<sup>6</sup>, which leads to aggravated pain and disability<sup>7</sup>. By the year of 2040 in South and South-east Asia, an approximate increase of about 384% of people aged 65 years and above is expected to have osteoarthritis<sup>8</sup>. Community - Oriented Program for the Control of Rheumatic Diseases (COPCORD) reported that knee pain was present in 20% of male and 30% of female population and the incidence of osteoarthritis was about 6% and 10% respectively. This was based on the survey done by COPCORD on 2594 Malaysians<sup>9</sup>. The prevalence rate of osteoarthritis in Malaysia was about 5.93%, based on the estimation of internationally leading health care provider right diagnosis.com. This estimation was reported based on their worldwide survey. The knee joint is the commonly affected joint in osteoarthritis<sup>10</sup> with a higher prevalence

rate among elderly population<sup>11</sup>. As it was pointed out by previous researcher, pain accompanied by weakness of quadriceps and abnormal posture lead to restriction of movement thereby causing disability<sup>12-14</sup>.

The recent trend in osteoarthritis research with respect to age has been observed on the basis of the research findings. The findings of the previous studies authenticate that the symptoms of osteoarthritis was expressed during the period of fifty to sixty years of age. and that elderly females were more susceptible for osteoarthritis<sup>15-20</sup>. Previous studies provoked thoughts concerning significance of more wide-ranged and rigorous experimentations encompassing various domains, to reduce deleterious effects of OA on human population. In sum, available bulk of studies warrant importance of exploring various causes and risk factors associated with osteoarthritis of knee. The next sub-section provides an overview of one significant factor associated with OA of knee.

### 1.2 Relationship between Proprioception and Osteoarthritis of Knee

Researchers who examined proprioception of knee joint, reportedly identified an advanced method of training proprioception, which required to keep the participants blind folded (eyes closed) during training. Working with participants suffering from stroke, Moon and Kim<sup>21</sup> found compared to treadmill training while keeping eyes open, training with blocked vision better improved the proprioception of knee joint. Comparing level of knee proprioception (which was measured by angle reposition error using digital goniometer) between 16 visually challenged sports person and 16 healthy sports person Silil and co-researchers<sup>22</sup> reported to have similar findings. Proprioceptive impairments found in OA of knee, which was assessed by evaluation of active repositioning error, however, are not seen in ankle and elbow joints or other joints as well<sup>23</sup>.

Shakoor and associates<sup>24</sup> conducting experiment on asymmetries in the muscle strength and proprioception between legs, reported that muscle strength, proprioception and joint loading are interrelated, and the asymmetry can exacerbate development of OA of the contralateral knee<sup>24</sup>. Investigating level of proprioception by using Biodex 2 on 117 participants (mean age 67.9 years), out of which 40 participants (68.3 years) had severe knee arthritis, Koralewicz and Engh<sup>25</sup> reported participants with OA of knee had poor proprioception compared to that of the control. Barrett and co-workers<sup>26</sup> assessed proprioception (perception of position on a visual analogue model and compared it with the actual angle of flexion were evaluated) in 81 normal knees, 45 osteoarthritic knees, 10 knees with semi constrained knee replacement and 11 knees with hinged replacement and found that arthritic knees had impaired joint position sense at all ages.

Aging causes decline in joint position sense<sup>27</sup>, and reduced proprioception of the knee joint<sup>28</sup> may worsen degeneration of the knee joint. Longitudinal study conducted on 2243 participants reported poor proprioceptive acuity was related to knee pain and its severity<sup>16</sup>. Poor joint position sense was identified as associated with worse physical function and pain in the long run<sup>16</sup>. De Oliveira and research associates<sup>28</sup> on the contrary, argued that perceived pain during ascending and descending of stairs, does not affect proprioception and motor behaviour of mild to moderate OA of knee patients. Numanoglu and co-workers<sup>29</sup> suggested that proprioceptive sense is less among persons who are overweight, and

furthermore, overweight individuals with increased body fat were more prone to have proprioceptive error. Impaired proprioception is hypothesized to reduce knee protection, thereby causing degenerative damage to the knee joint<sup>16,30-32</sup>. Aforementioned studies even though were evidentially suggestive of associating proprioception with perceived pain, available literatures are fairly inconsistent about it, as 6 studies were favouring association between pain and proprioception<sup>16</sup> whereas five studies did not support the findings<sup>33,34</sup>. Thus, discussion on available literatures so far could identify relationship between OA of knee and proprioception. The following sub-section of this review is intended to focus on the training/treatment regimens and effect of those protocols on proprioception.

### 1.3 Impact of Differential Proprioception Intervention Protocols on Osteoarthritis of Knee

Salles and research associates<sup>35</sup> investigated the effects of strength training on shoulder proprioception and confirmed that strength training improved the joint position sense of the shoulder. Likewise, Callaghan and co-workers<sup>36</sup> while investigating effects of patellar taping on knee joint proprioception assessed active angle reproduction, passive angle reproduction and threshold to detect passive motion using an isokinetic dynamometer on the knee joints. They observed that participants with poor proprioception improved significantly with patellar taping. Chen and co-researchers<sup>37</sup>, however, contradicted this finding, and argued that magnetic knee wraps worn on knee with osteoarthritis, in their experiment did not improve the joint position sense of the knee.

Lin and co-researchers<sup>38</sup> investigating effect of 2 non-weight bearing interventions, proprioception training and strength training on participants with knee osteoarthritis reported that non-weight bearing proprioceptive training improved the joint position sense. Duman and research associates<sup>39</sup> investigated impact of proprioceptive exercises on balance and proprioceptive perception and found that a regular physical therapy exercise program was beneficial for osteoarthritic participants. Proprioceptive exercises were less effective in advanced stage of knee osteoarthritis<sup>39</sup>. Jan and co-researchers<sup>40</sup> investigated the efficacy of high repetitive target-matching foot- stepping exercise performed (3 sessions per week for 6 weeks) in a sitting position on proprioception in participants with osteoarthritis of knee. At the end of the trial, researchers reported that, the exercise group had better proprioception than the control group. They also added that these exercises in sitting position can be considered as an option for participants complaining of pain in weight bearing exercises. However, the same researchers in 2009 reported that non-weight bearing exercises improve knee function and muscle strength but addition of weight bearing exercise tends to improve proprioception<sup>41</sup>. Research findings on whether weight bearing exercise or non-weight bearing exercises are effective in improving the proprioceptive accuracy of participants with osteoarthritis of knee, remained conflicting. Researchers<sup>38,40,42-44</sup> confirmed that both weight bearing and non-weight bearing exercises were effective, while some other studies<sup>38,41,43</sup> advocated that weight bearing exercises have an advantage in improving the proprioceptive accuracy.

## 2. METHODOLOGY

### 2.1 Meta-analysis on the Effect of Proprioceptive Training in Knee Osteoarthritis

A meta-analytic review was performed by the researchers to analyse impact of proprioceptive training on osteoarthritis of knee. The meta-analysis was conducted following some standard processes, which are explained in the following sub-sections.

### 2.2 Literature Search Strategy

With the intention of obtaining authentic and relevant research articles (RCTs - randomised controlled trials), detailed and exhaustively in-depth online search was carried out through the databases of Web of Science, SCOPUS, ProQuest, PubMed, Ebscohost, CINAHL, for the articles published in between 1990 and 2014. The search strategy consisted of terms “proprioceptive exercise” OR “proprioceptive training” AND “osteoarthritis of knee” OR ‘knee osteoarthritis’ OR “osteoarthritis of knee” OR “knee osteoarthritis”. In order to ensure



and identify articles not found with the initial search, cross-referencing of articles was carried out. The PRISMA flow diagram showing the selection of articles is shown in Figure 1.

### 2.3 Inclusion and exclusion criteria of the Research Literatures

The inclusion criteria were the followings-

- (i) Design: RCTs in which proprioceptive training protocols were incorporated on participants with osteoarthritis of knee, were explored and identified. Those RCTs were included irrespective of the study design.
- (ii) Interventions: The proprioceptive training and a comparative exercise only and/or other interventions used to increase the level of proprioception and functional outcomes were included.

- (iii) Study Populations: Participants with osteoarthritis of knee.

- (iv) Outcome Measure: Criteria for outcome measure, was the RCTs, which included investigation of the changes in proprioception and pain parameters.

- (v) Language: The articles written in English were only included in the review.

Following are the criteria for exclusion:

- I. Articles not published in English
- II. Research designs other than RCT (viz., NRCTs, pseudo RCTs etc.)
- III. Studies conducted on healthy participants (did not suffer from OA of knee)
- IV. Outcome measures other than level of proprioception and pain
- V. Research investigations in which the mean values of level of proprioception and pain were not given.

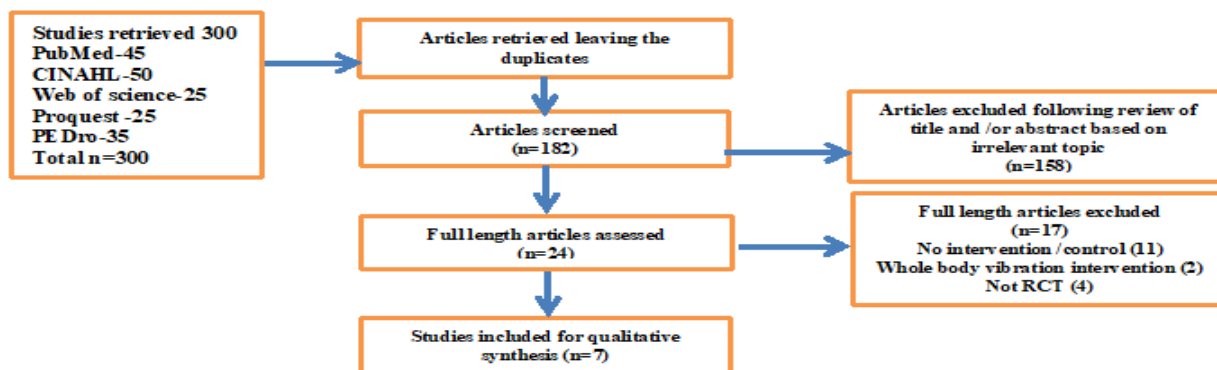


Figure 1. PRISMA Flow Diagram Showing the Selection of Trials

### 2.4 Methodological Quality Assessment:

All included articles were assessed using the Physiotherapy Evidence Database (PEDro) scale. This PEDro scale is an

extensively used critical appraisal tool, which consists of 11 – point scale, used to assess the methodological issues within articles. The PEDro scores are given in Table 1.

