

Special Issue on ASEAN Scholarly Researches on Health & Exercise Science

ASEAN Scholarly Researches on Health & Exercise Science

This special issue was conceived to provide a platform to disseminate outcomes of researches conducted in ASEAN Universities, employing cutting-edge technologies to investigate on intricate and yet unexplored aspects associated with enhancement in sport performance excellence, and factors associated with management of health risk factors as well. Meta-analytic systematic review studies were included, which examined impacts of exercise and behavioural interventions in reducing the level of HbA1c among Malaysian Type 2 Diabetes Mellitus patients. Apart from that, effects of conventional physiotherapy exercise training regimes in enhancing muscle strength and in reduction of pain among female osteoarthritis patients were also investigated.

Experimental researches included in this special issue, investigated on effectiveness as well as cost-effectiveness of differential exercise intervention programs on improvement in perceived health-status evident among Malaysian diabetic individuals. Differential impacts of isokinetic training and conventional physiotherapeutic exercise intervention on perceived discomfort and pain in osteoarthritis patients was also investigated. Further to that, randomised controlled trials incorporating impacts of isokinetic training regimes, which were introduced following rigorous methodology, were also included in this issue, which investigated extents of improvement in pain management. Further to that, in-depth analyses on facilitative effects of isokinetic training on improvement of proprioception (reduction of active repositioning error) and on increment in peak torque generation were also carried out, which explained intricate processes involved in pain management among osteoarthritic patients of Malaysia.

Psychotherapeutic advancements in modulating performance, were also included in this special issue. These experimental trials by virtue of randomization studies investigated on the causal association between psychological and psychobiological interventions introduced in differential regimes, and the resultant impacts on performance excellence of sport skills.

Impact of emotionality, mood and autonomic factors, and impacts of differential biofeedback interventions on mood and emotional regulation, and also impact of autonomic competence and mood factors on reaction performance and other psychomotor abilities were investigated. Furthermore, enhancement in soccer agility, juggling skills and also bilateral shooting performance evident among promising Malaysian soccer players were investigated. Apart from Malaysian participants, researches on Indonesian athletes were also included, which on the basis of structural models revealed significance of concentration, self-confidence and emotional regulation among promising sprinters. Further to all these, empirical evidences on impacts of nutritional supplementation (different dosage of sodium bicarbonate) on freestyle swimming performance evident among Malaysian competitive swimmers was also investigated.

All these researches were critically reviewed and evaluated on the basis of double-blind review and based on suggestions optimal modifications of the original research submissions were adequately ensured. As Guest-editors of this issue, no stone was left unturned by us to warrant quality and validity of the researches, although core integrity of the academic discipline in concern was always upheld. We can vouchsafe that our aspiring attempts were only to contribute to the academic and research milieu of ASEAN communities, in order to encourage further replicated studies enriching the prevailing notions on exercise and health science studies in these regions. Here I am being the Lead Guest-Editor, would like to acknowledge the dedication of all the Guest-Editors and Reviewers, and I would most sincerely like to thank all of them, who relentlessly took care of their responsibilities to ensure validity of the researches and high academic standard of this issue.

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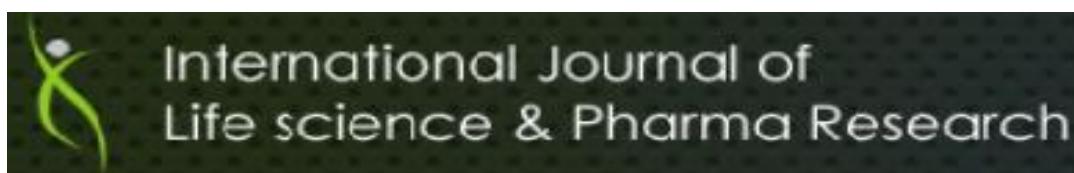
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SECTION III – Experimental Research

Report No.	Title	Authors	Page no.
ASEAN SP 1007	EFFECTS OF DIFFERENT DOSAGE OF SODIUM BICARBONATE ON 200 M FREESTYLE SWIMMING PERFORMANCE IN COMPETITIVE SWIMMERS	GEE YONG YONG, LER HUI YIN, WEE ENG HOE	66 - 71
ASEAN SP 1008	DIFFERENTIAL IMPACTS OF ISOKINETIC TRAINING ON PROPRIOCEPTIVE ACTIVE REPOSITIONING ERRORS COMMITTED BY OSTEOARTHRITIS PATIENTS	CHOO MORLEY LIZA; SOUMENDRA SAHA; AMRAN AHMED SHOKRI; NARESH BHASKAR RAJ; SRILEKHA SAHA AND FARIA SULTANA	72 - 84
ASEAN SP 1009	IMPACT OF EMOTIONALITY, MOOD AND AUTONOMIC FACTORS IN REGULATION OF OUTCOMES OF BIOFEEDBACK TRAINING ON SOCCER PERFORMANCE SKILLS	SRILEKHA SAHA; SOUMENDRA SAHA; FARIA SULTANA AND FOUJIA HUDA	85 - 95
ASEAN SP 1010	DIFFERENTIAL EFFICACY OF ISOKINETIC TRAINING AND CONVENTIONAL PHYSIOTHERAPEUTIC EXERCISE INTERVENTION ON PERCEIVED DISCOMFORT AND PAIN IN OSTEOARTHRITIS PATIENTS	SRILEKHA SAHA; CHO MORLEY LIZA; SOUMENDRA SAHA; HAIRUL ANUAR HASHIM; NARESH BHASKAR RAJ AND MOHD SAAT ISMAIL	96 - 109
ASEAN SP 1011	IMPACT OF BIOFEEDBACK INTERVENTIONS ON MOOD AND EMOTIONAL REGULATION AS PREDICTOR OF BILATERAL SHOOTING PERFORMANCE CHANGES AMONGST MALAYSIAN SOCCER PLAYERS	SRILEKHA SAHA; SOUMENDRA SAHA; FARIA SULTANA AND FOUJIA HUDA	110 - 119
ASEAN SP 1012	EFFECT OF ISOKINETIC TRAINING ON PEAK TORQUE GENERATED IN KNEE OSTEOARTHRITIS PATIENTS	MOHD ASRI ARIFFIN; ASOK KUMAR GHOSH AND MOHD SAAT ISMAIL	120 - 130
ASEAN SP 1013	EFFICACY OF DIFFERENTIAL EXERCISE INTERVENTION PROGRAMS ON IMPROVEMENT IN PERCEIVED HEALTH-STATUS AMONG MIDDLE AGED INDIVIDUALS WITH TYPE 2 DIABETES MELLITUS IN KELANTAN, MALAYSIA	FARIA SULTANA, SOUMENDRA SAHA, SRILEKHA SAHA, ROSMINAH MOHAMED, WAN MOHD IZANI WAN MOHAMED AND MOHD SAAT ISMAIL	131 - 140

ASEAN SP 1014	BENEFICIAL IMPACTS OF PSYCHOBIOLOGICAL CONDITIONING OBSERVED ON MOVEMENT COORDINATION IN ATHLETES	SOUMENDRA SAHA; NARESH BHASKAR RAJ; ASHOK KR. GHOSH AND NASREEN WADUD	141 - 151
ASEAN SP 1015	VARIATION IN MOOD AND EMOTIONAL REGULATION AS PREDICTOR OF ENHANCEMENT IN SOCCER AGILITY PERFORMANCE	SRILEKHA SAHA, SOUMENDRA SAHA AND FARIA SULTANA	152 - 165
ASEAN SP 1016	IMPACT OF BIOFEEDBACK INTERVENTION ON MOTOR ABILITY AND COORDINATION	SRILEKHA SAHA; MARUF AHMED; FARIA SULTANA AND SOUMENDRA SAHA	166- 175
ASEAN SP 1017	EFFECT OF ISOKINETIC TRAINING ON PAIN MANAGEMENT IN KNEE OSTEOARTHRITIS PATIENTS	ASOK KUMAR GHOSH AND MOHD ASRI ARIFFIN	176- 185
ASEAN SP 1018	FACILITATIVE IMPACTS OF BIOFEEDBACK INTERVENTION ON PSYCHOMOTOR ABILITIES IN IMPROVING SOCCER JUGGLING SKILLS	SRILEKHA SAHA; FARIA SULTANA; NASREEN WADUD AND ASOK KUMAR GHOSH	186 - 194
ASEAN SP 1019	IMPACT OF AUTONOMIC COMPETENCE AND MOOD FACTORS IN REGULATION OF OUTCOMES OF BIOFEEDBACK TRAINING ON REACTION PERFORMANCE EVIDENT AMONG MALAYSIAN PROMISING SOCCER PLAYERS	MOHD SAAT ISMAIL; SRILEKHA SAHA; SOUMENDRA SAHA; HAIRUL ANUAR HASHIM AND NASREEN WADUD	195 - 204
ASEAN SP 1020	BIOFEEDBACK INTERVENTION REGIMES AND ROLE OF DIFFERENT MEDIATORS IN ENHANCING SOCCER BALL JUGGLING PERFORMANCE	SOUMENDRA SAHA; FARIA SULTANA AND SRILEKHA SAHA	205 - 213
ASEAN SP 1021	COST-EFFECTIVE EXERCISE PROGRAMS ON HEALTH-STATUS OF MALAYSIAN DIABETIC INDIVIDUALS - A SOCIO-PSYCHOLOGICAL ANALYSIS	FARIA SULTANA, SRILEKHA SAHA, MOHD SAAT ISMAIL, ROSMINAH MOHAMED, WAN MOHD. IZANI WAN MOHAMED AND SOUMENDRA SAHA	214 - 222
ASEAN SP 1022	IMPACT OF COORDINATION TRAINING REGIMES ON PREDICTORS OF DEXTERITY IN MODULATING COORDINATION IN YOUNG RECREATIONAL PLAYERS	SOUMENDRA SAHA; SRILEKHA SAHA; FARIA SULTANA AND MARUF AHMED	223 - 236



EFFECTS OF DIFFERENT DOSAGE OF SODIUM BICARBONATE ON 200-M FREESTYLE SWIMMING PERFORMANCE IN RECREATIONAL SWIMMERS

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ABSTRACT

The purpose of this study was to investigate the ergogenic effects of different dosages of NaHCO_3 (0.2 vs. 0.3 $\text{g} \cdot \text{kg}^{-1}$ BW) in enhancing 200-m freestyle swimming performance. Eight male recreational swimmers (20.5 ± 1.6 yrs; 75.9 ± 14.0 kg; 174.9 ± 5.1 cm) undertook 4 trials which included 1 control trial and 3 experimental trials in randomised order. For experimental trials, subjects were either ingested with NaHCO_3 (0.3 $\text{g} \cdot \text{kg}^{-1}$ BW or 0.2 $\text{g} \cdot \text{kg}^{-1}$ BW) or PLA (0.045 $\text{g} \cdot \text{kg}^{-1}$ BW of NaCl), 90 min prior to the performance test. Results showed that the performance time of 200-m freestyle swim during 0.2 $\text{g} \cdot \text{kg}^{-1}$ BW of NaHCO_3 trial was significantly faster, associated with a lower blood lactate level and heart rate measures when compared with control trial (162 ± 12 sec vs. 175 ± 13 sec; $p = 0.019$). Thus, a dosage of 0.2 $\text{g} \cdot \text{kg}^{-1}$ BW of NaHCO_3 is imperative in improving 200-m swim performance in male recreational swimmer.

KEYWORDS: Lactate, Swimming Performance Time, Heart Rate, Abdominal Distress

1. INTRODUCTION

Sodium Bicarbonate (NaHCO_3) is an alkaline salt that can be found naturally in our human body.¹ It was documented that NaHCO_3 in our blood system could help in delaying the onset of fatigue during anaerobic exercise.² In addition, it helps in increasing the buffering capacity, reduce the rate of intramuscular hydrogen ions accumulation and facilitated the removal of the hydrogen ions associated with lactic acid from the muscle cell into the blood.³

Gao et al.⁴ reported that 2.9 mmol of $\text{NaHCO}_3 \text{ kg}^{-1}$ BW ingestion, 60 min before swimming in well-trained swimmers resulted a significant improvement in 5 x 100-yard performance times. Likewise, Zajac et al.⁵ observed during 4 x 50-m front crawl sprints interspersed by 1 min passive recovery and noted that the total swim time and

swimming speed during the first 50-m sprint, respectively, were faster in NaHCO_3 trial as compared to placebo trial. In another study, the effects of beta-alanine alone and co-ingestion with NaHCO_3 on 100 and 200-m swimming performance were examined and results showed improvement in 100-m and 200-m performances when participants were ingested with a combination of NaHCO_3 and beta-alanine of 3.2 $\text{g} \cdot \text{kg}^{-1}$ BW.³ Lindh et al.⁶ reported that NaHCO_3 0.3 $\text{g} \cdot \text{kg}^{-1}$ BW packed in gelatine capsules, ingested 90 to 60 min prior to each 200-m swim had significantly improved the 200-m swim performance in highly trained males. In addition, Siegler et al.⁷ suggested that single dosage of 0.2 and 0.3 $\text{g} \cdot \text{kg}^{-1}$ BW of NaHCO_3 appeared to be most effective for increasing blood buffering capacity. The 0.2 $\text{g} \cdot \text{kg}^{-1}$ BW dosage was best ingested 40 to 50 min before exercise and the 0.3 $\text{g} \cdot \text{kg}^{-1}$ BW

dosage 60 to 90 minutes before exercise. Furthermore, Siegler et al.⁸ found that a dosage of 0.3 g.kg⁻¹ BW ingested 2.5 hours before exercise enhanced the blood buffering potential and positively influenced swim performance.

Numerous studies have investigated the ergogenic potential of NaHCO₃ supplementation on short-distance swimming performance (i.e., 100 and 200-m) and interval swimming performance but not all research has demonstrated ergogenic benefit of NaHCO₃ ingestion on swimming performance.^{4, 6, 8-11} While Lindh et al.⁶ reported a positive effect of NaHCO₃ on swimming time trial, Pierce et al.¹⁰ reported that NaHCO₃ had no effects on 100 yard as part of relay or 200 yard as solo swimming performance. Similarly, Pruscino et al.¹¹ found no significant difference in the mean performance time (2 maximal 200 m freestyle swims with 30 min passive rest) with the ingestion of 0.3 g.kg⁻¹ BW of NaHCO₃. In addition, Campos et al.¹² in an investigation of six maximal front crawl efforts of 100-m interspaced by 6 min NaHCO₃ or Placebo (dextrose) revealed that NaHCO₃ did not improved performance swimming training but enhanced the glycolytic source without altering RPE. Similarly, Joyce et al.⁹ reported no effect of NaHCO₃ on swimming time trial performance.

The ergogenic effects of NaHCO₃ ingestion prior to swimming have not been clearly elucidated. Therefore, in this present study, we would like to investigate the ergogenic effects of different dosages of NaHCO₃ (0.2 vs. 0.3 g.kg⁻¹ BW) in enhancing 200-m freestyle swimming performance in recreational swimmers.

2. METHODS

2.1 Subjects

Eight recreationally active male swimmers (mean \pm SD; age: **20.5 \pm 1.6 years**; weight: **75.9 \pm 14.0 kg**; height: **174.9 \pm 5.1 cm**) were recruited in this study. The subjects trained approximately 2-3 times per week, 90 min -120 min per session. The subjects were informed about the nature of the study; the possible side effects, risks and benefits of the study prior to signing an informed consent. The experimental procedure and the informed consent in this study were approved by the Research Ethics Committee of the Tunku Abdul Rahman University College.

2.2 Experimental Design

The design of this study was a randomised, double blind, cross-over and placebo-controlled. The design involved a performance test of 200-m freestyle swimming. Each subject undertook 1 control trial during the first visit and 3 experimental trials in a randomised order. For the control trial, subjects performed 200-m freestyle swim without any nutritional aid to determine their best performance time in 200-m freestyle swimming. For the 3 experimental trials, subjects ingested NaHCO₃ 0.3 g.kg⁻¹ BW, NaHCO₃ 0.2 g.kg⁻¹ BW or Placebo (PLA) (0.045 g.kg⁻¹ BW of sodium chloride, NaCl), 90 min prior to 200-m freestyle swimming. Each experimental trial was separated for at least 7 days to ensure complete wash-out of the supplement from the body. In addition, subjects were required to record all food intakes in a dietary record form 3 days prior to the test to ensure subject have similar diet throughout the following 3 experimental trials. All performance tests were undertaken in the same swimming pool (Depth: 2 m; Length: 25 m; Width: 20 m) at the same time of day. The order of the 3 experimental trials is illustrated in Table 1.

Table 1
Allocation of the Treatment Order to Participants

Participant	Treatment	Wash-out	Treatment	Wash-out	Treatment
S1	NaHCO ₃ _0.2	1 week	Placebo	1 week	NaHCO ₃ _0.3
S2	NaHCO ₃ _0.3	1 week	NaHCO ₃ _0.2	1 week	Placebo
S3	Placebo	1 week	NaHCO ₃ _0.3	1 week	NaHCO ₃ _0.2
S4	NaHCO ₃ _0.2	1 week	Placebo	1 week	NaHCO ₃ _0.3
S5	NaHCO ₃ _0.3	1 week	NaHCO ₃ _0.2	1 week	Placebo
S6	Placebo	1 week	NaHCO ₃ _0.3	1 week	NaHCO ₃ _0.2
S7	NaHCO ₃ _0.2	1 week	Placebo	1 week	NaHCO ₃ _0.3
S8	NaHCO ₃ _0.3	1 week	NaHCO ₃ _0.2	1 week	Placebo

2.3 Supplementation and Placebo

The supplementation drinks were prepared using NaHCO_3 in different dosages of $0.2 \text{ g} \cdot \text{kg}^{-1}$ BW or $0.3 \text{ g} \cdot \text{kg}^{-1}$ BW; and the Placebo drink was prepared by mixing NaCl ($0.045 \text{ g} \cdot \text{kg}^{-1}$ BW) in the water, according to protocol suggested by Price et al.¹³ The NaHCO_3 supplement and placebo drinks were mixed with $1 \text{ ml} \cdot \text{kg}^{-1}$ BW of non-sweetened orange flavour substance and 2 g of Equal Sweeteners (Aspartame) [8 kcal, 0.04 g protein, 1.94 g carbohydrate, 1.64 g sugars and 0.18 mg sodium] which were subsequently diluted with 600 ml of plain water. The supplements and placebo drinks were prepared by the laboratory assistant and the researcher was blinded to the type of drinks given to the subjects during the experimental trials.

2.4 Experimental Protocol

Prior to the test trial, subjects were instructed to refrain from caffeine, alcohol and not to perform strenuous exercise for at least 24 hours prior to each trial. Subjects were advised to remain hydrated and replicate the same diet and hydration pattern for the 24-h period before each of the experimental trials. Upon arrival at the laboratory, urine sample was collected in a disposable urine container for urine specific gravity and urine pH analysis. Baseline finger-prick blood samples were taken for blood lactate analysis. Resting heart rate and blood pressure were monitored using a polar heart monitor (FT4M, Polar Electro Oy, Finland) and a digital automatic blood pressure monitor (HEM-907, OMRON, Japan), respectively. Rating of abdominal discomfort (AD) scale from 0 to 10 (completely comfortable to unbearable pain) and GUT fullness (GF) scale from 0 to 10 (empty to bloated) were rated by the subjects. After completion of baseline measurements, subjects were instructed to drink either supplement or placebo drinks. Subjects were required to rest at the laboratory for 90 min prior to the 200-m freestyle swimming performance test. After 90 min of resting, another urine sample was collected. Heart rate, blood pressure, and rating of AD and GF were recorded.

A standardised warm-up protocol (10 min) was performed prior to the 200-m freestyle swimming performance test. The subjects dived start from the diving blocks and were timed using a digital stop watch by the researcher. All subjects were encouraged to swim as fast as possible. Performance times were recorded, and heart rate measures were collected. Following the completion of each swimming performance test, urine sample, finger-prick blood samples, heart rate, blood pressure, rating of AD and GF were collected.

2.5 Urine and Blood Sampling Analysis

Urine specific gravity (USG) was analysed using a digital urine specific gravity refractometer (Atago® UG- α , Japan) to determine the hydration status: USG <1.020 was considered as euhydrated; whereas urine pH level was determined by using pH paper (MCColorpHast™). Finger-prick blood samples ($25\mu\text{L}$) were collected using lactate capillary tube. The lactate capillary tube was inserted into the blood lactate analyser (YSI 1500, YSI Incorporated, The Netherlands) to determine the blood lactate concentration.

2.6 Data Analysis

All data were analysed using the Statistics Package for Social Science (SPSS) version 21. Two-way repeated-measure ANOVA was used to compare the differences between the trials and across the trials. When a significant interaction was found, paired samples t-test was used to identify the difference between means. Differences were considered significant at $p < 0.05$. Results were expressed as mean and standard deviation.

3. RESULTS

3.1 Performance Time

Table 2 showed subjects swam significantly faster during NaHCO_3 _0.2 trial (162 ± 12 sec, $p = 0.012$) as compared with the control trial. No significant differences were found among the control, NaHCO_3 _0.3 and placebo trials.

Table 2
Performance Time (sec)

	Control	NaHCO₃ (g.kg⁻¹)	PLA (g.kg⁻¹)
Dosage		0.2	0.3
Time (sec)	175 ± 13	162 ± 12*	164 ± 17
			16917

*Significantly different from control trial at p<0.05

3.2 Blood Lactate Concentration

As shown in Table 3, post swim blood lactate concentration in all trials increased significantly

from baseline values (p<0.001), except the control trial (p>0.05).

Table 3
Blood Lactate Concentration during Baseline and Post-Swim

	Control	NaHCO₃ (g.kg⁻¹)	PLA (g.kg⁻¹)
Dosage		0.2	0.3
Baseline (mmol.L⁻¹)	1.77 ± 0.18	1.48 ± 0.28⁺	1.69 ± 0.22
Post Swim (mmol.L⁻¹)	9.58 ± 2.21	9.39 ± 2.16*	10.16 ± 1.39*
Δ Lactate (mmol.L⁻¹)	7.81 ± 2.18	8.89 ± 0.97	7.90 ± 2.10
			8.48 ± 1.27

*Significantly different from respective Baseline values at p<0.05.

⁺ Significantly different from respective Control values at p<0.05.

3.3 Urine pH

Urine pH level was similar during baseline measurements in all trials (~6.00 ± 0.00; p>0.05). After ingestion of supplement drinks, urine pH level increased significantly in both NaHCO₃ trials (NaHCO₃_0.2 trial: 7.00 ± 0.76; NaHCO₃_0.3 trial: 7.25 ± 0.71; p<0.05) as compared with the baseline and control trial values. With a higher dosage of NaHCO₃ in NaHCO₃_0.3 trial, urine pH level was significantly greater (8.13 ± 0.99) than pre-swim value (p=0.001) as compared with other trials.

3.4 Heart Rate

After the completion of the 200 m freestyle swimming performance test, heart rate was significantly lower in NaHCO₃_0.2 trial (172 ± 9 beats.min⁻¹; p<0.001) as compared with other trials (Control: 180 ± 11 beats.min⁻¹; PLA trial: 182 ± 8 beats.min⁻¹; NaHCO₃_0.3 trial: 175 ± 10 beats.min⁻¹)

3.5 Rating of Abdominal Discomfort (AD) and Rating of GUT Fullness (GF)

Subjects did not perceive any abdominal discomfort in all trials (p>0.05) and they perceived “slightly full” after supplement drink was ingested in the NaHCO₃_0.3 trial (2.13 ± 1.55).

4. DISCUSSION

This study found that the 200-m freestyle swimming performance was significantly improved in the NaHCO₃_0.2 trial (162 ± 12 sec) as compared with other trials. The plausible reason for the significant improvement might be due to the fact that the ingestion 0.2 g.kg⁻¹ BW of NaHCO₃ has facilitated the removal of excess hydrogen ions from the working muscle. For the NaHCO₃_0.3 trial, the performance time was slightly slower than NaHCO₃_0.2 trial and no significant difference was found between placebo trials. Lindh et al.⁶ reported that 0.3.kg⁻¹ BW of NaHCO₃ improved 200-m freestyle performance time in elite male competitors (British National Championships and European Championships). Their subjects were international swimmer and they can swim faster as compared to the subjects in present study (112.6 ± 4.7 vs. 161.6 ± 19.2 sec). Therefore, we postulated 0.3 g.kg⁻¹ BW is suitable for elite swimmers whereas 0.2 g.kg⁻¹ BW of NaHCO₃ ingestion prior to exercise is recommended for sub-elite / recreational swimmers. In addition, the present study showed with the 0.3 g.kg⁻¹ BW of NaHCO₃ ingestion prior to exercise had caused the feeling of “slightly full”

which may affect the performance time.

The blood lactate concentration during post swim in all trials were similar (Table 3; $p>0.05$). However, NaHCO_3 _0.2 trial has the greatest increment among the trials during post swim as compared with baseline value (Table 3). This result was similar to the finding reported by Lindh et al.⁶ The increase of blood lactate concentration in NaHCO_3 _0.2 trial might be due to a greater glycolytic activity, as the subjects performed their best performance time as compared to other trials. Interesting to note that heart rate was significantly lower in NaHCO_3 _0.2 trial (172 ± 9 beats. min^{-1}) as compared with other trials. Therefore, the ingestion of NaHCO_3 90 min prior to exercise could improve performance or delay fatigue in intermittent high-intensity exercise¹⁴ through its buffering feature.^{15, 16}

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5. CONCLUSION

In conclusion, the ingestion of $0.2 \text{ g} \cdot \text{kg}^{-1} \text{ BW}$ of NaHCO_3 90 min prior to exercise has an ergogenic benefit on 200-m freestyle swimming performance in recreational swimmers.

6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

GyY, LhY, WeH

Collected data and performed the experiments:

GyY, LhY, WeH

Contributed with materials/analysis tools:

GyY, LhY, WeH

Analysed the data: GyY, LhY, WeH

Wrote the paper: GyY, LhY, WeH

Checked and edited the format of the paper:

GyY, LhY, WeH

Final approval: GyY, LhY, WeH

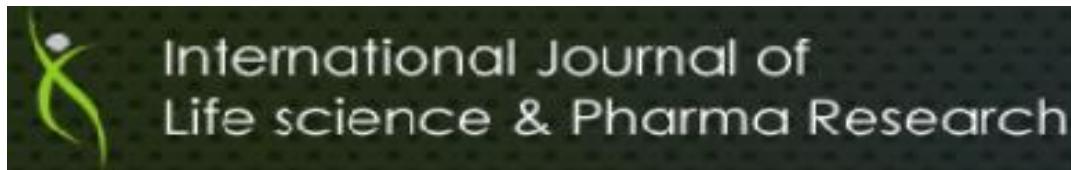
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DIFFERENTIAL IMPACTS OF PHYSIOTHERAPEUTIC TRAINING ON PROPRIOCEPTIVE ACTIVE REPOSITIONING ERRORS COMMITTED BY OSTEOARTHRITIS PATIENTS

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ABSTRACT

The purpose of the present study was to investigate the role of Conventional Physiotherapy (CP), Isokinetic Exercise Training (IET) and combined intervention (CI) of CP and IET in improving proprioception in participants with knee osteoarthritis (OA). 54 post-menopausal female participants in the age range of 45-65 years with knee OA of Grade II severity were recruited from the Orthopaedics Dept. of Hospital Universiti Sains Malaysia (USM). Baseline assessment on the participants were done in the Skill Laboratory of School of Medical Sciences and the Exercise and Sports science laboratory, USM. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to evaluate the subjective scale for pain, stiffness and physical function. Proprioception was assessed employing the isokinetic device BIODEX 4 System Pro. Thereafter participants were randomly classified into three groups (Gr.) (Viz. Gr. A, Gr. B and Gr. C, with n = 18/group). Gr. A participants received CP comprising of strengthening exercises; stretching exercises and range of motion (ROM) exercises. Gr. B received IET at velocities of 90° and 150°/sec. Gr. C participants received CI, with uniform protocol (25 - 30 min.s/ session; 2 sessions/week for 12 weeks). Mid-term evaluation was done after 6th week followed by the post intervention evaluation after 12th week following pre-intervention analyses protocol. Two-way repeated measure of ANOVA revealed effectiveness of the interventions in improving proprioception of knee joint in participants with OA of knee joint. IET was better effective in augmenting proprioception involving muscular sense, while CI was observed to facilitate in enhanced proprioception in ligament. Multiple linear regression analyses revealed the association between pain, level of stiffness and physical function with weight, height and level of proprioception.

KEYWORDS: Osteoarthritis, Physiotherapeutic Training, Active Repositioning Error

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1. INTRODUCTION

Sense of limb-joint position or proprioception refers to the sensory information received via sensory afferent pathway emerging from the muscles, joint capsules, ligaments and tendons, which add to stability of posture and sense of steadiness in the muscles and joints.¹ The sensory information evoked from the limb-joint movements provides the feel of self-position and body activity.² In the process of proprioception, the multi-component sensory system involves detection of numerous, specific signals conveyed by relevant peripheral receptors. These characteristically kinetic as well as kinematic signals carry sensory information, which are transmitted by major sensory afferent pathways through the spinal cord and eventually send up to the cortex of the brain.

Loss or reduction of knee-joint proprioception, as³ hypothesized, could occur both in joint position and joint movement senses. Etiology of impaired or loss of joint position sense, i.e., loss or reduction of proprioception, was postulated⁴ as due to disuse muscle atrophy around the knee-joint; unnatural loading in the knee-joint; muscle weakness⁵; reduction in size of neural components and loss of mechanoreceptor⁶ and capsular and collateral ligaments laxity as well.⁷ Thus, the reduction of proprioception in the knee-joint is considered as the early sign of joint damage and development of knee OA.⁸

As evidenced, proprioceptive exercises are usually performed in weight bearing positions.⁹⁻¹³ These exercises could be varied from plyometric exercise⁹, computer aided target matched foot stepping exercises (TMFSE)¹⁰ and balance training with wobble board and BOSU ball in standing position.¹¹ Furthermore, improvement in the accuracy of proprioception could also be achieved through weight bearing exercises.^{10,12} Although participants with knee OA revealed enhancement in proprioception, muscle strength and reduced joint stiffness after strengthening exercises^{10,13}, compression of the knee joint after continued weight bearing exercises have been suspected to cause more harm to the articular cartilage, aggravating the severity of the symptoms.^{10,13-14}. At this point, to prevent further worsening of the knee OA condition and to enhance the muscle strength and proprioception as well, introduction of non-weight bearing strength training exercise became essential.

Conventional physiotherapy (CP) treatment comprised of exercise therapy such as strengthening exercise, stretching exercise and range of motion exercise are included in the treatment of participants with knee OA.¹⁵ Although prognosis depends on exercise adherence, regular supervision, monitoring and motivation, required for long term compliance in knee OA participants (Hughes et al., 2004). Several literatures¹⁶⁻¹⁷ documented on significance of CP exercise trainings in reducing pain, improvement of muscle strength and function in participants, suffering from knee OA. Efficacy of CP exercise training in enhancing proprioception among participants suffering from knee OA, however; has rarely been investigated.

Advent of isokinetic exercise training (IET), could be tracked back from 1960, which evolved as an alternative to traditional exercise with various forms of resistance applications. Any exercise movement done under a constant velocity and at varying resistance is termed as isokinetic (denoted in degree per second) exercise.¹⁸⁻¹⁹ Optimal loading of the muscles in dynamic conditions and with constant pre-selected velocity of movement are the unique features of isokinetic exercise activity and dynamometric evaluation as well.¹⁹ IET has been widely used in rehabilitation of knee OA participants, for gaining strength and improving physical function.²⁰⁻²² Simultaneously, isokinetic dynamometric evaluations are increasingly becoming popular among sports medicine and physiotherapy researchers, as reliable and valid tool for assessment of dynamic strength and extent of musculoskeletal deficiency.²³⁻²⁶ This evaluation became popular, particularly because it can be applied to all ages and various population, such as healthy male individuals²⁷⁻²⁸; female²⁰; elderly²⁹⁻³⁰; children³¹ and also individuals with different kind of crises, like sport injury³², musculoskeletal disorders³³ and cardiopulmonary disorders.³⁴ The advantage of isokinetic training in enhancing proprioception in individuals having OA of knee, however, has not been investigated. Furthermore, comparative impacts of neither the CP nor IET on proprioception, as evaluated by the active repositioning error i.e., the errors identified in active angle reproduction, while actively replicating knee extension activity in varying degrees of extension.³⁵⁻³⁶ has never been investigated. Hence, with such a background, current study has been carried out with the main aim of identification of comparative efficacy of

the CP or conventional physiotherapeutic exercise intervention and IET or the isokinetic exercise training on proprioception in knee OA participants, as evaluated by the extent of progressive or regressive changes, if any, in the ability of active repositioning or active angle reproduction. Further to that, apart from the comparative impacts of CP and IET, this study has also attempted to investigate the combined effect of physiotherapeutic intervention and isokinetic training on proprioception in knee OA participants.

2. METHODOLOGY

2.1. Participants

54 elderly female individuals suffering from pain in knee (age-range 56 to 65 years), were selected based on Kellgren's (Grade - II)²⁶ criteria of deficit in proprioception. This study was approved by a University's Research Ethics Committee and participants provided informed consent prior to participating (Ethical permission reference number: **USM/JEPeM/15040143**).

2.2. Materials Used

An information schedule was prepared to collect relevant information about the participants. Apart from that, for collection of pre-intervention as well as post-intervention data, following equipment and items were required, viz., Isokinetic Biodek 4 Multi-Joint System Pro Machine; Stadiometer (Seca Bodymeter 208, Germany); Weighing Scale (Omron Karada Scan -HBF 356, Japan); Stop Watch (RESEE, China); Ankle air splint; Headphones; Blindfolds and Theraband (Blue).

2.3. Procedure

Participants were at first introduced to the study protocol, and after they could realise the whole procedure, written ethical consent was obtained from each of the participants. Thereafter, for evaluation of proprioception, they were subjected to assessment of Active Angle Reproduction or Active Repositioning Error. Detailed information on Isokinetic Biodek 4 Multi-Joint System is available in. Protocol for assessment of assessment of Proprioception by evaluation of active reposition error, are detailed herewith in the following sections (from 2.3.1 to 2.3.3).

After the pre-intervention analyses, participants were randomly categorized (following

Research Randomizer -Version 4.0³⁷, into three groups (Gr.) (Viz. Gr. 1, Gr. 2 and Gr. 3, N = 18 per group). Gr. 1 participants received training of strengthening and stretching exercises; and range of motion (ROM) exercises as well. These exercises were termed as Conventional Physiotherapy (CP) intervention. Gr. 2 participants on the contrary, received Isokinetic Training (IET) at velocities of 90° and 150° per second. This study was conducted to have better understanding associated with comparison between the efficacies of CP and Isokinetic training. To carry out that, a third group of (Gr. 3) participants were also recruited, who received combined (CG) intervention of CP and IET. Intervention protocols were maintained for 25 - 30 minutes/session; 2 sessions/ week for 12 weeks. After the completion of 6 weeks of intervention, a mid-term evaluation was carried out followed by the post intervention evaluation after 12th week, in which all the assessments of the pre-intervention analyses protocol, were carried out.

2.3.1 Assessment of Proprioception

BIODEX 4 isokinetic device was used to assess proprioception of knee joint, which was carried out following the protocol prepared by Koralewicz & Engh.⁷ In this study, active repositioning error or active angle reproduction methods was followed for measuring proprioception.

2.3.1.A Preparation of the Equipment

The positioning of the device for measuring the parameters associated with the knee joint was done in line with the recommendations of the manufacturer. The following alignment of the different parts of the device was maintained to assess the knee parameters.