Following tables (Tables 1, 2 & 3) are showing the Physiotherapy Evidence Database (PEDro) Scores of the Trials, demographic characteristics of the trial and characteristics of intervention of the included trial.

RCTs included	Eligibility criteria?	Allocated randomly?	Allocation concealed?	Baseline compared?	Participants blinded?	Therapist blinded?
Lin et al., 2007	√	√	√	√	x	x
Jan et al., 2008	√	√	x	√	x	x
Tsauo et al., 2008	√	√	x	√	x	x
Lin et al., 2009	√	√	x	√	x	x
Jan et al., 2009	√	√	x	√	x	x
Duman et al., 2012	√	√	x	√	x	x
Schmid et al., 2013	√	√	√	√	x	x

RCTs included	Assessors blinded?	Adequate follow up?	Intention to treat?	Between group analysis?	Point estimates and variability?	Score
Lin et al., 2007	√	x	√	√	√	7
Jan et al., 2008	√	√	√	√	√	7
Tsauo et al., 2008	√	√	x	√	√	6
Lin et al., 2009	√	√	x	√	√	6
Jan et al., 2009	√	√	√	√	√	7
Duman et al., 2012	x	√	√	√	√	6
Schmid et al., 2013	x	√	√	√	√	7

√-Yes x-No

Researcher	Diagnosis	Age	Population	Male/Female	Outcomes
Lin et al., 2007	Knee OA	61.6±8.1	89	62/19	Proprioception, muscle torque, WOMAC, walking speed.
Jan et al., 2008	Knee OA	63.3±8.1	43	12/31	Knee repositioning error, walking velocity, functional incapacity score.
Tsauo et al., 2008	Knee OA	62	29	24/5	Active joint repositioning, WOMAC, functional testing.
Lin et al., 2009	Knee OA	66.4±8.8	113	66/47	Proprioception, walking on three different terrains, knee strength, WOMAC.
Jan et al., 2009	Knee OA	62±6.7	106	33/73	Walking speed, muscle torque, repositioning error, WOMAC.
Duman et al., 2012	Knee OA	64±3.7	54	5/49	WOMAC, Balance, Repositioning error.
Schmid et al., 2013	Knee OA	65±7.8	40	10/30	Proprioception, WOMAC, 6 Minute walk test, Balance, Short Form 36.



Table 3 Characteristics of Intervention Protocols followed in the Studies Included in this Review

Researcher	Proprioceptive intervention	Other group intervention	No treatment control	Duration
Lin et al., 2007	Computer foot stepping games	Leg press- closed chain exercise - 10 times/10 sets	No intervention	3 days per week for 8 weeks
Jan et al., 2008	Target matching foot stepping exercise	-	No intervention	3 days per week for 6 weeks
Tsauo et al., 2008	Sensorimotor training program	Physiotherapy program of thermotherapy and exercise		3 days per week for 8 weeks
Lin et al., 2009	Computer foot stepping games	Open kinetic chain exercises 4 x 6 sets (50% of 1 RM)	No intervention	3 days per week for 8 weeks
Jan et al., 2009	Target matching foot stepping exercise for 20 mins		No intervention	3 days per week for 6 weeks
Duman et al., 2012	Strengthening exercises, walking zig zag, toe to heel, heel to toe, sideways walking	NSAID's Short wave therapy Infra-red therapy		5 days per week for 3 weeks
Schmid et al., 2013	60 mins of Tai chi sessions	Wellness education for 40 minutes and stretching for 20 minutes		2 days per week for 12 weeks

## 2.5 Statistical Analyses:

Descriptive data (i.e., means and standard deviations of the post intervention data) were collected for both the proprioceptive training and the other intervention groups. Standardised effect sizes and 95% confidence intervals were calculated. Few of the RCTs were not presented with the standard deviations, and hence those were not included for effect size calculation. A few other studies presented the mean in the form of percentage or proportion, and thereby for those studies, calculation of effect size was not possible. The

standardised effect sizes allowed us to compare the results among different studies. Retrieved data were separated based on the outcomes of muscle strength. As per the standardised methods, effect sizes were classified as weak ( $d \leq 0.2$ ), small ( $d = 0.2-0.5$ ) moderate ( $d = 0.5-0.8$ ) and strong ( $d \geq 0.8$ )<sup>45</sup>. The analysis was performed using Review Manager (RevMan, V.5.3.; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Following figures are showing the forest plot on improvement in proprioception, weight bearing and non-weight bearing training and reduction of pain in relation to proprioceptive training.

Figure 1. Forest Plot Depicting the Improvement in Proprioception

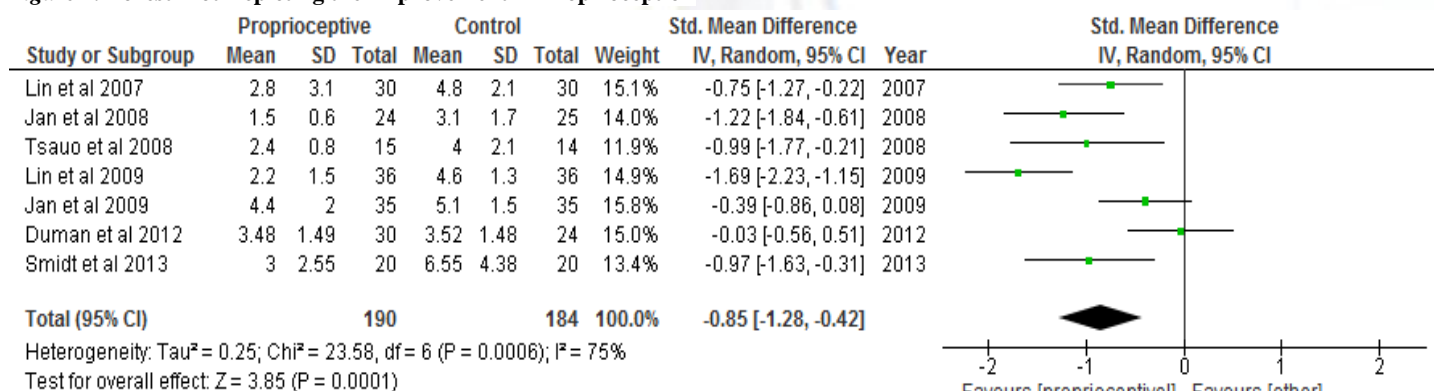


Figure 2. Forest Plot Depicting the Improvement in Proprioception with weight bearing and non-weight bearing exercises

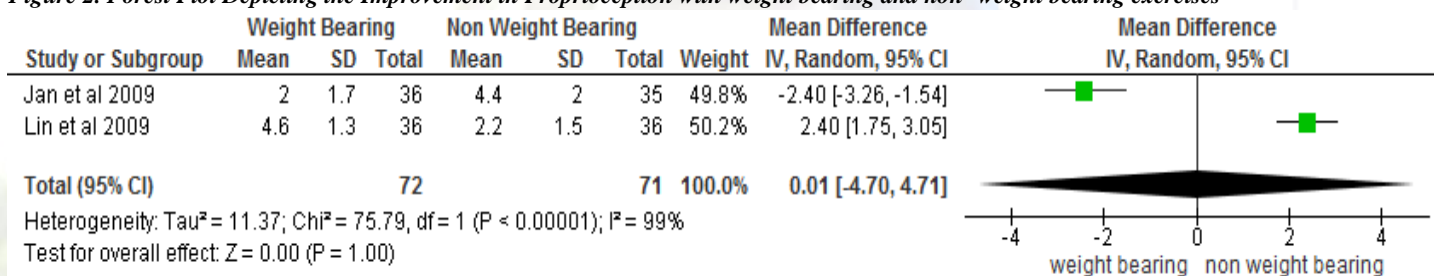
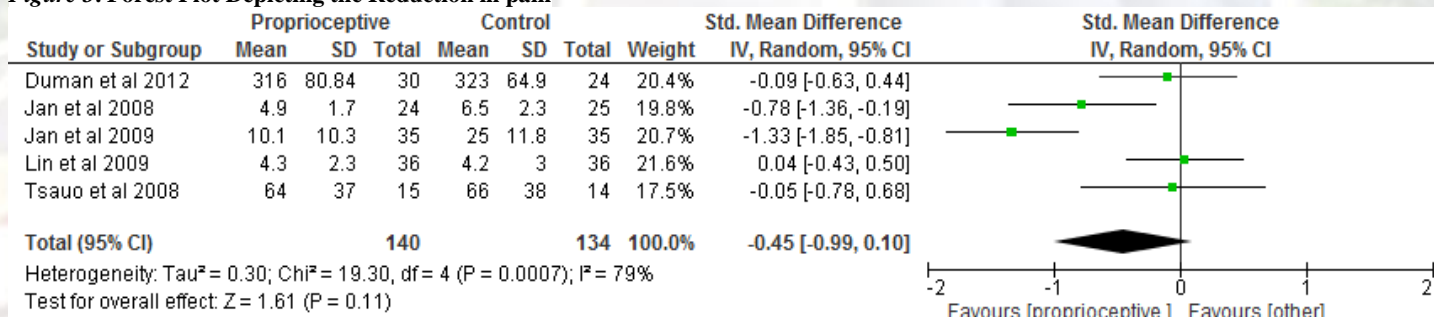


Figure 3. Forest Plot Depicting the Reduction in pain



### 3. RESULTS AND DISCUSSION

In this review only 7 trials were included, which altogether recruited a population of 374 participants, having complications pertaining to osteoarthritis of knee. Overall, the methodological quality of the studies included in this review was evident as good, with an average score of 7.5 out of 11. Hence, as far as Hillier<sup>46</sup> recommended, these studies are supposed to be considered as high-quality studies, having high strength of evidence. In-depth analyses revealed that, majority of the studies included in this study, were observed to have lacuna over concealment of allocation and blinding of participants, assessors, and therapists. Table 2 represented the demographic description of the trials included in this review, while details pertaining to the intervention protocols, viz., types of proprioceptive training introduced, duration of the intervention and the intervention imparted to the control group or other groups, are provided in Table 3. As all the trials, irrespective of the type of proprioceptive training incorporated, favoured proprioceptive training, the analyses emphasized importance of proprioceptive training in osteoarthritis of knee. The overall effect size of the analysis was -0.85 with a confidence interval of -1.28, -0.42. The I<sup>2</sup> value i.e., an index of measuring heterogeneity was 75 % which is expected to be high in a clinical trial, the possible reasons of the high heterogeneity was already discussed in the earlier sections of this review. The effect size of the trials included in this study, could be observed as high, moderate, and low. Five trials were found to have high effect size. One trial on the other hand, had a moderate effect size and another one had a low effect size. By virtue of the evident effect size of the trials, it could be inferred that proprioceptive training in any form is important for participants with osteoarthritis of knee.

Out of the seven trials included in the review, however, to find out the effect of weight bearing over non-weight bearing proprioceptive training, only 2 RCTs could be pooled for analysis. The actual reason behind the scarcity of RCTs in this domain was due to the fact that, most of the trials compared weight bearing proprioceptive training with no intervention control group or non-weight bearing proprioceptive training with no intervention control group. Only two trials were evident to compare weight bearing versus non-weight bearing training. Out of these two trials included in the pooled analysis, one trial favoured weight bearing, while the other trial favoured non-weight bearing. The trial conducted by Jan et al.<sup>41</sup>, performed weight bearing exercise in the form of leg press, which is a form of modified weight bearing activity, in which the weight bearing is not the same as that of standing. Hence this study was considered as favouring non-weight bearing proprioceptive training.

When reduction of pain associated with proprioceptive training was considered, three trials had a very small effect size, and two others were evident as carrying large effect size. Four trials were observed to favour proprioceptive training, while one trial did favour other intervention. Out of the four trials favouring proprioceptive training three investigations<sup>38,40,41</sup> in their studies employed a protocol for proprioceptive training, in which their participants were subjected to target matching foot stepping exercises in sitting position. While participants in the other RCT<sup>44</sup> performed proprioceptive training along with regular physiotherapy intervention, which was inclusive of activities in weight bearing that could explain the reason for a very low effect size and a marginal favour towards the reduction of pain in proprioceptive training. The overall effect size was moderate

with an effect size of -0.45 favouring reduction of pain in proprioceptive training. Although the question of whether proprioceptive exercises or strengthening exercises were better effective in improving the proprioception, no obvious conclusion in favour of either of those exercises could be drawn. Thus, available dearth of literatures, however, emphasized necessity for more in-depth search for a large number of current RCTs, conducted on various methods of strength training introduced to participants reported to have OA of knee. This further search is necessary to confirm the beneficial effects of strengthening exercises on proprioception.

To sum up, it is evident that participants with osteoarthritis of knee are faced with crisis due to loss of proprioception, and that has been largely ignored. Proprioceptive loss in the knee can lead to falls later in life in the elderly population. Various forms of proprioceptive training have been suggested for participants with osteoarthritis of knee, but the training forms have their own disadvantages. Hence there is a need for a research to identify new modality or training methods that could improve proprioception and strength in participants with osteoarthritis of knee.

### 4. CONCLUSION -

This review has offered crucial overview on consequences of loss of proprioception evident amongst elderly individuals suffering from OA of knee. Further to that, this review also highlighted the facts that weight bearing proprioceptive training could aggravate pain, while non-weight bearing proprioceptive training tends to improve proprioception, although muscle strength gets diminished. Since very few studies were included and examined, outcome of this review should be acknowledged with caution, and hence cannot be generalised. Authors of this study recommend inclusion of bulk of recent and authentic RCTs to arrive at any decisive conclusion on most effective proprioceptive training protocol, which would be beneficial for larger number of population suffering from OA of knee.

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### 6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments: NaBR SoS,

Literature search: NaBR, SrS, SoS

Evaluation of Quality of Literatures: NaBR SrS, SoS

Analysed the data: NaBR

Wrote the manuscript: NaBR, SoS

Checked and edited the format: NaBR SoS, SrS,

Final approval: NaBR, SoS, SrS

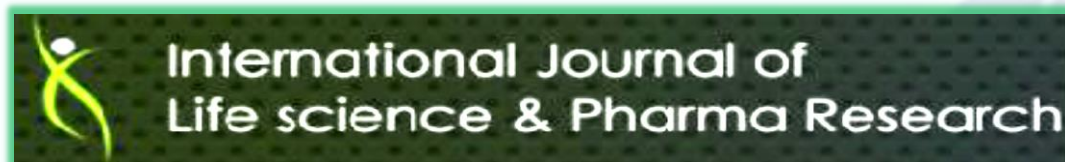
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## Conventional Coordination Training Intervention Regimes on Motor Coordination Deficiencies: A Meta-Analytic Systematic Review

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### KEYWORDS:

Motor Coordination, dyspraxia, DCD, Motor Skill, Movement disorder, performance, recreation, sport

### ABSTRACT

**Background:** Deficient motor and movement coordination is prevalent among young-adult healthy individuals delimit their recreational performance and maintenance of active lifestyle as well. Comprehensive study of the multidimensional aspects associated with motor coordination disorder, may range from physical musculoskeletal problems to physiological, psychomotor, psychobiological, and cognitive deficiencies as well. Bulk of experimental studies emphasized on methodologically sound coordination skill training.

**Aim:** This meta-analytic review intended to systematically examine research literatures published in authentic journals, in order to (i) provide relevant information on impacts of conventional coordination training on improvement in motor and movement coordination amongst young-adult recreational players, (ii) identify aetiological aspects pertaining to coordination problems evident among young-adult individuals and (iii) investigate on the quality of conventional coordination training regimes, and to identify the salient features of the regimes, and the methodological issues associated with training protocols, which had relative contribution on enhancement in coordination.

**Method:** Databases such as - PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, ProQuest, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL (National Digital Library) were systematically searched for recently published articles on effectiveness of conventional coordination training on coordinated performance.

**Results:** Findings of this systematic review work, based on available literatures, however, emphasized on developing authentic protocols for conventional coordination training regimes. Forest plot analysis, however, favoured other types of training methods as better effective compared to the conventional coordination training. The overall effect size was evident as 0.57, with a confidence interval of 0.08, 1.06.

**Conclusions:** A small numbers of studies on conventional coordination intervention were identified as authentic RCTs, which were having moderate level of quality. RCTs included in this review did not confirm efficacy of conventional coordination interventions in improving coordinative performances among recreational players.

## 1. INTRODUCTION

Motor developmental learning as like the other motor and movement development comprises of a set of cognitive processes, and adequate appraisal of those cognitive schemas enable us to restructure our movements into efficient and skilful performance. Precisely enhanced motor efficiency subsequently develop relatively stable modifications in motor behaviour<sup>1</sup>. Variations in genetic predispositions trigger differences in motor efficiency and enables an individual to achieve higher-order motor ability and to acquire the skills required for coordinated motor performance in all spheres of life<sup>2</sup>.

Impaired motor abilities (inherited or acquired) leads to coordination and skill deficiency, which disrupts day-to-day activities (American Psychiatric Association, 2000). Hence pursuit for viable interventions to tackle the coordination deficiencies evident among general population focussed more up on conventional coordination training protocols designed for cognitive-motor functional developments mediated by enhancement in procedural memory and ideomotor performance processes as well.

### 1.2 An Overview of the Study

Based on the reported findings this review study was taken up, in which generalised overview of the research outcomes was conducted, followed by that validity of the reported literatures was critically analysed. In this review, quality of the experimental trials was evaluated, and only authentic empirical evidence-based studies were included. Extensive search for literatures was carried out, which did not yield encouraging outcomes, and hence further searches were carried out (literature search strategy is detailed in the PRISMA flow diagram). On the basis of inclusion criteria, whatever studies were available (published in authentic journals), those were assessed as per the Methodological Quality Assessment guideline by employing the PEDro (Physiotherapy Evidence Database - PEDro, [www.pedro.org.au](http://www.pedro.org.au)) scale analysis<sup>3</sup> followed by meta-analytic review of literatures and Forest-plot analyses (Review Manager - RevMan, V.5.3.)<sup>4</sup>.

Extensive search on deficiencies in motor coordination and coordination related experimental studies revealed majority of investigations were carried out with children suffering from dyspraxia or developmental coordination disorder (DCD) and with elderly individuals

who are suffering from neurologically mediated coordination problems. Available dearth of literatures were evident as having methodological limitations, as majority of those did not evaluate coordination deficiency employing standardised tools and checklists, and hence those trials could not be included as authentic research. Furthermore, studies were mostly evident as incorporated some usual PE trainings, which cannot be validated as tailored for enhancement in coordination, while universally accepted coordination enhancement techniques conventionally and popularly being used, were seldom experimented. Thus, efficacy of those coordination enhancing techniques on grown up individuals identified with visible extent of coordination deficiency were never evaluated. Again, as enhancement in motor coordination mostly requires closed-loop trainings<sup>5-7</sup>, introduction of visually aided biofeedback-like visual-motor coordination training based on physiological or psychophysiological monitoring and guidance protocols were also never reported in research literatures. With such a background, present study was intended to investigate on efficacy of conventionally employed intervention protocols on coordination deficiencies evident among young-adult individuals.

### 1.3 Effects of Conventional Coordination Training on Psychomotor and Psychological Variables

In this part of the review, effect of conventional coordination training regimes on the psychomotor variables were thoroughly investigated, and differential components of motor coordination aspects were critically analysed and reported.

Borremans et al.<sup>8</sup> investigated the efficacy of the exercise program on motor ability of adolescents diagnosed with Asperger syndrome (AS). Twenty adolescents with Asperger syndrome (mean age -16 years and 9 months, SD-10 months) were randomly assigned into intervention group and control group. Pre-intervention assessment of Motor ability and physical fitness was done using Movement Assessment Battery for children (M-ABC-II), EUROFIT physical fitness test and informal descriptive questionnaire. The intervention group was exposed to conventional coordination exercise training program for 1 hour/session, which consisted of various motor activities, for 3 sessions/week for a period of 12 weeks. Abovementioned parameters were assessed both at post-intervention and post-follow up (6 months after the cessation of the intervention) phase of assessment was done, which revealed effectiveness of exercise training in improving motor ability and physical fitness in adolescents with AS. In spite of this interesting findings, due to small sample size and lack of alternative intervention group and evaluation of only movement and fitness aspect of AS, delimit generalisability of the facilitative impact of conventional training.