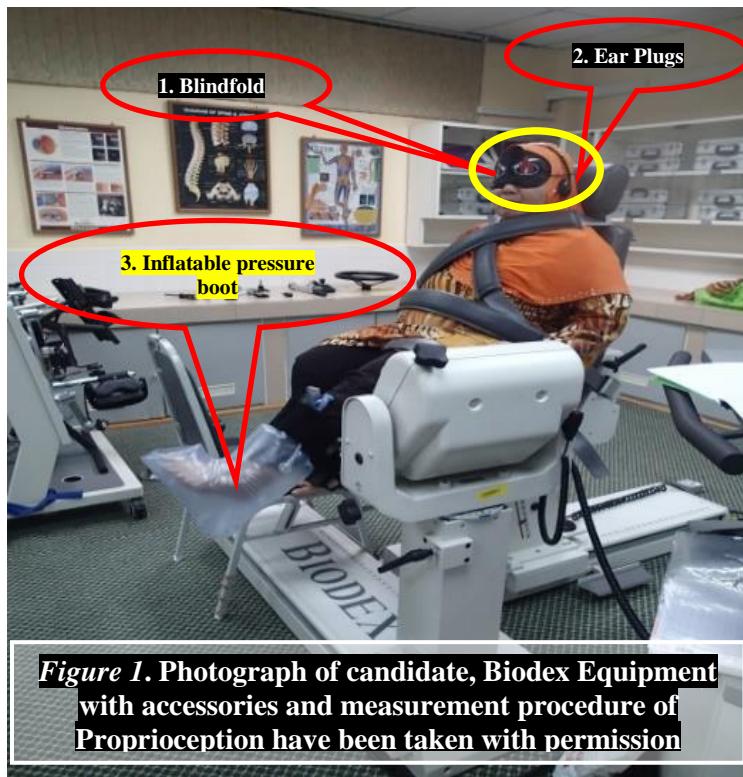
1. Dynamometer Orientation: 90°;
2. Dynamometer Tilt: 0°;
3. Seat Orientation: 90°;
4. Seatback Tilt: 70 - 85°;
5. Axis of Rotation: Axis is through the lateral femoral condyle on a sagittal plane;
6. Ready Position: Flexion of knee at 90°.

2.3.1.B Positioning of the Participant

The participants were positioned in sitting at an angle of 80 degree. The participants wore blindfold and ear plugs. This was done to prevent any stimulus from eyes and ears to provide any form of feedback that may aid in the process of assessment of proprioception. The amount of clothing was reduced to minimum over the part to

be tested so that any unwanted sensations coming from the skin are reduced (Figure 1). The participant's foot was placed in an inflatable pressure boot. The knee was moved actively and

passively at a velocity of 0.5 degree per second with an aid of the software in the Biode ³⁸



The resistance pad was fixed just above the medial malleolus. Familiarization was done with one practice test and three trials were performed for each measurement. Active joint position sense, passive joint position sense and threshold to detect passive motion were used to measure proprioception.

2.3.2. Measurement of Active Repositioning Error /Active Angle Reproduction

Starting at 90° of knee flexion, participants were instructed to actively move the limb to the target angle of 60° and 30° of flexion. The task was to maintain the limb at the target angle for 10 seconds, so that the participant gets opportunity to remember the position, and then the limb was supposed to be returned to 90° of knee flexion. After a pause for 5 seconds, the participant was asked to move the lower limb by active contraction at an angular velocity of 0.5°/second and to stop at the position, in which s/he thought that the target angle had been reached. Participants were not allowed to correct the angle. The absolute difference between the perceived

angle and the target angle was calculated for each trial. A maximum of three trials was performed.⁷

2.3.3. Analysis and Interpretation of Data

Determination of the level of proprioception in knee osteoarthritis using Biode 4 involved research participants to replicate knee extension actively (active repositioning error) at 60° and at 30°. Impairment of proprioception in knee osteoarthritis is denoted by an increase in the active repositioning error. In this study, to observe impairment of proprioception, only evaluation of active repositioning error was carried out.

3. RESULTS AND DISCUSSION

Outcomes of this study were analysed with major focus onto improvements in pain; physical dysfunction and discomfort observed amongst the participants suffering from OA of knee. Explanations on the outcomes of this experiment however have been attempted based on outcomes of repeated measure of ANOVA of the data on active repositioning error received from the participants.

3.1 Active Repositioning Error at 60°

Table 1

Descriptive Statistics of Active Repositioning Error at 60° Scores across the Different Interventions and Three Measurements

	Groups	Number of Measurements	Mean	Std. Deviation
	Conventional	Pre	54.5556	9.46338
Active Repositioning Error at 60°	Physiotherapy	Mid	56.5556	4.03255
	(CP) (Group - 1)	Post	57.3750	2.18708
	Isokinetic	Pre	56.1667	10.65088
	Training (IET)	Mid	55.8889	7.45093
	(Group - 2)	Post	57.0000	3.19722
	Combined (CG)	Pre	53.6667	8.55432
	(Group - 3)	Mid	56.0000	2.99018
		Post	57.0000	2.07550

Table 1 shows the descriptive statistics of active repositioning error at 60° scores (which were normally distributed) across the different interventions and three measurements (viz., Means & SDs). Reduction in the active repositioning error at 60° was evident amongst the

intervention groups, across various phases. Reports on Mauchly's Test of Sphericity for the active repositioning error at 60° score, indicated that the Assumption of Sphericity was not violated (as, $\chi^2(2) = 18.260$, $p = .069$) amongst the intervention groups across various levels of measurement.

Table 2
*Tests of Within- Subjects Effects on Active Repositioning Error at 60°**

	Source	Type III			F	Sig.	Partial Eta Squared
		Sum of Squares	df	Mean Square			
Active Repositioning Error at 60°	Intervention * Pain at pre-intervention phase	Sphericity Assumed	666.183	2	333.091	7.737	.013*
	Intervention * Weight	Sphericity Assumed	3925.014	16	245.313	5.698	.009*
	Phase	Sphericity Assumed	596.767	2	298.383	11.054	.005*
	Phase * Pain at pre-intervention phase	Sphericity Assumed	639.235	2	319.618	11.841	.004*
	Phase * Weight	Sphericity Assumed	12018.808	16	751.175	27.830	.000*
	Intervention*Phase*Pain at pre-intervention phase	Sphericity Assumed	1110.479	4	277.620	6.023	.004*
	Intervention * Phase * Weight	Sphericity Assumed	5518.078	32	172.440	3.741	.004*

*p<0.05; **p<0.01

From the results shown in Table 2, significant interactions were found between the level of pain and weight of the participants for pre-intervention on the repositioning error ($F=7.737, 5.698$; $p = 0.013, .009$, $\eta^2 = .659, .919$). Outcomes of partial eta squared (η^2) revealed that, based on pre-intervention level of perceived pain and difference in weight of the participants, very large effects of interventions on reduction of active repositioning error were observed. Similarly, significant interactions were found at various phases, between pain and weight at various phases of interventions ($F=11.054$,

11.841, 27.830; $p = 0.05, 0.004, 0.00$; $\eta^2 = .734, .747, .982$). Similar outcomes of very large effects of interventions on reduction of active repositioning error were also evident across different phases. Apart from that, profound interactions between intervention, pain and weight on active repositioning error at various phases of intervention ($F=6.023, 3.741$; $p = 0.04, 0.04$; $\eta^2 = .601, .882$) were also observed. We can report the results as for the participants of this experiment, that if the effects of other variables are ignored, significant main effect of level of pain, weight and intervention on the active

repositioning error at 60° (Table 2) were evident. Thus, the partial eta squared (η^2) outcomes revealed that, excluding confounding interference of

all other variances, effect of the interventions was evident.

Table 3**Pairwise Comparisons of Active Repositioning Error at 60° scores across the Different Interventions**

(I) Intervention	(J) Compared Between	Mean Difference (I-J)	Std. Error	Sig. ^b
Conventional	Isokinetic	4.177	.923	.032*
	Combined	-.342	1.724	1.000
Isokinetic	Conventional	-4.177	.923	.032*
	Combined	-4.519	1.944	.242
Combined	Conventional	.342	1.724	1.000
	Isokinetic	4.519	1.944	.242

*p<0.05; **p<0.01

Outcomes of Table 3 revealed significant difference in the active repositioning error

between conventional physiotherapy group and the isokinetic training group ($p = 0.032 < 0.05$).

Table 4**Pairwise Comparisons of Active Repositioning Error at 60° scores across the Different Phases**

(I) Phases	(J) Compared Between	Mean Difference (I-J)	Std. Error	Sig. ^b
Pre	Mid	-1.301	1.504	1.000
	Post	7.383	1.511	.024*
Mid	Pre	1.301	1.504	1.000
	Post	8.683	.468	.000**
Post	Pre	-7.383	1.511	.024*
	Mid	-8.683	.468	.000**

*p<0.05; **p<0.01

From Table 4, significant differences in the error scores between pre-intervention phase and post intervention phase ($p = 0.02 < 0.05$), and

between the mid-intervention phase and post intervention phase ($p = 0.00 < 0.05$) were evident, across the intervention groups.

3.2 Active Repositioning Error at 30°

Table 5**Descriptive Statistics of Active Repositioning Error at 30° Scores across the Different Interventions and Three Measurements**

	Groups	Number of Measurements	Mean	Std. Deviation
	Conventional	Pre	28.1667	7.80837
Active Repositioning Error at 30°	Physiotherapy	Mid	29.1667	2.89523
		Post	29.6875	1.95683
	Isokinetic	Pre	28.1667	8.37538
	Training	Mid	27.6667	5.59411
		Post	29.9000	2.72641
	Combined	Pre	27.8333	5.96312
		Mid	29.6667	3.12485
		Post	28.0714	2.33582

Table 5 shows the descriptive statistics of active repositioning error at 30° scores across the different interventions and three measurements (viz., Means & SDs). Outcomes revealed that the active repositioning error at 30° pertaining to the mid intervention phase in the conventional physiotherapy group was positively skewed whereas all the other parameters in the other

intervention groups in the different phase of the interventions were normally distributed. The skewed data were treated accordingly to resolve the issue of non-normality. It was evident that there was a decrease in the active repositioning error at 30° across various phases amongst the intervention groups.

Reduction in the active repositioning error at 30° was also evident amongst the participants of intervention groups, across various phases. Reports on Mauchly's Test of Sphericity for the active repositioning error at 30° score, indicated

that the Assumption of Sphericity was not violated (as, $\chi^2(2) = 10.318$, $p = 0.434$) amongst the intervention groups across various levels of measurement.

Table 6
*Tests of Within- Subjects Effects on Active Repositioning Error at 30°**

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Active Repositioning Error at 30°	Intervention * Pain at pre-intervention phase	Sphericity Assumed	110.947	2	55.474	13.302	.003*
	Intervention * Weight	Sphericity Assumed	545.713	16	34.107	8.178	.003*
	Phase	Sphericity Assumed	110.278	2	55.139	10.779	.005*
	Phase * Pain at pre-intervention phase	Sphericity Assumed	161.639	2	80.820	15.799	.002*
	Phase * Weight	Sphericity Assumed	3053.418	16	190.839	37.306	.000*
	Intervention * Phase	Sphericity Assumed	207.439	4	51.860	8.238	.001*
	Intervention * Phase * Pain at pre-intervention phase	Sphericity Assumed	289.361	4	72.340	11.491	.000*
	Intervention * Phase * Weight	Sphericity Assumed	1479.060	32	46.221	7.342	.000*
	Intervention * Pain at pre-intervention phase	Sphericity Assumed	110.947	2	55.474	13.302	.003*

* $p<0.05$; ** $p<0.01$

From the results shown in Table 6, significant interactions were found between the level of pain and weight of the participants at the pre-intervention phase on the active repositioning error at 30° scores ($F=13.302, 8.178$; $p = 0.003$, $0.003<0.05$). Similarly, significant interactions were found at various phases, between pain and weight at various phases of the intervention on the error scores ($F=10.779, 15.799, 37.306$; $p = 0.005$, $0.002, 0.00<0.05$). It was also observed that there

were significant interactions between intervention, pain and weight at various phases of the intervention on active repositioning error at various phases of intervention ($F=8.238, 11.491, 7.342$; $p = 0.001, 0.000, 0.00<0.05$). The results as for the participants of this experiment was, that if the effects of other variables are ignored, there was a significant main effect of level of pain, weight and intervention at different phases on the active repositioning error at 30° (Table 4.18).

Table 7
*Tests of Between- Subjects Effects on Active Repositioning Error at 30°**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	80.128	1	80.128	14.372	.019	.782
Pain at pre-intervention phase	126.327	1	126.327	22.659	.009*	.850
Pain at mid intervention phase	14.200	1	14.200	2.547	.186	.389
Pain at post intervention phase	.014	1	.014	.002	.963	.001
Weight	1492.698	8	186.587	33.468	.002*	.985

* $p<0.05$; ** $p<0.01$

From Table 7, significant interactions between pain at the pre-intervention level of the conventional physiotherapy group and the weight

of the participants on active repositioning error at 30° existed ($p = 0.009, 0.002<0.05$) was evident.

Table 8**Pairwise Comparisons of Active Repositioning Error at 30° scores across the Different Interventions**

(I) Intervention	(J) Compared Between	Mean Difference (I-J)	Std. Error	Sig. ^b
Conventional	Isokinetic	2.996	.527	.014*
	Combined	.495	.425	.926
	Conventional	-2.996	.527	.014*
	Combined	-2.502	.527	.027*
Isokinetic	Conventional	-.495	.425	.926
	Isokinetic	2.502	.527	.027*

*p<0.05; **p<0.01

From Table 8 it was evident that, in the active repositioning error at 30° significant differences between the outcomes of conventional physiotherapy group and the isokinetic training group ($p = 0.014 < 0.05$) was revealed. It was also observed that there existed significant differences between isokinetic training group and combined

intervention group ($p = 0.027 < 0.05$). Conventional physiotherapy group participants and their counterparts in the combined intervention group had significant reduction in errors compared with that of the participants of the isokinetic training group.

Table 9**Pairwise Comparisons of Active Repositioning Error at 30° scores across the Different Phases**

(I) Phases	(J) Compared Between	Mean Difference (I-J)	Std. Error	Sig. ^b
Pre	Mid	-27.686*	.516	.000*
	Post	-22.750*	.438	.000*
Mid	Pre	27.686*	.516	.000*
	Post	4.935*	.667	.005*
Post	Pre	22.750*	.438	.000*
	Mid	-4.935*	.667	.005*

*p<0.05; **p<0.01

Outcomes of Table 9 however revealed significant difference in the error scores between pre-intervention phase, mid-intervention and post intervention phase ($p = 0.000, 0.00, 0.00 < 0.05$). Significant changes in the error scores between mid-intervention phase and post intervention phase ($p = 0.005 < 0.05$) across the intervention groups were also observed.

Discussion on active repositioning error evident at 30°

Outcomes of the active repositioning error evident at 60° evidently indicated that across the different phases of assessment, an overall reduction in the repositioning errors performed by the participants was obvious. Precisely, this reduction in repositioning (active) error, which implied improvement in proprioception, was evident amongst the participants of all the intervention groups. A thorough analysis of the comparison amongst the group across the interventions revealed that, during the mid-term intervention assessment phase, only the participants of the CP were observed as capable of effectively reducing the errors compared to that of

Discussion on active repositioning error evident at 60°

their counterparts in the IET group and in the CG as well. In the post intervention assessment phase, however, the errors committed by the participants of the CP and the IET were evidently less compared to those of their counterparts in CG. Further to that, the CP trainees committed less errors in detecting the angle accurately, compared to the performance of their counterparts in the other intervention groups.

Findings on active repositioning error at 30° also indicated an overall reduction in the repositioning error performed by the participants across the different phases of assessment, amongst the different intervention groups. A thorough analysis of the comparison amongst the groups across the interventions revealed that, compared to the participants in the IET group, their counterparts in the conventional physiotherapy, i.e., the CP and combined intervention (CG) group as well, were better able to reduce the errors effectively. This trend was evident both in the mid intervention assessment phase and post intervention assessment phase. Comparative analyses however clarified that, when a combination of conventional physiotherapy and isokinetic training was imparted to the

participants, that combination resulted in better reduction of active repositioning error at 30°, compared to when isokinetic training was introduced alone. This might have been due to the

additional effect of isotonic contraction of the muscles surrounding the knee joint, which got coupled with isokinetic contraction, and perhaps improved the joint position sense.

The findings of this study revealed that, participants with osteoarthritis of knee were able to reduce errors in proprioception, which was found supported by the findings obtained in previous studies.^{7,39} In one of the previous experiments beneficial effect of IET in improving the joint position sense was confirmed⁴⁰, which contradicts the findings of our study, in which compared to all other interventions, only IET (Isokinetic Training) did not produce any significant improvement in the joint position sense. Careful scrutiny of the findings of Hazneci and co-researchers⁴¹ however, clarified that their study was undertaken on participants suffering from patellofemoral pain syndrome (PFPS), while participants in this present study were suffering from OA of knee. Further to that, PFPS usually occurs in younger population who have a comparatively good strength of the muscle of the knee joint, whereas our study was carried out on

elderly individuals suffering from OA of knee, with added feature of muscle-weakness.

Numerous studies investigating on the comparative difference between strength training exercises and proprioception enhancing exercises on participants with knee OA, have observed an overall better beneficial impact of the latter regime.^{12,41-42} This finding is further supported by the findings of Lin and co-researchers¹³, Jan and associates¹⁰, which revealed that proprioception can be trained in non-weight bearing positions too. It could also be observed that, the CP exercises involving stretching, strengthening and maintenance of movement were effective in improving the proprioception of the knee joint at 60°.^{10,13} Perhaps the exercises imparted to the participants of the conventional physiotherapy group, got benefitted from increased sensitivity of the mechanoreceptors of the joint, and consequently proprioception associated with movements got enhanced.

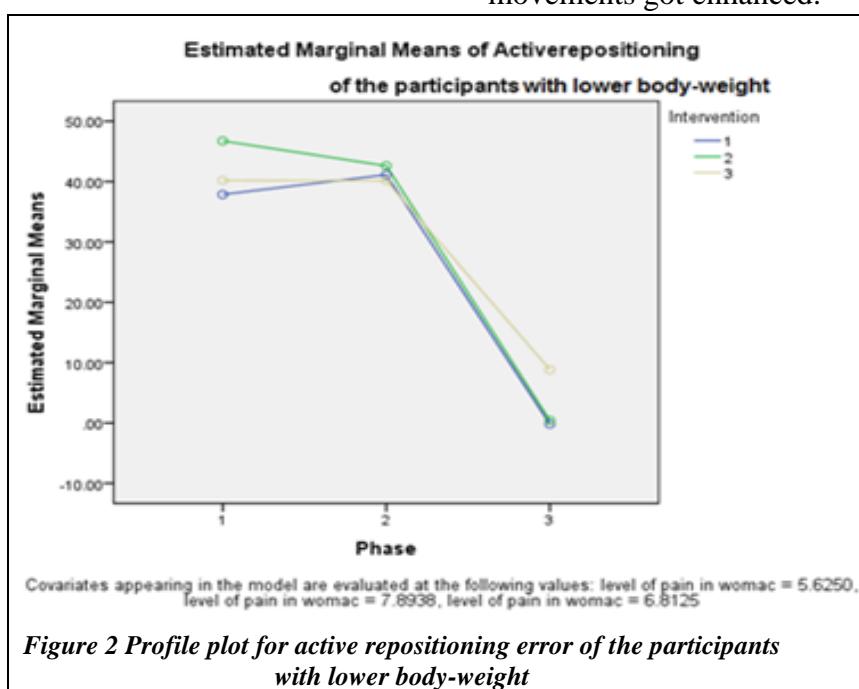


Figure 2 Profile plot for active repositioning error of the participants with lower body-weight

Overall the outcomes of interventions on the proprioception revealed by the indices of active repositioning error depicted mixed up impressions, which could mislead overall understanding of outcomes. Findings of this study, however provided an opportunity to interpret the

performance of the participants to minimize the errors, i.e., to reduce the active repositioning error in terms of some additional factors, which could have contributed in augmenting proprioceptive actions.

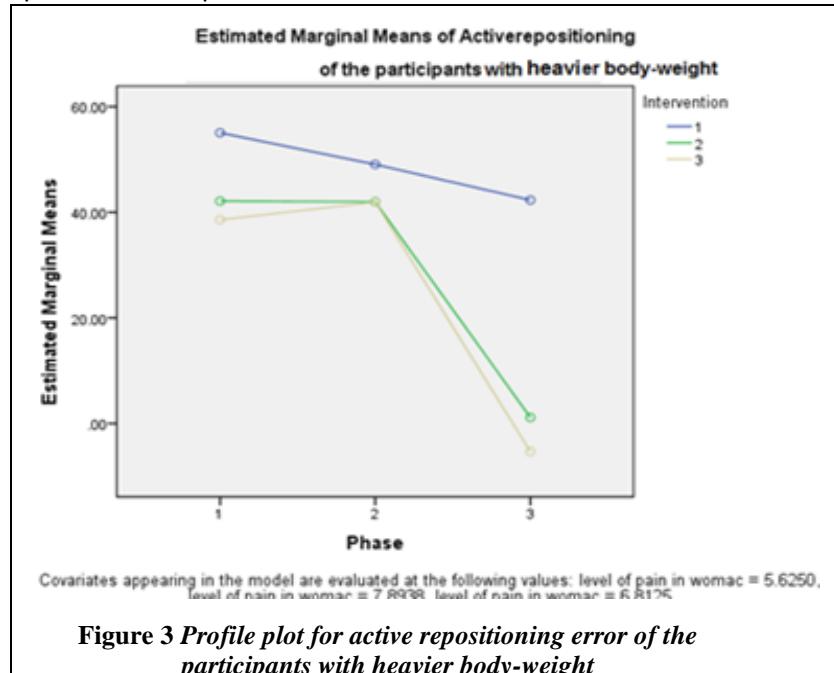


Figure 3 Profile plot for active repositioning error of the participants with heavier body-weight

Since, problems pertaining to OA are degenerative in nature and hence those are considered as the disorders having regressive orientations. Hence, in search of a novel explanation to the outcomes of this study, we opted to explore onto basic problems of OA, which has a usual association between extent of OA problems and weight of the OA individuals. This attempt however revealed that the individuals, identified as having relatively higher body-weight also experienced differential natures of crises compared to their counterparts, who were having characteristically lower level of body-weight. As the data for lower candidates having lower body-weight were analyzed separately, outcomes of the repeated measure of ANOVA clarified that, until the mid-term phase no difference between the interventions were evident, while marked improvement in proprioception, as revealed through reduction in active repositioning error was evident amongst participants of all the intervention groups (see figure 2 for the graphical representation of the outcomes). This finding however implied that, for individuals suffering from OA, if they have lower body-weight, irrespective of the types of intervention techniques employed, marked improvement in proprioception could be evident. While the graphical illustration (see figure 3) for the heavier individuals however clarified that, those who received treatments based on conventional physiotherapeutic training, could not have noticeable benefit from the intervention techniques applied on them, whereas their counterparts from the isokinetic as well as

combined intervention training could benefit mostly after the mid-term intervention.

4. CONCLUSIONS

Findings of this study led us to conclude that, based on evaluation of active repositioning error, compared to the isokinetic intervention training, both conventional and combined intervention techniques were evident as better effective techniques in enhancing proprioception. Evaluation of proprioception at 30° revealed that CP exercise was better effective compared to the isokinetic training, while evaluation at 60° clarified that, both the CP and combined intervention techniques were better effective interventions compared to the introduction of the isokinetic training alone. Thus, outcomes implied relatively poorer improvement in proprioception, followed by isokinetic training, which however gets altered, as the factor of difference in body-weight is considered.

Findings on impact of interventions on middle-aged female OA patients having lower body-weight however clarified that, until the mid-term phase of intervention, all the intervention techniques had minimal improvement in proprioception (both at 30° as well as at 60°), while at the end of stipulated period of intervention, all the techniques were evident as identically beneficial for improvement in proprioception. Contrary to that, for the female OA patients having higher body-weight, however, conventional intervention training appeared as less effective in bringing about progressive changes.

Both isokinetic and combined intervention on the other hand, were evident as capable of improving proprioception up to the identical extent. This finding of differential impacts of body-weight of the OA patients, could be considered as unique and unprecedented outcome. We wish to carry out further researches to arrive at any decisive conclusion about this issue, and furthermore, we expect that numerous replicated studies following this identically rigorous methodology, would enable us to arrive at any generalized conclusion concerning role of body-weight on proprioception in middle-aged OA patients.

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6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

SrS, SoS, AaS, NbR

Collected data and performed the experiments:

CmL, FaS, NbR, SoS

Contributed with materials/analysis tools: SrS, SoS, AaS, NbR

Analyzed the data: SrS, SoS, NbR

Wrote the paper: SoS, SrS, NbR

Checked and edited the format of the paper:

FaS, SrS, SoS, AaS, NbR

Final approval: FaS, SrS, SoS, AaS, NbR

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IMPACT OF EMOTIONALITY, MOOD AND AUTONOMIC FACTORS IN REGULATION OF OUTCOMES OF BIOFEEDBACK TRAINING ON SOCCER PERFORMANCE SKILLS

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ABSTRACT

Present experiment was carried out to examine the impacts of changes in mood and emotionality factors in influencing performance of soccer juggling task. Sixty-nine young male recreational athletes (matched in anthropometric, cardiovascular and performance status) identified as having disrupted emotionality were recruited as participant. Participants were subjected to assessment of psychological attributes (viz. self-esteem, somatization, anxiety, mood factors and emotional stability), psychobiological attributes (skin conductance or Sc habituation paradigm or phasic measures of arousal) physical performance parameter (vertical jump performance) and soccer skill parameter (juggling tasks). Participants were categorised into three groups, viz. Group A – no-intervention control group, Group B – experimental group I (received Sc biofeedback training) and Group C – experimental II (received electromyography or EMG biofeedback training). Interventions followed for 15 minutes/session, 2 sessions/week for 16 weeks. For the purpose of this study outcomes of the post-intervention analyses, which were carried out after the 16th week of intervention, was considered for investigation. Descriptive analyses, two-way repeated measure of ANOVA and multiple linear regression analyses were carried out after the post-intervention phase of analysis, which clarified interrelationships between the mood, emotionality and psychobiological influencing factors on the outcomes of soccer ball juggling skills, evident among the players of three different experimental conditions. Inhibitive as well as facilitative impacts of mood state factors, emotionality and psychobiological indices emerged as predictors of performance changes of soccer skills.

KEYWORDS: *Biofeedback, Motor Ability; Motor Coordination; Dexterity*

1. INTRODUCTION

Research attempts pertaining to the game of soccer have been observed as substantially wide-ranged. Researches conducted in last three decades, however have been observed that, the topics of interest ranged from science of soccer¹,

to ergonomics², notational performance analysis³, biomechanics of soccer kicking⁴, fitness⁵ and training aspects⁶ to even soccer economics⁷. Researches on South-Asian and South-East Asian players, however were scanty in numbers, and only handful of studies were keen on evaluation of psychological aspects associated with poorer

soccer performance⁸. This study intends to provide pertinent information related to deleterious impacts of emotional hindrances on soccer performance. Furthermore, this study aims to put specific emphasis on need for researches on valid intervention techniques to resolve emotional crises amongst soccer players in Malaysia, which can ensure excellence in soccer performance skills.⁹

In order to do that, first of all we wanted to focus on the need for optimum estimation of deep-rooted emotionality of the soccer players. It is well-understood that, other than physical qualities and skills, playing conditions, physical training and playing tactics, many conceivable perplexing elements may intermingle behind athletic enactment required for successful performance of soccer skills. Some of these perplexing emotional elements are associated with obscure emotional core problems like fear of success phobia.¹⁰⁻¹³ Apart from that, unresolved emotional hindrances pertaining apprehension of losing¹³⁻¹⁴ also put immense pressure on the players. Furthermore, elite players continuously tend to face with their own repressed desires to be on top of the world and conflicts pertaining aggressing over dominant opponents.¹⁵ Again, trying to become indomitable^{13,15} also lead to emotional overloading, which can potentially even restrict motor functionality¹⁷⁻¹⁸; joint and movement coordination¹⁹⁻¹⁸ and neuroendocrinological information processing^{17,19-20}. Any combination of some of these factors either alone or being intermingled with any other element may lead to catastrophic performance outcomes.^{8,21-24}

Majority of the aforementioned emotional core elements never come on to the surface of day-to-day life stress, and hence, players themselves do not remain consciously aware of those internalised mostly unconscious and hidden emotional crises. These are considered as inner core emotionality, which can disrupt cognitive-emotional make-up of the players, and hence can inhibit in optimal performance. These inner core disruptive emotional burdens could be revealed by projective assessments of thought-process dependent cognitive-emotionality²⁵, which could be aptly corroborated with habituation paradigm psychobiological estimation^{8,17,24,26} of emotional indices leading to objective and substantiated etiological evidences^{17,25-27}. The most significant methodological concern pertaining this

substantiated evaluation is that the outcomes of these analyses cannot be manoeuvred and contrived^{8,24-26} and hence would be by and large free from subjective biasness^{8,24}.

Since optimal evaluation of problems may enable us with adequate information regarding emotional crises and corresponding psychobiological issues of concern, comprehensive resolution of those crises. There is a popular misconception amongst coaches, officials, peers, fans and players themselves that coping with stress is a natural ability of the players^{8,14,24}. Further to that, this misconception leads to false belief that, elite players are psychologically strong or mentally tough, or they have hardy personality¹⁶. Thus, owing to these misconceptions and false beliefs majority of the elite-players, those who tend to ignore psychological skill training, without effective stress management skills training, sometimes they try to apply intervention techniques on their own, which obviously lead to derogatory impacts^{8,14,24}. Psychological skill training strategies are obviously required by the elite players as well, since these are influential contributors to successful competitive performance in sport^{8,14,24}. A part of this current research seeks to apply biofeedback as a specific psychological skill training. The application of biofeedback training in modulating emotionality is then measured to determine changes in soccer performance. If there is a positive change, the introduction of biofeedback training as part of routine soccer training may be supported.

2. METHODS

2.1 Participants

For the present experiment sample size was calculated using G power 3.1.9.2²⁸. The power of the study is set at 95% with 95% confident interval and the effect size F at 0.25. Total required sample size was calculated as 45 and hence sixty-nine young adult high-performing soccer players were recruited as participants (mean age = 21.39 and SD = 1. 67). They were selected based on the psychological evaluation of dispositional anxiety; kinanthropometric and cardiovascular status of the players and moderately high level of soccer performance skill levels.

[1] -- Monday, August 08, 2015 -- 15:39:43	
F tests - ANOVA: Repeated measures, within-between interaction	
Analysis:	A priori: Compute required sample size
Input:	Effect size f = 0.25
	α err prob = 0.05
	Power (1- β err prob) = 0.95
	Number of groups = 3
	Number of measurements = 4
	Corr among rep measures = 0.5
	Nonsphericity correction ϵ = 1
Output:	Noncentrality parameter λ = 22.5000000
	Critical F = 2.1713088
	Numerator df = 6.0000000
	Denominator df = 126
	Total sample size = 45
	Actual power = 0.9554764

2.2 Materials Used

For this experiment, some self-report inventories were administered along with psychobiological and psychomotor evaluations. Further to that, soccer performance related parameters were also assessed, and for all these evaluations following equipment and test materials were required.

- 1) State-Trait Anxiety Inventory (STAI)²⁹
- 2) Brunel Mood Scale³⁰
- 3) Rorschach Ink – Blot Test³¹
- 4) EMG Biofeedback Apparatus (ProComp Infinity5 equipment of Thought Technology, USA, 2014).
- 5) Skin Conductance Biofeedback Apparatus (Udyog, India 2000).
- 6) Materials for Performance Test: – Soccer Ball; 14 cones; Stopwatch; Marker; PVC box and Measuring tape.

2.3 Procedure

After the participants agreed to participate in the study and after they signed the consent form, they were subjected to evaluation of self-reported transitory and dispositional anxiety, based on State-Trait Anxiety Inventory (STAI)²⁹. Further to that, evaluations of psychological measure, such as, mood states was carried out by employing Brunel Mood Scale³⁰ and cognitive-emotional aspects based emotional core was evaluated by the Rorschach Ink Blot Test for projective analysis³¹. Apart from that, evaluation of few soccer skills (such as juggling; shooting and with the ball agility) were also carried out. All of these assessments were carried out following standardised protocols, and rigorous methodology was followed to collect data. Step-by-step methodology is detailed in the previous

research literatures, published based on the studies conducted in identical experimental set-up, with similar groups of soccer players.^{8,24,32,33} Thereafter, they were subjected to assessment of phasic skin conductance (Sc) indices, Sc electrodes were attached to the phalange of the fingers of the participants, and they were supposed to remain in reclining position with eyes closed and in relax composure. At this phase, they were prompted with a white noise as novel and benign stimulation to record phasic or habituation paradigm psychobiological responses (ERP). Projective analysis of emotional make-up was done by employing the Rorschach Ink-Blot evaluation system, in which the participants were supposed to watch colourful meaningless pictures and they were required to report on their perception about those pictures. Since Rorschach pictographs are ambiguous images, and there are no pre-fixed explanations on the images, players were supposed to report on their personal view about those images, pertaining to their perception concerning the images created by the ink-bLOTS. Thus, RIB enabled us to evaluate personality oriented cognitive-emotional make-up of the participants.

Thereafter, based on randomized sampling formula (employing Research Randomizer Software³⁴, participants were equally categorized into following groups – 1) Group A – No-intervention or control group (n = 23); 2) Group B – Experimental Group I, who received EMG Biofeedback intervention training (n = 23), and 3) Group C – Experimental Group II, who received Sc Biofeedback training (n = 23). Participants selected for intervention regimes were subjected to the training sessions for 15 - 20 minutes per session/ two sessions per week for 16 weeks (32

sessions in total). Control Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating the performance disaster amongst soccer players.

2.4. Statistical Analysis

The data were treated with SPSS 24.0, and analysis of descriptive statistics and a two-factor ANOVA with repeated measures was carried out to compare data on vertical jump and soccer ball

juggling performance obtained from the two intervention experimental conditions observed across different phases of analyses. Simple main-effects analyses and Bonferroni post hoc tests were undertaken when ANOVA revealed a significant interaction. Further to that, outcomes of multiple linear regression analyses were critically observed to identify whether various corroborative relationships between mood states and inner psychopathological make-up as derived by employing the projective evaluation system and the direct physiological measures (autonomic indices obtained by the skin conductance measures under habituation paradigm), which could reveal the intricate processes involved in catastrophic or disruptive emotionality observed in highly skilled but under-performing Malaysian Soccer players.

3. RESULTS

Outcomes of this study are presented based on the descriptive information (refer to tables 1

and 2), pairwise comparison (tables 3 and 4) and multiple linear regression reports (Tables 5 to 7).

Table 1

Descriptive Statistics of Performance Parameters Analysis on Vertical Jump score Across the Groups

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
Vertical jump scores pre-intervention	16.17 ± 9.25	19.31 ± 2.33	16.50 ± 5.04
Vertical jump scores mid-intervention	28.27 ± 15.23	36.17 ± 4.45	32.00 ± 10.49
Vertical jump scores post-intervention	29.03 ± 15.56	38.00 ± 3.87	33.37 ± 10.80
Vertical jump scores follow up-intervention	29.73 ± 15.91	38.40 ± 3.67	33.67 ± 10.64

Table 2

Descriptive Statistics of Performance Parameters Analysis on Soccer juggling score Across the Groups

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
Soccer juggling score at pre-intervention level	46.27 ± 2.87	47.73 ± 3.87	49.47 ± 3.44
Soccer juggling score at mid-intervention level	46.40 ± 2.72	62.53 ± 2.50	63.53 ± 5.18
Soccer juggling score at post-intervention level	47.47 ± 5.49	72.33 ± 4.89	69.87 ± 5.19
Soccer juggling score at follow up-intervention level	48.00 ± 4.16	71.67 ± 5.25	69.67 ± 4.82

Tables 1 and 2 were conceived to represent phase wise alterations observed in the physical performance parameter and soccer performance parameters, which were observed amongst participants of three different groups. Observations based on the shapiro-wilk test for normality however revealed that indices were mostly free from huge dispersions and identical features in the obtained pre-intervention data

mostly revealed that, participants did not have any pre-existing differences. Hence, whatever differences were observed in the mid-term as well as in the post-intervention and post-follow-up phases could be attributed to the interventions introduced to the participants.

Table 3
Pairwise Comparisons Vertical Jump Across the Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback	.026**	.008	.007
	Sc Biofeedback	.027*	.008	.012
EMG Biofeedback	Control group	-.026**	.008	.007
	Sc Biofeedback	-.010	.006	.492
Sc Biofeedback	Control group	-.027*	.008	.012
	EMG Biofeedback	.010	.006	.492

*p<0.05; **p<0.01

In the Table 3 differences amongst the participants existed. Findings in this performance index revealed that, compared to the participants of both EMG and Sc Biofeedback intervention groups, the control group participants had significantly better ability to have higher vertical jump (p<0.01; p<0.05). Thus, the outcomes of this

analysis revealed that, in enhancing vertical jump performance scores, both EMG and Sc Biofeedback training techniques were not adequately effective. No difference amongst the participants of the two intervention groups was revealed.

Table 4
Pairwise Comparisons Soccer Juggling Across the Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback	-4.222**	.643	.000
	Sc Biofeedback	-8.533**	.866	.000
EMG Biofeedback	Control group	4.222**	.643	.000
	Sc Biofeedback	-4.311**	.412	.000
Sc Biofeedback	Control group	8.533**	.866	.000
	EMG Biofeedback	4.311**	.412	.000

*p<0.05; **p<0.01

Outcomes of the pairwise comparisons represented in the Table 4 depicted that, at the post-intervention assessment, differences amongst the participants were evident. Findings however revealed that, compared to the participants of the no-intervention group, both the EMG and Sc Biofeedback intervention groups of participants had significantly better juggling scores p<0.01,

p<0.01). Thus, the outcomes of this analysis revealed that, in enhancing soccer ball juggling performance, both EMG and Sc Biofeedback training techniques were adequately effective. Apart from that, compared to the participants of EMG BF group, the Sc BF group players were observed as significantly better in juggling performance (p<0.01).

Table 5
Model a - Summary of multiple linear regression analysis on Juggling Ability in Control group (based on emotionality variables)

Dep. Variable - Juggling Ability	Unstandardized Coefficients		t	Sig.	Correlations			Collinearity Statistics	
	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	79.16	4.89	16.19	.000					
Self-esteem	-4.48	1.07	-.49	-4.19	.006	-.375	-.416	-.612	.906

^a(F (3, 19) = 4.713, P < 0.022), Adj.R² = 43.9%

In Table 5 the model **a** emerged significant as the psychological measure of self-esteem could explain 43.9 % variance of changes in the extent of juggling task performed at the post-intervention phase. Model **a** explained the inverse relationship between self-esteem and the extent of juggling

score observed among the players during post-intervention phase of assessment. Hence, findings revealed that the players having lesser self-esteem were evident as having better improvement in juggling performance.

Table 6
Model b - Summary of multiple linear regression analysis on Juggling Ability in EMG Biofeedback group (based on psychobiological and mood variables)

Dep. Variable - Juggling Ability	Unstandardized Coefficients		Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	82.09	15.27		5.38	.000***					
Adaptation Level post	-.23	.07	-.99	-3.06	.004**	.220	-.460	-.370	.138	7.230
Recovery Time post	1.06	.26	.75	4.07	.000***	.231	.566	.491	.428	2.335
Positive mood	-.61	.26	-.33	-2.34	.025*	-.088	-.368	-.283	.753	1.328

^b(F (2, 20) = 3.716, P < 0.002), Adj.R² = 35.7%

In Table 6 the model **b** emerged significant as the post-intervention outcomes of the psychophysiological measures of adaptation level and recovery time; psychological measures of positive mood together could explain 35.7% variance of changes in the extent of juggling performance outcomes observed amongst the players of the EMG biofeedback group.

Model **b** explained the inverse relationship among post-intervention observations of Sc adaptation level and positive mood and the extent

of juggling ability observed in the athletes. Apart from that, recovery time was found directly associated with higher extent of juggling ability. Henceforth, findings shown that the athletes having lesser extent of adaptation level and lower extent of positive mood were evidently having better juggling performance score. Contrary to that, delayed Sc recovery time observed during post-intervention assessment was also evident as associated with higher extent of juggling ability.

Table 7
Model c - Summary of multiple linear regression analysis on Juggling Ability in Sc Biofeedback group (based on emotionality variables)

Dep. Variable - Juggling Ability	Unstandardized Coefficients		Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	96.84	13.95		6.94	.000					
State Anxiety	-3.77	1.20	-.46	-3.13	.003**	-.27	-.45	-.42	.843	1.186
Anger	-.27	.12	-.34	-2.32	.026*	-.13	-.35	-.31	.836	1.196
Phasic post-intervention Amplitude	.30	.11	.88	2.81	.008**	.25	.42	.38	.184	5.449
Phasic post-intervention Latency	-.34	.16	-.99	-2.16	.037*	.15	-.33	-.29	.086	11.561

^c(F (2, 21) = 5.67, P < 0.001), Adj.R² = 39.4%

In Table 7 the model **c** emerged significant as the health parameters such as, state anxiety, anger, phasic Sc amplitude and latency at post-intervention phase, together could explain 39.4 % variance of changes in the extent of juggling ability observed amongst the players who received Sc BF training. Model **c** explained the inverse relationship between the outcomes of state anxiety, anger and phasic Sc latency evident

at post-intervention phase and the extent of improvement observed in the juggling ability amongst the players. Apart from that, phasic Sc amplitude observed at post-intervention phase was found directly associated with higher extent of juggling ability. Therefore, findings revealed that the athletes having lower state anxiety, lower extent of anger and faster Sc latency and relatively higher Sc amplitude, could display better juggling performance outcome.

4. DISCUSSION

Findings of this experiment revealed beneficial impacts of both the EMG and Sc Biofeedback intervention techniques in improving vertical jump performance. Findings of this experiment however revealed that in case of vertical jump performance, compared to the players of control condition the EMG BF participants were observed to display better performance (table 3 is referred). Similarly, outcomes also revealed that compared to their counterparts in the control condition, players of Sc BF group also were observed to display better vertical jump performance (table 3 is referred). Since the players of the control group did not receive any intervention training, this observed better edge in vertical jump could be attributed to their usual improvement in the physical performance level. Vertical jump performance depends on anaerobic capacity of the players, and hence the control group of players were being allowed to continue with their regularised training could only enhance in the gross motor dependent explosive performance^{5,35}. This observed beneficial outcome of both EMG and Sc biofeedback training techniques however got supported by the previous findings reported by^{16,36-38}. Thus, this study has been found successful in confirming facilitative impact of both EMG and Sc biofeedback training regimes on physical performance parameters, which was evident amongst the Malaysian soccer players. Here, we were interested to evaluate comparative edge of intervention techniques, which however revealed no difference between the intervention regimes (table 3 is referred). Mean difference of vertical jump performance outcomes, however offered enough reasons to claim that in terms of effectiveness, there exist no difference between the EMG and Sc biofeedback intervention training regimes.

At this point we paid attention to the outcomes of the soccer ball juggling performance. Findings in case of juggling performance revealed that compared to the players of control condition, both the EMG and Sc BF participants were observed to display better juggling performance (table 4 is referred). This observed beneficial impact of both the EMG and Sc biofeedback training however got supported by the previous findings reported by^{8,15,16,18,36}. Improvements in juggling performance evident among the players

of EMG BF group could be attributed to enhancement in autonomic processing that involves excitatory control by the premotor cortex descending through the pyramidal tract¹⁷. For the Sc BF group of participants, improvements evident in juggling performance could be attributed to enhancement in regulation of excitatory potential and control by the premotor cortex in Broadman area¹⁷. Further to that, autonomic processing involving the descending tract reticular system or DRAS through the pyramidal tract^{17,39}.

As in case of vertical jump performance, no comparative difference between the effectiveness of the interventions was evident, regarding soccer ball juggling performance also we assumed similar outcome of beneficial impacts of the biofeedback interventions. Outcomes of this study however revealed that compared to the players of EMG BF condition, the Sc BF group participants were observed to display better juggling performance (table 4 is referred). This observed beneficial impact of Sc biofeedback training over the EMG BF training however got supported by the previous findings reported by^{16-17,36}. Improvements evident in juggling performance could be attributed to enhancement in regulation of excitatory potential and control by the premotor cortex in Broadman area 6¹⁷. Further to that, autonomic processing involving the descending tract reticular system or DRAS through the pyramidal tract^{17,39}.

The comparative better edge of Sc biofeedback incited us to explore into the aspects such as, motor control, psychobiological and psychological factors, which could possibly mediate differentially among players of different groups, who were exposed to differential biofeedback training. Further to that, players of the control group were observed to have no improvement at all in juggling performance outcomes, although they were evident to display improvement in vertical jump performance. Hence, this finding clarified that, for any soccer player, at least for this group of players, mere increment in anaerobic power or improvement in physical performance skill, cannot ensure improvement in soccer skill. Again, out of the two intervention techniques, Sc biofeedback training appeared better effective in case of juggling performance, while no such comparative

difference between the intervention techniques were evident in case of vertical jump performance, in which both the intervention techniques were observed as not successful in bringing on desired extent of improvement. With such a background, we intended to pay attention to the outcomes of multiple regression reports, which provided us with the information on predictive contribution of relevant mediator variables.

At first, attempts have been made on explaining roles of predictors variables associated with emotional make-up of the players as contributor of their *juggling performance* scores. In case of the *control group participants*, higher tolerance indices evident in collinearity statistics (Table 5, Model **a**) suggested that – in explaining juggling performance score, very high extent of (90.6%) variance in self-esteem was not predicted by other measures. Model **a** also explained that for every 1% reduction in self-esteem, .49% improvement in juggling score might be evident. Thus, the model implied that for the players of control group, lower self-esteem was associated with relatively higher juggling performance score. Outcomes of this model although clarified that, at the post-intervention phase of assessment, the control group participants were observed to display poorer juggling scores, and hence the inverse relationship signified that players of this group had relatively higher extent of self-esteem, which was observed as associated with relatively poorer juggling performance. This higher extent of self-esteem obviously alone cannot contribute on improvement in juggling performance, and hence cannot predict higher juggling score, and further to that, higher un-realistic self-esteem, may also lead to disastrous performance outcomes.

Next, we wanted to explore into the possible reasons behind improved *juggling performance* scores evident among players who received the *EMG BF treatment*. Emotional make-up of those players, however clarified that, the higher tolerance index observed in collinearity statistics (Table 6, Model **b**) suggested that – in explaining juggling ability very high extent of variances in positive mood (75.3%) was not predicted by other measures. Model **b** also explained that reduction of every 1% of positive mood, was associated with .33% improvement in juggling score among the EMG BF group of players. Similarly, moderate extent of variances in Sc recovery time (42.8%) and slight extent of variances in Sc adaptation level (13.8%) were not predicted by other measures. Model **b** also

explained that, reduction of every 1% of positive mood and adaptation level, were associated with .33% and .99% improvement respectively in juggling score among the EMG BF group of players. Further to that among the EMG BF group of players, every 1% of increment in Sc recovery time, .75% improvement in juggling score would be evident.

Outcomes of this model explained that, improvement in juggling score evident at the post-intervention phase, among the players of the EMG-BF group, were observed as associated with lower level of positive mood. Findings thus suggested that, those who had lower level of positive mood, were better able to perform juggling tasks. Thus, it could be postulated that, the EMG-BF intervention did not have any definite impact on mood elevation and the resultant juggling performance as well. These players were also observed to have relatively delayed autonomic recovery, which however facilitated in having higher extent of juggling performance score. Now under this perplexing condition, it could be assumed that, perhaps the players of EMG BF group were more extroverted, and since extroverted individuals enjoy stimulation rather than avoiding the stimulation, the heightened autonomic arousal condition perhaps resulted in delayed recovery from Sc arousal. This assumption gets further strengthened, as these players were also characterised by shorter Sc adaptation level, and hence recovery from autonomic arousal got delayed and also autonomic adaptation for these players at the post-intervention phase was not adequate. Thus, finally it could be assumed that, the EMG BF intervention was not effective enough in ensuring faster autonomic recovery, although that did not have huge deleterious impact on juggling performance.

Similarly, we wanted to examine the predictive influence of mood constellations and emotional make-up of the players of the *Sc BF group*, on their *juggling performance*. Higher tolerance index (Table 7, Model **c**) however revealed that – in explaining juggling ability very high extent of variances in state anxiety (84.3%) and in anger (83.6%) were not predicted by other measures. Model **c** also explained that for every 1% reduction in state anxiety .457% increment in juggling ability would occur, whereas for every 1% reduction in anger, .340% increment in juggling ability would be evident. Further to that the model also explained that, for every 1%

increment in post-intervention level of phasic Sc amplitude .881% improvement in juggling ability would occur, while for phasic Sc latency, every 1% reduction latency would lead to .985% of improvement in juggling ability would be evident. Outcomes of this model however clarified that, at the post-intervention phase of assessment, the Sc - BF group participants were observed as having lower levels of perceived anger and they were also characteristically having lower level of transient anxiety. Thus players, who were observed as having low state anxiety, if they have lesser perceived anger, can perform juggling task better than others. This observation of perceived lower extent of anger perhaps got mediated by the Sc BF training which perhaps enabled the players to have lesser perceived anger compared to their counterparts in the EMG BF group and the control condition as well. Further to that, these players were also observed to have benefitted by enhanced autonomic competence, which could definitely be attributed to the Sc biofeedback intervention training. Players who received Sc BF training, could get faster latency and enhanced Sc amplitude, which perhaps have led to faster orienting response, leading to enhanced information processing, and consequent heightened juggling performance outcomes.

Here in nutshell, we would like to highlight on enhanced autonomic efficiency of the players of the Sc BF group, since this autonomic efficiency was characterised by improvement in Sc amplitude. This outcome of enhanced Sc amplitude however got support from the outcomes reported in the previous literatures^{8,18,24,36}. Findings obtained in other researches³³, however contradicted this outcome, as in those literatures either reduction in amplitude or no changes in Sc amplitude was observed. Reason behind this incongruence in outcomes could be attributed to the Sc biofeedback training protocol followed. As in cases of Zahir et al.,³⁶ and Saha et al.,^{8,24,33} Sc-BF intervention was based on Sc orienting responses training. In this study also, Sc biofeedback training was carried out involving training of regulation over Sc orienting responses. For other researchers^{33,39} however, SC-BF training was carried out following regulation over tonic Sc level only.

Thus, in sum the outcomes of regression analyses clarified that, players of control group were characterised by relatively higher extent of self-esteem, which could not facilitate in juggling performance. Players of EMG biofeedback group

were on the contrary, characterised by lower extent of positive mood and deficient autonomic competence (i.e., lower Sc adaptation level and delayed Sc recovery time), which was evident as effective in producing better juggling performance. But, the players of Sc biofeedback group were observed as having lower extent of state anxiety, lesser perceived anger. Lower extent of inhibitive mood and emotional make-up was further supported by enhanced autonomic competence (for instance, faster latency and enhanced Sc amplitude), which perhaps have led them to have faster orienting response, leading to enhanced information processing, and consequent heightened juggling performance outcomes.

5. CONCLUSION

Findings of this study revealed that in case of vertical jump performance evident among the soccer players, neither EMG nor Sc biofeedback intervention was found effective in improving performance outcomes. In case of soccer ball juggling performance, however, both skin conductance and EMG biofeedback intervention techniques were found effective. Skin conductance biofeedback intervention appeared as better intervention technique in modulating mood and emotional factors, and in enhancing autonomic competence, which in turn enabled the young-adult Malaysian promising soccer players to display better soccer ball juggling performance.

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7. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:
SrS, SoS

Collected data and performed the experiments:
FaS, SrS, SoS, FoH

Contributed with materials/analysis tools:
FaS, SrS, SoS

Analysed the data: SrS, SoS

Wrote the paper: SoS

Checked and edited the format of the paper:
FaS, SrS, SoS

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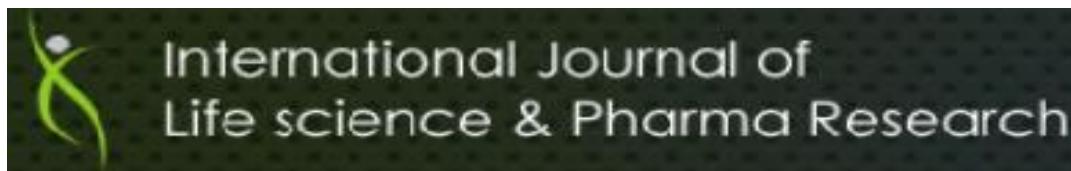
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DIFFERENTIAL EFFICACY OF ISOKINETIC TRAINING AND CONVENTIONAL PHYSIOTHERAPEUTIC EXERCISE INTERVENTION ON PERCEIVED DISCOMFORT IN OSTEOARTHRITIS PATIENTS

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ABSTRACT

Present experiment was conducted to investigate the role of Conventional Physiotherapy (CP), Isokinetic Exercise Training (IET) and combined intervention (CI) of CP and IET in reducing pain and stiffness by improving proprioception in participants with knee osteoarthritis. 54 post-menopausal female participants in the age range of 45-65 years with knee osteoarthritis (OA) of Grade II (Kellgren-Lawrence criteria) severity were recruited from the Department of Orthopaedics, Hospital Universiti Sains Malaysia. Participants were subjected to assessment of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) for baseline assessment to evaluate the subjective scale for pain, stiffness and physical function. Deficits in proprioception was assessed employing the isokinetic device BIODEX 4 System. After the baseline assessment, participants were randomly classified into three groups (Gr.) (Viz. Gr. A, Gr. B and Gr. C) and each group comprised of 18 participants. Gr. A participant received CP comprising of strengthening exercises; stretching exercises and range of motion (ROM) exercises. Gr. B received IET at velocities of 90 degrees and 150 degrees per second. Gr. C participants received CI training. All the interventions were conducted for 25 - 30 minutes per session; 2 sessions per week for 12 weeks. Mid-term evaluation was done after 6th week followed by the post intervention evaluation after 12th week following pre-intervention analyses protocol. Analyses revealed that interventions were beneficial in improving the strength and proprioception of knee joint in participants with OA of knee joint, which however resulted in reduction of pain and stiffness. For CI and IET participants, pre-intervention level of poor proprioception was found associated with higher extent of pain; stiffness and physical function, which did not improve up to adequate extent. During the post-intervention phase, CP trainees were observed to have better improvement compared to their counterparts in CI and IET, while IET trainees were observed to have no improvement at all. Multiple linear regression analyses revealed the association between pain, level of stiffness and physical function with weight, height and level of proprioception.

KEYWORDS: Osteoarthritis; Pain; Physiotherapy; Isokinetic Training; Proprioception

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1. INTRODUCTION

Osteoarthritis (OA), is a degenerative disease of the cartilage, which is mostly prevalent in the knee joint (Davis, 1988)¹ of elderly population (Felson et al., 1990).² As it was predicted by Lawrence and his co-researchers (2008)³ by the year 2020, the prevalence of OA would be doubled due to the upsurge in the number of obese individuals and elderly population. Similar assumption was made on projected rise of OA incidences in South-East Asia, particularly in Malaysia, as an estimated rise of about 269% of people aged more than 65 years is expected in Malaysia by the year 2040.⁴

Researchers were observed to have disagreements over aetiology of OA, either pertaining to anatomical morphology of the OA knee joint^{5,6} or associated with functional morphology⁷⁻¹¹ of the knee joint. As structural problems in capsule, ligaments, periarticular muscles, articular cartilage and synovial membrane were emphasized⁵, occurrence of fissures, ulceration, full thickness destruction of the knee joint surface and fibrillation at the articular cartilage in knee osteoarthritis⁶ were also highlighted as anatomical irregularities. Contrary to that muscle weakness, increased joint compression and reduction in physical activity were pointed out as the reasons behind increase in the risk of OA among obese individuals⁷, changes of joint loading mechanism were also highlighted as the reason behind progression of knee OA.⁸ Several other researchers pointed out to the inhibitive contribution of incongruent gait of participants, pertaining to decrease in knee flexion during mid-stance, limited range of motion of the knee joint and reduced walking speed.⁹⁻¹¹

In search of effective intervention techniques to treat knee OA, conventional physiotherapy treatment (which is basically non-pharmacological treatments)¹² comprising exercise therapy, manual therapy, electrotherapy, hydrotherapy is suggested by several authors in reducing pain, improving muscle strength and function in participants with knee OA.^{13,14} Manual therapy and exercise such as strengthening exercise, stretching exercise and range of motion exercise were also suggested by other researchers as potentially beneficial intervention techniques.¹⁵ Apart from all theses, in advent of technological development isokinetic training evolved as an alternative to traditional exercise, which is done

under a constant velocity and at varying resistance applications.^{16,17} Isokinetic exercise intervention has been widely used in the arena of rehabilitation to all ages and various population such as healthy male individuals^{18,19}; female²⁰; elderly^{21,22}; musculoskeletal disorders²³. Isokinetic training has been utilized in knee OA participants for gaining strength and improving physical function^{24,25} however, the advantage of isokinetic training in reducing perceived discomfort and pain and in enhancing proprioception for knee OA has not yet been thoroughly investigated.

The main aims of the current study are as follows:

- i. To identify the effects of conventional physiotherapeutic intervention on proprioception and impact of that on perceived pain and discomfort in knee OA participants.
- ii. To investigate the effect of isokinetic training on proprioception and impact of that on perceived pain and discomfort in knee OA participants.
- iii. To compare the impacts of conventional physiotherapeutic intervention and isokinetic training on proprioception and impact of that on perceived pain and discomfort in knee OA participants.

2. METHODOLOGY

2.1. Participants

From a pool of sixty-nine elderly female individuals suffering from pain in knee, fifty-four individuals aging between fifty-six to sixty-five years were selected based on Kellgren's (Grade - II)²⁶ criteria of deficit in proprioception. The sample size was calculated using G power 3.1.9.²⁷ The power of the study is set at 95% with 95% confidence interval and the effect size F was set at 0.05. Thus, finally sample size for this present study was set at N = 54, comprising of female (Mean age - 59.43 SD- 4.89) participants suffering from OA, based on Kellgren's (Grade - II)²⁶ criteria of deficit in proprioception. This study was approved by a University's Research Ethics Committee and participants provided informed consent prior to participating (Reference number for ethical permission: USM/JEPeM/15040143).

2.2. Materials Used

An information schedule was prepared to collect relevant information about the participants.

1. Western Ontario and McMaster Universities Arthritis Index (WOMAC) Inventory
2. Isokinetic Bidex 4 Multi-Joint System Pro Machine
3. Stadiometer (Seca Bodymeter 208, Germany)
4. Weighing Scale (Omron Karada Scan – HBF 356, Japan)
5. Stop Watch (RESEE, China)
6. Ankle air splint
7. Headphones
8. Blindfolds
9. Theraband (Blue)

2.3. Procedure

All the participants upon arrival at the laboratory of the Exercise & Sports Science programme of the School of Health Science, of the Universiti Sains Malaysia were at first introduced to the study protocol, and after they could realise the whole procedure, written ethical consent was obtained from each of the participants. Thereafter they were subjected to assessment of WOMAC self-report inventory following standard procedure of administration. Further to that, assessment of Passive Angle Reproduction or Passive Repositioning Error was done as measure of proprioception. Detailed protocol for assessment of WOMAC and Passive Reposition error, are detailed herewith in the following sections (from 2.3.1. to 2.3.4.). After the pre-intervention analyses, participants were randomly categorized into three groups (Gr.) (Viz. Gr. A, Gr. B and Gr. C) and each group was comprised of 18 participants. Gr. A participant received Conventional Physiotherapy containing of strengthening exercises; stretching exercises and range of motion (ROM) exercises. Gr. B received Isokinetic Training at velocities of 90 degrees and 150 degrees per second. Since in this study, we wanted to compare between the efficacies CP and Isokinetic training, another group of (Gr. C) participants were considered, who received combined intervention of CP and Isokinetic Training. All the interventions were conducted for 25 - 30 minutes per session; 2

sessions per week for 12 weeks. Mid-term evaluation was done after 6th week followed by the post intervention evaluation after 12th week following pre-intervention analyses protocol.

2.3.1. Assessment of WOMAC

Western Ontario and McMaster Universities Arthritis Index (WOMAC) measures self-reported information based on perceived difficulties in five items for feelings of pain (score range 0–20); two items for perceived stiffness (score range 0–8), and 17 for functional limitation (score range 0–68). Physical functioning problems cover everyday activities such as stair use, standing up from a sitting or lying position, standing, bending, walking, getting in and out of a car, shopping, putting on or taking off socks, lying in bed, getting in or out of a bath, sitting, and heavy and light household duties.

2.3.2. Assessment of Isokinetic Bidex 4 Multi-Joint System

Isokinetic is any form of movement, exercise or type of testing that is done under a constant velocity and at various resistances.¹⁷ The unit used to denote isokinetic movement is degree per second. The device consists of monitor, system 4 CDS cart, five multi-joint power system cord connections, chair, dynamometer control and adjustment, and multi-joint system accessory cart which include position attachment. For assessment of Proprioception standard protocol was administered (Figure 1). It was done on individual basis, in which patients were subjected to sit in upright position at 80°angle. They were blindfolded, to nullify interference from visual cues; and They also had to wear headphones, to nullify interference from auditory cues. Furthermore, they were suggested to have less clothing over the knee and they had to wear inflatable pressure boot (air splint). One resistance pad was fixed just above the medial malleolus of the participants. For each of the measurements, three trials were given.

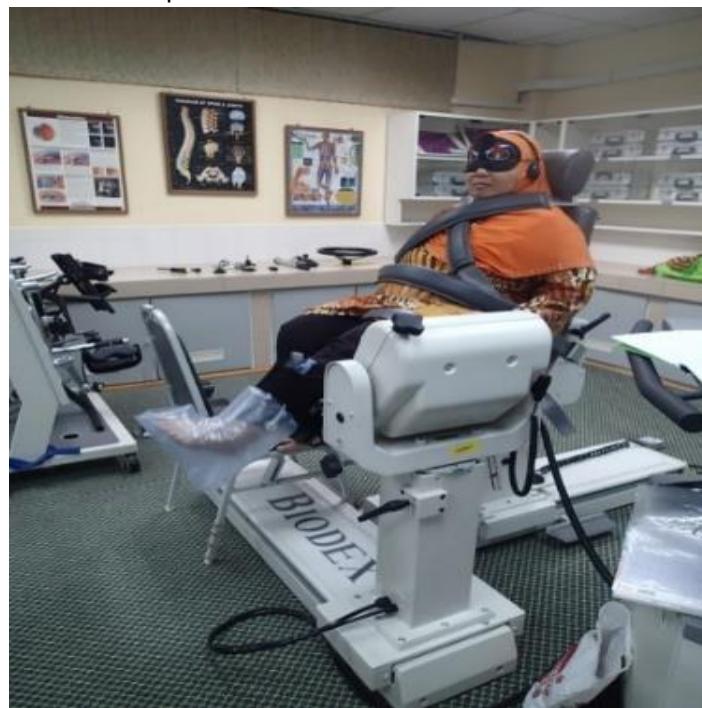


Figure 1
Biodex 4 Isokinetic Device

2.3.3. Measurement of Passive Repositioning Error/Passive Angle Reproduction

Participants were seated in upright position at 90° of knee flexion, the lever arm passively extended the test limb, without resistance to the movement, the target angle were 60° and 30°. Passive movement was set at an angular velocity of 0.5°/second to limit reflexive muscle contractions. Participants were required not to voluntarily contract their muscles, and the researcher assumed that there was no contraction of the muscles. The limb was maintained at the target angle for 10 seconds to enable the participant to remember the position. After the limb was passively returned back to 90°, there was a 5-second pause, and the cycle was performed again. At this moment, the participant activated a handheld stop button when she felt the target angle had been achieved. Once the button had been pressed, the participants were not permitted to correct the angle. The angle was identified via on screen goniometer. Three readings were taken, and the absolute difference between the perceived angle and the target angle was calculated for each reading.²⁸

2.3.4. Analysis and Interpretation of Data

Determination of the level of proprioception in knee osteoarthritis using Biodex 4 involved research participants to replicate knee extension passively (passive repositioning error) in 60° and 30°. Impairment of proprioception in

knee osteoarthritis is denoted by an increase in the passive repositioning error. In this study evaluation of only passive repositioning error was carried out, to observe impairment of proprioception. A reduction in the average peak torque indicate muscle weakness and limitation of joint range.

2.3.5. Statistical Analysis

The data were treated with SPSS 24.0, and outcomes of repeated measure of ANOVA and multiple linear regression analyses were critically observed to identify whether various metabolic and daily activity related aspects and the corroborative differential extents of situational factors had any contributory impacts onto the extent of proprioception and perceived sense of discomfort and dysfunctions observed in the Malaysian elderly female individuals suffering from osteoarthritis.

3. RESULTS AND DISCUSSION

Outcomes of this study were analysed with major focus onto improvements in pain; physical dysfunction and discomfort observed amongst the participants suffering from OA of knee. Explanations on the outcomes of this experiment however have been attempted based on outcomes of repeated measure of ANOVA and multiple linear regression, which were conceived out of pain and stiffness perceived by the participants.

3.1 Physical Function (WOMAC)

Table 1
Descriptive Statistics of Physical Function – WOMAC Scores across the Different Interventions and Three Measurements

Physical Function – WOMAC Scores						
Interventions Phases of Assessment \ Statistics	Conventional Physiotherapy		Isokinetic Training Intervention		Combined Intervention	
Pre-intervention Assessment	Mean	SD	Mean	SD	Mean	SD
Pre-intervention Assessment	21.67	11.03	20.89	8.40	23.33	9.37
Mid-term intervention Assessment	15.39	11.31	12.56	7.44	16.17	8.13
Post-intervention Assessment	8.88	6.16	10.00	7.59	11.86	9.25

Table 1 shows the descriptive statistics of physical function – WOMAC Scores across the different interventions and three measurements (viz., Means & SDs). Based on WOMAC scores,

outcomes revealed that there was a reduction in the physical function scores across various phases amongst the intervention groups.

Table 2
Pairwise Comparisons of Physical Function – WOMAC scores across the Different Phases

Intervention	Compared Between	Mean Difference	S. E	Sig.
Pre-intervention	Mid-intervention	9.642	.950	.002**
	Post-intervention	13.194	.867	.000**
Mid-term intervention	Pre-intervention	-9.642	.950	.002**
	Post-intervention	3.552	.766	.029*
Post-intervention	Pre-intervention	-13.194	.867	.000**
	Mid-intervention	-3.552	.766	.029*

*p<0.05; **p<0.01

Outcomes of Table 2 however revealed significant differences in the physical function scores between pre-intervention phase and mid intervention phase ($p = 0.02 < 0.05$), and between

mid-intervention phase and post intervention phase ($p = 0.02 < 0.05$) and finally between pre-intervention phase and post intervention phase ($p = 0.00 < 0.05$) across the intervention groups.

3.2 Passive Repositioning Error at 60°

Table 3
Descriptive Statistics of Passive Repositioning Error at 60° Scores across the Different Interventions and Three Measurements

Passive Repositioning Error at 60°						
Interventions Phases of Assessment \ Statistics	Conventional Physiotherapy		Isokinetic Training Intervention		Combined Intervention	
Statistics	Mean	SD	Mean	SD	Mean	SD
Pre-intervention Assessment	55.61	8.90	58.50	12.60	54.00	8.17
Mid-term intervention Assessment	55.72	8.92	58.44	8.03	53.28	9.21
Post-intervention Assessment	51.94	7.14	60.00	2.62	57.50	4.84

Table 3 shows the descriptive statistics of passive repositioning error at 60° scores across the different interventions and three measurements (viz., Means & SDs). Outcomes revealed that

there was a decrease in the passive repositioning error at 60° across various phases amongst the intervention groups.

Table 4**Pairwise Comparisons of Passive Repositioning Error at 60° scores across the Different Interventions**

Intervention	Compared Between	Mean Difference	S. E	Sig.
Conventional	Isokinetic	-3.286	1.911	.482
	Combined	5.306	3.001	.455
Isokinetic	Conventional	3.286	1.911	.482
	Combined	8.592	1.774	.025*
Combined	Conventional	-5.306	3.001	.455
	Isokinetic	-8.592	1.774	.025*

*p<0.05

From Table 4, it was observed that significant difference between isokinetic training group and combined intervention group ($p = 0.025 < 0.05$)

existed. Isokinetic training group had significantly better reduction in errors compared to that of the participants of the combined intervention group.

Table 5**Pairwise Comparisons of Passive Repositioning Error at 60° scores across the Different Phases**

Intervention	Compared Between	Mean Difference	S. E	Sig.
Pre-intervention	Mid-intervention	6.768	1.847	.064
	Post-intervention	53.449	3.591	.000**
Mid-term intervention	Pre-intervention	-6.768	1.847	.064
	Post-intervention	46.681	2.074	.000**
Post-intervention	Pre-intervention	-53.449	3.591	.000**
	Mid-intervention	-46.681	2.074	.000**

**p<0.01

Outcomes of Table 5 however revealed significant differences in the error scores between pre-intervention phase and post intervention phase ($p = 0.000 < 0.05$). Apart from that, significant

changes in the error scores between mid-intervention phase and post intervention phase ($p = 0.000 < 0.05$) across the intervention groups, was also evident.

Table 6**Descriptive Statistics of Passive Repositioning Error at 30° Scores across the Different Interventions and Three Measurements**

Passive Repositioning Error at 30°						
Interventions Phases of Assessment	Conventional Physiotherapy		Isokinetic Training Intervention		Combined Intervention	
Statistics	Mean	SD	Mean	SD	Mean	SD
Pre-intervention Assessment	26.83	7.30	30.67	11.96	23.72	8.63
Mid-term intervention Assessment	27.22	7.24	28.83	8.70	20.89	8.01
Post-intervention Assessment	19.50	6.79	27.72	3.40	26.21	3.19

Table 6 shows the descriptive statistics of passive repositioning error at 30° scores across the different interventions and three measurements (viz., Means & SDs). Outcomes revealed that

there was a decrease in the passive repositioning error at 30° across the participants in the combined intervention group compared to that of the participants in the other intervention groups.

Table 7

Pairwise Comparisons of Passive Repositioning Error at 30° scores across the Different Interventions

Intervention	Compared Between	Mean Difference	S. E	Sig.
Conventional	Isokinetic	-2.475	.970	.189
	Combined	4.624	1.794	.184
Isokinetic	Conventional	2.475	.970	.189
	Combined	7.099	.971	.006**
Combined	Conventional	-4.624	1.794	.184
	Isokinetic	-7.099	.971	.006**

**p<0.01

From Table 7, it was observed that significant differences between isokinetic training group and combined intervention group ($p = 0.006 < 0.05$) existed. Further to that, combined intervention

group participants had significant reduction in errors compared to counterparts in the isokinetic training group.

Table 8

Pairwise Comparisons of Passive Repositioning Error at 30° scores across the Different Phases

Intervention	Compared Between	Mean Difference	S. E	Sig.
Pre-intervention	Mid-intervention	4.631	1.333	.076
	Post-intervention	26.025	1.859	.000**
Mid-term intervention	Pre-intervention	-4.631	1.333	.076
	Post-intervention	21.393	1.280	.000**
Post-intervention	Pre-intervention	-26.025	1.859	.000**
	Mid-intervention	-21.393	1.280	.000**

**p<0.01

Outcomes of Table 8 however revealed significant differences in the error scores between pre-intervention phase and post intervention phase ($p = 0.00 < 0.05$). There were significant changes in

the error scores between mid-intervention phase and post intervention phase ($p = 0.00 < 0.05$) across the intervention groups.

relationships between the independent variables in explaining relevant contributory influence on the dependent measure of observed reduction in perceived pain at the post-intervention phase of analyses.

Table - 9

Multiple linear regression outcomes (for participants who received conventional physiotherapy exercise training)

Model A Level of pain perceived in the Post-intervention phase	Unstandardized Coefficients			Standardized Coefficients			Correlations			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Zero- order	Partial	Part	Tolerance	VIF	
(Intercept)	-6.012	1.209		-4.971	.000						
Height of the Participants	.045	.009	.956	5.270	.000	.628	.825	.818	.731	1.368	
Avg. peak torque in 300° Extension	-.623	.179	-.633	-3.491	.004	-.137	-.696	-.541	.731	1.368	

^a($F (2, 13) = 14.279, p < 0.001$), Adj. $R^2 = 63.9\%$

In Table 9, the model *a* emerged significant as for the conventional physiotherapeutic exercise trainee patients, the independent factors such as height of the participants and average peak torque observed during the post-intervention phase in performing isokinetic extension activity at 300°,

were found associated to the dependent measure of level of pain perceived in the post-intervention phase. These predictors together could explain 63.9% variance of changes in the extent of level of pain perceived in the post-intervention phase.