Niklasson et al.<sup>9</sup> on the other hand, investigated the effect of sensorimotor training (SMT) on psychological and physiological development. 14 participants with an average age of 35 years were recruited, who underwent SMT (15 minutes/day) for a period of 3 years. The participants were compared with a reference group of 100 participants aged between 11-17 years. The Retraining for Balance –Physiological test, Retraining for Balance Orientation and Balance Test, Retraining for Balance – Audiometric test, Keystone visual Skills test parameters were measured. The researcher confirmed that the SMT was effective for improvement in physiological and psychological parameters. The main shortfall of this research was that parameters were compared with that of children and adolescent individuals rather than that of same age counterparts.

Study by Henry et al.<sup>10</sup>, however, examined impact of aerobic training and interval circuit training on physical fitness and changes in body image among unfit college women (N = 72, age

range 18 to 26 years ( $\bar{x}/\sigma = 21.4/2.21$ ), having eating disorder. These candidates remained undiagnosed as having coordination deficiency. Post-intervention analyses revealed that, fitness was found to increase in the aerobic and strength training group whereas body image was found to increase in the circuit training group, although no concern for changes in movement coordination was accounted. The main drawback of this research is that the participants were not randomized hence it might have affected the internal validity of the study. The other limitation of the study is that the control group was not a no-intervention control.

Another study following PE set-up<sup>11</sup>, recruited 72 boys in the age group of 7 and 10 years and categorized them into control and experimental groups. The experimental group was subjected to cycling on an ergometer for 30 mins while watching a popular children's show. The control group on the other hand watched the same show sitting on the bicycle ergometer without cycling. The simple reaction time and choice response time were recorded for all the participants recruited. They concluded that the children in the experimental group had a significantly faster reaction time and choice response time, compared with that of their counterparts. The main drawback of this study was that only boys were included in this research. Hence the possibility of gender differences in the reaction time could not be analysed. Further to that, researchers could not confirm the question of sustainability of the beneficial impact of aerobic exercise on reaction time.

The aforementioned studies<sup>10,11</sup> were conducted on young people and children, in which coordination related exercises were included, and improvement in health and fitness related parameters were focussed, while no adequate consideration on improvement in coordination was emphasized. Hereafter, studies carried out on individuals diagnosed with DCD were reviewed. Shoemaker et al.<sup>12</sup> conducted a pilot study to evaluate the effectiveness of a neuromotor task training (following a protocol 30 minutes/day, 1 day/week for 18 weeks) in the treatment of children with DCD. Fifteen children with DCD were recruited for the study (10 were included in the intervention group and five others were categorized into control group). Movement Assessment Battery for children and the concise assessment method for children's handwriting were employed for assessment of movement. Although researchers confirmed significant improvement in the intervention group, result of this study should be inferred with caution, due to inclusion of small sample size and unequal distribution of the participants in the intervention and control groups.

Ashkenazi and colleagues<sup>13</sup> instead conducted a research recruiting 30 children with DCD, who were randomly divided into two groups of 15 each. One group underwent conventional coordination training whereas, the other group was introduced to virtual reality games (with a protocol for 60-minute/session; 10 sessions/week, for 12 weeks). Activities such as aerobics, eye hand coordination, balance activities, and specific tasks such as catching and bouncing the ball were given. The other group was introduced to virtual reality in the form of accomplishing task in games. Movement assessment battery for children, development coordination disorder questionnaire (DCDQ), parents' subjective report, walking and talking test and short feedback questionnaire (SFQ) were assessed prior to the intervention and one week after the intervention. Both the conventional training and virtual reality-based games were evident as equally beneficial for young children with DCD. The main drawback of this research was small sample size, lack of control group and absence of follow up analysis to observe the level of sustainability of the intervention.

Hung and Pang<sup>14</sup> recruited 23 children (4 girls) with DCD ( $\bar{x}/\sigma = 8/1.16$  years) and investigated effects of group-based and individual-based motor skill training on motor performance in children with DCD. Motor ability was assessed using The Movement Assessment Battery for Children (MABC). Children were randomized into 2 groups and Gr. 1 (n = 12) underwent motor training program in a group setting situation (protocol was 1/week for 8 weeks), whereas the other 11 children received the same treatment individually. Each child was also instructed



to perform home exercises on daily basis. Exercise compliance, home exercise compliance and parental satisfaction with the programs were evaluated. Outcomes of this study revealed effectiveness of motor training programme administered individually and in a group setting as well. The researcher of this study themselves identified various shortfalls, such as, small sample size, absence of no treatment control group, and the low power of the study. Further to that, long-term effects of the intervention performed, could not be ascertained, and more importantly the researchers were not sure whether the improved performance noted were due to the intervention used or due to the normal development of the children.

In the spectrum of conventional coordination training on psychological variables, Saha et al.<sup>15</sup> examined the effect of muscle relaxation training as a function of improvement in attentiveness in children. Sixty-four school children, half of them from Bangladesh and half of them from India, having a high trait anxiety and attention deficit were recruited. They were randomized into 2 groups. One group received Abbreviated Progressive Muscle Relaxation (APMR) training and other group were the control group. Baseline information on attentive capacity, muscle potentiality and skin conductance (for protocol refer to Saha et al.,<sup>16</sup>) were recorded. The intervention group was exposed to APMR, 15mins/day and three days per week for 2 months. Post intervention assessment and follow up were done after two months, to examine the sustainability of the intervention. The researchers concluded that APMR was found to reduce the levels of anxiety and improve the attentive capacity of the students. Certain drawbacks were observed such as lack of concealment of allocation and blinding of participants, or that of researchers or the assessor in the study which could have resulted in some methodological biases in the research. Lack of other intervention groups in the research apart from APMR can be visualized as one of the shortfalls of this research.

With an intention to assess functional motor skills of children

with DCD, Männistö et al.,<sup>17</sup> investigated the effectiveness of a school-based movement programme for children with motor learning difficulty. A total of 51 children were recruited from 6 primary schools, who were randomized into 4 different groups (viz., motor learning difficulty group n = 10; borderline motor learning difficulty group, n = 5; trained control group (n = 9, and untrained control group n = 9) based on the level of motor learning difficulty. Motor performance of the children were assessed by employing Movement assessment Battery for children (MABC). The treatment protocol comprised of structured group play, individualized skill training, relaxation and cooling down for 20, 25 and 15 minutes, respectively, which altogether took one hour/session. Total programme consisted of 26 weekly sessions. The motor assessment was carried out at 1<sup>st</sup>, 12<sup>th</sup> and 26<sup>th</sup> session. The authors concluded that the Task-oriented intervention principles were effective in enhancing the functional motor skills of children with MLD. Hosseini et al.,<sup>18</sup> on the other hand, examined effect of training on cognitive motor skills and physical fitness factors on preschool children. 50 children were randomly chosen and categorised into an experimental and a control group. The experimental group underwent a combined training program (strength, aerobic and anaerobic exercises) for three sessions a week, each session lasting 45 minutes for 8 weeks. The control group was allowed to continue with their daily activities. Outcomes revealed that combined training group had significant improvement in cognitive motor skills compared to their counterparts in the control group. Several limitations diminished significance of this study, as control group participants could not be rigorously monitored. Furthermore, the exercise group underwent an exercise training program involving combination of strength, aerobic and anaerobic exercises. Hence the observed improvement could not be attributed specifically to any particular form of exercise, or contribution of a combined form of exercise also could not be ascertained. Erickson and Kramer<sup>19</sup> reviewed the effects of aerobic exercise on the cognitive and neural plasticity on older adults has observed that aerobic exercise improved the cognitive function and control of movements. Since coordination is also a cognitive and motor function, it could be considered that aerobic exercise can be used to train coordination.

for evaluating the size of impacts of the interventions were also confirmed. Next sub-sections carry details pertaining to step-by-step discussions on the systematic review process, which included literature search strategy, inclusion and exclusion criteria, evaluation of quality and characteristics of the studies, analysis of the RCTs included, PRISMA Flow diagram, PEDro Scale analysis, and Forest-Plot analysis.

## 2. METHODOLOGY

### 2.1 Methods of Literature Survey

This literature review was considered following objective evaluation of the available research literatures. Thus, relevance, authenticity, and quality of the research literatures included in this review were ensured. Further to that, authentic methodology

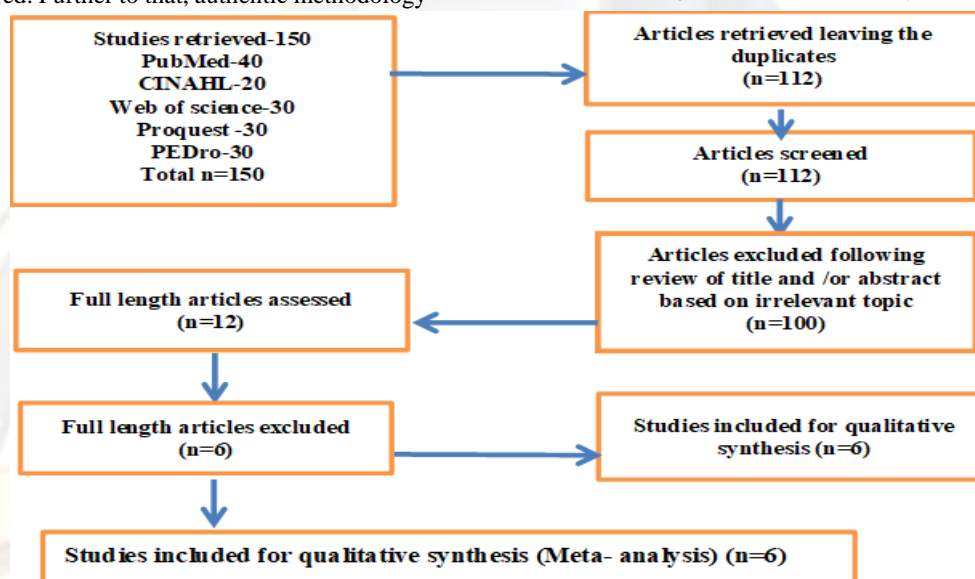


Figure 1. PRISMA Flow Diagram Showing the Selection of Trials

## 2.2 Literature Search Strategy

A thorough online search using Web of Science, ProQuest, PubMed, Ebscohost, CINAHL was performed to obtain articles published between 1990 and 2014. The search strategy consisted of terms conventional coordination training or coordination training. Cross-referencing of articles was done to identify any articles not found with the initial search. The PRISMA flow diagram showing the selection of articles is shown in Figure 1. Search strategy used some authentic, relevant, and valid keywords, and terms, such as - “coordination”, “coordination disorder”, “motor problem”, “motor coordination”, “movement coordination”, “motor skill”, “motor learning problem” which were introduced in intervention-oriented RCTs. Combining aforementioned keywords, focussing on outcomes, terms for instance, “improvement in motor skill”, “improvement in motor and movement performance”, “motor performance improvement”, “coordination improvement”, “movement coordination enhancement” etc., were used to search studies focussing on outcomes. This literature search was exclusively

limited to studies published in indexed Journals, peer reviewed, and written only in English language. In the next sub-sections, inclusion criteria of the included RCTs have been discussed, and as per the inclusion criteria and the evaluation guidelines, following the search strategies and using appropriate terms or keywords RCTs pertaining to conventional coordination intervention were searched.