The model *a* further explained that the direct relationship between height of the patients and the dependent measure of pain reported by the participants, evident amongst CP trainees, implied that those who were relatively less tall, they were observed to have further reduction in perceived pain during the post-intervention phase of assessment. This finding is supported by the previous research which clarified that higher the height of the individual, the higher is the position of the knee and higher is the prevalence of radiographic and symptomatic osteoarthritis.²⁹ These researchers confirmed that, taller individuals were observed to have higher knee adduction moments across the medial compartment of the knee. Further to that, inverse

relationship implied that, those who were able to produce higher level of average peak torque in 300°/sec extension activity during the post-intervention phase, were reportedly having lower level of perceived pain during the post-intervention phase of assessment. This finding of production of higher average peak torque and the resultant increase in the strength of quadriceps muscle in reducing pain amongst OA patients is found supported by previous research.³⁰ It could also be observed that this reduction in pain was evident at 300°/sec velocity due to the fact that higher the velocity of the movement, lower is the friction across the joint thereby leading to reduced pain in participants with osteoarthritis of knee.^{31,32}

Table 10

Multiple linear regression outcomes (for participants who received Isokinetic exercise training)

Model B Level of pain perceived in the Post-intervention phase	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	-5.273	1.322		-3.987	.002					
Height of the Participants	.039	.009	.830	4.263	.001	.628	.764	.755	.829	1.207
Avg. peak torque in 180° extension	-.432	.172	-.488	-2.509	.026	-.145	-.571	-.445	.829	1.207

^b (F (2, 13) = 9.420, p < 0.003)), Adj. R² = 52.9%

In Table 10, the model *b* emerged significant as the independent factors such as, height of the participants and average peak torque observed during the post-intervention phase in performing isokinetic extension activity at 180°, were found associated to the dependent measure of level of pain perceived in the post-intervention phase. These predictors together could explain 52.9% variance of changes in the extent of level of pain perceived in the post-intervention phase.

Multiple regression analyses were also carried out to identify relative contribution of different independent factors associated with improvement in the extent of stiffness perceived by the participants, and hereto, separate models were conceived for different groups of participants to identify differential extents of impacts of the independent variables on the dependent measure of perceived stiffness evident during the post-intervention phase of assessment.

3.4 Multiple Regression Analyses – Explanations on Reduction in Perceived stiffness

Table 11

Multiple linear regression outcomes (for participants who received conventional physiotherapy exercise training)

Model C Level of stiffness perceived in the Post-intervention phase	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	-7.475	2.023		-3.696	.003					
Weight of the Participants	.037	.011	.904	3.326	.005	.203	.678	.616	.465	2.152
Active Repositioning Error at 45°	.123	.035	.735	3.479	.004	.410	.694	.645	.770	1.299
Passive Repositioning Error at 60°	.631	.254	.615	2.485	.027	.111	.567	.461	.561	1.781

^c(F (3, 13) = 5.369, p < 0.013)), Adj. R² = 45.0%

In Table 11, the model *c* emerged significant as for the conventional physiotherapeutic exercise trainee patients, the independent factors such as weight of the participants; active repositioning error at 45° and passive repositioning error at 60° observed during the post-intervention phase were

found associated to the dependent measure of level of stiffness perceived in the post-intervention phase. These predictors together could explain 45.0% variance of changes in the extent of level of stiffness perceived in the post-intervention phase.

Table 12

Multiple linear regression outcomes (for participants who received Isokinetic exercise training)

Model D Level of stiffness perceived in the Post-intervention phase	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Beta	Zero-order	Partial	Part	Tolerance
	(Intercept)	1.909	.492			3.882	.004			
Weight of the Participants	.113	.014	2.756	7.902	.000	.203	.935	.741	.072	13.831
BMI of participants	-.237	.032	-2.033	-7.376	.000	.078	-.926	-.692	.116	8.633
Pain in Pre-intervention phase	-.129	.020	-1.602	-6.435	.000	.171	-.906	-.604	.142	7.044
Stiffness in Pre-intervention phase	.774	.137	.903	5.649	.000	.202	.883	.530	.345	2.902
Avg. peak torque in 180° Extension	-.030	.007	-1.022	-4.097	.003	-.317	-.807	-.384	.141	7.070
Avg. peak torque in 300° Extension	-1.798	.465	-1.464	-3.869	.004	-.174	-.790	-.363	.061	16.285
Avg. peak torque in 300° Flexion	.036	.006	1.052	5.719	.000	.031	.886	.536	.260	3.849

^a(F (6, 12) = 14.954, p < 0.000), Adj. R² = 85.9%

In Table 12, the model *d* emerged significant as the independent factors such as, weight and BMI of the participants; pain and stiffness in the pre-

intervention phase and average peak torque observed during the post-intervention phase in performing isokinetic extension activity at 180° and 300°, and flexion activity at 300°, were found to contribute to the changes in the dependent measure of level of stiffness perceived in the post-intervention phase. These predictors together could explain 85.9% variance of changes in the extent of level of stiffness perceived in the post-intervention phase.

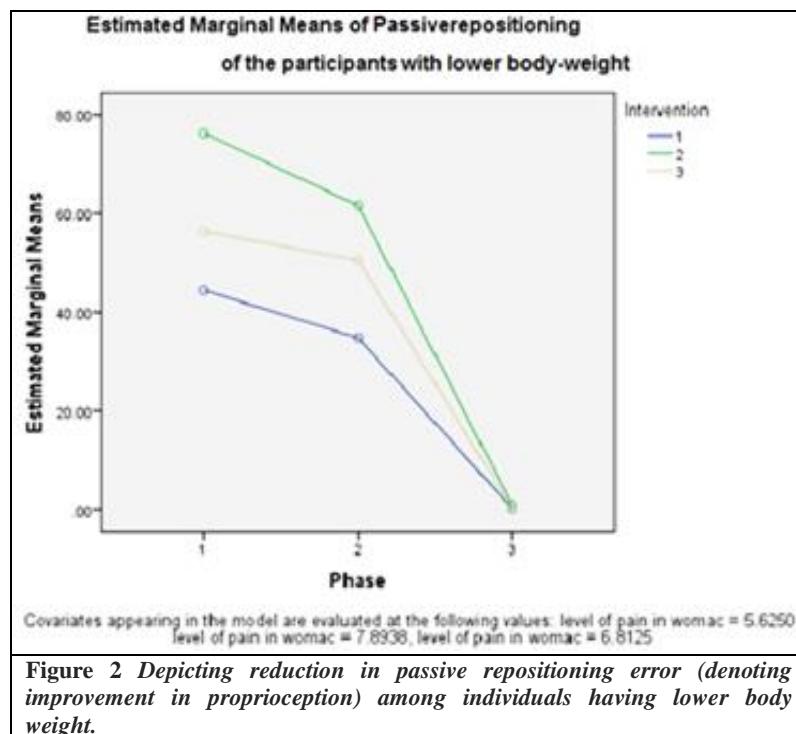
The observation made in the current study was found similar to those of the previous research findings in which CP was introduced in various forms for participants with OA of knee.^{15,33,34} CP protocol used in the current study was comprised of stretching exercises, strengthening exercises and range of motion, and hence it could be assumed that the improvement was noticed in all three aspects in improving the strength of the muscle, increasing the length of the muscle and in the maintenance of the range of motion. Likewise, isokinetic training also improved the strength and movement of the knee musculature thereby reducing the physical

The findings of the passive repositioning error at 30° revealed that compared with the participants in the combined intervention group, in the mid-term phase of assessment errors in repositioning tasks got increased amongst the participants of both the CP and isokinetic training

Passive Repositioning Error at 30° function associated with osteoarthritis of knee. It could be proposed that improvement in these three aspects probably, could have resulted in reduction of the level of physical function in participants with osteoarthritis of knee.

groups. Contrary to that, at the post-intervention phase passive repositioning error was evidently least amongst the participants of CP group, while a significant increase in the errors The observations of passive repositioning error at 30° across various intervention phases shows that

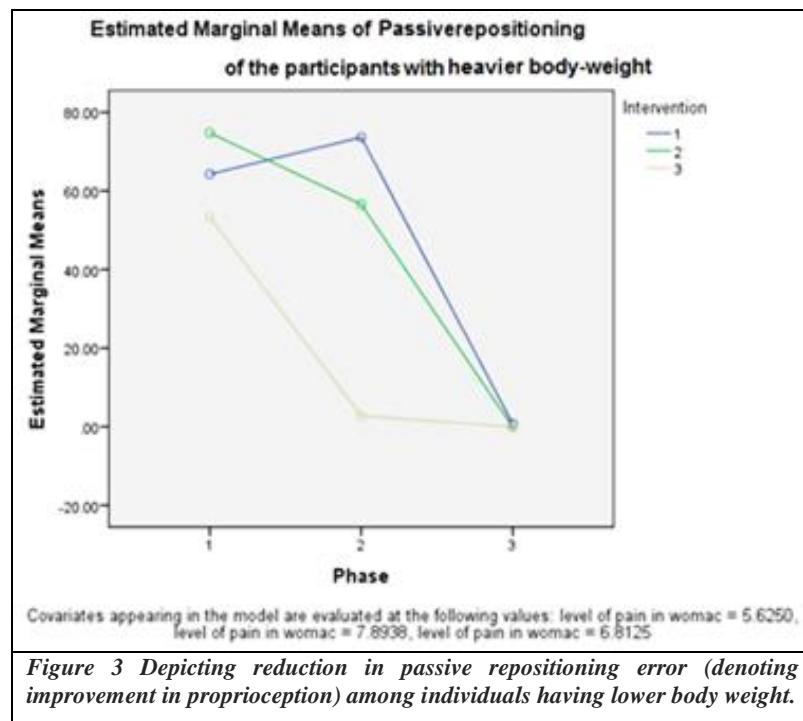
there was a significant increase in the errors in the participants of CP and isokinetic training group at post intervention assessment phase and a reduction in the errors in participants of the combined intervention group at the post intervention assessment phase.



Outcomes of interventions on the changes in proprioception revealed by the indices of passive repositioning error were evident at different phases of assessment. These indices of improvement in proprioception were also attempted to be clarified by the graphical representations of the repeated measure of ANOVA outcomes, which clearly revealed that, body-weight of the OA patients had differential impacts on the nature of improvement in proprioception. Figure - 2 revealed the nature of improvement occurred across the phases, in individuals having lower body-weight, (irrespective of the intervention training they received). Individuals who were evident as comparatively heavier, (see Figure - 3) however, also had benefit from their respective intervention trainings, but the nature of improvement was not identical, since from an identical pre-existing status of errors in proprioception, for the participants of the combined intervention group, a marked improvement in proprioception was noticed during the mid-term assessment. This marked improvement during the mid-term

although was not evident amongst the participants of the other groups, although for the isokinetic trainees a moderate reduction in errors during the mid-term finally got remarkably improved during the post-intervention analysis phase. Similar drastic improvement after the mid-term phase was also noticed amongst the CP participants. Thus, finally at the post-intervention level, all the participants having heavier body-weight, irrespective of their intervention conditions, were evident to have identical improvement in proprioception.

To sum up the outcomes of this research, we need to remember that, numerous studies investigating the effect of proprioceptive exercises on participants with knee OA have observed an overall beneficial effect compared with that of the strength training exercises.^{35 -37} This study however contradicts to those outcomes, since CP intervention comprising strengthening exercises were observed to produce beneficial outcomes, while proprioceptive exercises were not convincingly beneficial for reduction in perceived pain and stiffness.



Reason behind this debatable outcome was explained by the previous findings, which clarified that strengthening exercises carried out with higher velocity of the movement, may lower the friction across the joint and thereby may lead to reduction of pain in participants with osteoarthritis of knee.^{31,32} Further to that, studies conducted with training of proprioception carried out in non-weight bearing positions, could be beneficial in reducing pain and physical discomfort too.³⁸⁻³⁹ Finally, we need to acknowledge that, outcomes of WOMAC revealed self-report information on individual-specific perception of discomfort during differential physical activities, which however may contain personal bias, while indices on proprioception revealed direct indices of improvement retrieved from the dynamic movement of knee-joints, and hence could provide us with more valid information on improvement in OA condition. Further researches on these phenomena of involvement of personal bias in reporting on perceived sense of discomfort associated with OA problems would be required to take separate account of these issues of individual-specific inconsistencies in reporting on health issues.

4. CONCLUSION

Compared to the participants of isokinetic intervention group, CP exercise trainees had better improvement in increasing muscle strength, which

evidentially facilitated reduction of pain and stiffness in OA patients. Poor proprioception evident at the pre-intervention phase (both in participants of conventional exercise and isokinetic exercise intervention groups), was found associated with higher extent of pain; stiffness and physical function. Up to the mid-intervention phase, in both of the groups, improvement in proprioception was found inadequate. At the post-intervention phase, however, CP trainees were observed to have better improvement compared to their counterparts in other groups, while isokinetic trainees were observed to have no improvement at all and hence, it could be concluded that the isokinetic intervention was not effective enough for reduction of perceived pain and stiffness in participants with OA knee. For participants in isokinetic exercise intervention group, pre-existing poor proprioception was found associated with higher extent of pain; stiffness and physical function, which was observed to improve marginally during the mid-term intervention. Body composition, height and weight differences, reduction in proprioception emerged as significant factors contributing for increased pain and stiffness of knee joint in osteoarthritis of knee observed amongst Malaysian elderly female patients. Differential extents of contribution of differential predictors of perceived stiffness were identified, which explained the phenomenon of difficulties faced in the elderly patients.

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6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

SrS, SoS

Collected data and performed the experiments:

CmL, NbR, SrS, SoS

Contributed with materials/analysis tools:

CmL, NbR, SrS, SoS

Analysed the data: SrS, NbR, SoS

Wrote the paper: SrS, SoS

Checked and edited the format of the paper:

SrS, NbR, SoS

Final approval: SrS, NbR, SoS, HaH, MsI

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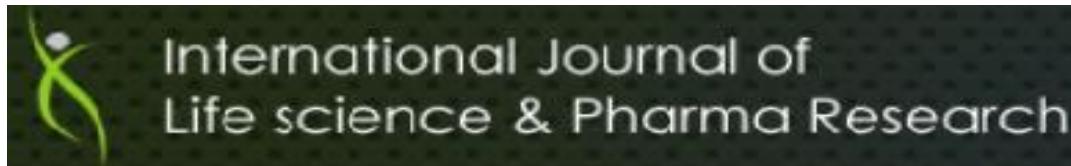
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IMPACT OF BIOFEEDBACK INTERVENTIONS ON MOOD AND EMOTIONAL REGULATION AS PREDICTOR OF BILATERAL SHOOTING PERFORMANCE CHANGES AMONGST MALAYSIAN SOCCER PLAYERS

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ABSTRACT

This study was conducted to examine the impacts of changes in mood and emotionality factors in influencing performance of soccer skills. Forty-five young male promising soccer players (matched in anthropometric, cardiovascular and performance status) were identified as having disrupted emotionality, and hence they were recruited as participant. Participants were subjected to assessment of psychological attributes (viz. cognitive flexibility, somatization, anxiety, mood factors and emotional stability), and soccer skill parameter (bilateral shooting task). Participants were categorised into three groups, viz. Group A – no-intervention control group, Group B – experimental group I (received Sc biofeedback training) and Group C – experimental II (received electromyography or EMG biofeedback training). Interventions followed for 15 minutes/ session, 2 sessions/week for 16 weeks. For the purpose of this study outcomes of the post-intervention analyses, which were carried out after the 16th week of intervention, was considered for investigation. Descriptive analyses, repeated measure of ANOVA and multiple linear regression analyses were carried out at the post-intervention phase of analysis, which clarified interrelationships between the mood, emotionality and psychobiological influencing factors on the outcomes of soccer performance skills, evident among the players of three different experimental conditions. Inhibitive as well as facilitative impacts of mood state factors and emotionality indices emerged as predictors of performance changes of bilateral soccer shooting performance skills.

KEYWORDS: Mood states; Anxiety; Emotionality; Bilateral Soccer shooting performance

1. INTRODUCTION

Soccer performance is the outcome of numerous elementary skills, and successful adoption of those skills ensures success in soccer performance.¹ Successful performance of soccer skills in the actual competitive situations, however refers to outcome of optimal level of positive transfer of correctly learned and practiced skills.²

Regularised and tedious practice of basic skills, through continuous and dynamic practice sessions, become automatic²⁻³ and during actual competitive situations, players can perform those skills, as they perform from their zone of excellence.⁴⁻⁶

As such, one of the focus of this current research is to determine whether Malaysian soccer players are able to transfer elementary skills

during training to soccer performance during competitive situations. In this research we wanted to limit our focus onto one of the soccer skills, i.e., the bilaterally performed soccer shooting skill. A question that arises is whether learned soccer shooting skills become automatic. Another question is whether uncontrollable variables outside the training sessions impact soccer performance, and if so, do players need training in different skills?

Here we wanted to pay attention to the roles of negative stressors, and also to the ability of the players to cope with those negative stressors. In case of successful performance of soccer, perception of stress is considered as one of the most common and debilitating factors.² Researches on stress process, as viewed in the Sport Psychology literatures, has mostly been dealt with the apprehensive feelings and negative expectancies in the players, which are commonly considered as aspects of anxiety. Anxiety as a negative psychological state has been identified as multi-dimensional, viz. – cognitive (mental) and somatic (physiological) components, and reaction of these two components to the stressors within the environment are different from each other.⁷ Theoretical considerations pertaining to impact of stress and anxiety and subsequent performance failure have arguably most viably been discussed in the ‘Catastrophe theory’.⁸⁻⁹ Here, we intended to explore into possible deleterious impacts of other disruptive mood factors and emotional hindrances, such as depression, anger, fatigue, confusion, irritability, somatization or somatised anxiety etc.

As we have already narrated on the inhibitive impacts of emotional overloading and hindrances, numerous psychological skill training strategies are now seen as influential contributors

to successful competitive performance in sport.^{2,6,10-13} This research sought to apply biofeedback as specific psychological skill training in modulating emotionality, and thereby improvement in performance of soccer skills. Furthermore, compared to individual sports, in team sports such as, field hockey or in soccer, playing against a team full of opponents require adjusting stressors based on interpersonal issues across opponents as well as own team members (especially depending on personal issues associated with the success or failure of the team). Further to that, all other performance related overt and covert environmental issues also interplay crucial roles.^{3-5,8,10-13}

Under such circumstances, this study has been conducted to investigate on the effectiveness of biofeedback intervention techniques on changes in emotional and mood state factors, and the resultant changes in any, on the bilateral soccer shooting performance outcomes evident among Malaysian young-adult promising soccer players.

2. METHODS

2.1 Participants

For the present experiment sample size was calculated using G power 3.1.9.2.¹⁴ The power of the study is set at 95% with 95% confident interval and the effect size F at 0.25. Total required sample size was calculated as 45 and hence high-performing young adult soccer players were recruited as participants (mean age = 21.39 and SD = 1. 67). They were selected based on the psychological evaluation of dispositional anxiety; kinanthropometric and cardiovascular status of the players and moderately high level of soccer performance skill levels.

[1] -- Monday, August 08, 2015 -- 15:39:43	
F tests - ANOVA: Repeated measures, within-between interaction	
Analysis:	A priori: Compute required sample size
Input:	Effect size f = 0.25 α err prob = 0.05 Power (1- β err prob) = 0.95 Number of groups = 3 Number of measurements = 4 Corr among rep measures = 0.5 Nonsphericity correction ϵ = 1 Noncentrality parameter λ = 22.500000 Critical F = 2.1713088 Numerator df = 6.0000000 Denominator df = 126 Total sample size = 45 Actual power = 0.9554764
Output:	

2.2 Materials Used

For this experiment, some self-report inventories were administered along with psychobiological and psychomotor evaluations. Further to that, soccer performance related parameters were also assessed, and for all these evaluations following equipment and test materials were required.

- 7) State-Trait Anxiety Inventory (STAI)¹⁵
- 8) Brunel Mood Scale¹⁶
- 9) Rorschach Ink – Blot Test¹⁷
- 10) Skin Conductance biofeedback apparatus (Udyog, India 2000)
- 11) EMG biofeedback apparatus (ProComp Infinity5 equipment of Thought Technology, USA, 2014).
- 12) Materials for Performance Test: –
Soccer Ball; 14 cones; Stopwatch; Marker; PVC box and Measuring tape

2.3 Procedure

After the participants agreed to participate in the study and after they signed the consent form, they were subjected to evaluation of self-reported transitory and dispositional anxiety, based on State-Trait Anxiety Inventory.¹⁵ Further to that, evaluations of psychological measure, such as, mood states was carried out by employing Brunel Mood Scale¹⁶ and cognitive-emotional aspects based emotional core was evaluated by the Rorschach Ink Blot Test for projective analysis.¹⁷ Apart from that, evaluation of bilateral soccer shooting performance was carried out. All of these assessments were carried out following standardised protocols, and rigorous methodology was followed to collect data. Step-by-step methodology is detailed in the previous research literatures, published based on the studies conducted in identical experimental set-up, with similar groups of soccer players.^{6,10,18-19}

Thereafter, based on randomized sampling formula (employing Research Randomizer Software²⁰ , participants were equally categorized into following groups – 1) Group A – No-intervention or control group (n = 15); 2) Group B – Experimental Group I, who received EMG Biofeedback intervention training (n = 15), and 3) Group C – Experimental Group II, who received Sc Biofeedback training (n = 15). Participants

selected for intervention regimes were subjected to the training sessions for 15 - 20 minutes per session/ two sessions per week for 16 weeks (32 sessions in total). Control Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating the performance disaster amongst soccer players.

2.4. Statistical Analysis

The data were treated with SPSS 24.0, and outcomes of descriptive analysis, two-way repeated measure of ANOVA were carried out to investigate on effectiveness of the intervention techniques in improving soccer performance outcome. Further to that, multiple linear regression analyses were critically observed to identify whether various corroborative relationships between mood states and inner psychopathological make-up as derived by employing the projective evaluation system could reveal the intricate processes involved in catastrophic or disruptive emotionality observed in highly skilled but under-performing Malaysian Soccer players.

3. RESULTS

Outcomes of this study are presented based on the descriptive information (refer to table 1) pairwise comparison (table 2) and multiple linear regression reports (tables 3 to 7).

Table 1
Descriptive Statistics of Performance Parameters Analysis on Bilateral Shooting Score Across the Groups

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
Bilateral shooting score at pre-intervention level	6.20 \pm 2.65	7.80 \pm 3.65	6.20 \pm 3.12
Bilateral shooting score at mid-intervention level	7.93 \pm 2.52	9.20 \pm 2.21	9.27 \pm 1.98
Bilateral shooting score at post-intervention level	9.60 \pm 2.85	10.27 \pm 2.18	10.33 \pm 2.09
Bilateral shooting score at follow up-intervention level	9.47 \pm 3.54	10.13 \pm 2.26	9.80 \pm 2.37

Tables 1 was conceived to represent phase wise alterations observed in the bilateral shooting performance parameter which was observed amongst participants of three different groups. Observations based on the shapiro-wilk test for normality however revealed that indices were mostly free from huge dispersions. Furthermore,

identical features in the obtained pre-intervention data mostly revealed that, participants did not have any pre-existing differences. Hence, whatever differences were observed in the mid-term as well as in the post-intervention and post-follow-up phases could be attributed to the interventions introduced to the participants.

Table 2
Pairwise Comparisons Bilateral Shooting Across the Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	-1.886**	.435	.001
	Sc Biofeedback group	-3.295**	.477	.000
EMG Biofeedback group	Control group	1.886**	.435	.001
	Sc Biofeedback group	-1.409**	.259	.000
Sc Biofeedback group	Control group	3.295**	.477	.000
	EMG Biofeedback group	1.409**	.259	.000

*p<0.05; **p<0.01

In Table 2, the post-intervention assessment outcomes in terms of the pairwise comparisons revealed that differences amongst the participants were evident. Findings however revealed that, compared to the participants of the no-intervention group, the EMG Biofeedback

intervention group participants had significantly better bilateral shooting ability (p<0.01). Apart from that, compared to the participants of EMG BF group, the Sc BF group players were observed as significantly better in bilateral shooting ability (p<0.01).

Table 3
Model a - Summary of multiple linear regression analysis on Bilateral Shooting Ability in Control group (based on mood variable)

Dep. Variable – Bilateral Shooting Ability	Unstandardized Coefficients			t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero- order	Partial	Part	Tolerance	VIF
(Intercept)	16.182	2.029		7.974	.000					
Inhibitive mood	-.105	.038	-.387	-2.751	.009	-.387	-.387	-.387	1.000	1.000

^a(F (1, 13) = 7.566, P < 0.009), Adj.R² = 13.0%

In Table 3 the model *a* emerged significant as the psychological measure of inhibitive mood could explain 13.0% variance of changes in the extent of soccer shoot best. Model *a* explained the

inverse relationship between inhibitive mood and bilateral soccer shooting ability, which revealed that the athletes who had lesser inhibitive mood had higher extent of bilateral shooting ability.

Table 4

Model b - Summary of multiple linear regression analysis on Bilateral Shooting Ability in Control group (based on psychobiological and mood variables)

Dep. Variable - Bilateral Shooting Ability	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	15.423	1.985		7.770	.000					
Spontaneous Fluctuations post	.225	.106	.286	2.116	.040	.282	.310	.286	1.000	1.000
Inhibitive mood	-.106	.037	-.390	-2.883	.006	-.387	-.406	-.390	1.000	1.000

^b(F (2, 12) = 6.327, P < 0.004), Adj.R² = 19.5%

In Table 4 the model **b** emerged significant as the psychophysiological measure of spontaneous fluctuations evident at post-intervention phase and inhibitive mood together could explain 19.5% variance of changes in the extent of soccer shoot best. Model **b** also explained the inverse relationship between inhibitive mood and bilateral shooting ability, which revealed that the athletes who had lesser

inhibitive mood at the post-intervention phase of assessment, had higher extent of shooting ability. Apart from that, the post-intervention outcome of spontaneous fluctuations was found directly associated with higher extent of bilateral shooting ability. Finding thus implied that, lesser extent of inhibitive mood and relatively more frequent spontaneous fluctuations contributed in the players to have better bilateral shooting ability.

Table 5

Model c - Summary of multiple linear regression analysis on Bilateral Shooting Ability in EMG Biofeedback group (based on mood and cognitive-emotional variables)

Dep. Variable - Bilateral Shooting Ability	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	20.454	4.272		4.788	.000					
Depression	.177	.052	.771	3.435	.002	.130	.531	.361	.219	4.573
Anger	-.181	.069	-.625	-2.618	.014	.034	-.431	-.275	.193	5.174
Fatigue	-.163	.057	-.417	-2.873	.007	-.140	-.465	-.302	.522	1.915
Perceptual motor control	.504	.177	.440	2.853	.008	.310	.462	.299	.463	2.159
Irritability	-.365	.162	-.333	-2.251	.032	-.015	-.380	-.236	.502	1.992
Somatization	-.505	.133	-.595	-3.794	.001	-.372	-.569	-.398	.448	2.234

^c(F (1, 13) = 4.675, P < 0.000), Adj.R² = 52.6%

In Table 5 the model **c** emerged significant as the psychological measure of depression, sit up, anger, fatigue, motor control, irritability and somatization together could explain 52.6 % variance of changes in the extent of shooting ability. Model **c** explained the inverse relationship among anger, fatigue and irritability as well as somatization and the extent of shooting ability

observed in the players. Apart from that, depression, perceptual motor control was found directly associated with higher extent of shooting ability. Findings thus revealed that the players having lower level of anger, fatigue, irritability and somatization and relatively higher extents of depression and perceptual motor control were evident as having higher extent of shooting ability.

Table 6

Model d - Summary of multiple linear regression analysis on Bilateral Shooting Ability in Sc Biofeedback group (based on mood and cognitive-emotional variables)

Dep. Variable - Bilateral Shooting Ability	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	8.442	2.332		3.620	.001					
Somatization	-.425	.117	-.500	-3.634	.001	-.340	-.513	-.438	.766	1.305
Irritability	-.548	.176	-.495	-3.107	.004	-.018	-.455	-.374	.572	1.748
State Anxiety	-.149	.049	-.471	-3.045	.004	-.295	-.448	-.367	.607	1.646

^d(F (1, 13) = 4.560, P < 0.001), Adj.R² = 36.2%

In Table 6 the model **d** emerged significant as the psychological measure of somatization, irritability and State Anxiety together could explain 36.2 % variance of changes in the extent of shooting ability. Model **d** explained the inverse relationship among somatization, irritability, and

state anxiety and the extent of shooting ability observed in the athletes. Findings thus revealed that the athletes having lesser somatization, irritability, and lower extent of state anxiety were evident as having higher extent of shooting ability.

Table 7

Model e - Summary of multiple linear regression analysis on Bilateral Shooting Ability in Sc Biofeedback group (based on emotionality variables)

Dep. Variable - Bilateral Shooting Ability	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero- order	Partial	Part	Tolerance	VIF
(Intercept)	12.946	2.653		4.879	.000					
State Anxiety	-.152	.045	-.485	-3.368	.002	-.292	-.495	-.350	.522	1.917
Vigour	.153	.042	.489	3.614	.001	-.039	.521	.376	.592	1.689
Confusion	-.062	.027	-.268	-2.262	.030	-.090	-.357	-.235	.770	1.299

^a(F(2, 13) = 7.174, P < 0.000), Adj.R² = 53.5%

In Table 7 the model **e** emerged significant as the psychological measures such as state anxiety, vigour and confusion observed during post-intervention assessment together could explain 53.5 % variance of changes in the extent of shooting ability. Model **e** further explained the inverse relationships between state anxiety, confusion and bilateral shooting ability were observed amongst the athletes. Apart from that,

vigour was found directly associated with higher extent of shooting ability. Hence, findings revealed that the players having lesser extent of state anxiety and confusion were observed to have higher shooting ability. Whereas direct relationship implied that, participants observed with higher extent of vigour were evident as having higher extent of shooting ability.

4. DISCUSSION

Outcomes of this study revealed beneficial impacts of both the EMG and Sc Biofeedback intervention techniques in improving bilateral shooting performance. Findings of this experiment however revealed that in case of bilateral shooting performance, compared to the players of control condition the EMG BF participants were observed to display better performance (table 2 is referred). This observed beneficial impact of EMG biofeedback training however got supported by the previous findings reported by.^{10,21-25} Observed improvements in the bilateral shooting ability could be attributed to the EMG biofeedback training, which enhances isometric contractibility in the players, and in turn improves joint mobility and proprioceptive ability in muscle joints.²⁶⁻²⁸ Further to that, enhancement in the excitatory potentials generated in the basal ganglion and in the mid-brain²⁹⁻³⁰, might have facilitated in the bilateral coordination, which was also evident in the enhancement in psychomotor ability.

Outcomes of this experiment also revealed the efficacy of Sc biofeedback training in improving bilateral shooting performance, and hence compared to the players of control condition the Sc BF participants were observed to display better performance (table 2 is referred). This observed beneficial impact of Sc biofeedback training however got supported by the previous findings reported by.^{24-25,21,10} Precisely, improvements evident in the bilateral shooting ability could be attributed to the Sc biofeedback training, which enhances symmetry in motor coordination in the players.²⁸ Further to that, enhancement in control over the bidirectional and symmetrical movement gets energized by excitatory control in frontal cortex and pre-motor cortical activation in the Brodmann area 6; could have facilitated in the motor coordination task requiring higher-order orienting and attentional engagement.³¹⁻³²

Here we opted for comparison between the efficacy of the intervention techniques employed. Findings of this experiment however revealed that in case of bilateral shooting

performance also, compared to the players of the EMG BF group, the participants of Sc BF intervention group were observed to display better performance (table 2 is referred). This observed comparative better edge of Sc biofeedback training over the EMG BF training however got supported by the previous findings reported by.^{25,28} In explaining reasons behind better impact of Sc biofeedback it could be assumed that, EMG biofeedback training is supposed to enhance isometric contractility of the rectus femoris muscles of the players, which may in turn improve joint mobility and proprioceptive ability in muscle joints. These enhancements although may increase muscle potentiality of the players, those alone cannot ensure better performance in bilateral shooting tasks, as apart from enhanced motor efficiency, the bilateral soccer ball shooting task itself may also demand improvement in selective attention^{25,28} and visual-motor integration.³³ Further to that, guided Sc biofeedback training (as it was implemented in this experiment as intervention) is supposed to enhance the excitatory control in frontal cortex and pre-motor cortical activation in the Brodmann area 6, which in turn can facilitate in attentional engagement and higher-order covert orienting of attentional shifts³¹⁻³² requiring bilateral shooting task. Apart from that, Sc biofeedback intervention can also enhance in cognitively mediated perceptual motor visual priming³⁴, which may enhance posterior upper alpha³⁵ activity in the frontal as well as parietal region.³⁶ In bilateral soccer shooting performance, visual-motor integration process³³ engages the cognitive-perceptual information associated with similarity in the previous and later repetitive movements.³⁷ Hence, the cognitive-perceptual process mediated “how-to-do” component of the bilateral shooting task gets clarified and gets processed as spontaneous performance process, as the procedural memory³⁸ and the working memory dependent repetitive soccer shooting task, alike other serial reaction tasks³⁹ gets spontaneous and automated.

At this point, we looked into the multiple regression analyses outcomes, which explained predictive contributory influence of the mood states and emotionality factors and bilateral soccer shooting outcomes obtained from three different groups of players, which were evident at the post-intervention phase of analysis. In the next section, discussion on the outcomes of intervention regimes on the players of different intervention groups have been presented, and the predictive

impacts of the mood and emotionality factors have been discussed.

At first, discussion on the emotional make-up of the EMG BF group participants as contributor of shooting ability has been carried out. Based on the outcomes of regression analysis, the higher tolerance index observed in collinearity statistics (Table 5) suggested that – in explaining shooting ability very high extents of variances in feelings of fatigue as well as in irritability (50.2%) were not predicted by any other measures. Model **c** also explained that for the players of the EMG BF group, for every 1% reduction in anger, .63%; 1% reduction in somatization, .60%; 1% reduction in feelings of fatigue, .42% and for every 1% reduction in irritability .33% increment in shooting ability would occur, whereas, for every 1% increment in motor visual priming dependent perceptual motor control, .44% and for every 1% increment in depressive mood, .77% improvement in bilateral shooting performance would be evident.

Outcomes of this model revealed that, at the post-intervention phase of assessment, the EMG BF group participants were observed as having relatively higher levels of bilateral shooting ability, which was observed as directly contributed by relatively higher feeling of depression. Further to that, the model also clarified that, relatively lower feelings of anger and fatigue accompanied by higher perceptual motor control and lower irritability and somatization observed in these players, helped them to achieve successful bilateral soccer shooting ability.

Next, we have paid attention to the emotional make-up of the Sc BF group participants as contributor of shooting ability. Based on the intricate relationships evident, two significant models emerged, and we have attempted to discuss on the outcomes separately. Here too, based on the findings of higher tolerance index observed in collinearity statistics (Table 6) suggested that – in explaining shooting ability very high extents of (76.6%) variances in somatization and in irritability (57.2%) were not predicted by other measures of emotionality. Similarly, high extent of (60.7%) variance in State Anxiety the situation-specific anxiety was not predicted by other measures of emotionality. Model **d** also explained that for every 1% reduction in somatization, 50%; and for every 1% reduction in irritability .49%, and for every 1%

reduction in State Anxiety, .47% increment in shooting ability would be observed.

Similarly, higher tolerance index has also been observed in collinearity statistics (Table 7), which have suggested that – in explaining bilateral shooting ability very high extent of variances in confusion (77.0%) was not predicted by other mood measures. Similarly, high extent of (59.2 %) variances in vigour and 52.2% variances in State Anxiety were not predicted by any other measures. Model *e* also explained that for every 1% reductions in State Anxiety and in confusion, respectively .49% and .27% improvement in shooting ability would occur. Similarly, for every 1% increment in vigour, .49% increment in shooting ability would be evident.

Outcomes of these models revealed that, at the post-intervention phase of assessment, the Sc BF group participants were observed as having relatively higher levels of bilateral shooting ability, which was observed as directly contributed by the higher extent of motor control; lower level of somatization; irritability and SA (transient subjective feeling of anxiety). The next model once again confirmed that, lower SA accompanied by lower extent of confusion and higher feeling of vigour were significant predictors for improved bilateral shooting performance skills.