## 2.3 Inclusion criteria of the Research Literatures

In this review, internal validity of the experimental studies and literatures included was analysed. Apart from that, criteria for studies included were on -

- (i) **Design:** Trials in which coordination training were used on participants were included irrespective of the study design.
- (ii) **Interventions:** The coordination training and a comparative exercise only and/or other intervention used to increase the level of psychomotor performance.
- (iii) **Study Populations:** Participants with coordination deficiencies.
- (iv) **Outcome Measure:** The study included needed to investigate the changes in psychomotor skills.
- (v) **Language:** The articles written in English were only included in the review.

**Table 1 PEDro Scores of the Trials**

RCTs included	Eligibility criteria?	Allocated randomly?	Allocation concealed?	Baseline compared?	Participants blinded?	Therapist blinded?
Ashkenazi et al., 2013	√	√	x	√	x	√
Hung & Pang, 2010	√	√	√	√	x	x
Mannisto et al., 2006	x	x	x	x	x	x
Fong et al., 2016	√	√	√	√	x	x
Henry et al., 2006	√	x	x	√	x	x
Shin et al., 2015	√	x	x	√	x	x

**Table 1 PEDro Scores of the Trials (Continued)**

RCTs included	Assessors blinded?	Adequate follow up?	Intention to treat?	Between group analysis?	Point estimates and variability?	Score
Ashkenazi et al., 2013	√	x	√	√	√	8
Hung & Pang, 2010	√	√	√	√	√	9
Mannisto et al., 2006	x	√	√	√	√	4
Fong et al., 2016	√	√	√	√	√	9
Henry et al., 2006	√	√	√	√	√	7
Shin et al., 2015	x	√	√	√	√	6

**Table 2 Demographic Characteristics of the Trial**

Researcher	Diagnosis	Age (years)	Population	Male/Female	Outcomes
Ashkenazi et al., 2013	DCD	5.2±0.6	30	25/5	- Movement Assessment Battery for Children (M-ABC-2) - Developmental Coordination Disorder Questionnaire-07 (DCDQ-07) - Parents' subjective report - Walking and Talking test - Short Feedback Questionnaire for children (SFQ-Child)
Hung & Pang, 2010	DCD	8.0±1.2	23	19/4	- Motor performance - Home exercise compliance - Parental satisfaction
Mannisto et al., 2006	Motor Learning Difficulty	6.2±0.8	33	13 /20	- Movement Assessment Battery for Children (ABC)
Fong et al., 2016	DCD	7.9 ± 1.4	130	89/41	- Sensory organization test (SOT) - Maximum isometric muscle strength (peak force)
Henry et al., 2006	Eating Disorders	19.1± 1.6	72	0/72	- Body Image
Shin et al., 2015	Cerebral Palsy	100.8±16.1 (months)	16	9/7	- Eye hand coordination

## 3. RESULTS AND DISCUSSION

### 3.1 Methodological Quality Assessment:

All included articles were assessed using the Physiotherapy Evidence Database (PEDro) scale. PEDro scale is an extensively used critical appraisal tool consisting of 11 – point scale used to assess the methodological issues within articles. The PEDro scores are given in Table 1. Followed by the table of PEDro (Physiotherapy Evidence Database Scale Scores) of the trials, in the tables 2 and 3, demographic characteristics of the included trials and characteristics of intervention of the included trial are presented.

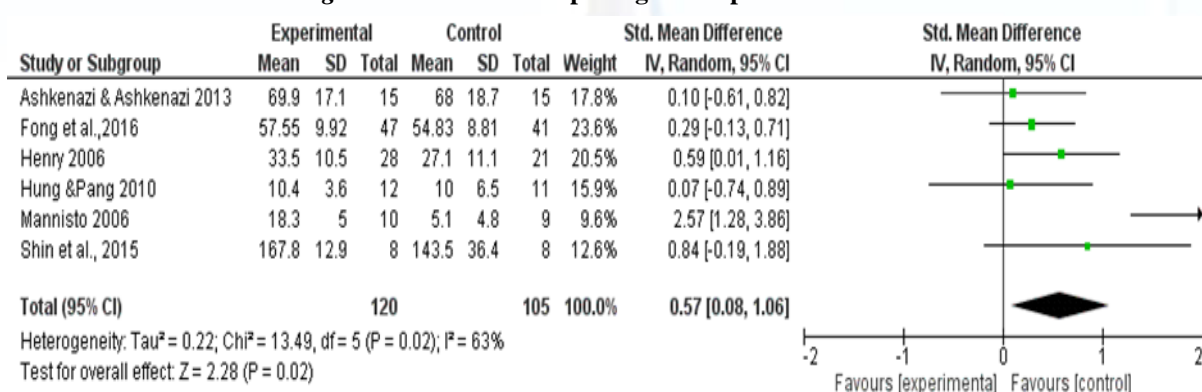
### 3.2 Statistical Analyses:

The means and standard deviations of the post intervention data were collected for both the coordination training and the other intervention groups. Standardised effect sizes and 95% confidence intervals were calculated. The standardised effect sizes allowed us to compare the results among different studies. The data were separated based on the outcomes of movement. Effect sizes were classified as weak ( $d \leq 0.2$ ), small ( $d = 0.2-0.5$ ) moderate ( $d = 0.5-0.8$ ) and strong ( $d \geq 0.8$ ) (Cohen, 1992). The analysis was performed using Review Manager (RevMan, V.5.3.; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).



Researcher	Conventional training	Other group intervention	No treatment control	Duration
Ashkenazi et al., 2013	Playing any game like bowling, basketball etc by using the usual physiotherapy equipment like, bench, balls, ladder etc.	Virtual Reality Games		1 day per week for 12 weeks
Hung & Pang, 2010	Individual based Motor skill training programme	Group based Motor skill training programme		1 day per week for 8 weeks
Mannisto et al., 2006	Task grouping approach- practiced both balance and ball skills.	Task grouping approach- practiced only ball skills.  An extra session of balance and ball skill training with regular physical education	No intervention	1 day per week for 26 weeks
Fong et al., 2016	Functional Movement Training	Functional Movement–Power Training	No intervention	2 days per week for 3 months
Henry et al., 2006	Interval circuit training	Aerobic exercise	No intervention	3 days per week for 12 weeks
Shin et al., 2015	Conventional neurological physical therapy	Virtual reality training		2 days per week for 8 weeks

Figure 2. Forest Plot Depicting the Improvement in Movement



Six trials involving a population of 225 participants were included in this review. The methodological quality of the studies included in the review was found to be good with an average score of 7.17 out of 11. Most of the studies<sup>10,13,17,21</sup> were found to lack in concealed allocation and blinding of participants, assessors and/or clinicians. Two studies<sup>14,20</sup> were evident as having best quality of evidence, and both received 9 out of 11. The demographic description of the included trials can be viewed in Table 2. The details regarding the type of coordination training, duration of the intervention and the intervention imparted to the control group or other groups is provided in Table 3. Analysis of the importance of coordination training is showed that all the trials favoured the control group. The overall effect size of the analysis was 0.57 with a confidence interval of 0.08, 1.06. The  $I^2$  value i.e., an index of measuring heterogeneity was 63% showing moderate heterogeneity. The possible reasons of the moderate to high heterogeneity was already discussed in the earlier sections of this review. The effect size of the trials was observed to be high, moderate, and low. One trial was found to have high effect size, two trials had a moderate effect size and two trials had a weak effect size. It can be inferred that coordination training did not seem to be beneficial compared to the control groups. The  $\tau^2$  value was 0.22 and the  $\chi^2$  value was 13.49 with degree of freedom ( $df$ ) 5. The  $P$  value was at 0.02. It could be observed that in most of the experimental studies, the participants in the control groups were subjected to some form of training, which could have resulted in outcome of the meta-analysis to show a result favouring the control group. The heterogeneity observed in the meta-analysis is due to too much of variations among the trials. There was huge disparity among the sample size of studies, the population, among the intervention techniques followed and the duration of intervention sessions as well, which might have resulted in the outcome observed in the meta-analysis.

### 3.3 Summary of the Previous Literatures and Implication for the Present Study

Conventional coordination training has so far been acknowledged as the mainstay of treatment for coordination deficiencies. Present review even though has once again confirmed this phenomenon, but also has been able to uncover some inadequacies in coordination training protocols being followed. This review has highlighted on role of perceptual motor training on various parameters in different individuals. Apart from that this review also has emphasized introduction of EMG biofeedback technique in muscular activation training in players and other individuals to improve coordinated performance. But overall lots of disparities and deficiencies have been observed in the methodology of those investigations. The study on application of EMG Biofeedback and perceptual motor training, has been evident as having minimal focus on training of coordination deficiencies. Likewise, the effect of the combined intervention of perceptual motor training and EMG Biofeedback has not been researched following rigorous methodology and especially in the field of sports for recreational athletes. Hence more emphasis on investigations in the field of EMG assisted perceptual motor training should have been warranted to find out the real effect of these interventions.