Here in nutshell we would like to mention that, the players of control group evidently could not perform the bilateral soccer shooting task as good as the players of intervention groups, probably because they had relatively more frequent extent of spontaneous fluctuations (SFs), which depends on sudomotor nerve activity (SNA) and works like a startle response even in absence of any real stress.²⁹ These frequent SFs and the resultant sudden stress perhaps kept the players of control group overwhelmed and frequently threatened⁴⁰, and hence perhaps they remained pre-occupied with their previous failures or inadequate performance and couldn't perform better in bilateral shooting tasks.^{11-12,40}

Thus, in sum the outcomes of this study implied that, although both EMG and Sc biofeedback techniques were found effective in bringing on desired extent of improvement in bilateral soccer shooting performance, role of Sc biofeedback emerged as comparatively better than that of the EMG biofeedback technique. In attempting to explain of this comparative edge of Sc BF techniques, we hypothesized on the differential roles of psychobiological mechanisms

and neural pathways, while the outcomes of regression analyses models clarified differential roles of mood and emotional make-ups of the players as probable contributing factors behind differential extents of improvement in soccer shooting performance evident among the players.

5. CONCLUSION

In improving bilateral soccer shooting performance, effectiveness of both EMG and Sc biofeedback techniques have been revealed. Comparative better improvement evident among players of Sc biofeedback group, could be attributed to the improvement in the emotional make-up of the players, as reduction of irritability, somatised anxiety and SA (transient subjective feeling of anxiety) and lesser extent of confusion, along with heightened extent of vigour were evident to facilitate in soccer shooting performance. For the players of EMG biofeedback group, reduction of irritability, somatised anxiety, anger and feeling of fatigue were although found to facilitate in improving soccer shooting performance, probably due to the direct contribution of higher extent of feeling of depression, consistent high performance was not possible for all of them. We intend to carry out further researches to on larger sample to arrive at convincing conclusion on the predictive impacts of mood and emotionality factors on soccer performance parameters, and we also hope that these outcomes will encourage future researchers to clarify these relationships with more valid explanations.

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7. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

SrS, SoS

Collected data and performed the experiments:

FaS, SrS, SoS, FoH

Contributed with materials/analysis tools:

FaS, SrS, SoS

Analysed the data: SrS, SoS

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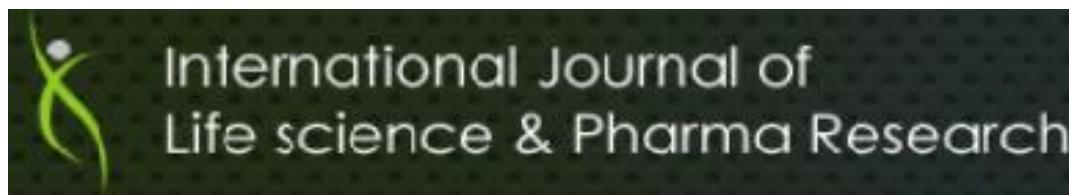
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EFFECT OF ISOKINETIC TRAINING ON PEAK TORQUE GENERATED IN KNEE OSTEOARTHRITIS PATIENTS

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ABSTRACT

The present study was carried out to investigate the efficacy of a 12-week isokinetic training programme, two times per week at two different angular velocities ($60^{\circ}.\text{sec}^{-1}$ and $120^{\circ}.\text{sec}^{-1}$) on the peak torque of patients with knee osteoarthritis. Thirty volunteers ($N= 30$), aged 40 to 65 years, were randomly assigned to 3 groups: $60^{\circ}.\text{sec}^{-1}$ trained group ($n= 10$), $120^{\circ}.\text{sec}^{-1}$ trained group ($n= 10$) and control group ($n= 10$). The first intervention group ($n=10$) underwent prescribed training at $60^{\circ} \text{ sec}^{-1}$ on a Biodex Isokinetic system along with existing conventional physiotherapy. The second intervention group ($n=10$) underwent training at $120^{\circ} \text{ sec}^{-1}$ along with existing conventional physiotherapy. The control group ($n=10$) continued with conventional physiotherapy only. There was significant improvement ($p<0.05$) in peak torque in both the intervention groups as compared to control group. There was a significant main effect of time different ($p<0.05$) in thigh circumference at post training in $120^{\circ} \text{ sec}^{-1}$ trained group compared to other groups. The present study highlighted that with the isokinetic resistance training used in this study along with conventional physiotherapy, could improve functional capacity in patients with OA of the knee. It is postulated that extensive training involving a high number of repetitions and eccentric contractions is safe, effective, and well tolerated for the patients with knee osteoarthritis.

KEYWORDS: Osteoarthritis; Isokinetic Training; Peak Torque

1. INTRODUCTION

Osteoarthritis (OA) is one of the most common joint disorders in adults¹. It is characterised by a non-inflammatory deterioration

of the articular cartilage with reactive new bone formation at the joint surface and margin². OA is also regarded as one of the major health problems in the world³. It appears in the cartilage and affects the large weight bearing joints, for example the knees,

hindering the knee cushioning effect. Severity of knee OA is more as compared to OA of other joints. The main complaints of patients are pain, stiffness, instability and loss of normal functional ability⁴. The incidence of osteoarthritis is estimated to double by the year 2020 due to the increase in the elderly population and the number of obese individuals⁵. Less physical activity, decreased muscle strength and increased joint compression are found to increase the risk and severity of knee osteoarthritis in obese individuals⁶.

Latest guidelines for the management of knee OA are emphasising on the central role of exercise⁷, majority of the studies only investigated the effectiveness of regular exercises and aerobic training for knee OA. Studies on the effect of isokinetic resistance training on knee OA patients are seldom in the world literature.

The concept of isokinetic exercise had been introduced in scientific literature in 1967⁸. Isokinetic contraction is the muscular contraction that accompanies constant velocity limb movements around a joint. The velocity of movement is maintained constant by a special dynamometer. The resistance of the dynamometer is equal to the muscular forces applied throughout the range of movement. This method allows the measurement of the muscular forces in dynamic conditions and provides optimal loading of the muscles⁹.

The most frequently used isokinetic variables are the torque and the angular position, the torque output at different angular velocities of movement, the torque ratio of reciprocal muscle groups and the torque output during repeated contractions. The important features of isokinetic dynamometry include optimal loading of the muscles in dynamic conditions at constant pre-selected velocities of movement. These features provide safety in the rehabilitation of patients, especially with muscular and ligamentous injuries¹⁰.

The main objectives of the present study were

- (i) To evaluate the effectiveness of isokinetic resistance training programme in the patients with knee osteoarthritis based

on knee flexor and extensor group of muscle strength;

- (ii) To identify the specific effective angular velocity exercise training on an isokinetic dynamometer for rehabilitation of knee Osteoarthritis;
- (iii) To identify the minimum duration of isokinetic training to get significant improvement in the knee extensor and flexor group of muscles.

2. METHOD

Thirty knee OA patients aged between 40 and 65, with moderate bilateral knee OA (Altman grade II) were recruited from the physiotherapy unit of Universiti Sains Malaysia Hospital, Kubang Kerian. The subjects were randomised into three groups; a control group and two intervention groups, each consisting of 10 subjects. Each subject was given an explanation on the objectives and protocol of the study. The study was approved by the Universiti Sains Malaysia Research and Ethical Committee. The complete methodology followed in this project has been described in a flow chart (Figure 1).

2.1 Sample Size Calculation

The sample size was calculated using PS Power and Sample Size Calculation version 2.1.30 with the power of the study was set at 80% with 95% confident interval while standard deviation (σ) observed is 1.8 and difference in population means (δ) is set at 2.2¹¹. The sample size calculated for each group is 7; however, the researcher set the size at 10 in each group.

2.2 Randomisation into Intervention and Control Group

Subjects were age and gender matched before they were randomly assigned to an intervention groups and control group (Table 1). A simple randomisation method of drawing lots was carried out. Subjects in the control group followed the existing physician prescribed physiotherapy

treatment programs which consisted of heat treatment, (either treated with hot pack or shortwave diathermy SWD) for 12 sessions. The first intervention group were prescribed with a training programme which involved isokinetic resistance training at $60^{\circ}.\text{sec}^{-1}$ angular velocity while the second intervention group were prescribed with isokinetic resistance training at $120^{\circ}.\text{sec}^{-1}$ angular

velocity. All subjects in both groups were required to attend training 2 times per week for consecutive 12 weeks (24 sessions), besides continuing with pre-existing physiotherapy treatment two times per week for six weeks. Isokinetic strength assessments were carried out on the control group at the same time intervals as for the intervention groups at pre, mid and post training sessions.

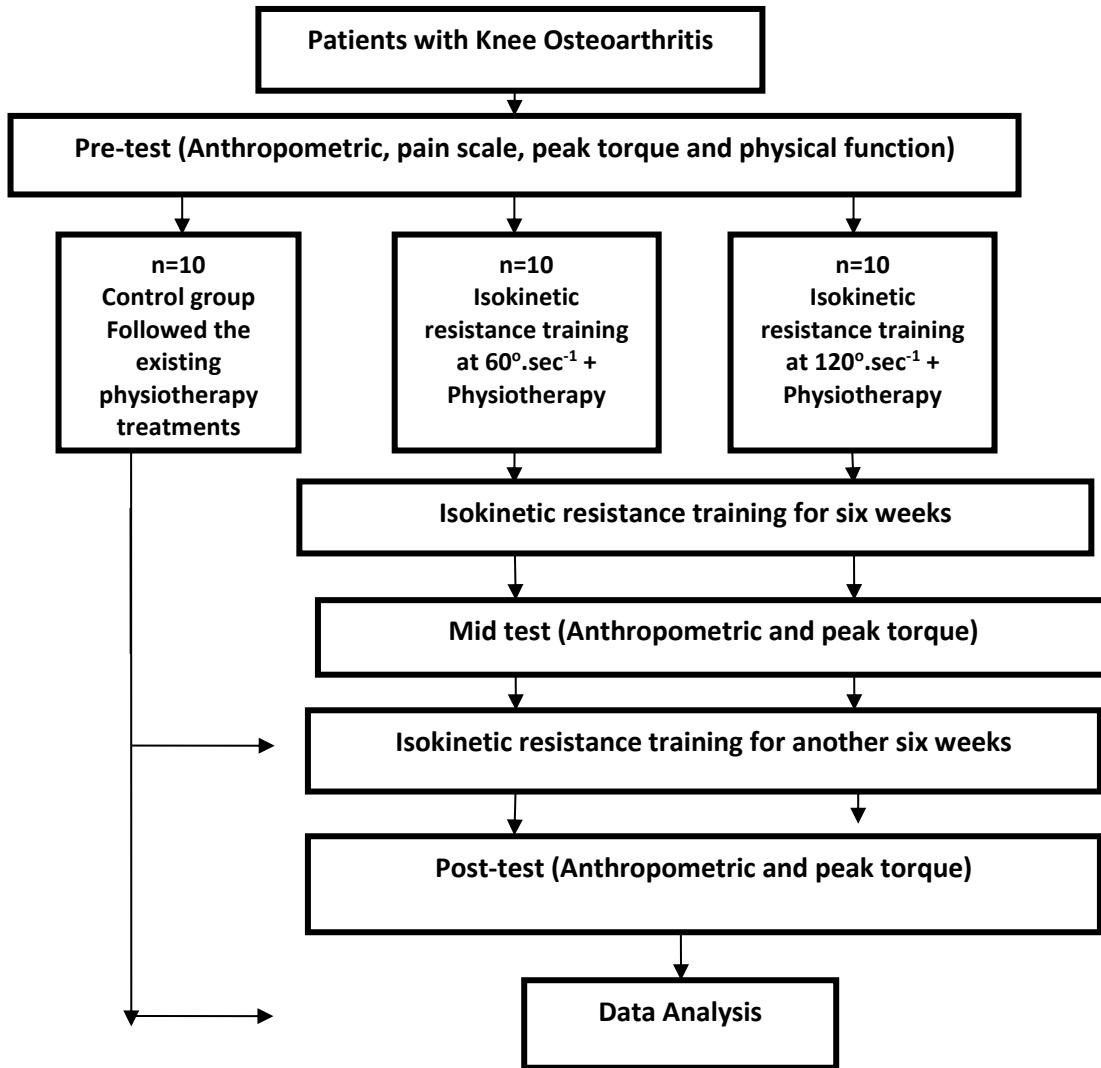


Figure 1
The methodology followed in this study

2.3 Inclusion criteria

All patients who were diagnosed with primary knee osteoarthritis with significant knee stiffness or reduction in active knee range of motion, but without any previous surgery to the tested knee.

2.4 Exclusion criteria

Patients with severe knee pain restricting active range of motion and patients with previous history of knee injuries which involve either extra-articular or intra-articular structures were excluded from this study. Patients with history of medical

illnesses causing poor effort tolerance and patients with severe pain requiring analgesics other than NSAID e.g., opioids were also not included.

2.5 Isokinetic Strength Testing

Muscular strength was measured according to a standard protocol using an isokinetic dynamometer (Multi-Joint System 3 Pro; Biodex Medical Systems, Shirley, New York, USA). Strict adherence to the guidelines of the Biodex isokinetic dynamometer operations manual was followed. Participants were familiarized with use of the dynamometer and testing procedures prior to baseline measurements to reduce possible influences of test habituation on muscular performance. Each participant completed a warm-up protocol prior to muscular strength testing. The warm up session included a 5 minutes cycling on a stationary bike (Monark Ergomedic 824E) set without resistance and a standard quadriceps and hamstrings stretching exercises. After a 10-minutes rest on completion of the warm up, the subjects were instructed to continue with testing procedure.

2.6 Knee Extension/ Flexion Testing Protocol

The subject was seated; leaning against a backrest inclined at 16° from the vertical and with the seat inclined 6° from horizontal. The axis of the knee was aligned with the axis of the Biodex dynamometer exercise arm. The accuracy of alignment was checked by allowing the subject to extend the leg while pushing against the shin pad that was positioned over the lower third of the leg. If the pad did not move up or down the leg over the range of motion to be tested, the knee was aligned with the axis of the exercise arm. The subject's positions were secured using thigh, pelvic and torso straps to minimize body movement during the test. Shoulder straps were applied diagonally across the chest with the subject's arms cross and their palm opposite shoulders to attenuate excessive upper body movement and muscular substitution. The lateral femoral epicondyle was used as a bony landmark for matching the axis rotation of the knee joint and the axis rotation of the dynamometer shaft.

Subjects were asked to look forward during the testing. To calculate torque, the distance between the point of application of the generated force and the axis of rotation of the exercise arm was measured by using the scale on the arm itself and keyed into the computer. Each subject used the same radius for all tests. Testing angular velocities were set at 90°sec⁻¹ and 180°sec⁻¹, respectively. The subjects were asked to do 5 repetitions for each angular velocity. 10 second rest was given between each angular velocity.

2.7 Knee Flexion/ Extension Training Protocol

In terms of preparation of subjects, similar protocols were used as in testing; several differences are the repetitions and sets. For the first 6 weeks, each training session consists of three sets of eight repetitions. For the next 6 week, each training session consists of three sets of 10 repetitions. Subjects were required to attend the training sessions two times per week for 12 weeks completing 24 sessions. Each training session began with five minutes warming up as described earlier and subjects could rest for 10 seconds between each set. Subjects with both knees being tested simultaneously could rest for three minutes before the contra-lateral knee was exercised.

2.8 Data Analysis

The data were analysed using Statistical Package for Social Science (SPSS) version 14.0 software. Normality of data was determined through histogram where the normality curve was used as an indication whether the data was normally distributed or not. Non-parametric test was utilised if the data was not normally distributed. If the data was normally distributed, oneway ANOVA repeated measure was utilised to analyse the main effects of time (pre, mid and post) differences, while two-way ANOVA was used to analyse between group differences in isokinetic strength, pain score, thigh circumference and physical functions score.

For within-group differences, Bonferroni adjustment for multiple comparisons was used to determine the differences when one-way ANOVA

repeated measure showed a significant main effect of time. For between group differences, simple effect test was used to locate the differences when

two-way ANOVA repeated measure revealed a significant interaction. Significance level was set at $p < 0.05$, and all data were presented as means \pm SD.

3. RESULTS

The age, height and weight of the participants are illustrated in Table 1.

Table 1

Physical characteristic data for intervention and control groups of Knee Osteoarthritis patients

Parameters	Control	$60^{\circ}\text{sec}^{-1}$	$120^{\circ}\text{sec}^{-1}$
Age (years)	54 ± 5	52 ± 6	54 ± 6
Height (m)	155.3 ± 5.3	154.4 ± 5.3	155.3 ± 6.3
Weight (kg)	67.7 ± 14.2	61.0 ± 10.7	69.7 ± 8.7
Gender	8 females 2 males	8 females 2 males	8 females 2 males

Values shown as mean \pm SD

3.1 Right Knee Flexion Peak Torque at $90^{\circ}\text{sec}^{-1}$ and at $180^{\circ}\text{sec}^{-1}$

Right knee flexion peak torque at $90^{\circ}\text{sec}^{-1}$ and at $180^{\circ}\text{sec}^{-1}$ of the control and intervention subjects during pre, mid and post was illustrated in Figure 2 and Figure 3. There was significant main

effect of time on knee isokinetic peak torque ($p < 0.05$) in both intervention groups at mid and post training measurements. However, there was no significant main effect of time in control group at all 3 time points, i.e., at pre-, mid- and post-training levels.

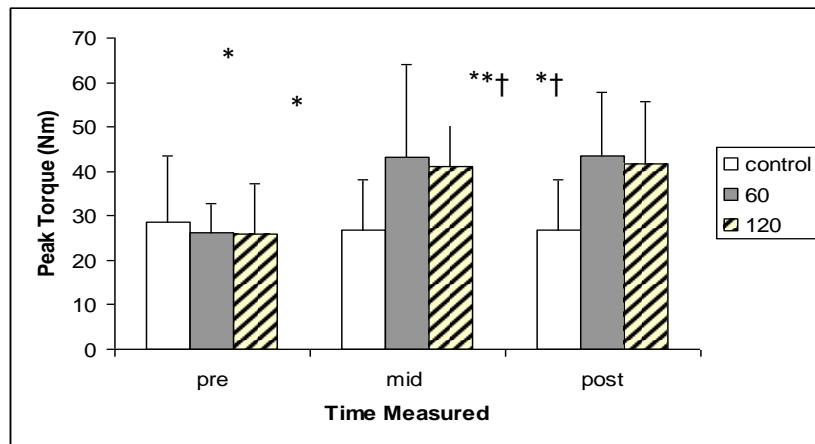


Figure 2

*Peak Torque of Right Knee Flexion at $90^{\circ}\text{sec}^{-1}$. * Significant different from pre-test ($p < 0.05$)*

*** Significant different from pre-test ($p < 0.01$), † Significant different from control group ($p < 0.05$)*

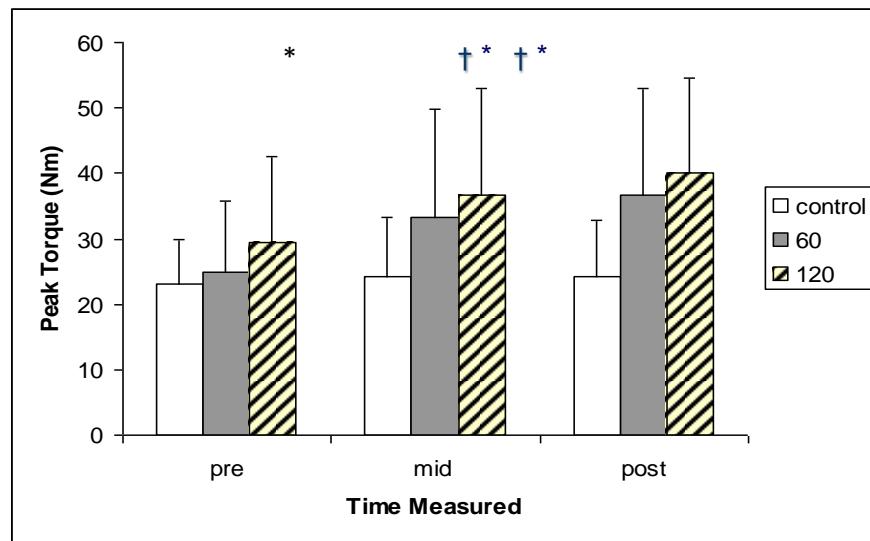


Figure 3
Peak Torque of Right Knee Flexion at 180°.sec⁻¹.

* Significant different from pre-test ($p<0.05$) † Significant different from control group ($p<0.05$).

3.2 Left Knee Flexion Peak Torque at 90°.sec⁻¹ and at 180°.sec⁻¹

Left knee flexion peak torque of the control and intervention groups at 90°.sec⁻¹ during pre, mid and post training level was illustrated in Figure 4. A significant main effect of time on knee isokinetic

peak torque ($p<0.05$) in both intervention groups at post training measurement was observed. However, there was no significant main effect of time in control group at all 3 time points. We observed similar results when evaluated at 180°.sec⁻¹ (Figure 5).

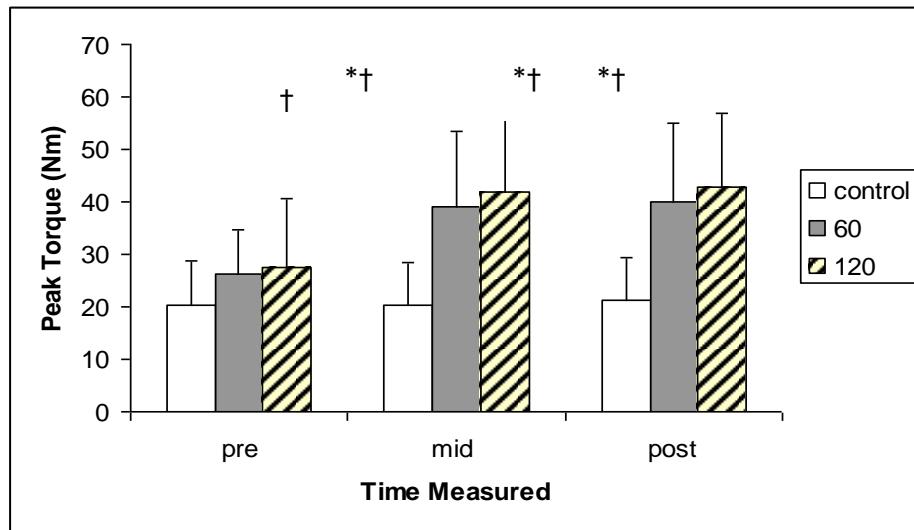


Figure 4
Peak Torque of Left Knee Flexion at 90°.sec⁻¹.

* Significant different from pre-test ($p<0.05$) † Significant different from control group ($p<0.05$).

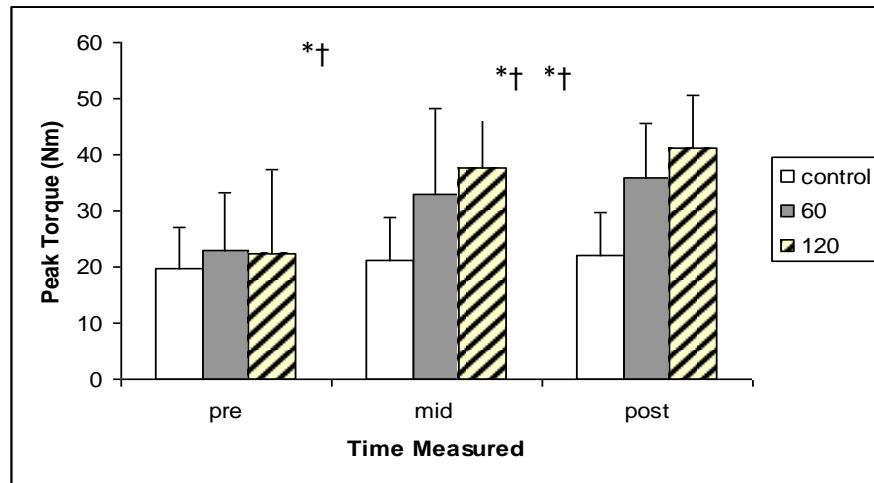


Figure 5
Peak Torque of Left Knee Flexion at 180°.sec⁻¹.

* Significant different from pre-test ($p<0.05$) † Significant different from control group ($p<0.05$).

3.3 Right Knee Extension Peak Torque at 90°.sec⁻¹ and at 180°.sec⁻¹

Right knee extension peak torque of the control and intervention groups at 90°.sec⁻¹ and at 180°.sec⁻¹ during pre, mid and post training had been illustrated in Figure 6 and 7, respectively. A

significant main effect of time on knee isokinetic peak torque ($p<0.05$) in both intervention groups at post training measurement was observed. However, there was no significant main effect of time in control group at all 3 time points.

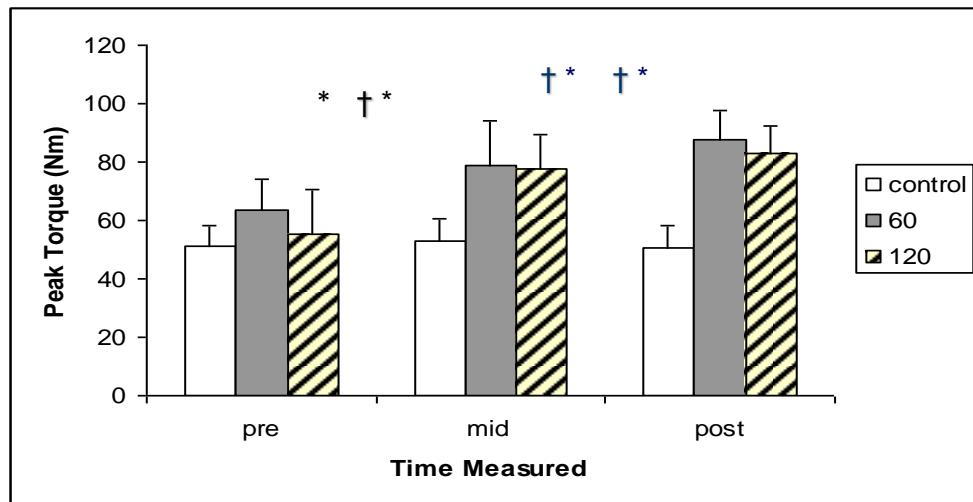


Figure 6
Peak Torque of Right Knee Extension at 90°.sec⁻¹.

* Significant different from pre-test ($p<0.05$). † Significant different from control group ($p<0.05$).

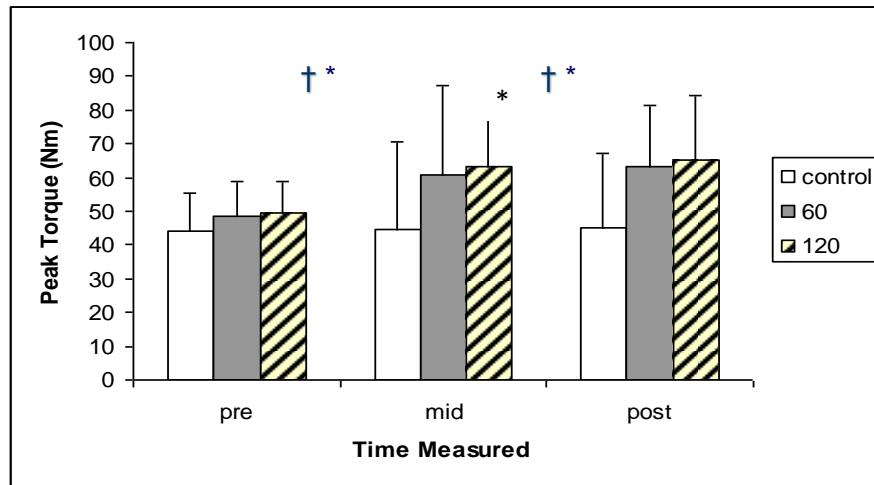


Figure 7
Peak Torque of Right Knee Extension at 180°.sec⁻¹.

* Significant different from pre-test (p<0.05). † Significant different from control group (p<0.05)

3.4 Left Knee Extension Peak Torque at 90°.sec⁻¹ and at 180°.sec⁻¹

Left knee extension peak torque of the control and intervention groups at 90°.sec⁻¹ and at 180°.sec⁻¹ during pre, mid and post was illustrated in figure 8 and 9, respectively. Simple effect test revealed that there was a significant difference

(p<0.05) of peak torque at mid and post training level in both the intervention groups as compared to the control group. However, there was no significant difference in the peak torque of both the intervention groups. No significant main effect of time in the peak torque of the control group at all 3 time points.

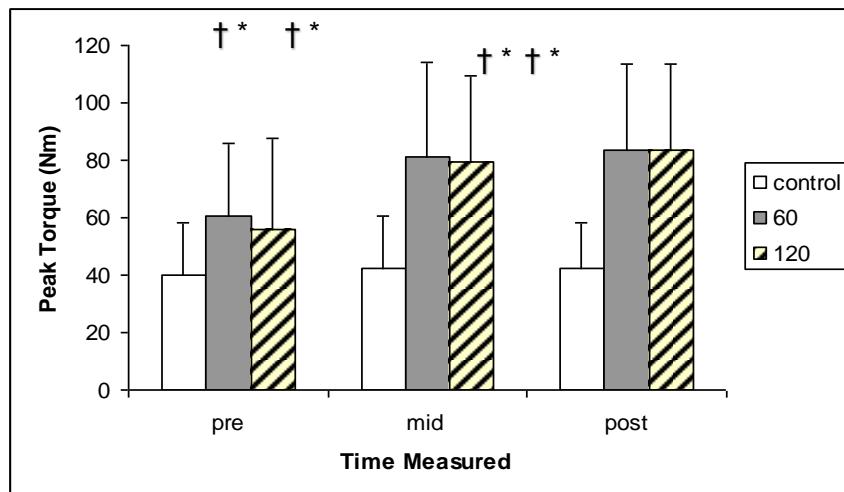


Figure 8
Peak Torque of Left Knee Extension at 90°.sec⁻¹.

* Significant different from pre-test (p<0.05) † Significant different from control group (p<0.05)

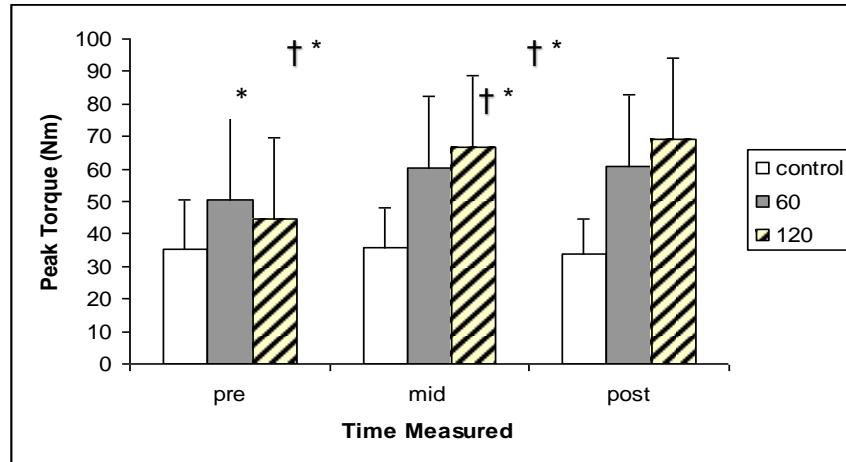


Figure 9
Peak Torque of Left Knee Extension at 180°.sec⁻¹.

* Significant different from pre-test ($p<0.05$). † Significant different from control group ($p<0.05$)

4. DISCUSSION

Most of the treatments in knee OA, are aimed to reduce the symptoms and to prevent further deterioration of the knee joint. Treatment of knee OA includes pain relief with analgesics and non-steroidal anti-inflammatory drugs (NSAIDs), surgical correction, and conservative physical interventions¹². Weight control, physical therapy and weak analgesics are suggested as initial treatment for knee OA patients. Fransen et al.¹³ found that drugs, physical modalities, and the role of exercise were beneficial in reducing pain and increasing muscle power of the affected knee. Moreover, a well-controlled trial involving 8 weeks of isokinetic resistance training showed significant improvement in functional status of patients with OA of the knee joints¹⁴.

The concept of isokinetic exercise was initially developed by James Perrine in 1967¹⁵. Isokinetic contraction is the muscular contraction that accompanies constant velocity limb movements around a joint. The velocity of movement is maintained constant by a special dynamometer. Isokinetic dynamometry has also been used for the training of various muscle groups to improve the muscular performance in dynamic conditions. The movement velocity of different activities can be simulated during training to improve the training

effect. Data acquisition and analysis have been improved by using computer systems interfaced to isokinetic dynamometers. Recently developed computer systems provide correction for gravitational and inertial errors, accurate computation of isokinetic parameters and real-time display of the torque output.

The present findings are in agreement with those reported by Schike et al.¹⁴ and Fisher et al.¹⁶ on isokinetic resistance training for patients with knee OA. In our study, after 12 weeks of prescribed isokinetic resistance training, peak torque of knee extension and flexion increased significantly from the control group as at mid and post-test evaluation.

We observed that isokinetic resistance training improved knee extension peak torque at 90° sec⁻¹, for patients with osteoarthritis of the knee by 37.7% for right knee and 38.7% for the left knee in 60°sec⁻¹ trained group. Whereas, in 120°sec⁻¹ trained group, the peak torque of right knee improved by 50.5% while for the left knee, the peak torque improved by 49.6%. But when evaluated at 180°sec⁻¹, right knee peak torque improved by 31% and the left knee the peak torque improved by 20% in 60°sec⁻¹ trained group. On the other hand, the 120°sec⁻¹ trained group showed improvement by 32% and by 55%, on right and left knee peak torque, respectively. Hence, we observed

improvement in flexors and extensors' strength in knee OA patients as a result of isokinetic training. Significant improvement of extensor muscle strength for both trained knees following isokinetic resistance training, have been observed by many researchers^{17,18}. Higbie et al.¹⁹ reported 18.4–36.2% gain in muscular strength of concentrically and eccentrically-trained legs, in young sedentary women aged 19–21 years.

Huang et al.¹¹ investigated the therapeutic effects of different strengthening exercises on the functional status of patients with knee OA and observed that the greatest muscle strength gain in $60^{\circ}.\text{sec}^{-1}$ angular velocity peak torques in the isokinetic and isotonic exercise groups. But at $180^{\circ}.\text{sec}^{-1}$ angular velocity, only the isokinetic group exhibited a significant muscle strength gain.

The present study highlighted that isokinetic resistance training improved knee flexion peak torque for patients with osteoarthritis of the knee by 67% in right knee and 53.6% in left knee in $60^{\circ}.\text{sec}^{-1}$ trained group. In $120^{\circ}.\text{sec}^{-1}$ trained group, the peak torque of right knee improved by 60% while in the left knee, the peak torque improved by 54.7%, when tested at $90^{\circ}.\text{sec}^{-1}$. Similarly, when evaluated at $180^{\circ}.\text{sec}^{-1}$, right knee peak torque improved by 46.8%, while for the left knee, the peak torque improved by 56.1% in 60° trained group, and in 120° trained group, right knee improved by 36.4% and left knee peak torque increased by 84%.

In this study, significant improvement was observed even after six weeks of isokinetic resistance in both intervention groups. Hence, our study highlighted that a minimum of 6 weeks of isokinetic resistance training combined with existing physiotherapy treatment is sufficient to give benefit to the muscle strength of knee OA patients. Further training for another six weeks did not show significant changes to the knee muscle strength. Therefore, six weeks isokinetic training is considered optimum training period for this group of patients. There was no significant gain in muscle strength in control group either at mid or post-test. The subjects in control group were not involved in isokinetic exercise, excepting physiotherapy

treatments and light workout such as static cycling without resistance and walking in treadmill for 10 minutes.

Schike et al.¹⁴ and Fisher et al.¹⁶ administered isokinetic and isometric strength training knee OA patients. In their studies, most of the patients were having both knees OA. In our study, most of the subjects complained that their left knee was more afflicted than the right knee. The results of the present study showed significant differences in the left knee as compared to the right knee. Hence, this study indicated that with administration of isokinetic strength training, the affected knee showed greater improvement than the less affected or unaffected knee.

5. CONCLUSIONS

1. Isokinetic resistance training at both angular velocities, $60^{\circ}.\text{sec}^{-1}$ and $120^{\circ}.\text{sec}^{-1}$ have given benefits to the knee OA patients, by improving strength of both the knee flexors and extensors.
2. Even, a six-week isokinetic resistance training combined with existing physiotherapy treatments was observed to be sufficient to improve the knee extensors and flexors group of muscles.