## 4. CONCLUSION -

In summary, review of literature clarified some pertinent issues, as coordination deficiencies are commonly evident among normal, healthy and among physically active individuals. In case of individuals identified as having coordination deficiencies, conventionally developed and practised coordination training regimes should be considered as the backbone of coordination training. As universally acceptable and standardised protocol for coordination training regime is not yet available, need for development of perceptual motor training for facilitating motor and movement coordination is being solicited. Authors further recommend a rigorously developed EMG-assisted perceptual motor

training protocol, which could be applied for improvement in psychomotor, psychobiological as well as psychological aspects of recreation athletes having coordination deficiencies. Since there is a dearth of literatures, which incorporated combined intervention protocol of EMG assisted perceptual motor training and conventional coordination training, authors of this review recommend future studies implementing combined intervention protocol following rigorous methodology.

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## 6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments: SoS, SrS

Literature search: MaA, FaS, SoS

Evaluation of Quality of Literatures: SrS, SoS

Analysed the data: FaS, SoS

Wrote the manuscript: SrS, SoS

Checked and edited the format: SoS, SrS, SeN

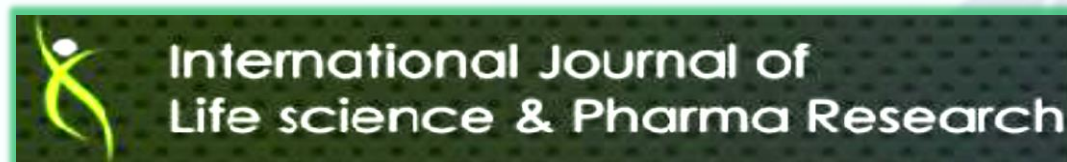
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# Effectiveness of Differential Biofeedback Intervention Regimes on Athletic Performance: A Meta-Analytic Systematic Review

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Biofeedback, skin conductance, EMG, EEG,  
athletics, performance, sport skill

## ABSTRACT

**Background:** Performance disaster in athletes stem from multifaceted areas of crises, which may range from physical musculoskeletal problems to physiological, psychomotor, and psychobiological deficiencies as well. Bulk of experimental studies emphasized on introduction of biofeedback intervention as effective psychological skill training.

**Aim:** This present review intended to systematically review published research literatures to (i) provide some authentic information on impacts of biofeedback or neurofeedback intervention training on performance enhancement in some specific athletic skills, (ii) identify etiological issues associated with disastrous performance evident among athletes and (iii) investigate on the biofeedback training regimes, and to identify the salient features of the regimes, which had relative contribution on athletic performance enhancement. This article also intended to examine the prevalent and existing theoretical constructs and to recommend future course of research experimentation in this domain of interest.

**Method:** Several databases such as - PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, ProQuest, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL (National Digital Library) databases were methodically searched for articles on effectiveness of Biofeedback intervention training on skilful athletic performance, published between 2010 and 2020.

**Results:** Findings of this systematic review work, based on available literatures, however, claimed the possible beneficial impact of composite introduction of biofeedback intervention in different modalities, on athletic performance. The overall effect size was evident as 1.11, with a confidence interval of 0.76, 1.45.

**Conclusions:** Numerous studies were on biofeedback intervention were conducted, but majority of those were evident to lack in authenticity and methodological transparency. Authentic RCT studies on biofeedback intervention, however, confirmed efficacy of biofeedback interventions on athletic performance.

## 1. INTRODUCTION

Athletes all over the world acknowledge the significance of mental skill training in augmenting optimal performance, as much as it is contingent upon physical skill and technical or tactical preparations<sup>1,2</sup>. Track and field athletes, alike all other players pass through extreme challenges due to time-constraint, and competitive stress intensifies that up to a catastrophic end<sup>3-5</sup>. Apart from the widespread misconceptions in the prevailing milieu concerning natural stress-inoculation ability of the elite athletes<sup>3-6</sup>, athletes themselves also reported to have false belief that, they are psychologically strong or mentally tough<sup>7-12</sup>, or they possess hardy personality<sup>10-13</sup>. These ambiguous and unworthy conceptions and false self-beliefs often provoke them to neglect essential aspects of psychological skill training, which in turn obviously lead to dismal athletic performance<sup>3-5</sup> and resultant sense of dejection and apathetic feelings<sup>6-10</sup> toward athletic achievements<sup>12</sup>.

Performance disaster has so far been explained based on cognitive constrictions concerning motor and movement skill and coordination<sup>14</sup>, debilitating impacts of heightened arousal and anxiety, arousal, and narrowing of attention, anxious apprehension

etc. concerning athletic performance<sup>15</sup>. Multidimensional aetiology of sport performance catastrophe, however, was clarified by Martens and colleagues<sup>16</sup>, who highlighted on differential influence of cognitive and somatic anxiety on athletes. Porges<sup>17</sup> on the other hand, stressed on autonomic functions and explained heart-rate variability as the basis of emotionality among athletes. Based on those theoretical underpinning, it was considered essential to observe impact of biofeedback intervention on psychobiological, physiological, psychomotor, and physical performance parameters as well.

### 1.1 An Overview of the Study

This review work was carried out based on the reported findings, in which generalised overview of the outcomes of the research were carried out, and thereafter validity of the reported literatures was critically analysed. In order to justify the research questions based on authentic empirical evidence-based studies, quality of the experimental trails was evaluated. Hence, prior to discuss on the reports of scrutiny of the previous literatures, extensive literature search was conducted, and based on the literature search strategy the PRISMA flow diagram was prepared. Based on the extensive search of the literatures, overall

scenario appeared not promising, and thus based on inclusion criteria, whatever research available (published in authentic journals) were appraised by the Methodological Quality Assessment, which was carried out by employing the (PEDro) scale (detailed in next section) analysis, followed by meta-analytic review of literatures and Forest-plot analyses.

## 2. METHODOLOGY

### 2.2 Methods of Literature Survey

In this study, objective evaluation of the available research literatures was considered. This was primarily done to nullify the problems pertaining to lack of authenticity and relevance of the studies. Next objective was to quantifiably present the studies, based on quality of the research and with the evaluation of size of impacts of the interventions as well. In the next sub-sections, step-by-step discussions on the systematic review process are kept in details, which included literature search strategy, inclusion and exclusion criteria, evaluation of quality and characteristics of the studies, analysis of the RCTs included, PRISMA Flow diagram, PEDro Scale analysis, Forest-Plot analysis.

### 2.2 Literature Search Strategy

In order to make the review of literature more authentic and objectively based, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement guidelines<sup>18</sup>, were followed. As Moher et al.,<sup>18</sup> emphasized, the main purpose of considering PRISMA, was to ensure adequate accuracy, completeness, transparency, and frequency of reported systematic review and meta-analysis protocols. Adherence to PRISMA ensured transparency in the literature search, data extraction, and data analysis procedures. The guidelines included rigorously followed four-step systematic approach (viz., identification, screening, eligibility, and inclusion). Meticulous search of experimental studies was conducted to search for RCTs (randomised controlled trials) only, which investigated impacts of Biofeedback on improvement in athletic skills. Research reports were obtained primarily through electronic journal searches and also manually (up to August 2020). This review utilized the archives of PubMed, WOS, SCOPUS, SportDiscus, PsychINFO, PsycARTICLES, Google Scholar, ScienceDirect, ResearchGate, Academia.edu, and NDL (National Digital Library) databases. Search strategy used some authentic, relevant, and valid keywords, and terms, such as - "biofeedback", "Sc biofeedback", "EMG biofeedback", "neurofeedback", which were introduced in intervention-oriented RCTs. Combined aforementioned keywords, focussing on outcomes, terms for instance, "improvement in athletic and sports skill", "improvement in sport and athletic performance", "athletic performance improvement", "sport performance improvement", "performance enhancement" etc., were used to search studies focussing on outcomes. This literature search was exclusively limited to studies published in peer reviewed, indexed Journals and written only in English language. In the next sub- sections, inclusion as well as exclusion criteria of the included RCTs have been discussed, and as per the inclusion criteria and the evaluation guidelines, following the search strategies and using appropriate terms or keywords RCTs pertaining to biofeedback intervention were searched.

### 2.3 Inclusion and exclusion criteria of the Research Literatures

In this review, internal validity of the experimental studies and literatures included was analysed. Apart from that, criteria for studies included were on - (a) RCT studies, (b) having control or no-intervention group, (c) assessed performance outcomes, (d) employed valid and highly reliable gadgets, and (e) recruited healthy athletes having no complications as participants.

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation of quality of the studies to be included

One of the standard procedures for systematic review or meta-analysis, is evaluation of RCTs following Physiotherapy Evidence Database (PEDro) scale<sup>19</sup>, which appropriately evaluates the quality of the studies included. PEDro analysis rates validity of research studies following 11 criteria, viz: (a) specified inclusion or eligibility criteria, (b) random allocation of participants, (c) concealed or masked allocation, (d) similar baseline or pre-intervention level, (e) participants blinded, (f) blinding of therapist or intervention trainer, (g) blinding evaluators, (h) less than 15% dropouts, (i) intention of treatment (j) between-group statistical comparisons, and (k) variability of the data. Item 1 is related to external validity, and hence it is not used in the scoring.

The next sub-section (Figure 1 is referred) represented the PRISMA flow diagram associated with the intervention regimes. Thereafter, the list of Studies carried out employing different types of biofeedback intervention techniques, viz., Sc, EMG etc biofeedback, neurofeedback interventions employed in enhancing sport performance (refer to table at <https://dx.doi.org/10.13140/RG.2.2.29578.18880>) were included. Based on PEDro analysis scores RCTs in this review were included.

### 3.2 Characteristics of studies on impact of Biofeedback or Neurofeedback included

Based on the of electronic database search strategy for the RCTs on biofeedback intervention, 328 potentially relevant studies were identified by initial literature search. 97 other RCTs were retrieved by additional searches of reference lists from other sources. Altogether 247 studies were excluded for duplication. Among the remaining 178 studies, only 107 studies met the criteria (as those RCTs dealt with biofeedback intervention on sports population) for data extraction requirements and had sufficient information to be included in this review. Rest of the studies were excluded from the review process. Thereafter, out of the 107 included articles, only 47 were evident as meeting the criteria for impact of biofeedback or neurofeedback training, on sport performance enhancement, and hence, those 47 records were thoroughly assessed based on the eligibility criteria. Based on PEDro scale analyses, out of those 47 RCTs only 19 studies were evident as quality RCTs, and hence, those were selected and included in the review. Under the intervention programs, few forms of intervention regimes were studied: biofeedback intervention in different modalities, viz., Sc; EMG; HR; HRV etc and neurofeedback training EEG alpha, beta, theta and delta waves, and combination of two different biofeedback or neurofeedback training. Some of the studies were evident to include more than one form of biofeedback or neurofeedback training (please refer to the Figure 1- PRISMA flow diagram).