6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

AkG, MaA

Collected data and performed the experiments:

AkG, MaA

Contributed with materials/analysis tools:

AkG, MaA, MsI

Analysed the data: AkG

Wrote the paper: AkG

Checked and edited the format of the paper:

AkG

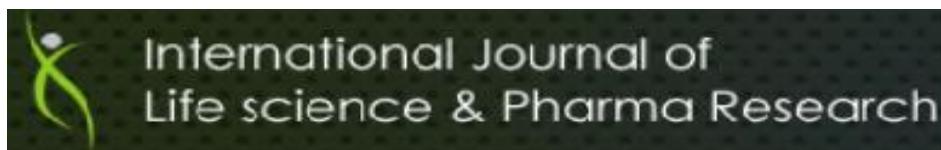
Final approval: AkG, MsI

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EFFICACY OF DIFFERENTIAL EXERCISE INTERVENTION PROGRAMS ON IMPROVEMENT IN PERCEIVED HEALTH-STATUS AMONG MIDDLE AGED INDIVIDUALS WITH TYPE 2 DIABETES MELLITUS IN KELANTAN, MALAYSIA

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ABSTRACT

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1. INTRODUCTION

Lifestyle-related diseases like diabetes mellitus (DM) have emerged as major public health problems in all over the world. In a study it was stated that DM will see the greatest increase in the developing countries of Africa, Asia, and South America and among them 90% of diabetic individuals will be having T2DM¹. International Diabetes Federation (IDF) has also stated that 77% of people with Type 2 Diabetes Mellitus

(T2DM) resides in countries with high percentage of low- and middle-income population². T2DM is a major source of premature mortality and morbidity related to cardiovascular disease (CVD), kidney disease (diabetic nephropathy), eye disease (diabetic retinopathy), and nerve disease (diabetic neuropathy)³.

There were 3.3 million cases of DM in Malaysia and the prevalence in adults (20-79 years) is 16.6% in 2015⁴. The rate of prevalence

of diabetes in Malaysia is much higher than the world prevalence and the trend shows that a growing population over the age of 50, makes up

the largest proportion of diabetes prevalence in this country (Figure 1).

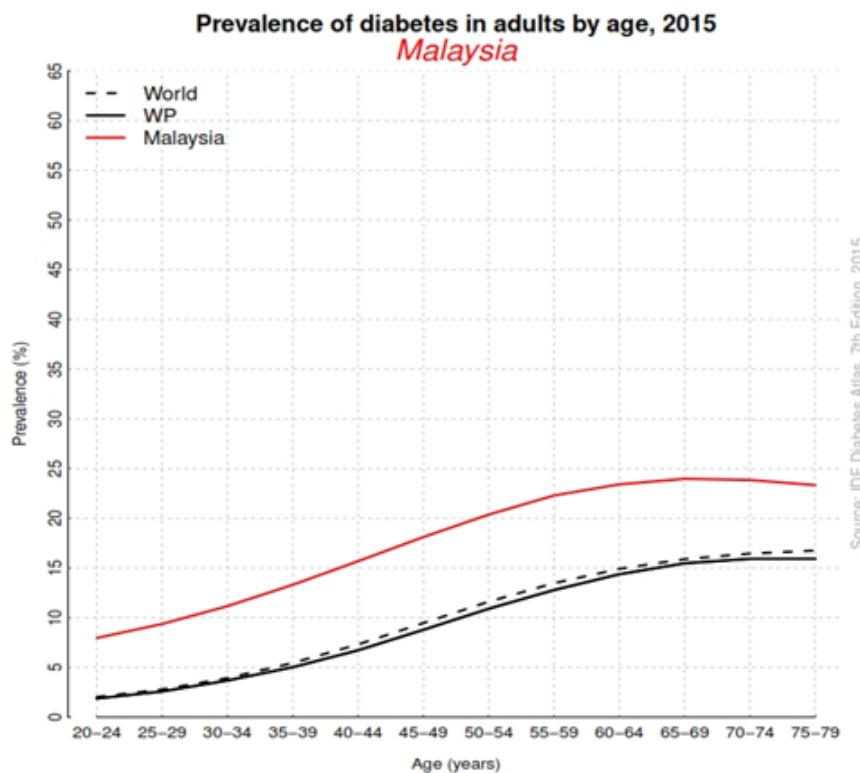


Figure 1
Prevalence of Diabetes in Adults by Age in Malaysia, 2015
Source: IDF Diabetes Atlas, 7th edition, 2015

T2DM requires constant medical care, patient self-care and education to prevent various complications and to reduce the risk of long-term diseases to maintain a healthy life style³. Exercise along with diet and medication has been considered as one of the three keystones of diabetes therapy⁵. Since decades, physical activity and exercises have been recommended by the American Diabetes Association (ADA)⁶ and American College of Sports Medicine (ACSM)⁷ for the T2DM individuals to control their level of diabetes. The low-cost, non-pharmacological nature of exercise further enhances its therapeutic appeal. Many studies have demonstrated the positive adaptations of aerobic exercise on glucose control⁸⁻⁹ in people with T2DM. Various statements from the ADA⁶ and the ACSM⁷ recommended that a complete rehabilitation program for individuals with diabetes should combine both resistance and aerobic exercise. However, the impacts of exercise intervention programs for T2DM individuals may differ based

on the components and protocols used for the exercises on different population fragment¹⁰. Self-administered evaluative indices such as EuroQol 5D-5L (EQ 5D-5L)¹¹⁻¹² and others were extensively utilised to measure the health status of T2DM population. In this research, authors have used EQ 5D-5L questionnaire¹³ as the measure of perceived health status of T2DM population in Kelantan, Malaysia.

Several researches were previously conducted to evaluate and assess different aspects of T2DM mainly on the basis of biological indices specifically for developed regions of the world. It is imperative to assess the perceived health status of this disease by the diabetic individuals as well because it implies enormous strains on the overall psyche of an individual. Having said that, there was no research done on the Malaysian population to assess and recommend alternatives to enhance the health status of middle aged T2DM population from self-perceived health status perspective. Therefore, it becomes necessary to assess different

alternatives which can be beneficial for the T2DM population from self-perceived health status perspective. Hence, the present study has been conducted to assess the effects of differential exercise interventions on the improvement in

2. METHODOLOGY

2.1 Participants

Regarding the recruitment of participants, the sample size was calculated as 60 participants but considering the possibilities of dropout rates, altogether approximately 118 participants were invited. Participants were invited from the Diabetic clinic (outpatient), Hospital Universiti Sains Malaysia (HUSM) and also from the community centre of Gunong (Kawasan Rukun Tatangga, Gunong, Bachok, Kelantan) and then all the participants were assessed based on the following inclusion and exclusion criteria in the Diabetic clinic of HUSM.

2.1.1 Inclusion Criteria of the Participants

1. Individuals who were diagnosed as having T2DM for 7 to 10 years.
2. T2DM individuals having $\text{HbA1C} \geq 7 \text{ mmol/l (126 mg/dl)}$ and $\leq 14 \text{ mmol/l (252 mg/dl)}$
3. Individuals aged between 40 – 60 years i.e. middle-aged individuals and monthly income ranges between RM 2,300 to RM 7,000.
4. Individuals who were identified based on their activation heart-rate as capable of performing aerobic training (with 40% of HR max for only 20 mins) and combined exercise (with 40% of HR max for only 15 mins and 40% of 1 RM of resistance training for 10 repetitions for only 1 set per muscle group) activities.
5. Participants using insulin therapy starting from 0.3 to 0.75 unit per day per kg of body weight.
6. Participants diagnosed as having no cardiovascular autonomic neuropathy (CAN), no peripheral vascular disease, having no peripheral neuropathy, having no neurological disorder which may result in weakness, no angina, no proliferative retinopathy.

perceived health status of the middle-aged individuals with type 2 diabetes in Kelantan, Malaysia.

7. Participants who were not in high risk of exercise-induced acute coronary syndrome.
8. Participants with T2DM not taking β -blockers, diuretic medicines.
9. Participants having no knee injury or any other kind of orthopaedic difficulties which may interrupt the intervention program.
10. Participants having no major operation.

2.1.2 Exclusion Criteria of the Participants

1. Participants who were not willing to answer the questionnaire and cooperate.
2. Participants who were not able to learn the intervention within three sessions.
3. Participants who were not able to attend to at least 80% of the intervention sessions.
4. Participants who passed through any major change in life-stress or living style or involved in any other exercise program except the prescribed exercise programs.
5. Participants who passed through any major illness and injury during the study period.

Ethical approval for this study was obtained from the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPem/15060229).

After completing the baseline assessment, 75 participants were randomly categorized into three different groups. Each group had 25 individuals. The three groups were: Group A: Control group (received no intervention); Group B: Experimental Group I (received aerobic exercise training i.e. walking) and Group C: Experimental Group II (received combined exercise, i.e. aerobic exercise training and resistance/strengthening exercise training). Allocation of the groups was concealed and all the intervention sessions were supervised by qualified exercise trainers. In regard to preventing methodological bias, the

participants, researcher and the trainers for the study was blinded. Furthermore, participants had all the rights to withdraw themselves from the study whenever they felt distress and discomfort.

2.2 Assessment Protocol

The EuroQol 5D-5L (EQ 5D-5L) questionnaire¹³ was used to assess mobility, anxiety/depression, usual activities, self-care and pain/discomfort. The EQ-5D-5L descriptive framework, contains 5 dimensions. Under each dimension there are 5 statements. Each of these statements can be categorized as 5 levels such as no problems, slight problems, moderate problems, severe problems, and extreme problems faced by the respondents. It is important to note that the numerals (1-5) have no arithmetic properties and cannot be used as a cardinal score. EQ 5D-5L questionnaire also has an EQ Visual Analogue scale (EQ VAS). EQ VAS records the respondent's self-appraised wellbeing on a 20 cm vertical, visual analogue scale. This scale comes with two endpoints marked as the best health a respondent can imagine, which denotes "100 points" on the scale and the worst health a respondent can imagine indicates "0 point" on the scale.

2.3 Intervention Technique

In this research two different exercise interventions were used for two different intervention groups following standardised protocol. These 2 exercise interventions were:

1. Aerobic Exercise Training (supervised walking has been chosen for the aerobic exercise training followed by stretching exercises).
2. Combined Exercise Training (supervised walking and strengthening exercises where incorporated to target the major muscle groups with different coloured theraband/resistance band as per requirements).

The intervention sessions were outlined based on the Joint Position Statement prepared by the American College of Sports Medicine (ACSM) and American Diabetes Association (ADA)¹⁴. The present study has designed 14 weeks of intervention sessions for the middle aged T2DM population living in Kelantan, Malaysia to assess and evaluate the outcome. Afterwards, the intervention sessions were discontinued, and all

the participants were told not to come to attend the intervention sessions for the next 14 weeks to assess the sustainability of the intervention programs.

2.4 Data Analysis

In this study all the data were analysed with the Statistical Package for the Social Sciences (SPSS) version 23.0. In this study, Wilcoxon signed-rank test and Two-way repeated measures of ANOVA/ Mixed factorial ANOVA were used to analyse the data. The significance level for all the analysis was set at $p < .05$.

3. RESULTS

At the end, 64 Malaysian participants' data have been analysed. There were overall 21 men (32.8%) and 43 women (67.2%) with a mean age of 53 years. In addition to that there were 19 (29.7%) people within the age range of 40-50 years and the rest 45 (70.4%) people were within the age range of 50-60 years. The Malaysian participants from Kelantan, Malaysia were basically existed in the middle-income range (RM 2,300 to RM 7,000) with a mean monthly income of MYR 3407.81 (Table 1).

Table 2 (see appendix) displays that after 14 weeks of aerobic exercise (supervised walking) intervention, significant improvement in state of mobility ($p = .001$) and pain or discomfort ($p = .011$) was observed. Further to that, an increment in the percentage of T2DM participants, reporting "no problem" in mobility (pre = 52%; post = 95.5%) and pain (pre = 48%; post = 72.7%) was also evident. In the follow up phase, majority of the T2DM individuals assigned to the aerobic group were observed to report "no problem" in most of the dimensions except for feelings of anxiety/depression, as only 35% of participants reported to have no problems of anxiety/depression (post = 45.5%; FU = 35%). In case of the participants of the combined exercise (supervised walking with resistance exercises) group, post-intervention improvements in perceived sense of mobility ($p = .001$) were evident. The improvement has sustained within the aerobic and combined exercise groups in the follow up phase as well. Evidently, T2DM individuals under control group have not seen any significant difference in their health statuses across different phases.

Table 1
Socio-Demographic data of the T2DM population

Variables	Overall	Control (No Exercise) Group n=23	Aerobic Exercise Group n=20	Combined Exercise Group n=21
	N=64			
	Number (%) Mean ± SD	Number (%) Mean ± SD	Number (%) Mean ± SD	Number (%) Mean ± SD
Gender				
Male	21 (32.8)	9 (39.1)	6 (30)	6 (28.6)
Female	43 (67.2)	14 (60.9)	14 (70)	15 (71.4)
Age (Years)	53.13 ± 4.74	53.6 ± 5.78	54.55 ± 3.49	50.75 ± 4.22
40 - 50	19 (29.7)	6 (25.9)	5 (25)	8 (38.2)
51 – 60	45 (70.4)	17 (75.8)	15 (75)	13 (61.8)
BMI (kg/m ²)	28.66 ± 4.24	30.16 ± 4.08	26.77 ± 4.40	29.06 ± 3.66
Underweight	0 (0)	0 (0)	0 (0)	0 (0)
Normal	12 (18.8)	3 (13)	8 (40)	1 (4.8)
Overweight	24 (37.5)	9 (39.1)	7 (35)	8 (38.1)
Obese	28 (43.8)	11 (47.8)	5 (25)	12 (57.1)
Height (cm)	154.03 ± 5.04	155.15 ± 5.03	154.35 ± 6.29	152.60 ± 3.20
Weight (kg)	68.03 ± 10.86	72.70 ± 11.17	63.70 ± 10.70	67.70 ± 9.19
Diabetic year (Years)	8.15 ± 1.12	8.30 ± 0.98	8.80 ± 1.20	7.35 ± .59
HbA1c (m.mol/l)	10.88 ± 1.35	10.76 ± 1.55	11.12 ± .99	10.77 ± 1.50
Monthly Income (MYR)	3407.81 ± 930.15	3050.00 ± 595.16	3810.00 ± 1190.27	3335.00 ± 844.35

Now, Table 3 below depicts that during the pre-intervention phase there was significant difference between aerobic and combined group ($p = .022$) with a negative mean difference presenting higher scores of EQ-VAS of EuroQol 5D-5L in the combined group. In case of the post intervention

phase there were also significant differences observed between control and combined group ($p = .000$) and also between aerobic and combined group ($p = .003$) with negative mean differences indicating higher values in the combined group.

Table 3
Pairwise Comparisons for EQ-VAS Score across different groups based on phases

Phases	Groups	MD (95% CI)	p-value
Pre	Control - Aerobic	9.00 (-1.88, 19.88)	.138
	Control - Combined	-3.25(-14.13, 7.63)	1.000
	Aerobic – Combined	-12.25(-23.13, -1.38)	.022*
Post	Control - Aerobic	-1.70(-7.67, 4.27)	1.000
	Control - Combined	-10.00(-15.97, -4.03)	.000**
	Aerobic – Combined	-8.30(-14.27, -2.33)	.003**
Follow-up	Control - Aerobic	-4.75(-14.59, 5.09)	.716
	Control - Combined	-16.00(-25.84, -6.16)	.001**
	Aerobic – Combined	-11.25(-21.09, -1.41)	.020*

* $p < .05$; ** $p < .001$

Two-way repeated measure of ANOVA between group analysis regarding phases were applied followed by pairwise comparisons with 95%

confidence interval adjusted by Bonferroni correction. Assumption of normality,

homogeneity of variances and compound symmetry were checked and fulfilled.

Similarly, in the follow up phase there were significant differences witnessed between control and combined group ($p = .001$) and

4. DISCUSSION

In this study, EQ-5D- 5L questionnaire¹³ was used to assess the perceived health status. Considerable number of studies has used this assessment protocol for evaluation of the health-related quality of life (HRQoL) of individuals with T2DM in different countries¹⁵⁻¹⁸. However, application of EQ-5D- 5L assessment was barely noticeable in interventional studies, which were carried out to evaluate changes in the health status of T2DM individuals. Here it is worthy to be mentioned that, in this research EQ-5D- 5L was introduced to measure outcomes of differential exercise intervention techniques, on different health states of the T2DM individuals in Kelantan, Malaysia across various phases and groups to identify probable significant improvements in different dimensions of health status.

Now, from the outcomes it can be postulated that, participants in the aerobic and combined exercise groups had improvements in the perceived level of mobility, as majority of the T2DM individuals reported to 'no problem' in mobility. Reason behind the evident perceived improvement in mobility could be attributed to the exercise interventions introduced to them. This present evidence of beneficial impacts of exercise have been supported by the findings of quite a few previous researches, as Aoki and colleagues (1993)¹⁹ acknowledged, individuals with type 2 diabetes may experience limited joint mobility due to glycation of joint structures, and hence flexibility training such as stretching activities are extremely essential for maintenance of full range of motion (ROM) of joints. Further to that, Herriott and the co-researchers (2004)²⁰ affirmed that combined stretching and resistance training for only eight weeks resulted in significant strength gains in elderly individuals with and without type 2 diabetes. Researchers further claimed that, following training type 2 diabetic subjects could significantly improve their level of flexibility. As they proposed this might have happened, since T2DM individuals perhaps had to

between aerobic and combined group ($p = .020$) with negative mean differences signifying higher scores in the combined group compared to control and aerobic group (Table 3).

overcome more delicate and harmful effects of diabetes on joint mobility²⁰. In a more recent research Francia and the colleagues (2014)²¹ confirmed that, in case of problems pertaining to limited joint mobility, daily stretching exercises helped in prevention and/or further delaying the development of progressive joint stiffness in the T2DM patients.

Since, in this study, aerobic exercise protocol consisting supervised walking with stretching exercises and combined exercise protocol amalgamated strengthening exercises along with supervised walking and stretching exercises were introduced, those exercises escalated the range of movement at the joints, and consequently more synovial fluid was released into the joints, which perhaps finally improved the level of mobility of the T2DM individuals²². Apart from the observed improvements in mobility, perceived improvement in the levels of self-care, usual activities, pain in aerobic and combined exercise group were also evident.

Hence, it can be said that there were improvements in the overall health status in T2DM individuals after 14 weeks of intervention period. The results of the current study are supported by the findings of the study done by Myers et al., in 2013²³. Interestingly, this improvement has sustained within the aerobic and combined exercise groups after the follow up phase as well.

5. CONCLUSIONS

This research has showed that participants in the aerobic and combined exercise intervention has shown improvement in overall perceived health status of T2DM individuals measured by EQ 5D-5L questionnaire in Kelantan, Malaysia. Moreover, combined exercise program had shown the best outcome compared to aerobic and no exercise program.

6. LIMITATIONS

In this research only 64 middle aged Type 2 Diabetic individuals who belonged to the

middle-income group were included. In addition to that only people who were diagnosed as having T2DM for 7 -10 years were taken for this research. Further to that participants were selected only from one state of Malaysia due to logistical problems. Therefore, it would be difficult to conclude about the improvement in perceived health status for the entire Malaysian T2DM population.

7. RECOMMENDATIONS

This kind of research can be carried out with larger sample including all states of Malaysia with different income groups (low-income, middle income, high income) to have an overall scenario of the effects of exercise intervention in

9. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

FaS, SrS, SoS

Collected data and performed the experiments:

FaS, SrS, SoS

Contributed with materials/analysis tools:

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improving perceived health status of T2DM population in Malaysia. Further research can be done with health economic analyses such as cost effectiveness or cost benefit analysis of the exercise interventions for the T2DM population in future endeavours.

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FaS, RoM, SrS, SoS, WmI

Analysed the data: FaS, SrS, SoS

Wrote the paper: FaS, SoS, SrS

Checked and edited the format of the paper:

FaS, SrS, SoS

Final approval: FaS, SrS, SoS, MsI

of Aerobic Training, Resistance Training, or Both on Glycemic Control in Type 2 Diabetes Randomized Trial Effects of Aerobic and Resistance Training on Glycemic Control in Type 2 Diabetes. *Annals of internal medicine.* 2007 Sep 18;147(6):357-69.

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APPENDIX

Table 2

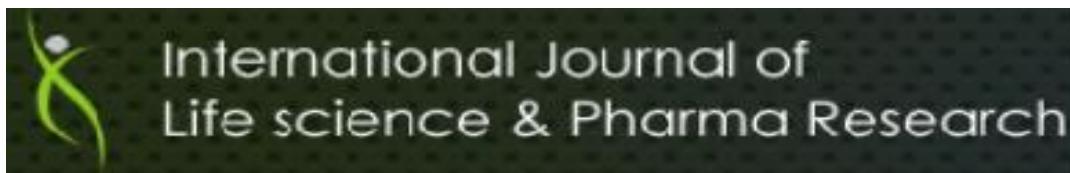
A comparison of pre, post and follow-up exercise intervention effect on self-reported descriptions of health problems using five dimensional EuroQoL-5D health state scores GroupWise (Wilcoxon Matched Pairs Signed Ranks Test)

EQ-5D Individual Dimensions	Pre-Intervention		Post intervention		Follow-up (FU)		P value (Pre-Post)	P value (Post-FU)	
	n	%	n	%	n	%			
CONTROL GROUP									
Mobility	25		24		23		.741	.092	
No problem	10	40.0	8	33.3	7	30.4			
Slight problem	15	60.0	16	66.7	16	69.6			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Self-care	25		24		23		.101	.062	
No problem	19	76.0	10	41.7	8	34.8			
Slight problem	6	24.0	14	58.3	15	65.2			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Pain/discomfort	25		24		23		1.00	.667	
No problem	10	40.0	8	33.3	6	26.1			
Slight problem	15	60.0	16	66.7	17	73.9			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Activity	25		24		23		.667	1.00	
No problem	18	72.0	16	66.7	15	65.2			
Slight problem	7	28.0	8	33.3	8	34.8			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Anxiety/depression	25		24		23		.301	1.00	
No problem	12	48.0	15	62.5	16	69.6			
Slight problem	13	52.0	9	37.5	7	30.4			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
EQ-5D Individual Dimensions									
		Pre-Intervention		Post intervention		Follow-up (FU)		P value (Pre-Post)	
		n	%	n	%	n	%	P value (Post-FU)	
AEROBIC EXERCISE GROUP									
Mobility	25		22		20		.001**	1.00	
No problem	13	52.0	21	95.5	19	95.0			
Slight problem	12	48.0	1	4.5	1	5.0			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Self-care	25		22		20		.100	1.00	
No problem	16	64.0	19	86.4	16	80.0			
Slight problem	9	36.0	3	13.6	4	20.0			
Moderate problem	0	0	0	0	0	0			
Severe problem	0	0	0	0	0	0			
Unable to do	0	0	0	0	0	0			
Pain/discomfort	25		22		20		.011**	.011**	
No problem	12	48.0	16	72.7	18	90.0			
Slight problem	9	36.0	6	27.3	2	10.0			

Moderate problem	4	16.0	0	0	0		
Severe problem	0	0	0	0	0		
Unable to do	0	0	0	0	0		
Activity	25		22		20		
No problem	14	56.0	18	81.8	16	70.0	
Slight problem	11	44.0	4	18.2	4	30.0	
Moderate problem	0	0	0	0	0	0	
Severe problem	0	0	0	0	0	0	
Unable to do	0	0	0	0	0	0	
Anxiety/depression	25		22		20		
No problem	19	76.0	10	45.5	7	15.0	
Slight problem	6	24.0	12	54.5	13	75.0	
Moderate problem	0	0	0	0	0	0	
Severe problem	0	0	0	0	0	0	
Unable to do	0	0	0	0	0	0	

EQ-5D Individual Dimensions	Pre-Intervention		Post intervention		Follow-up (FU)		P value (Pre-Post)	P value (Post-FU)
	n	%	n	%	n	%		
COMBINED EXERCISE GROUP								
Mobility	25		24		21		.001**	.322
No problem	10	40.0	23	95.8	21	100.0		
Slight problem	15	60.0	1	4.2	0	0		
Moderate problem	0	0	0	0	0	0		
Severe problem	0	0	0	0	0	0		
Unable to do	0	0	0	0	0	0		
Self-care	25		24		21		.100	.185
No problem	14	56.0	20	83.3	21	100.0		
Slight problem	11	44.0	4	16.7	0	0		
Moderate problem	0	0	0	0	0	0		
Severe problem	0	0	0	0	0	0		
Unable to do	0	0	0	0	0	0		
Pain/discomfort	25		24		21		1.00	.183
No problem	16	64.0	19	79.2	19	90.5		
Slight problem	9	36.0	5	20.8	2	9.5		
Moderate problem	0	0	0	0	0	0		
Severe problem	0	0	0	0	0	0		
Unable to do	0	0	0	0	0	0		
Activity	25		24		21		.661	1.00
No problem	20	80.0	22	91.7	20	95.2		
Slight problem	5	20.0	2	8.3	1	4.8		
Moderate problem	0	0	0	0	0	0		
Severe problem	0	0	0	0	0	0		
Unable to do	0	0	0	0	0	0		
Anxiety/depression	25		24		21		.567	1.00
No problem	21	84.0	20	83.3	19	90.5		
Slight problem	4	16.0	4	16.7	2	9.5		
Moderate problem	0	0	0	0	0	0		
Severe problem	0	0	0	0	0	0		
Unable to do	0	0	0	0	0	0		

*p<.05; **p<.001



BENEFICIAL IMPACTS OF PSYCHOBIOLOGICAL CONDITIONING OBSERVED ON MOVEMENT COORDINATION IN ATHLETES

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ABSTRACT

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This study was conducted to investigate the role of biofeedback interventions carried out in different modalities, with an objective to improve movement coordination in athletes. Sixty-nine young male recreational athletes (matched in anthropometric, cardiovascular and performance status) identified as having disrupted emotionality and deficiency in movement coordination were recruited as participant. Participants were subjected to assessment of psychobiological (skin conductance or Sc orienting reflex activity judged by ERP of autonomic and peripheral measures of arousal) and psychomotor attributes (lateral motor control and bilateral movement coordination parameters) in relation to performance excellence in soccer. Participants were categorised into three groups, viz. Group A – no-intervention control group, Group B – experimental group I (received Sc biofeedback training) and Group C – experimental II (received electromyography or EMG biofeedback training). Interventions followed for 15 minutes/ session, 2 sessions/week for 16 weeks. After the eighth week of intervention, mid-term analysis on all the parameters was carried out, and the post-intervention analyses were done after the 16th week of intervention. Furthermore, to evaluate the level of sustainability, post follow-up analysis of all the parameters of the baseline assessment as conducted to the participants. Two-way repeated measure of ANOVA revealed that both Sc and EMG biofeedback were found to facilitate in movement coordination, while Sc biofeedback training appeared as better effective technique in improving left and right lateral motor coordination and bilateral movement coordination performed in clockwise direction. Findings however clarified impact of enhanced psychobiological competence on improvement in movement coordination evident among Malaysian recreational athletes.

Keywords: Movement coordination; Laterality; Athletes; Biofeedback; Psychobiology

1. INTRODUCTION

Human being in course of life-endeavour matures through continuous modifications, which

eventually brings forth relatively permanent changes in behaviour. Motor behaviour also gets matured through developmental processes, which

enhances motor educability of the individual, which comprises a set of cognitive processes.¹ Enhancements in motor efficiency, thus, bring forth subsequent relatively stable modifications in motor behaviour.² Higher-order improvement of motor ability leads to enhancement in motor skills and coordination, which enable an individual to engage in performance of day-to-day essential chores and active daily living conveniently and without any hindrance.

Motor coordination up to the recreational level of sports performance may refer to an ability to accomplish some considerably tough spatio-temporal movements faster and with adequate accuracy.³ Here, motor coordination abilities are considered as overt manifestation of motor control and regulation of motor processes of the central nervous system.¹ Athletes in course of their training learn several skills specific to their sport and game involvement, but unless a player gets conditioned or habituated with majority of the sub-components of movement coordination, deficiencies in coordination tasks become obvious in almost all the activities.⁴⁻⁵ Precisely, coordination deficiency may appear subtle in gross-motor skills activities, associated with balance, gait⁶⁻⁷ movement coordination⁸⁻¹² and laterality¹¹⁻¹⁵ as well.

Movement coordination may get disrupted under stressful conditions. Impact of heightened stress and anxiety and subsequent performance failure has been discussed in the 'Catastrophe theory',¹⁷⁻¹⁸ which has hypothesized that, with certain degree of upsurge in cognitive anxiety, physiological arousal gets dramatically heightened, which puts deleterious effects on coordinated performance.¹⁷⁻¹⁸ Hence, we intended to pay attention to psychobiological competence of the athletes as precursor for symmetric and coordinated display of movement tasks.

Kicking a soccer ball for instance, requires optimal perceptual – motor coordination and speedy positioning¹⁸; vigilant actions and change of directions¹⁹. Hence the excellence in psychomotor coordination performance requires unique sympathovagal adaptation⁹⁻¹⁰ and strong regulation over monoamine neurotransmitters.²⁰ In course of transfer of training from practice to competitive situations, certain amount of stress is required for optimal performance, which if gets increased, can put tremendous debilitative impacts on coordinated performance. With such a background, we hypothesized possible inhibitive impacts of deep-rooted emotional constriction on

obscure emotional core problems like "fear of success phobia".²¹⁻²⁴ Athletes under extreme competitive often resort to the defence mechanism and try out to become indomitable²⁴⁻²⁵ also lead to emotional overloading, which can potentially even restrict motor functionality^{9,26}; joint and movement coordination²⁷⁻²⁸ and neuroendocrinological information processing.^{20,26,29}

With such a background the present study purports to investigate impacts of differentially designed psychobiological intervention techniques, which function as self-regulation mechanism, such as the biofeedback intervention techniques. Further to that, we felt it necessary to realise the intricate psychobiological processes, which may have beneficial impacts on coordinative movement performances.

2. METHODS

2.1 Participants

For the present experiment sample size was calculated using G power 3.1.9.2.³⁰ The power of the study is set at 95% with 95% confident interval and the effect size F at 0.20. Total required sample size was calculated as 69 and hence sixty-nine young adult high-performing soccer players were recruited as participants (mean age = 22.31 and SD = 1.4446). They were selected based on the psychological evaluation of dispositional anxiety; kinanthropometric and cardiovascular status of the players and moderately high level of soccer performance skill levels.

2.2 Materials Used

For this experiment, some self-report inventories were administered along with psychobiological and psychomotor evaluations. Further to that, soccer performance related parameters were also assessed, and for all these evaluations following equipment and test materials were required.

- 13) Skin Conductance Biofeedback Apparatus (Udyog, India 2000 and ProComp Infinity5 equipment of Thought Technology, USA, 2014).
- 14) Electrical Muscle Potentiometry (EMG Apparatus) (ME6000, 2008).
- 15) Materials for Performance Test: – Soccer Ball; 14 cones; Stopwatch; Marker; PVC box and Measuring tape

2.3 Procedure

After the participants agreed to participate in the study and after they signed the consent form, they were subjected to evaluation of WRT (whole-body visual reaction activity) following the standardised protocol.³¹⁻³⁴ Thereafter, they were subjected to assessment of Basal Skin conductance (Sc) as well as basal Electrical Muscle Potentiability of (SEMG) by employing surface Sc and electromyography (SEMG) assessment systems, for which they had to remain in reclining position and some surface EMG disposable electrodes were attached to the frontalis muscle (forehead muscle), and Sc electrodes were attached to the phalange of the fingers of the participants, and they were supposed to remain in reclining position with eyes closed and in relax composure. At this phase, they were prompted with a white noise as novel and benign stimulation to record phasic or habituation paradigm psychobiological responses (ERP). Thereafter following standard protocols (methodology detailed in Zahir et al., 2016¹¹ and Saha et al., 2016¹³), evaluation of left and right-lateral motor learning ability (see figure 1 for the equipment), two arm bilateral movement co-ordination abilities were carried out.

Thereafter, based on randomized sampling formula (employing Research Randomizer Software³⁵, participants were equally categorized into following groups – 1) Group A – No-intervention or control group (n = 23); 2) Group B – Experimental Group I, who received EMG Biofeedback intervention training (n = 23), and 3) Group C – Experimental Group II, who received Sc Biofeedback training (n = 23). Both the Sc and EMG biofeedback training regimes are detailed in the previous studies carried out by the researchers of this study, in identical set-ups and from the same experimental conditions.¹⁰⁻¹¹

Participants selected for intervention regimes were subjected to the training sessions for 15 - 20 minutes per session/ two sessions per week for 16 weeks (32 sessions in total). Control

Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating the performance disaster amongst soccer players.

2.4. Statistical Analysis

The data were treated with SPSS 24.0, and analysis of descriptive statistics and a two-factor ANOVA with repeated measures was carried out to compare data from the three intervention experimental conditions observed across different phases of analyses. Simple main-effects analyses and Bonferroni post hoc tests were undertaken when ANOVA revealed a significant interaction. The significance criterion was set at $p < 0.05$ and all descriptive data were presented as means and SD.

3. RESULTS

In case of pre-intervention analyses of both tonic and phasic components of Sc evaluation parameters, there was likelihood of observing skewness in the data of few parameters, which could be considered as the most characteristic features of analyses of Sc parameters. Outcomes in pre-intervention conditions however revealed no such non-normality in the data and hence, for participants of neither the control group nor the experimental groups, the data evidently were not skewed. For obtaining a better understanding on the outcomes of different Sc parameters, data of tonic Sc (basal Sc data) and the habituation paradigm data or the phasic Sc data are represented herewith based on all of the sub-component measures of Sc analyses.

Table 1

Descriptive statistics of skin conductance parameters analysis on tonic skin conductance across the groups

Variables	Control group Mean \pm SD	EMG Biofeedback group Mean \pm SD	Sc Biofeedback group Mean \pm SD
Tonic skin conductance at pre-intervention level	65.02 \pm 28.64	44.65 \pm 56.45	93.01 \pm 66.38
Tonic skin conductance at mid-intervention level	154.44 \pm 81.70	270.33 \pm 158.69	244.39 \pm 155.79
Tonic skin conductance at post-intervention level	236.44 \pm 161.94	112.53 \pm 27.61	168.37 \pm 151.10
Tonic skin conductance at follow-up intervention level	164.54 \pm 62.80	182.68 \pm 86.80	131.05 \pm 39.10

Table 2
Descriptive statistics of skin conductance parameters analysis on adaptation level across the groups

Variables	Control group Mean \pm SD	EMG Biofeedback group Mean \pm SD	Sc Biofeedback group Mean \pm SD
Adaptation level at pre-intervention level	-9.07 \pm 17.40	-3.87 \pm 21.30	-9.80 \pm 22.36
Adaptation level at mild-intervention level	-81.20 \pm 79.46	-97.87 \pm 62.05	-77.07 \pm 91.97
Adaptation level at post-intervention level	-59.27 \pm 51.07	-25.13 \pm 24.87	-37.93 \pm 82.07
Adaptation level at follow up-intervention level	-55.07 \pm 60.02	-88.40 \pm 12.09	-39.40 \pm 51.05

Table 3
Descriptive statistics of skin conductance parameters analysis on latency across the groups

Variables	Control group Mean \pm SD	EMG Biofeedback group Mean \pm SD	Sc Biofeedback group Mean \pm SD
Latency at pre-intervention level	1.58 \pm 2.04	1.42 \pm 2.18	1.52 \pm .83
Latency at mid-intervention level	2.23 \pm 1.12	1.97 \pm 1.09	1.62 \pm .99
Latency at post-intervention level	1.47 \pm .88	1.65 \pm .57	1.87 \pm 3.68
Latency at follow up-intervention level	2.40 \pm .33	1.62 \pm .52	1.98 \pm 1.06

Table 4
Descriptive statistics of skin conductance parameters analysis on recovery time across the groups

Variables	Control group Mean \pm SD	EMG Biofeedback group Mean \pm SD	Sc Biofeedback group Mean \pm SD
Recovery time at pre-intervention level	11.68 \pm 9.76	3.17 \pm 4.50	11.68 \pm 11.29
Recovery time at mid-intervention level	14.22 \pm 11.37	8.77 \pm 8.01	14.55 \pm 11.31
Recovery time at post-intervention level	8.63 \pm 8.12	14.57 \pm 10.12	14.07 \pm 8.88
Recovery time at follow up-intervention level	20.90 \pm 15.11	18.00 \pm 7.80	17.87 \pm 7.56

Table 5
Descriptive statistics of performance parameters analysis on bilateral motor coordination score with clockwise movements across the groups in different phases

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
Bilateral motor coordination score with clockwise movements at the pre-intervention level	1796.65 \pm 409.04	1795.40 \pm 289.75	2052.75 \pm 501.14
Bilateral motor coordination score with clockwise movements at the at mid-intervention level	2053.15 \pm 334.51	8865.00 \pm 1370.08	8229.05 \pm 1030.39
Bilateral motor coordination score with clockwise movements at the at post-intervention level	2724.75 \pm 226.69	9915.00 \pm 380.13	10000.46 \pm 153.65
Bilateral motor coordination score with clockwise movements at the at follow up-intervention level	1816.75 \pm 214.76	9435.00 \pm 696.82	8845.36 \pm 1237.35

Table 6
Descriptive statistics of performance parameters analysis on bilateral motor coordination score with counter-clockwise movements across the groups in different phases

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
Bilateral motor coordination score with counter-clockwise movements at the pre-intervention level	1394.84 \pm 248.34	1335.52 \pm 209.03	1337.37 \pm 111.17
Bilateral motor coordination score with counter-clockwise movements at the at mid-intervention level	1839.69 \pm 376.56	3040.09 \pm 197.08	3010.93 \pm 391.99
Bilateral motor coordination score with counter-clockwise movements at the at post-intervention level	1343.30 \pm 682.29	3025.29 \pm 262.32	3096.96 \pm 103.69
Bilateral motor coordination score with counter-clockwise movements at the at follow up-intervention level	1248.47 \pm 168.28	2387.78 \pm 453.30	2951.91 \pm 501.61

Tables 1 - 4 were conceived to represent phase wise alterations observed in the psychobiological (Sc components) data and in the movement coordination performance parameters (i.e., tables 5 and 6, representing descriptive information on bilateral clockwise and counter-clockwise direction movement coordination performance parameters) which were observed amongst participants of three different groups.

Observations however revealed that indices were mostly free from huge dispersions and observed identical features in the obtained pre-intervention data mostly revealed that, participants did not have any pre-existing differences, and hence whatever differences were observed in the mid-intervention; post-intervention and post-follow-up interventions could be attributed to the interventions introduced to the participants.

Table 7

Pairwise comparisons left-lateral motor coordination scores evident across the different groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	-4.511*	1.360	.011
	Sc Biofeedback group	-5.267*	1.574	.010
	Control group	4.511*	1.360	.011
EMG Biofeedback group	Sc Biofeedback group	-4.800	2.530	.388
	Control group	5.267*	1.574	.010
	EMG Biofeedback group	4.800	2.530	.388

*p<0.05; **p<0.01

As it is evident in the Table 7, after the post-intervention assessment, outcomes in terms of the pairwise comparisons revealed that the participants of both intervention groups displayed

better indices of left-lateral motor coordination performance, compared to their counterparts in the control group. No such comparative difference between the experimental groups was observed.

Table 8

Pairwise comparisons right-lateral motor coordination scores evident across the different groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	-15.667**	2.726	.000
	Sc Biofeedback group	-22.556**	3.756	.000
	Control group	15.667**	2.726	.000
EMG Biofeedback group	Sc Biofeedback group	-6.889*	2.304	.028
	Control group	22.556**	3.756	.000
	EMG Biofeedback group	6.889*	2.304	.028

*p<0.05; **p<0.01

Outcomes of the pairwise comparisons represented in the Table 8, depicted that at the post-intervention assessment, differences amongst the participants were evident. Again, these findings implied that, while performing right-lateral motor coordination tasks the participants of

the both intervention groups showed significantly better improvement in their coordination performance (p<0.01). Further to that, compared to the participants of EMG BF group, the Sc BF group players were observed to have better improvement.

Table 9

Pairwise comparisons symmetry in bilateral coordination scores in clockwise direction evident across the different groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	-8.911**	1.411	.000
	Sc Biofeedback group	-9.667**	1.388	.000
	Control group	8.911**	1.411	.000
EMG Biofeedback group	Sc Biofeedback group	-8.200**	1.620	.000
	Control group	9.667**	1.388	.000
	EMG Biofeedback group	8.200**	1.620	.000

*p<0.05; **p<0.01

In the Table 9, impact of interventions on bilateral coordination ability was observed, and the post-intervention assessment outcomes in terms of the pairwise comparisons revealed that

differences amongst the participants existed. Outcomes revealed that, compared to the participants of the no-intervention or control group the experimental group participants

displayed significant improvements in bilateral coordination movement performances ($p<0.01$) performed in clockwise direction. Apart from that, compared to the participants of EMG BF group,

the Sc BF group players were observed to have better improvement in symmetrical bilateral coordination ability.

Table 10

Pairwise comparisons symmetry in bilateral coordination scores performed in counter-clockwise direction, evident across the groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	.146**	.041	.006
	Sc Biofeedback group	.174*	.053	.012
EMG Biofeedback group	Control group	-.146**	.041	.006
	Sc Biofeedback group	.031	.035	1.000
Sc Biofeedback group	Control group	-.174*	.053	.012
	EMG Biofeedback group	-.031	.035	1.000

* $p<0.05$; ** $p<0.01$

In the Table 10, the post-intervention assessment outcomes in terms of the pairwise comparisons revealed that differences amongst the participants were evident. Findings however implied that, in counter-clockwise performance too, compared to the participants of the control group the experimental group participants displayed significant improvements in symmetrical bilateral coordination performance ($p<0.01$). No such difference between the participants of intervention groups were evident.

4. DISCUSSION

Based on the results obtained, we intended to revisit the reasons behind those outcomes. The prime objective of this study was to investigate the facilitative impacts of biofeedback intervention training regimes on enhancement in psychobiological conditioning and resultant improvement in psychomotor, especially movement coordination related aspects of athletic performance. Outcomes thus revealed that both the intervention techniques (viz., Sc and EMG biofeedback intervention) were effective in bringing about the improvements in motor and movement coordination performances, in which the Sc BF was evident as better effective in inducing desired modifications in motor learning tasks performed both in left and right-lateral motor coordination tasks. Such improvements however were also evident in the bilateral movement coordination activities performed by the players, in both clockwise and counter-clockwise directions.

While focussing on discussion on **motor learning ability**, it was observed the players of the Sc biofeedback intervention group showed significant improvement in left and right-lateral

motor coordination tasks, and also in cases of bilateral movement coordination tasks performed (tables 7 to 10 are referred). Further to that, compared to the EMG biofeedback training, excepting the bilateral coordination performed in counter-clockwise direction, in all other tasks, Sc biofeedback intervention training was evident as better effective. Observed findings implied that the Sc biofeedback training involving autonomic driven self-regulation and subsequent optimal relaxation, has modified psychobiological adaptations, leading to neurocognitive enhancement.³⁶ This enhancement in neurocognitive efficiency was also evident among the players who received EMG BF training. Thus, alike the Sc BF training, EMG BF training also could have facilitated in reduction of the double-blind resistances, which might have occurred in the ligaments and muscles close to the limb-joints and in the major muscles³⁷, which symmetrically developed neuromuscular facilitation in the major groups of muscles, and in turn causes regulation in motor movement.³⁷⁻³⁹ Findings revealed that compared to the players of control condition and also compared to their counterparts in the EMG BF group, the Sc BF participants were better able to perform motor tasks symmetrically (table 9 is referred). This outcome of positive changes in motor learning and movement coordination, got supported by the previous researchers.³⁹⁻⁴¹

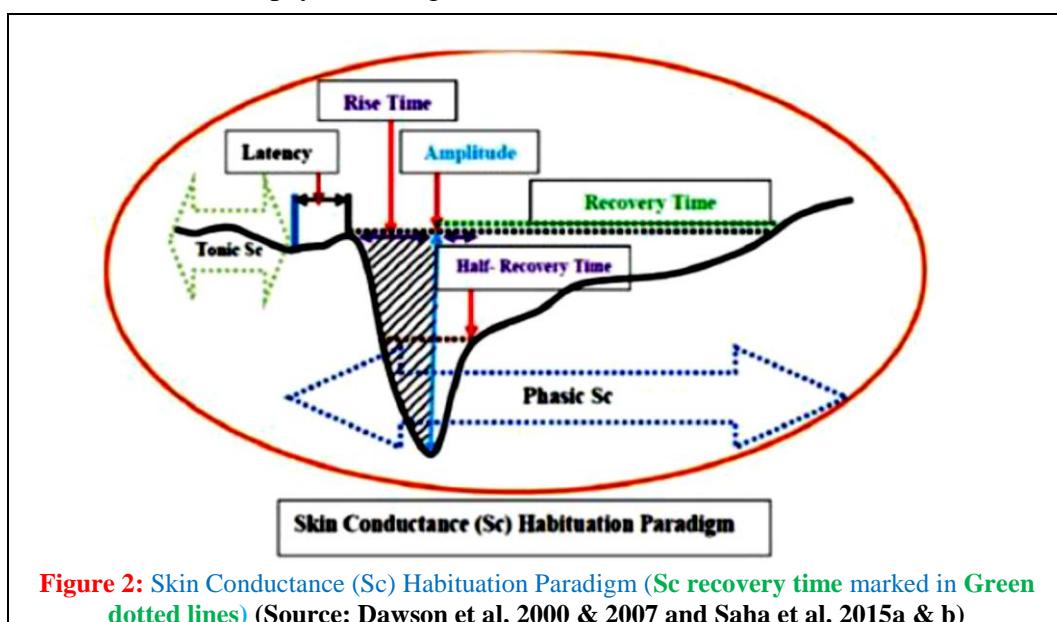
Now, let us focus on the discussion on **bilateral motor coordination ability**. Outcomes of the study revealed that alike what was evident in motor learning (i.e., left and right-lateral motor coordination) performances, post-intervention findings on bilateral motor coordination also revealed marked improvement among both the EMG and the Sc biofeedback trainee players (tables 9 and 10 are referred). Explanation on

improvement followed by EMG biofeedback training, lies on enhancement in isometric contractibility in the players, which in course of time improves joint mobility and proprioceptive ability in muscle joints.^{13,42-43} This improvement in muscle contractibility was not possible for the players of control condition and hence no improvement in bilateral motor coordination was observed. As it was already pointed out, Sc biofeedback training enhances psychobiological and neurocognitive adaptations³⁶, leading to reduction in double-blind resistance in the major muscles and joints.³⁷ Apart from that, enhancement in cognitive-emotional competence⁴⁴ might have facilitated in faster information processing, leading to better response programming⁴⁵ and resultant better coordinative performance.⁴⁶

Outcomes on different aspects of psychomotor performances characterised by movement coordination tasks, however categorically explained that, both Sc and EMG biofeedback intervention techniques had beneficial effects on the aforementioned parameters, in which Sc BF training appeared to be better effective intervention technique. Thus, this study has been found successful in confirming facilitative impact of Sc biofeedback training on psychomotor performance parameters, which was evident amongst the Malaysian soccer players. Here, we intended to pay close attention to the contributory roles of psychobiological

mechanisms, which might have facilitated in improvement in coordinative performances. Findings in this context revealed that compared to the players of control condition, the Sc BF and EMG BF participants were observed to elicit higher Tonic or Basal Skin Conductance Indices. This observed beneficial impact of Sc as well as EMG biofeedback training however got supported by the previous findings reported by.^{11-12,47-48} Precisely, as Dawson et al.²⁶ (emphasized, improvements evident in basal Sc indices could be resulted from optimal excitatory and inhibitory regulations originating in the frontal cortex, and also partially by virtue of enhancement in autonomic influence originating in the neo-frontal cortex.^{27,31-32}

Here, more in-depth attention was given on to the habituation paradigm or phasic components of psychobiological, hereafter skin conductance recovery time index. We felt it was necessary for us to explore into this phenomenon since, in order to ensure autonomic competence, athletes require faster emotional adaptation. For this, better understanding of the ability of the athletes to cope with the stress, based on their extent of autonomic recovery from heightened stress was essential. Prior to providing explanations on outcomes of Sc as well as EMG BF intervention techniques on phasic Sc variables, understanding on Sc habituation paradigm would be necessary.



Here it should be mentioned that, changes in basal Sc level indicate transient or situation-specific or state-like inconsistent response changes.^{27,31-32,47,49-50} Compared to this basal Sc

tonic Sc information, the phasic skin-conductance (Sc) habituation-paradigm indices such as, Sc amplitude, recovery time, spontaneous fluctuations (SF) or non-specific Sc response

In this present study, out of the Sc phasic indices, explanation on outcomes of Sc recovery time only was considered as essential, since optimal autonomic recovery was postulated to facilitate in coping leading to enhanced psychobiological competence required for more flexible and higher-order motor and movement coordination.^{36-39,42-43} In this study, both Sc and EMG BF training were observed as effective interventions, to induce faster autonomic recovery (Sc Recovery time), and once again compared to the control group of players, their counterparts in the intervention groups were better able to recover faster (table 4.10 is referred). These findings of improvement also get support from the outcomes reported in the previous literatures.^{31-32,51} Zahir et al.¹⁴ on the contrary, observed delayed Sc recovery time after introduction of both Sc and EMG BF, while Saha et al.⁹ observed no impact of Sc BF as well as of the EMG BF training at all on the observed Sc recovery indices. Dissimilarity in the outcomes, however could be attributed to the frequency and duration of the biofeedback intervention training imparted. As Zahir et al.¹² introduced both Sc and EMG BF with a protocol of 15 min.s/day; 2 days/week for 5 weeks, and observed delayed recovery time, Saha et al.⁹ evidenced no change at all as 10min.s/day 3 days/week for 10 weeks, perhaps was not adequate to yield beneficial outcomes. In this experiment; however, both the Sc and EMG BF training was imparted for 15 min.s/day; 2 days/week for 16 weeks, which could ensure beneficial outcomes.

Explanations on the outcomes on different aspects of psychobiological parameters clarified that, both Sc and EMG biofeedback intervention techniques have beneficial effects on enhancing basal or tonic Sc index and in inducing faster Sc recover time. Thus, the effectiveness of the both the Sc and EMG BF training on the

forementioned psychobiology variables are confirmed. Thus, this study has been found successful in confirming beneficial impacts of biofeedback training regimes on psychobiology parameters, which was evident amongst the Malaysian soccer players. Finally, enhancement in psychobiological competence facilitated in displaying higher-order motor and movement coordination among the recreational athletes.

5. CONCLUSIONS

This research revealed efficacy of both skin conductance and EMG biofeedback intervention techniques in improving movement coordination among Malaysian recreational athletes. Overall enhancement in psychobiological processes, especially autonomic competence in inducing faster recovery was evident to facilitate in movement coordination.

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7. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

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Collected data and performed the experiments:

SoS, NbR

Contributed with materials/analysis tools:

SoS, NbR

Analysed the data: SoS

Wrote the paper: SoS

Checked and edited the format of the paper:

SoS, NbR AkG, NwC

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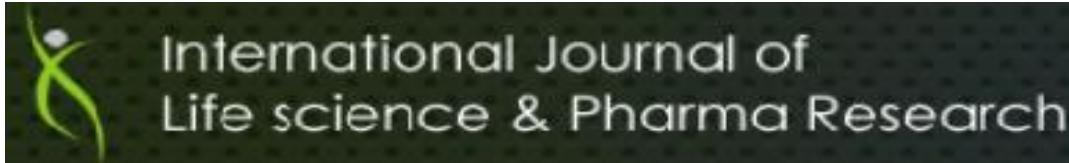
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VARIATION IN MOOD AND EMOTIONAL REGULATION AS PREDICTOR OF ENHANCEMENT IN SOCCER AGILITY PERFORMANCE

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ABSTRACT

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Present experiment was carried out to examine the impacts of changes in mood and emotionality factors in influencing performance of soccer skills. Forty-five young male recreational athletes (matched in anthropometric, cardiovascular and performance status) identified as having disrupted emotionality were recruited as participant. Participants were subjected to assessment of psychological attributes (viz. cognitive flexibility, somatization, anxiety, mood factors and emotional stability), psychobiological attributes (skin conductance or Sc habituation paradigm or phasic measures of arousal) and soccer skill parameters (i.e., 'with the ball agility' task). Participants were categorised into three groups, viz. Group A – no-intervention control group, Group B – experimental group I (received Sc biofeedback training) and Group C – experimental II (received electromyography or EMG biofeedback training). Interventions followed for 15 minutes/session, 2 sessions/week for 16 weeks. For the purpose of this study outcomes of the post-intervention analyses, which were carried out after the 16th week of intervention, was considered for investigation. Descriptive analyses, repeated measure of ANOVA and multiple linear regression analyses were carried out at the post-intervention phase of analysis clarified interrelationships between the mood, emotionality and psychobiological influencing factors on the outcomes of soccer performance skills, evident among the players of three different experimental conditions. Inhibitive as well as facilitative impacts of mood state factors, emotionality and psychobiological indices emerged as predictors of performance changes of soccer 'with the ball agility' skills.

KEYWORDS: *Mood states; Anxiety; Emotionality; Psychobiology; Soccer Agility*

2. INTRODUCTION

Soccer performance is the outcome of numerous elementary skills, and successful adoption of those skills ensures success in soccer performance.¹ Successful performance of soccer skills in the actual competitive situations, however refers to outcome of optimal level of positive transfer of correctly learned and practiced skills.² Regularised and tedious practice of basic skills, through

continuous and dynamic practice sessions, become automatic²⁻³ and during actual competitive situations, players can perform those skills, as they perform from their zone of excellence.⁴⁻⁶

This is so stated, since excellence in soccer performance could be achieved through stages of motor learning efficiency, which passes through three phases of development: Cognitive Phase (learning on movement coordination)⁷, Associative Phase (acquiring accuracy in

movement coordination)⁸ and Autonomous Phase (stabilizing movement coordination under critical and challenging situations).⁹ Once a skill is learned and adequately adopted, with practice it becomes almost spontaneous and when carried out, it is supposed to bring forth ascertained outcomes of excellence, with minimum efforts and energy expenditure yielding maximum certainty.¹⁰⁻¹⁵

It is well-known that, one of the dominant aspects of soccer is kicking the ball¹⁶ which can be seen as a means of channelizing suppressed hostility and obstruction or catharsis.¹⁷⁻¹⁸ This feature could be alternatively hypothesized as the players who are able to channelize or catharsis their hidden cognitive-emotional overloading and repressed emotional turmoil, and can optimally regulate their emotional upheavals, perhaps can also enable themselves to improve in their performance of soccer skills.^{6,13,14-15,19}

With such a background we wanted explore into the problems pertaining to the agility factor, and in the field of soccer, the “with the ball agility” aspect. Previous researches carried out on soccer performers of South-East-Asian origin¹⁴⁻¹⁵, revealed that, inept psychological especially emotional and psychobiological efficiency reduced performance efficiency of certain soccer skills. These inhibitive impacts of

psychobiological, precisely pertaining to autonomic arousal modulation ability accompanied by debilitating effects of dispositional anxiety, resulted in disruptive soccer performance in Indian soccer players as well.⁶ These aforementioned outcomes incited us to investigate into possible predictive influence of emotional regulation and mood factors on performance of soccer “with the ball agility” task among Malaysian young-adult talented soccer performers.

2. METHODS

2.1 Participants

For the present experiment sample size was calculated using G power 3.1.9.2.²⁰ The power of the study is set at 95% with 95% confident interval and the effect size F at 0.25. Total required sample size was calculated as 45, hence the required number of young adult high-performing soccer players were recruited as participants (mean age = 21.39 and SD = 1. 67). They were selected based on the psychological evaluation of dispositional anxiety; kinanthropometric and cardiovascular status of the players and moderately high level of soccer performance skill levels.

[1] -- Monday, August 08, 2015 -- 15:39:43	
F tests - ANOVA: Repeated measures, within-between interaction	
Analysis:	A priori: Compute required sample size
Input:	Effect size f = 0.25 α err prob = 0.05 Power (1- β err prob) = 0.95 Number of groups = 3 Number of measurements = 4 Corr among rep measures = 0.5 Nonsphericity correction ϵ = 1
Output:	Noncentrality parameter λ = 22.5000000 Critical F = 2.1713088 Numerator df = 6.0000000 Denominator df = 126 Total sample size = 45 Actual power = 0.9554764

2.2 Materials Used

For this experiment, some self-report inventories were administered along with psychobiological and psychomotor evaluations. Further to that, soccer performance related parameters were also assessed, and for all these evaluations following equipment and test materials were required.

- 1) State-Trait Anxiety Inventory (STAI)²⁹
- 2) Brunel Mood Scale³⁰

- 3) Rorschach Ink – Blot Test³¹
- 4) Skin Conductance Biofeedback Apparatus (Udyog, India 2000 and ProComp Infinity5 equipment of Thought Technology, USA, 2014).
- 5) Materials for Performance Test: – Soccer Ball; 14 cones; Stopwatch; Marker; PVC box and Measuring tape.

2.3 Procedure

After the participants agreed to participate in the study and after they signed the consent form, they were subjected to evaluation of self-reported transitory and dispositional anxiety, based on State-Trait Anxiety Inventory (STAI).²¹ Further to that, evaluations of psychological measure, such as, mood states was carried out by employing Brunel Mood Scale²² and cognitive-emotional aspects based emotional core was evaluated by the Rorschach Ink Blot Test for projective analysis.²³ Apart from that, evaluation of soccer 'with the ball agility' skills were also carried out (methodological steps detailed later on). All of these assessments were carried out following standardised protocols, and rigorous methodology was followed to collect data. Step-by-step methodology is detailed in the previous research literatures, published based on the studies conducted in identical experimental set-up, with similar groups of soccer players.^{6,15,24-25} Thereafter, they were subjected to assessment of phasic skin conductance (Sc) indices, Sc electrodes were attached to the phalange of the fingers of the participants, and they were supposed to remain in reclining position with eyes closed and in relax composure. At this phase, they were prompted with a white noise as novel and benign stimulation to record phasic or habituation paradigm psychobiological responses (ERP). Projective analysis of emotional make-up was done by employing the Rorschach Ink-Blot evaluation system, in which the participants were supposed to watch colourful meaningless pictures and they were required to report on their perception about those pictures. Since Rorschach pictographs are ambiguous images, and there are no pre-fixed explanations on the images, players were supposed to report on their personal view about those images, pertaining to their perception concerning the images created by the ink-bLOTS. Thus, RIB enabled us to evaluate personality oriented cognitive-emotional make-up of the participants.

2.4. Performance Test

2.4.1 Tests of Soccer Skill ('with the ball agility')

Out of the numerous possibilities of assessment of soccer-specific skills and abilities, most essential would be shooting skills and with the ball running ability or agility.²⁶

2.4.2 Test of Agility-Specific Drills

In modern soccer, games are usually characterized by many changes of direction, starts and sudden stops, and we often see short bursts of speed which more than 20-30 yards/meters are usually no long. Thus, soccer agility drills are fundamental components required for improvement in balance, body control, foot speed and coordination, which are absolutely essential for soccer performance. Training of improvement in agility is significant since soccer players obviously need to stop, change direction, sprint and stop again. Hence, test of soccer-specific agility training is focused on enhancing muscle memory related to skilful agile performance.

2.4.2.1 Test of Slalom Soccer Agility Drills – Set Up

1. Altogether fourteen cones were placed in a typical way (represented in the diagram) with varied distances ranged from 1 meter to 2.5 meters distance between them no more than 2 yards or meters of distance between them, in order to maintain variable difficulty level;
2. Cones were placed in five different diagonal rows, in an order of 2 -3 - 2 -3 -2 cones per row (refer to the diagram);
3. In order to increase difficulty level of with-the-ball agile movements, diagonal rows were not kept as parallel, so that the players face easier and sharp turns to maintain the speed of their agility performance;

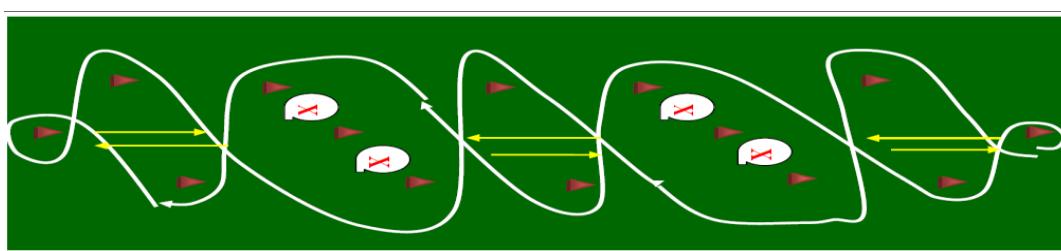


Figure 1
Slalom Agility Drills Test²⁷

4. Rows containing three cones were fixed as the walls (i.e., players cannot pass the balls through those cones, while they were kept allowed to pass the ball through the rows containing two cones (refer to the diagram).

Group A – No-intervention or control group (n = 23); 2) Group B – Experimental Group I, who received EMG Biofeedback intervention training (n = 23), and 3) Group C – Experimental Group II, who received Sc Biofeedback training (n = 23). Participants selected for intervention regimes were subjected to the training sessions for 15 - 20



Figure 2
Slalom Soccer Agility Test

2.4.2.2 Instructions

“First of all, look carefully at the SLAOM with-the-ball agility²⁷ drill pathway. You have to start running with the ball from one end and you will turn around at the opposite end and will come back to the same cone, where you began. You have to the whole running activity for 3 times. Start the drill by sprinting, while turning around from the first cone towards the left side to turn around the second cone. Keep on sprinting with the ball towards the third cone, without touching the cones either by ball or by foot. Sprint through the path keeping the wall of cones 4-5-6 at your left and turn around to reach at the cone 7 and go through similarly without touching the cones through the pathway (keeping the wall of cones 9-10-11 at your left) and once again turn around to reach cone 12 and finally you will finish the lap at the cone 14th, where you need to turn around to come back to the first cone following the similar pathway. You have to do it for thrice”.

2.5 Interventions

Thereafter, based on randomized sampling formula (employing Research Randomizer Software²⁸ , participants were equally categorized into following groups – 1)

minutes per session/ two sessions per week for 16 weeks (32 sessions in total). Control Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating the performance disaster amongst soccer players.

2.6 Statistical Analysis

The data were treated with SPSS 24.0, and outcomes of multiple linear regression analyses were critically observed to identify whether various Corroborative relationships between mood states and inner psychopathological make-up as derived by employing the projective evaluation system and the direct physiological measures (autonomic indices obtained by the skin conductance measures under habituation paradigm) could reveal the intricate processes involved in catastrophic or disruptive emotionality observed in highly skilled but under-performing Malaysian Soccer players.

3. RESULTS

Outcomes of this study are presented based on the descriptive information (refer to Tables 1) and on the multiple linear regression reports (Tables 2 to 5). In case of pre-intervention analyses of both tonic and phasic components of Sc evaluation parameters, there was likelihood of observing skewness in the data of few parameters, which could be considered as the most characteristic features of analyses of Sc

parameters. Outcomes in pre-intervention conditions however revealed no such non-normality in the data and hence, for participants of neither the control group nor the experimental groups, the data evidentially were not skewed. For obtaining a better understanding on the outcomes of different Sc parameters, data of tonic Sc (basal Sc data) and the habituation paradigm data or the phasic Sc data are represented herewith based on all of the sub-component measures of Sc analyses.

Table 1
Descriptive Statistics of Performance Parameters Analysis on 'With the ball agility' Across the Groups

Variables	Control group Mean /SD	EMG Biofeedback group Mean/SD	Sc Biofeedback group Mean/SD
'With the ball agility' at pre-intervention level	1.60 ± .33	1.47 ±.09	1.55 ±.28
'With the ball agility' at mid-intervention level	1.56 ± .34	1.41±.10	1.47 ±.30
'With the ball agility' at post-intervention level	1.49 ± .32	1.37 ±.09	1.33 ±.09
'With the ball agility' at follow up-intervention level	1.39 ± .50	1.40 ±.10	1.37 ±.11

Tables 1 was conceived to represent phase wise alterations observed in the performance parameter ('with the ball agility' performance) which were observed amongst participants of three different groups. Observations based on the shapiro-wilk test for normality however revealed that indices were mostly free from huge dispersions and

identical features in the obtained pre-intervention data mostly revealed that, participants did not have any pre-existing differences. Hence, whatever differences were observed in the mid-term as well as in the post-intervention and post-follow-up phases could be attributed to the interventions introduced to the participants.

Table 2
Pairwise comparisons 'with the ball agility' scores evident among the different groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback group	.150**	.040	.004
	Sc Biofeedback group	.168*	.050	.010
EMG Biofeedback group	Control group	-.150**	.040	.004
	Sc Biofeedback group	.031	.034	1.000
Sc Biofeedback group	Control group	-.168*	.050	.010
	EMG Biofeedback group	-.031	.034	1.000

*p<0.05; **p<0.01

Outcomes of the pairwise comparisons represented in the Table 2 depicted that, at the post-intervention assessment, differences amongst the participants were evident. Findings however revealed that, compared to the participants of the no-intervention group, players of both the EMG and Sc Biofeedback intervention groups had significantly faster "with the ball agility". But no such difference amongst the participants of the two intervention groups was revealed. Thus, the outcomes of the pairwise comparisons clarified that the both the EMG and Sc biofeedback

intervention techniques were effective in producing faster 'with the ball agility' performances. Here, at this stage, it was felt necessary to get ensured regarding the impacts of intervention techniques employed. This was done precisely, to evaluate the additive and mediating factors, such as the roles of EMG and Sc biofeedback techniques in inducing modifications in the psychomotor, psychophysiological and emotional factors, and the summated or regressed contributions of those variables interacting on the physical performance parameters.

Table 3

Model a - Summary of multiple linear regression analysis on 'With the ball agility' in Control group (based on psychobiological variables)

Dep. Variable - 'With the ball agility'	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	1.377	.085		16.178	.000					
Adaptation Level post	.004	.001	1.316	4.022	.000	.031	.541	.519	.155	6.437
Spontaneous Fluctuations post	-.021	.009	-.357	-2.206	.033	-.115	-.333	-.285	.636	1.572

^a(F (4, 11) = 4.221, P < 0.004), Adj.R² = 26.8%

In Table 3 the model **a** emerged significant as the psychophysiological measure of post-intervention improvements in adaptation level and in spontaneous fluctuations together could explain 26.8 % variance of changes in the extent of 'with the ball agility' soccer skill. Model **a** explained the inverse relationship between spontaneous fluctuations and with the ball agility observed in

the athletes. Apart from that, improvement in adaptation level was found directly associated with higher extent of 'with the ball agility'. Thus, findings revealed that the players having relatively more frequent spontaneous fluctuations and lower post-intervention level of Sc adaptation could display faster 'with the ball agility'.

Table 4

Model b - Summary of multiple linear regression analysis on 'With the ball agility' in EMG Biofeedback group (based on emotionality variables) evident at the post-intervention phase

Dep. Variable - 'With the ball agility'	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	1.062	.190		5.592	.000					
Somatization	.043	.013	.432	3.230	.002	.449	.446	.431	.994	1.006

^b(F (2, 12) = 7.125, p < 0.002), Adj.R² = 21.8%

In Table 4 the model **b** emerged significant as the psychological measure of somatization could explain 21.8 % variance of changes in the extent of 'with the ball agility'. Model **b** explained that, in case of the EMG - BF group pf players,

somatization index had direct association with faster soccer agility performance. Therefore, findings thus revealed that the players having lower extent of somatization were evident as having faster with the ball soccer agility.

Table 5

Model c - Summary of multiple linear regression analysis on 'With the ball agility' in Sc Biofeedback group (based on emotionality variables) evident at post-intervention phase

Dep. Variable - 'With the ball agility'	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	.136	.391		.348	.730					
State Anxiety	.011	.005	.306	2.472	.018	.258	.381	.275	.811	1.234
Vigour	-.011	.005	-.284	-2.268	.029	-.078	-.354	-.253	.794	1.260
Somatization	.053	.013	.525	4.153	.000	.472	.569	.463	.776	1.289

^c(F (2, 13) = 6.369, P < 0.000), Adj.R² = 46.6%

In Table 5 the model **c** emerged significant as the fitness variables and psychological measures of state anxiety, vigour and somatization together could explain 46.6 % variance of changes in the extent of soccer agility. Model **c** explained the inverse relationship between vigour and the extent of soccer agility observed in the players. Apart

from that state anxiety and somatization were found directly associated with higher extent of with the ball agility. Findings thus revealed that the players having higher extent of vigour-perception and lower state anxiety and lower extent of somatization were evident as having faster with the ball agility.

Table 6

Model d - Summary of multiple linear regression analysis on 'With the ball agility' in Sc BF group (based on psychobiological and emotionality variables) at post-intervention phase

Dep. Variable - 'With the ball agility'	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	.301	.143		2.105	.043					
Recovery Time post	.009	.002	.418	4.679	.000	.376	.643	.340	.662	1.510
Inhibitive mood	.005	.002	.236	2.913	.007	.224	.464	.212	.805	1.243
Trait Anxiety	-.008	.003	-.273	-2.607	.014	.068	-.424	-.190	.483	2.069
State Anxiety	.007	.003	.261	2.511	.017	.202	.411	.183	.489	2.046

^a(F (1, 13) = 12.150, P < 0.000), Adj.R² = 76.7%

In Table 6 the model **d** emerged significant as the post-intervention outcomes of psychophysiological measure recovery time; psychological measure – such as, inhibitive mood, trait anxiety and state anxiety together could explain 76.7 % variance of changes in the extent of 'with the ball agility'. Model **d** explained the inverse relationship among trait anxiety, and the extent of 'with the ball agility' observed in the athletes. Apart from that, recovery time, inhibitive mood and state anxiety were found directly associated with higher extent of 'with the ball agility'. Findings thus revealed that the athletes having relatively higher trait anxiety, were observed to have faster 'with the ball agility'. Contrary to that, the direct relationships imply that, those who had faster recovery time, lower extent of inhibitive mood, lower state anxiety were also observed to have faster 'with the ball agility'.

4. DISCUSSION

Findings of this research hinted up on improvement in 'with the ball agility' performance, followed by both the EMG and Sc biofeedback intervention trainings, imparted to Malaysian young-adult soccer players. Although both intervention techniques were reported to have beneficial impacts on the agility performance outcomes, no difference between those techniques in enhancing agility was evident. Discussion on the obtained findings have been attempted based on the mean differences, and based on the outcomes of regression analysis, which revealed predictive contributions of different emotionality parameters and mood factors as well onto the soccer 'with the ball agility' performance outcomes.