In this review nineteen studies consisting of 542 sports persons were included, out of which 269 athletes and players received biofeedback or neurofeedback training. The included studies had a good score in methodological quality with an average of 6.263, with the highest score of 7, and the lowest was 4, which according to PEDro scale, is considered as moderately high score for RCTs<sup>20,21</sup> (refer to the table at <https://dx.doi.org/10.13140/RG.2.2.29578.18880>).

As per the PEDro Scale<sup>20,21</sup> evaluations, NH & MRC<sup>22</sup> criteria of demarcation; best evidence synthesis technique<sup>23</sup>, out of 19 RCTs included in this meta-analytic review, 2 studies<sup>24,25</sup> were observed to have grade - III-3 level of evidence, while 5 others<sup>26-30</sup> were evident to fall under grade - III-2 level of evidence. All of the remaining 12 studies<sup>6,7,15&31-39</sup>, however, were identified as having Grade II category of strong evidence<sup>20,21</sup> (<https://dx.doi.org/10.13140/RG.2.2.29578.18880>). Apart from that, two studies<sup>24,25</sup> were evident to receive PEDro Scale quality score 4 and 4.5 respectively and the study of Saha and coresearchers<sup>26</sup> received PEDro Scale quality score 5. Four other studies<sup>27-30</sup>, however, received PEDro Scale quality score 6 out of 11. Hence, as far as Hillier<sup>40</sup> recommended, these studies are supposed to be



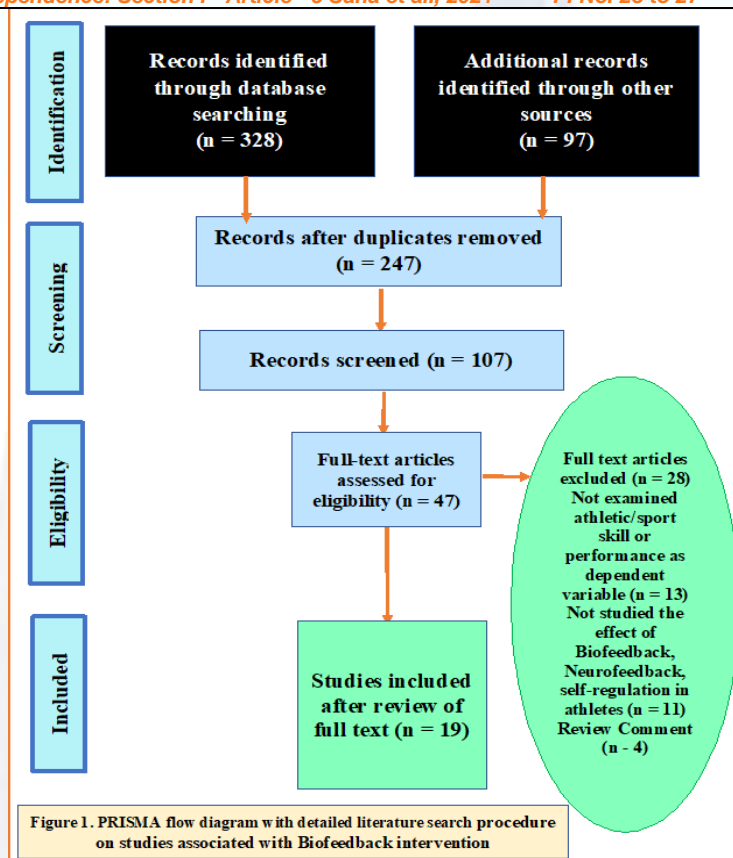
considered as above average quality studies, having high strength of evidence<sup>27</sup>. Moreover, quite a few other studies<sup>6,7,15&31-39</sup>, were observed to achieve PEDro scores within the range of 6.5 to 7 (refer to table <https://dx.doi.org/10.13140/RG.2.2.29578.18880>). Thus, these studies revealed moderately high level of authentic quality of evidence. To sum up, it may be postulated that the outcomes of this study indicated beneficial impact of the biofeedback or neurofeedback training regimes in improving performance among promising athletes or sport persons. Based on the data retrieved from the aforementioned RCTs Forest Plot analysis was carried out (REVMAN. Review ID: 662721012714331182).

The Forest Plot analysis (REVMAN. Review ID: 662721012714331182), however, revealed a valid meta-analytic outcome, which confirmed beneficial impact of the intervention techniques employed in those RCTs. Risk of bias analysis score of 6.05, indicated that the RCTs were carried out with adequately safe methodology employed. Thus, the RCTs included in this systematic review were observed to carry higher level of strength of evidence (based on PEDro scale score) and higher level of methodological clarity as well. Hence, the outcomes evident in the Forest Plot analysis favouring the beneficial impacts of interventions introduced, got further strength, as the overall effect size was evident as 1.11, with a confidence interval of .76, 1.45. The heterogeneity of the included studies was evident as 68%, which is considered to be at the moderate level in the arena of intervention trials. Reason behind this heterogeneity, could be attributed to range of differences evident in RCTs, which were already detailed in the earlier section. The  $\chi^2$  value was observed as 56.87 ( $P=0.00001$ ), with degrees of freedom of 18.

The meta-analysis, however, indicated that all of the nineteen studies included in this survey clearly confirmed efficacy of biofeedback interventions in improving athletic skills. In sum up it may be postulated that, impact of biofeedback intervention on improvement in athletic skill is favourable, although outcomes from larger number of RCTs could yield more generalised information. Furthermore, studies did not confirm efficacy of any particular mode of biofeedback or neurofeedback, and hence, outcomes could not be considered as adequately convincing. If RCTs on biofeedback training itself could be designed following rigorous methodology, and outcomes on athletic performance skills could be analysed on a large number of participants, outcomes could be more comprehensively reliable. Apart from that, the extent of heterogeneity evident, however, also raised questions on the methodological clarity of the RCTs evaluated, and hence the outcomes also highlighted the need of more authentic research on this issue.

### 3.3 Summary of the Meta-Analyses on impact of VMBR

Outcomes of this systematic review of RCTs retrieved from the databases on impacts of biofeedback on athletic performance emphasized on some significant aspects pertaining to the paradigms should be incorporated in RCTs. Those issues were categorically evaluated in this review through the forest-plot analysis, and those are being summarised as major issues of concern for the methodological preparation. In this review, Dziembowska and colleagues<sup>27</sup> for instance, working with male soccer and basketball players, confirmed that, HRV BF intervention substantially improved the HRV indices and modified both alpha and theta brain waves. Thus, this research highlighted on the interrelationships between the brain-heart functions and coordination between the systems in developing psychobiological mechanism for optimal sport performance. Saha and his coresearchers<sup>15</sup>, engaging soccer players reported on efficacy of both Sc and EMG BF interventions in improving soccer shooting. They hinted upon the role of different mediators, as Sc BF facilitated faster autonomic recovery, EMG BF triggered larger amplitude (MVC), which resulted in improved bilateral shooting performance. Contemporarily, working



with 54 soccer players, Saha et al<sup>33</sup>, confirmed the previous outcome of improvement in bilateral shooting ability and convincingly reported that, both Sc and EMG BF intervention techniques had beneficial impacts in emotional adaptation and in control of electrical muscle potentiality (MVC), while Sc BF alone modulated non-specific emotional startle response better than the combined introduction of Sc and EMG BF intervention.

Deschodt-Arsac et al.<sup>29</sup>, working with smaller sample (only 18 students), confirmed that training of HRV BF for twelve weeks had better impact on both autonomic regulation and on inoculating performance anxiety. Carrying out a series of studies, Saha et al<sup>6,35</sup> on promising soccer players confirmed efficacy of both Sc BF and EMG BF intervention in improving movement coordination. They clarified that, enhanced autonomic competence induced faster recovery, which had better movement coordination<sup>6</sup>. Employing similar paradigm on larger sample, Saha et al<sup>35</sup>, reported facilitative impacts of BF interventions in improving soccer ball juggling performance. They proposed that, compared to Sc BF, frontalis EMG BF emerged as better effective intervention regime, in improving soccer juggling skills, as improved peripheral regulation was hypothesized as the mediator for this development.

Ismail et al.<sup>30</sup>, contemporarily conducting research on HP soccer players, evidenced beneficial impacts of both Sc BF and EMG BF intervention in improving reaction performance. According to them, compared to EMG BF, Sc BF technique produced faster reaction performance, which was mediated by enhancement in mood states, reduction in dispositional and transient anxiety and improved psychobiological competence, which finally induced faster recovery, and in turn facilitated reaction performance. Similarly, Saha et al.<sup>35</sup>, conducting series of research on soccer players examined the impacts of both EMG and Sc BF techniques, and reported on improvement in bilateral soccer shooting skills, although Sc BF players emerged as having better outcomes. They further commented that, players of EMG BF group evidenced reduction of irritability, somatised anxiety, anger and feeling of fatigue, but they faced with problems pertaining to higher extent of feeling of depression, which directly inhibited in consistent high soccer shooting performance.

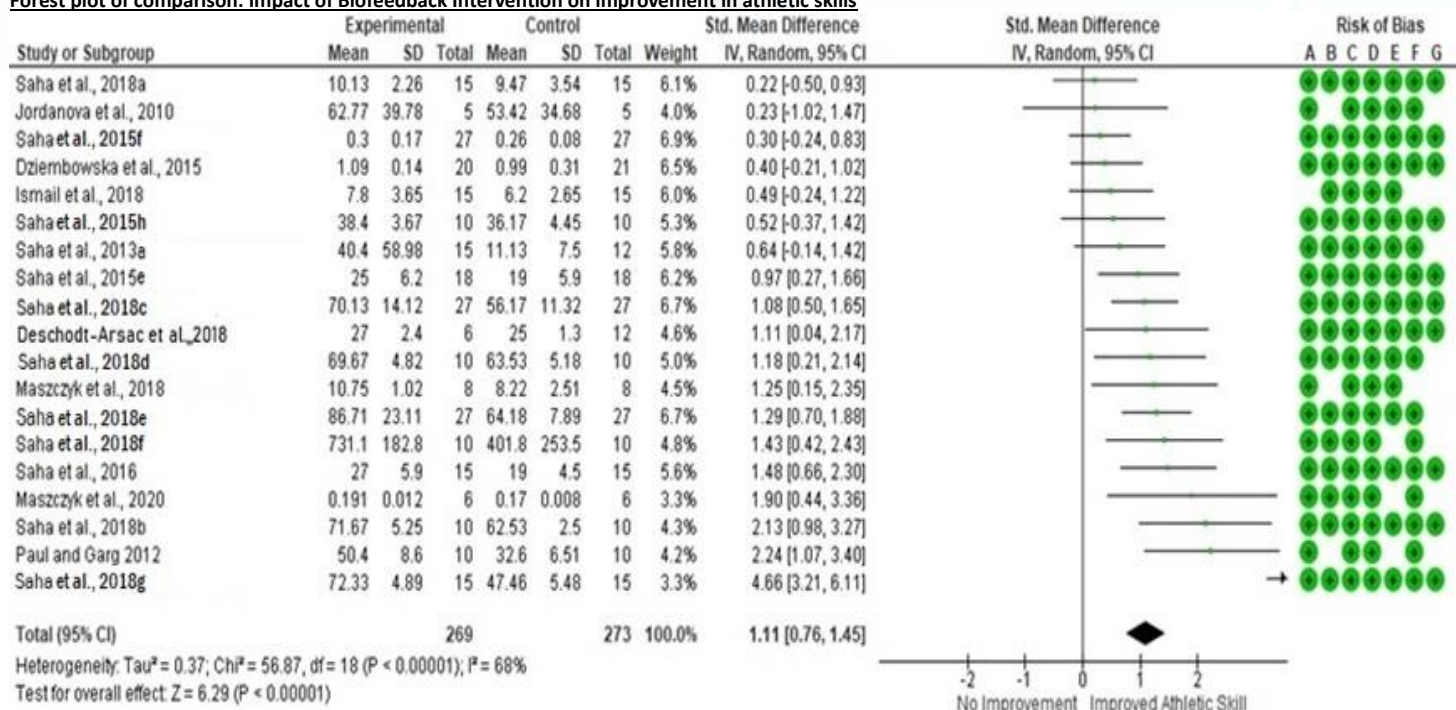
In their next studies on players following identical paradigms, Saha et al.<sup>35,39</sup>, reported differential outcomes of BF intervention techniques, as they observed no impact of both Sc and EMG BF interventions in improving vertical jump performance, although both of the BF interventions had beneficial impacts in improving soccer ball juggling performance skill. Furthermore, Sc BF intervention was evident as better technique in modulating mood and emotional factors, which mediated enhancement of autonomic competence, facilitating improved soccer ball juggling performance. Saha et al.<sup>35</sup>, on the contrary reported that, frontalis EMG BF intervention training reduced peripheral neural tension and enhanced neuromuscular adaptation at the lower limb, which was hypothesized as effective in producing better juggling performance. As in the previous study<sup>35</sup>, EMG BF on rectus femoris muscles was found effective in soccer juggling, frontalis EMG BF was also evident in improving juggling performance<sup>39</sup>. Sc BF technique contrarily improved cognitive

emotional adaptation leading to enhanced autonomic competence and bimanual coordination, which perhaps helped the players to remain task-focussed and led to enhancement in juggling performance.

Contemporarily, Maszczyk et al.<sup>31,34</sup>, conducting studies on male Judo athletes, reported reduction in theta and alpha values and increment in the beta values, observed in the experimental group. They postulated that these changes in EEG waves facilitated in dynamic balance. The other research on Judo athletes<sup>34</sup>, however, introduced NFB based training on theta-wave inhibition and amplification of beta-wave, and confirmed that NFB improved the reaction time in judo athletes. Outcomes of these two studies, suggested significance of neural regulation in strength and conditioning in sports requiring quick and precise reactions for success. Finally, Saha et al.<sup>37</sup>, studying on soccer players claimed BF interventions caused improved interrelations between mood-states, emotionality, and autonomic factors, which had differential contributions on soccer performance skills.

REVMAN. Review ID: 662721012714331182

Forest plot of comparison: Impact of Biofeedback Intervention on improvement in athletic skills



Risk of bias score was evident as 6.05 (very much safe scores to be considered in meta-analysis)

## 4. CONCLUSION -

### Summary of the literature review

This meta-analytic review investigating current evidence on effectiveness of biofeedback intervention regimes on performance of specific athletic skills requiring agile reaction, offered a decisive summary on the aspect. Since literatures based on the existing theoretical considerations revealed several limitations, authors of this review attempted to examine research conducted on differential sub-components of physiological; psychophysiological; psychomotor, and physical performance

factors associated with athletic performance. As per the methodological considerations, quite a few of the available RCTs were evident as not of vital significance, hence those were evaluated as per PEDro Scale scores. In consequence, meta-analytic Forest Plot evaluation was performed on fewer relevant RCTs only, which confirmed efficacy of biofeedback intervention in enhancing athletic performance. Authors of this study recommend introduction of composite biofeedback training protocol, designed with multiple modalities of biofeedback training regimes. Impacts of biofeedback and neurofeedback training following rigorous methodology on athletics require more authentic and in-depth investigations.



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## 6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments: SoS, , HaH, FoH,  
Literature search: SrS, SoS, FoH,  
Evaluation of Quality of Literatures: SrS, SoS  
Analysed the data: SoS  
Wrote the manuscript: SrS, SoS  
Checked and edited the format: SoS, SrS,  
Final approval: SoS, SrS, HaH


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## Process of Acceptance for SECTION I articles (Systematic Review Articles)

Article ID	Reviewer	Affiliation	Assigned as	Decision
<b>MS-BD50</b> <b>Lit-Rev. - 1</b>	Asso. Prof. Dr. Santanu Dutta	Associate Professor, Dept. of CTVS, Inst. of PG Medical Education and Research, Kolkata, India	First reviewer on <b>March 11<sup>th</sup> 2021</b>	Accepted with minor change
	Dr. Satyapriya De Sarkar	Gastroenterologist G D Hospital & Diabetes Institute Kolkata, India	Second reviewer on <b>March 24<sup>th</sup> 2021</b>	Accepted after major Change
	Prof. Dr. Asok Ghosh	Professor, Sports Science RKMV University, Kolkata, India	Final reviewer on <b>April 23<sup>rd</sup> 2021</b>	Accepted for publication on <b>7<sup>th</sup> of July 2021</b>
Article ID	Reviewer	Affiliation	Assigned as	Decision
<b>MS-BD50</b> <b>Lit-Rev. - 2</b>	Dr. Maibam Chourjit Singh	Asso. Prof. Department of Physical Education & Sport Sciences, Manipur University, Canchipur, Manipur, India	First reviewer on <b>March 4<sup>th</sup> 2021</b>	Accepted with minor change
	Dr. Miftakhul Jannah	Professor, Training and Education Development Centre State University of Surabaya Surabaya, Indonesia	Second reviewer on <b>March 12<sup>th</sup> 2021</b>	Accepted after major Change
	Dr. Debashish Chowdhury	Sport Physician and Asst. Gen. Manager, Bangladesh Cricket Board, Dhaka, Bangladesh	Final reviewer on <b>April 3<sup>rd</sup> 2021</b>	Accepted for publication on <b>11<sup>th</sup> of July 2021</b>
Article ID	Reviewer	Affiliation	Assigned as	Decision
<b>MS-BD50</b> <b>Lit-Rev. - 3</b>	Dr. Dilsad Ahmed	Research Coordinator University of Macau, Macau, Guangdong, China	First reviewer on <b>March 14<sup>th</sup> 2021</b>	Accepted with minor change
	Asso. Prof. Dr. Nasrin Wadud	Associate Professor, Dept. of Psychology, Dhaka University, Dhaka, Bangladesh	Second reviewer on <b>March 18<sup>th</sup> 2021</b>	Accepted after major Change
	Dr. Miftakhul Jannah	Professor, Training and Education Development Centre State University of Surabaya Surabaya, Indonesia	Final reviewer on <b>May 3<sup>rd</sup> 2021</b>	Accepted for publication on <b>13<sup>th</sup> of July 2021</b>
Article ID	Reviewer	Affiliation	Assigned as	Decision
<b>MS-BD50</b> <b>Lit-Rev. - 4</b>	Dr. Debashish Chowdhury	Sport Physician and Asst. Gen. Manager, Bangladesh Cricket Board, Dhaka, Bangladesh	First reviewer on <b>March 4<sup>th</sup> 2021</b>	Accepted with minor change
	Dr. Dilsad Ahmed	Research Coordinator University of Macau, Macau, Guangdong, China	Second reviewer on <b>March 15<sup>th</sup> 2021</b>	Accepted after major Change
	Dr. Miftakhul Jannah	Professor, Training and Education Development Centre State University of Surabaya Surabaya, Indonesia	Final reviewer on <b>April 23<sup>rd</sup> 2021</b>	Accepted for publication on <b>11<sup>th</sup> of July 2021</b>
Article ID	Reviewer	Affiliation	Assigned as	Decision
<b>MS-BD50</b> <b>Lit-Rev. - 5</b>	Dr. Maibam Chourjit Singh	Asso. Prof. Department of Physical Education & Sport Sciences, Manipur University, Canchipur, Manipur, India	First reviewer on <b>March 7<sup>th</sup> 2021</b>	Accepted with minor change
	Dr. Dilsad Ahmed	Research Coordinator University of Macau, Macau, Guangdong, China	Second reviewer on <b>March 12<sup>th</sup> 2021</b>	Accepted after major Change
	Dr. Debashish Chowdhury	Sport Physician and Asst. Gen. Manager, Bangladesh Cricket Board, Dhaka, Bangladesh	Final reviewer on <b>April 3<sup>rd</sup> 2021</b>	Accepted for publication on <b>4<sup>th</sup> of July 2021</b>

## Finalised by the Guest Editors

Name of the Section Guest Editors	Affiliation of the Section Guest Editors	E- Signature of the Section Guest Editors
Prof. Dr. Asok Ghosh	Professor, Sports Science, RKMV University, Kolkata, India	
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