4.1 Discussion on impact of EMG - BF intervention on the 'With the Ball Agility' performance

Results of this experiment clarified that in case of with the ball agility performance, compared to the players of the control condition, the EMG BF participants were observed to display better performance (table 2 is referred). It was observed that, players in the EMG BF group were very fast in the agility performance. This observed beneficial impact of EMG biofeedback training in facilitating agility performance however got supported by the previous findings reported by.^{24,29-33} Precisely, the "with ball agility task" requires faster ipsilateral as well as contralateral coordination of limb joints³⁴ and hence the improvements evident in the "with ball agility task" could be attributed to the symmetrical enhancement in muscle contractility in the rectus femoris muscles of the players, which however could definitely be attributed to the EMG biofeedback training.³⁵⁻³⁶ Here it could be argued that, the mechanism of EMG biofeedback training followed in the study of Raj et al.³⁵ was different from the EMG BF technique followed in this study by the players. Findings of Raj et al.³⁵ although revealed symmetrical enhancement in muscle contractility in the rectus femoris muscles followed by EMG biofeedback training, that study was conducted on elderly osteoarthritis patients. Further to that, in the study of Raj et al.³⁵ feedback of EMG indices was received from vastus medialis and vastus lateralis muscles, and hence, it was easier for the patients to get adapted to the biofeedback training regime and consequently

enhancement in self-regulation occurred. In this study, on the contrary, players of EMG BF group received EMG signals from their frontalis muscles, which is supposed to induce enhancement in self-regulation through overall improvement in muscle perception and enhanced feeling of muscular relaxation. Members of present group of researchers through meticulous monitoring, supervision and guidance, trained the participants of EMG BF group. Perhaps those rigorous and meticulous training helped the players of EMG BF group to regulate themselves in modulating their cognitively mediated muscle perception, from feelings of fatigue; stiffness; rigidity and uneasiness to feelings of comfort, relaxation and enhanced circulation.³⁷⁻³⁸

4.2 Discussion on impact of Sc - BF intervention on the 'With the Ball Agility' performance

Similarly, the results of this experiment also clarified that in case of "with the ball agility" performance, compared to the players of control condition, their counterparts in the Sc BF condition were observed to display better performance (please see table 2). It was observed that, players in the Sc BF group performed faster agility performance. This observed beneficial impact of Sc biofeedback training in facilitating agility performance however got supported by the previous findings reported by.^{24,31,33} Precisely, the "with ball agility task" requires faster control over bilateral movements in order to perform faster whole-body reactions.^{34,39}

Here, we would like to mention that the whole-body reaction task evaluated by the previous researchers^{34,39} were quite similar to the slalom soccer ball agility task²⁷, hereafter the "with ball agility task". Previous research literature hypothesized that Sc biofeedback intervention training might result in optimal regulation of heightened levels of autonomic activation.⁴⁰ Thus, in this study players who received Sc BF training perhaps were able to regulate their psychobiological (heightened autonomic) overloading successfully.^{14,40-41}

4.3 Discussion on comparison of impacts of EMG- BF and Sc - BF intervention techniques on the 'With the Ball Agility' performance

Findings however clarified that in case of "with the ball agility" performance, no difference in effectiveness of the EMG BF and Sc BF training regimes were observed (tables 2 is referred). This

observed no difference between the interventions however implied that, both of the intervention techniques had similar beneficial impacts in facilitating "with the ball agility" performance. This observed no difference in impacts, however was not supported by the previous findings.^{24,31,33} Precisely, the "with ball agility task" requires faster control over bilateral movements to perform faster whole-body reactions.^{34,39} It is revealed that, players of both interventions could perform better than the control condition players, but no intervention had better edge over the other one.

Thus, in sum discussion on impact of biofeedback training regimes on soccer performance task provides us with enough reasons to claim that in terms of effectiveness, no difference between the EMG and Sc biofeedback intervention training regimes was evident. Although, this study has been found successful in confirming that both EMG and Sc biofeedback training regimes were evident as effective in facilitating faster 'with the ball agility' task, and no difference between the effectiveness of these interventions were evident amongst the Malaysian soccer players. At this point we assumed that, both the intervention techniques might have contributed on few psychobiological mechanisms, which might have interacted with existing emotional, cognitive-emotional and mood states of the players, and consequently mediated behind successful performance outcomes.

4.4 Emotional make-up of the soccer players

No difference between the effectiveness of the intervention techniques, confirmed that both the techniques had identical extent of positive impacts on the soccer skill performance, hereafter 'with the ball agility' task. At this point, we wanted to explore into the intricate mechanisms, which resulted in the improvement in soccer agility skills. It was hypothesized that, improvement in soccer agility followed by different types of biofeedback intervention techniques mediated through differential pathways. Skin conductance or Sc biofeedback technique is supposed to follow autonomic pathways, while EMG BF works following peripheral neural pathways.

4.4.1 Emotional make-up of the control group participants

In explaining outcomes of this study, we opted to discuss briefly on the pre-existing mood states and

emotional make ups of the players assigned to different experimental conditions. In discussing on the emotional make-up of the control group participants evident at the pre-intervention phase of assessment, we observed that higher tolerance index in collinearity statistics was evident, which however suggested that – in clarifying problems of somatization perceived among players of control group, very high extent of (69.3%) variance in tension as well as in confusion was not predicted by other mood measures. Model for the control group participants explained that, for every 1% reduction in tension, .298% increment in somatization would occur, whereas, for every 1% increment in confusion, .435% increment in somatization would be evident. Further to that, higher tolerance index observed in collinearity statistics also suggested that – in explaining emotional confusion, very high extents of (81.9%) variances in enthusiasm as well as in somatization (83.3%) and in hyper excitability (90.0%) were not predicted by other emotional measures. The model also explained that for every 1% reduction in enthusiasm, .334% increment in confusion would occur, whereas, for every 1% increment in somatization, .425% increment and for every 1% increment in hyper excitability .266% of reduction in confusion would be evident. Findings basically revealed that, the control group participants though had lower level of tension, they were observed to have higher extent of somatization, which accompanied by observed lower extent of enthusiasm led to increased confusion, which in turn resulted in heightened level of irritability in their emotional make-up.

4.4.2 Emotional make-up of the EMG BF group participants

Emotional make-up of the EMG BF group participants at the pre-intervention phase of assessment, on the other hand was quite different from their counterparts in the control group. Higher tolerance index observed in collinearity statistics for them suggested that – in explaining feelings of negativity, very high extent of variance in enthusiasm as well as in stereotypy were not predicted by other measures of emotionality. The model however also explained that for every 1% reduction in feelings of enthusiasm, .328% increment in negativity would occur, whereas, for every 1% increment in stereotypy, .436% increment

in negativity would be evident. Tolerance indices also suggested that – in explaining anger, very high extent of variance in flexibility was not predicted by other mood and emotionality measures. Similarly, high extents of variances in stereotypy, as well as in motor control, were not predicted by other mood and emotionality measures. Model for them also explained that for every 1% reduction in enthusiasm, anger might increase by .929%. Furthermore, every 1% increase in stereotyped thoughts, anger might increase by .735%. Outcomes of these two models however revealed that, at the pre-intervention phase of assessment, the EMG BF group participants were observed as having lower level of negativity, which was influenced by reduction in stereotyped feelings and enhancement of enthusiasm observed in those players. Models also revealed that, lower stereotyped cognitive-emotional thought processes and higher feelings of enthusiasm also facilitated in reducing feeling of anger in them. Contrary to that, those players were also observed to have relatively lower level of emotional flexibility, which might be considered as a hindrance, and perhaps that reduced their emotional adaptability, and hence maintenance of very sound emotional make-up within themselves had also been difficult for some of them.

4.4.3 Emotional make-up of the Sc BF group participants

In explaining the emotional make-up of the Sc BF group participants, we observed that the higher tolerance index evident in collinearity statistics suggested that while explaining motor control high extent of variance in tension as well as in confusion was not predicted by other mood measures. Model for them also explained that for every 1% increment in Tension, .394% increment in motor control would occur, whereas, for every 1% increment in Confusion, .485% reduction in motor control would be evident. Outcomes of the previous model however revealed that, at the pre-intervention phase of assessment, the Sc BF group participants were observed as having higher level of cognitive-emotional regulation on their motor control and motor educability, which was influenced by lower extent of perceived confusion in them. This model also revealed that, these players had higher extent of tension, and that might be a reason, these players

were not capable of displaying outstanding soccer performance.

4.4.4 Summary of Discussion on Emotional make-up of the participants

With such a pre-existing background associated with level of interdependent mood states and emotionality evident among players assigned to three different experimental conditions, EMG as well as Sc biofeedback trainings were imparted to the players of intervention conditions. Here in this section, we would like to focus our discussion on outcomes of those interventions on emotionality and the mood factors as predictors of changes in soccer skill performance outcomes. Here, to provide ease of understanding, we would like to discuss on the impacts of the predictors, based on dependent measures of different soccer skill components.

4.4.5 Emotional make-up of the control group participants as contributor of “with the ball agility”

Higher tolerance index observed in collinearity statistics Table 3 suggested that – in explaining ‘with the ball agility’ very high extent of variances in spontaneous fluctuation (63.6%) and also slight extent of variances in autonomic adaptation (Sc adaptation level - 15.5%) were not predicted by other measures. Model *a* also explained that for every 1% increment in autonomic adaptation, 1.326% increment in ‘with the ball agility’ would occur, whereas for every 1% reduction in sudomotor nerve activity (SNA) or autonomic SF, .357% increment in ‘with the ball agility’ would be evident.

Outcomes of this model revealed that, at the post-intervention phase of assessment, the control group participants were observed as having relatively delayed with the ball agility, which was contributed by delayed autonomic adaptation and infrequent or lesser extent of sudomotor nerve activity (SNA) or autonomic SFs observed amongst the players. Here it is required to be mentioned that, frequency of spontaneous fluctuations (SFs) depends on sudomotor nerve activity (SNA), which works like a startle response even in absence of any real stress⁴⁰ and the resultant sudden stress frequently threatens the individual under stress.⁴³ Very frequent elicitation of SFs indicates presence of pre-occupations concerning previous failure or

inadequate performance⁴²⁻⁴⁴ which might have delayed “with the ball agility” performance evident among player of control group. Furthermore, as the players of control group were characterised by higher extent of somatised anxiety; lower enthusiasm; high confusion and heightened level of irritability, those all might have resulted in delayed autonomic adaptation and the resultant slower “with the ball agility” performance.

4.4.6 Emotional make-up of the EMG BF group participants as contributor of “with the ball agility”

Higher tolerance index observed in collinearity statistics (Table 4) suggested that – in explaining soccer ‘with the ball agility’, very high extents of (99.4%) variances in somatization was not predicted by any other measures. Model *b* also explained that for every 1% reduction in somatization, .432% increment in ‘with the ball agility’ would be observed. Here let us pay attention to the emotional make-up of the players of EMG-BF group. They were less stereotyped in their thought processes and had higher enthusiasm and lower feeling of anger. Contrarily some of the EMG-BF group of players were characterised by lower emotional flexibility and reduced emotional adaptability.

Thus, these players were evident as having both positive as well as negative pre-existing emotional make-ups, which might have been hindrance in maintenance of very sound emotional make-up within themselves. After the methodologically designed prolong training of EMG-BF intervention, post-intervention regression relationships revealed the EMG BF group participants were observed as having relatively faster ‘with the ball agility’. Thus, it could be postulated that, EMG BF training perhaps also modulated inner feelings of emotional negativity, and hence reduction in somatised anxiety was evident, which in turn facilitated in displaying faster ‘with the ball agility’ performance.

4.4.7 Emotional make-up of the Sc BF group participants as contributor of “with the ball agility”

Higher tolerance index observed in collinearity statistics (Table 5) suggested that – in explaining with the ball agility very high extents of (81.1%) variances in State Anxiety; vigour (79.4%) and in somatization (77.6%) were not predicted by any other measures of emotionality. Model *c* also explained that for every 1% reduction in State

Anxiety, .306%; 1% reduction in somatization, .525% increment in 'with the ball agility' would occur, whereas, for every 1% increment in vigour, .284% increment in 'with the ball agility' would be evident.

In the Table 6, higher indices of tolerance evident in collinearity statistics suggested that – in explaining 'with the ball agility' high extent of variances in recovery time (66.2%) and very high extent of (80.5%) variances in inhibitive mood were not predicted by other measures. Apart from that, indices also revealed that, moderate extents of variances in both trait (i.e., 48.3%) and state anxiety (48.9%) were not predicted by other measures. Model **d** also explained that for every 1% reduction in recovery time .418% increment in faster 'with the ball agility' would occur, whereas for every 1% reduction in the inhibitive mood, .236% increment in 'with the ball agility' would be evident. Contrary to that, for every 1% increment in trait anxiety, .273% faster 'with the ball agility' would be displayed. Reduction of state anxiety for every 1% was however evident to produce .261% faster 'with the ball agility'.

Here, we need to reiterate that, the Sc-BF player at the pre-intervention phase were characterised by lower extent of confusion in them. This lower confusion was not beneficial, since they were also characterised by higher extent of tension, and that might be a reason, these players were not capable of displaying outstanding soccer performance.

At the post-intervention phase of assessment, outcomes revealed that the Sc BF group participants were observed as having relatively faster with the ball agility. Outcomes of the regression models revealed that, the faster "with the ball agility" performance evident among the Sc-BF group of players was directly contributed by the lowering of transient anxiety and lower somatization and improvement in vigour. The next model however further clarified that, faster autonomic recovery time; lower inhibitive mood and lower state anxiety were associated with faster agility observed amongst the players. The model however also explained that, players who had relatively higher dispositional anxiety or moderately higher TA, were also able to display faster with the ball agility.

4.4.8 Summary of Discussion on Emotional make-up of the participants as contributor of "with the ball agility"

Outcomes of the regression models, however helped us to arrive at convincing conclusions concerning the predictive contributions of the mood factors and emotional make-up of the players. Players who received EMG- BF intervention training, at the pre-intervention phase of experiment they were characteristically identified as having relatively stereotyped cognitive-emotional thought processes; relatively lower level of emotional flexibility; lower level of emotional adaptability; lowering of feelings of enthusiasm and heightened feelings of anger in them. Outcomes of regression analysis however revealed that, perhaps after 16 weeks of EMG BF intervention, players of this group could regulate their cognitive-emotional processes better than before, which however resulted in lowering of feelings of somatization. This reduced somatised feelings by virtue of peripheral regulation of muscle tension, perhaps facilitated in enhanced muscular adaptation and resultant relatively faster 'with the ball agility' performance outcomes.

Similarly, for the players of Sc-BF group, outcomes of the previous model however revealed that, at the pre-intervention phase of assessment, they were observed as having higher level of cognitive-emotional regulation on their motor control and motor educability, which was influenced by lower extent of perceived confusion in them. Thus, although they had favourable emotional make-up, owing to higher extent of tension (revealed through another model), probably these players were not capable of displaying outstanding soccer performance.

Outcomes of post-intervention phase of assessment revealed that, the Sc BF group participants were observed as having relatively faster with the ball agility, which was observed as directly contributed by the lower level of state anxiety; lower somatization and higher vigour. Further to that, they were also benefitted by higher extent of autonomic competence (i.e., faster autonomic recovery time); lowering of inhibitive mood and lower state or transient anxiety, and together all these contributed in displaying faster agility observed amongst the players. Further to that, these players were also evident as having relatively higher dispositional anxiety or moderately higher TA, which along with

enhanced autonomic competence and lowering of inhibitive mood and lower extent of situation-specific anxiety, could be effective enough, as moderate extent of TA, would facilitate in alert monitoring and enhanced attentional engagement and focus required for faster with the ball agility performance.

5. CONCLUSION

Findings of this study confirmed that the skilled soccer players of Malaysia although had inhibitive mood states, higher extent of perceived anxiety and higher extent of somatization of anxiety, being benefitted by optimally designed electromyography and skin conductance biofeedback training regimes, they could improve their autonomic and peripheral neural competence, and consequently, could display faster with the ball agility performance.

6. ACKNOWLEDGEMENT

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7. CONTRIBUTION OF AUTHORS

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Collected data and performed the experiments:

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Contributed with materials/analysis tools:

FaS, SrS, SoS

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Wrote the paper: SoS

Checked and edited the format of the paper:

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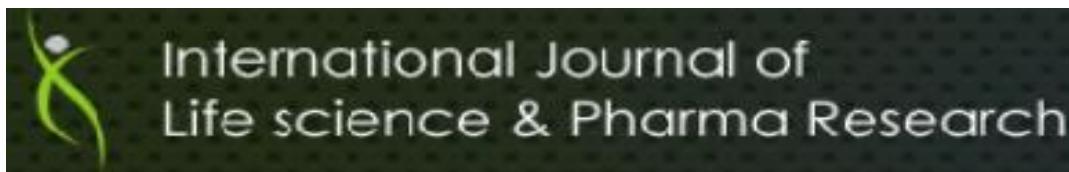
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IMPACT OF BIOFEEDBACK INTERVENTION ON MOTOR ABILITY AND COORDINATION

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1. INTRODUCTION

Performance excellence in soccer demands optimal coordination of multi-limb movements, in which characteristic ipsilateral or contra lateral constraints may occur.¹ In soccer though gross motor movement coordination is more obvious, but without fine motor control related to the coordination of muscles, bones, and neural processes, precise and intricate movements involved in controlling the ball and in movement regulation may not be so successful.² Any impairment in cortical functionality or any neural network related delay in the spinal cord and peripheral nerves may result in inhibited muscular, or joints activity and in consequence gross impairment in fine motor control may be evident.

ABSTRACT

This experiment was conducted to observe inherent relationships between ipsilateral and cross-lateral coordination activities observed among soccer performers. Cognitive-Perceptual mediators of motor skill performance were attempted to be examined in forty-five young male high performing soccer players, while they were engaged in differential types of biofeedback training. Evaluation of motor learning ability; motor skills; transfer of training abilities; steadiness related to dexterity and coordination pertaining to bidirectional and bilateral coordination were carried out in different (pre- to mid-term and post intervention) phases to identify core areas of perceptual-motor efficiencies.

Based on two-decades-long, huge numbers of studies carried out following rigorous methodology, a great deal of thoroughly documented evidence confirmed that the left brain and the right brain are not identical in their capabilities.³⁻⁵ Since each half of our brain controls the contralateral side of the body, participants with right-lateral dominance facing mirror-image-tracing task are supposed to take longer time to complete the task compared to while using their left hand.⁵ Outcomes of these studies however claimed that, individuals capable of displaying right-hand dominance specializes mostly in emotional, nonverbal, and performance of visual-spatial tasks, while dominance of left-lateral side leads to performance excellence in verbal and analytical tasks.

As in present situations stress in competitive sports is mostly obvious, players with right-hand dominance, although having better skill in emotional regulation, may face with problems in coping with cognitive demands to meet the performance achievement targets. This study will focus on the use of psychotherapeutic interventions such as Electromyography (EMG) Biofeedback and Skin Conductance (Sc) Biofeedback therapy in enhancing emotional regulation which in turn may facilitate in improvement of coordinated performance in young-adult soccer performers.

Thus, main aims of the present study are as follows:

- 1) To study the effect of EMG biofeedback intervention training on different performance parameters among soccer players.
- 2) To investigate the effect of Sc biofeedback intervention training on different performance parameters among soccer players.
- 3) To compare the relative effectiveness of EMG biofeedback and Sc biofeedback intervention on different performance parameters among soccer players.

2. METHODOLOGY

2.1. Participants

Forty-five high-performing (based on consistency in high-performance) soccer players of Kelantan province of Malaysia, aged between 20 – 23 years volunteered as participants. The sample

size was calculated using G power 3.1.7 in which the power of the study is set at 95% with 95% confident interval and the effect size F at 0.2523.

2.2. Materials Used

1. Mirror-Tracing Apparatus (Figures-1) – was administered to evaluate motor learning ability of the participants.
2. Two-arm Coordination Test Apparatus (Figure-2) – was used to evaluate bilateral coordination ability of the players.
3. Neuromuscular Steadiness tester or Dexterity Apparatus (Figure-3) – was used to assess level of dexterity or steadiness evident amongst the players.

2.3. Procedure

After obtaining proper Ethical approval from the Human Research Ethics Committee (HREC) USM (No: -USM/JEPeM/14070266), of the institution, all of the participants were subjected to evaluation of bilateral symmetry in motor coordination and hand-eye coordination by employing the Mirror Drawing/Tracing Apparatus; Two-arm Coordination Test Apparatus. Thereafter evaluation of dexterity (employing neuromuscular steadiness tester) was done. Here we need to confirm that, participants were selected as having right handedness (diagnosed by Edinburgh inventory).⁶⁻⁷ Here we would like to provide details of the evaluation techniques.



Figure 1
Mirror drawing apparatus with impulse counter

The Mirror Drawing equipment, also known as Mirror Tracing apparatus, is used to identify an individual's motor educability; reversal ability and the level of hand-eye coordination. The index candidate is subjected to move a metal-tipped stylus through a channel-like path designed like a star

pattern, while watching the mirror image of that path of the star only. While moving the stylus every time the stylus touches the metallic edges of the path of the star, an impulse counter attached with the unit, denotes that an error has been committed.



Figure 2 Two Arm Coordination

Two-arm coordination test is designed to evaluate bilateral (both ipsilateral and contralateral) motor coordination and learning ability to move both arms simultaneously in a synchronized and coordinated manner. Participants are subjected to move a metal-tipped pointer (attached at the middle portion of the metallic arms) through the anodized channel-like star pattern path. The pointer needs to

be manipulated by moving; navigating; pulling closer and spreading the handles. The actual task involves moving the handles to navigate the pointer both in clockwise and in counter-clockwise direction, and every time the stylus touches the metallic edges of the path of the star, the impulse counter denotes the errors committed.



Figure 3
Neuromuscular Steadiness Tester

The Neuromuscular steadiness or dexterity task has been designed to measure steadiness aspect of the psychomotor ability. This assessment procedure refers to holding a metal-tipped pointer stylus steadily enough within nine progressively smaller holes engraved on a metallic arched structure without touching the sides of the holes. This assessment unit is connected to an impulse counter to record the number of errors committed by the assessed.

Thereafter they were equally categorised into three groups (i.e., Control group; and two Experimental groups, who received skin conductance & frontalis EMG biofeedback training – for 15 min.s/day; 2 days/week for 12 weeks). Mid-term evaluation was carried out after 6th week and the post-intervention analyses were done at the end of 12th week.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

Descriptive statistics (Tables 1 – 4) however revealed that indices were mostly free from huge dispersions and observed identical features in the obtained pre-intervention data mostly revealed that,

participants did not have any pre-existing differences, and hence whatever differences were observed in the mid-intervention; post-intervention and post-follow-up interventions could be attributed to the interventions introduced to the participants.

Table 1

Means and mean differences of Bilateral Coordination for three different groups across the experimental sessions

Groups	Bilateral Coordination (Two-Arm coordination – in Sec.s)		
	Pre-intervention	Mid-intervention	Post-intervention
Control	91.39	95.19	86.70
EMG Biofeedback	88.78	77.67	63.33
Sc Biofeedback	93.09	73.88	64.18

Table 2

Means of Motor Learning Performance for three different groups across the experimental sessions

Groups	Motor Learning Performance (Right –hand Clockwise in Sec.s)		
	Pre-intervention	Mid-intervention	Post-intervention
Control	18.93	17.05	17.14
EMG Biofeedback	17.45	16.41	12.07
Sc Biofeedback	19.11	14.16	11.09

Table 3

Means of Motor Learning Performance for three different groups across the experimental sessions

Groups	Motor Learning Performance (Left-hand Anti Clockwise in Sec.s)		
	Pre-intervention	Mid-intervention	Post-intervention
Control	17.50	16.70	17.84
EMG Biofeedback	17.69	13.22	11.02
Sc Biofeedback	19.71	14.19	10.96

Table 4

Means of Motor Learning Performance for three different groups across the experimental sessions

Groups	Dexterity Performance (Right-handed performance)		
	Pre-intervention	Mid-intervention	Post-intervention
Control	26.17	26.10	24.84
EMG Biofeedback	25.92	20.22	18.81
Sc Biofeedback	27.77	21.19	19.01

3.2 Repeated Measure of ANOVA

Mauchly's test of sphericity for the main effect of phase differences were evaluated to observe, if the main effects of phase differences observed between the groups of

participants in different parameters assessed, violated the assumption of sphericity or not. In cases of violations, the F-values for those effects were corrected.

Table 5
Mauchly's Test of Sphericity (Psychomotor parameter)

Measure: Motor Learning Ability (counter-clockwise) with Left Hand (With higher difficulty)

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Epsilon ^b	
						Huynh-Feldt	Lower-bound
Phase	.229	60.098	5	.000	.560	.608	.333

Table 6

Tests of Within- Subjects Effects on Motor Learning Ability (counter-clockwise) with Left Hand

	Source	Type III Sum of Squares		df	Mean Square	F	Sig.
		Greenhouse-Geisser					
Motor Learning Ability (counter-clockwise) with Left Hand	Phase	Greenhouse-Geisser	993.083	1.680	591.242	3.636	.039
	Error (Phase)	Greenhouse-Geisser	11470.867	70.546	162.602		

The result of ANOVA with corrected F-value is represented in the Table 6 (table of tests of within subjects' effects). We can report the results as for the participants of this experiment, 'there was a significant main effect of phase

difference, $F(1.68, 70.54) = 3.64, p < .039$, which implied that, if effects of other variables are ignored, psychomotor outcomes pertaining to motor learning ability (counter-clockwise) with left hand was different from each other (Table 6).

Table 7

Pairwise Comparisons Motor Learning Ability (counter-clockwise) with Left Hand across the Different Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	-4.511*	1.360	.011	-8.277	-.745
	3	-5.267*	1.574	.010	-9.624	-.909
2	1	4.511*	1.360	.011	.745	8.277
	3	-4.800	2.530	.388	-11.807	-2.207
3	1	5.267*	1.574	.010	.909	9.624
	2	4.800	2.530	.388	2.207	11.807

* $p < 0.05$; ** $p < 0.01$

As it is evident in the Table 7, after the post-intervention assessment, outcomes in terms of the pairwise comparisons revealed that the participants of both of the intervention groups displayed better indices of motor ability compared

to their counterparts in the control group. This phenomenon of beneficial impact of biofeedback interventions on motor ability got support from previously carried out researches on identical population.⁸⁻¹⁰

Table 8
Mauchly's Test of Sphericity

Measure: Motor Learning Ability With Right Hand (<i>clockwise</i>) With lower difficulty level							Epsilon ^b
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Phase	.399	37.431	5	.000	.618	.677	.333

Table 9
Tests of Within- Subjects Effects

	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Motor Learning Ability with Right Hand	Phase	Greenhouse-Geisser	16735.972	1.855	9021.645	31.178	.000
	Error (Phase)	Greenhouse-Geisser	22545.000	77.914	289.358		

Thus the result of ANOVA with corrected F-value is represented in the Table 9, which may be reported as for the participants of this experiment, 'there was a significant main effect of phase difference, $F(1.85, 77.91) = 31.18, p < .000$, which

implied that, if effects of other variables are ignored, psychomotor outcomes pertaining to motor learning ability with right hand was different from each other (Table 9).

Table 10
Pairwise Comparisons Motor Learning Ability with Right Hand

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	-15.667**	2.726	.000	-23.214	-8.120
	3	-22.556**	3.756	.000	-32.955	-12.156
2	1	15.667**	2.726	.000	8.120	23.214
	3	-6.889*	2.304	.028	-13.269	-.509
3	1	22.556**	3.756	.000	12.156	32.955
	2	6.889*	2.304	.028	.509	13.269

* $p < 0.05$; ** $p < 0.01$

Outcomes of the pairwise comparisons represented in the Table 10, depicted that at the post-intervention assessment, the participants of the both of the intervention groups showed significant

improvement in their motor ability performed in clockwise direction, while using their right-hands ($p < 0.01$).⁸⁻¹⁰

Table 11
Mauchly's Test of Sphericity

Measure: Dexterity Ability							Epsilon ^b
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Phase	.024	151.482	5	.000	.400	.425	.333

Table 12
Tests of Within- Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Dexterity Ability	Phase	Greenhouse-Geisser	527.439	1.199	439.838	23.667 .000
	Error (Phase)	Greenhouse-Geisser	936.000	50.365	18.584	

The output is represented in the Table 12 which revealed that as for the participants of this experiment, 'there was a significant main effect of phase difference, $F(1.20, 50.37) = 23.67, p < .000$,

which implied that, if effects of other variables are ignored, psychomotor outcomes pertaining to dexterity ability was different from each other (Table 12).

Table 13
Pairwise Comparisons Dexterity Ability

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	4.067**	.817	.000	1.804	6.330
	3	3.956**	.751	.000	1.875	6.036
2	1	-4.067**	.817	.000	-6.330	-1.804
	3	-3.822**	.778	.000	-5.978	-1.667
3	1	-3.956**	.751	.000	-6.036	-1.875
	2	3.822**	.778	.000	1.667	5.978

* $p < 0.05$; ** $p < 0.01$

In the Table 13, the post-intervention assessment outcomes in terms of the pairwise comparisons revealed that differences amongst the participants existed, which implied that the participants of the intervention groups (hereafter groups 2 & 3) showed significant reduction in the

errors committed in dexterity performances, compared to the participants of the no-intervention or control group ($p < 0.01$). This outcome could be attributed to enhanced neural competence facilitated by peripheral stimulation.²

Table 14
Mauchly's Test of Sphericity

Measure: Bilateral Coordination (clockwise) Ability

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Epsilon ^b	Huynh-Feldt	Lower-bound
Phase	.480	29.925	5	.000	.675	.743	.743	.333

Table 15
Tests of Within- Subjects Effects on Bilateral Coordination

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Bilateral Coordination (clockwise) Error	Phase	Greenhouse-Geisser	2737.350	2.024	1352.282	27.066 .000
	Error (Phase)	Greenhouse-Geisser	4247.667	85.018	49.962	

Thus, the output (result of ANOVA with corrected F-value) is represented in the Table 15 (table of tests of within subjects' effects). We can report the results as for the participants of this experiment, 'there was a significant main effect of

phase difference, $F(2.02, 85.02) = 27.10, p < .000$, which implied that, if effects of other variables are ignored, psychomotor outcomes pertaining to bilateral coordination clockwise error was different from each other (Table 15).

Table 16
Pairwise Comparisons Bilateral Coordination Ability Clockwise

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	-8.911**	1.411	.000	-12.817	-5.005
	3	-9.667**	1.388	.000	-13.511	-5.823
2	1	8.911**	1.411	.000	5.005	12.817
	3	-8.200**	1.620	.000	-12.686	-3.714
3	1	9.667**	1.388	.000	5.823	13.511
	2	8.200**	1.620	.000	3.714	12.686

* $p < 0.05$; ** $p < 0.01$

In the Table 16, impact of interventions on bilateral coordination ability was observed, and the post-intervention assessment outcomes in terms of

the pairwise comparisons revealed that differences amongst the participants existed.

Table 17
Mauchly's Test of Sphericity

Measure: Bilateral Coordination (Counter-clockwise performance) Ability							
Within Subjects Effect	Mauchly 's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Epsilon ^b	Huynh-Feldt
Phase	.569	22.973	5	.000	.798	.890	.333

Table 18
Tests of Within- Subjects Effects on Bilateral Coordination (Counter-clockwise performance)

	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Bilateral Coordination Ability (Counter-clockwise)	Phase	Greenhouse-Geisser	.753	2.395	.314	4.877	.006
	Error (Phase)	Greenhouse-Geisser	6.483	100.583	.064		

Thus, the output (result of ANOVA with corrected F-value) is represented in the Table 18 (table of tests of within subjects' effects). We can report the results as for the participants of this experiment, 'there was a significant main effect of phase difference, $F(2.39, 100.58) = 4.88, p < .006$, which implied that, if effects of other variables are ignored, performance outcomes pertaining to Bilateral Coordination (Counter-clockwise

performance) Ability was different from each other (Table 18). Since high performer soccer players were having considerably higher extent of ipsilateral and contralateral motor coordination ability, by virtue of EMG intervention, as steadiness and motor learning ability got enhanced, symmetrical motor coordination performance were also evidenced.^{2, 8-9}

Table 19

Pairwise Comparisons Bilateral Coordination (Counter-clockwise performance)

Groups	Compared between	Mean Difference	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	.146**	.041	.006	.032	.261
	3	.174*	.053	.012	.028	.321
2	1	-.146**	.041	.006	-.261	-.032
	3	.031	.035	1.000	-.067	.129
3	1	-.174*	.053	.012	-.321	-.028
	2	-.031	.035	1.000	-.129	.067

* $p<0.05$; ** $p<0.01$

In the Table 19, the post-intervention assessment outcomes in terms of the pairwise comparisons revealed that differences amongst the participants were evident. Outcomes of the

pairwise comparisons represented in the Table 19, depicted that, at the post-intervention assessment, differences amongst the participants were evident.

4. CONCLUSION

- 1) Frontalis EMG biofeedback intervention training was evident as beneficial for enhancement in all of the psychomotor performances observed among soccer players.
- 2) Skin Conductance biofeedback intervention was also evident as having beneficial impact on all of the psychomotor performance skills performed by the soccer players.
- 3) Compared to the Sc intervention, frontalis EMG intervention was observed as more facilitative in dexterity and in bidirectional motor learning performance, and also in clockwise direction motor coordination performance.

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6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments: SrS
Collected data and performed the experiments:
 FaS, SrS, SoS, MaA
Contributed with materials/analysis tools:
 FaS, SrS, SoS
Analysed the data: SrS, SoS
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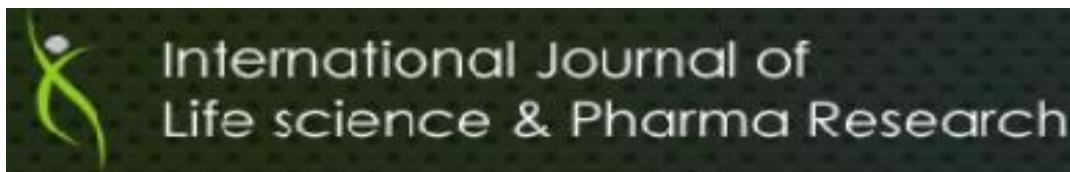
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EFFECT OF ISOKINETIC TRAINING ON PAIN MANAGEMENT AND PHYSICAL FUNCTIONAL ABILITIES IN KNEE OSTEOARTHRITIS PATIENTS

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ABSTRACT

The purpose of this study was to investigate the effects 12 weeks of isokinetic training program at two different angular velocities ($60^{\circ} \text{ sec}^{-1}$ and $120^{\circ} \text{ sec}^{-1}$) on pain score, thigh circumference and functional abilities of patients with knee osteoarthritis. The first intervention group ($60^{\circ} \text{ sec}^{-1}$ trained group) age 52 ± 6 yrs participated in the prescribed training along with existing conventional physiotherapy. The second intervention group ($120^{\circ} \text{ sec}^{-1}$ trained group) aged 54 ± 6 yrs also participated in the prescribed training along with existing conventional physiotherapy. The control group aged 54 ± 5 continued with conventional physiotherapy only. There was no significant different ($p>0.05$) between the control and intervention groups in terms of pain score. However, there was a tendency to decrease in post training pain score was observed in control and $120^{\circ} \text{ sec}^{-1}$ training group. There was a significant main effect of time ($p<0.05$) in thigh circumference at post training in $120^{\circ} \text{ sec}^{-1}$ trained group compared to other groups. In terms of physical function, there was a significant improvement ($p<0.05$) in both intervention groups at mid and post-test as compared to control group. This study revealed that 12 weeks of isokinetic resistance training combined with existing conventional physiotherapy was effective to improve the thigh muscle girth. The prescribed training programme was also able to help in muscle hypertrophy especially in the fast-angular velocity trained group ($120^{\circ} \text{ sec}^{-1}$). However, in terms of pain reduction, only the $120^{\circ} \text{ sec}^{-1}$ trained group showed no significant improvement in pain score. Therefore, in conclusion, isokinetic resistance training program, combined with existing conventional physiotherapy failed to reduce pain.

KEYWORDS: *Osteoarthritis; Isokinetic Training; Pain; Physical Function*

1. INTRODUCTION

Osteoarthritis (OA) is one of the leading causes of physical disability, increase in health utilization and impaired quality of life¹. As the life span of the population is increasing, soon more regressive impacts of arthritic condition have been expected². It appears in the cartilage and affects the large weight bearing joints, for example the knees. Knee OA is associated with more disability compared to OA of any other joint. The main complaints of patients are pain, stiffness, instability and loss of function³. According to Eyigor⁴, as far as functional impairment was concerned, isokinetic resistance training found to be more beneficial when compared to other forms of resistance training such as progressive resistance training. A few publications supported his study^{5, 6}. In terms of pain, it was observed that the patients in the isokinetic group discontinued treatment sooner than those in the isotonic and isometric groups, suggesting that isokinetic exercises induce more knee pain. However, those patients who completed the isokinetic exercises had greater pain reduction and improvement of disability, walking speed, and leg muscle power⁷. Eyigor⁴, on the other hand, found that both isokinetic exercise and progressive resistive exercise with the De Lorme' technique were found to be effective on pain and functionality.

Analgesics, nonsteroidal anti-inflammatory drugs (NSAIDs), intraarticular injections, physical therapy (rehabilitation) and a surgical approach are mostly used to address this issue. Rehabilitation science approaches are recommended for prophylaxis and restoration at all stages of the disease, as they can relieve pain, decrease functional impairment and minimize physical damage. In addition, exercise therapy aims directly at the reduction of disability. Therapeutic exercise in OA might prevent accelerated degeneration caused by disuse, without causing further degeneration and pain, stemming from joint deformity or incongruence. Precisely, this is stated as it has been reported that pain and disability improve in patients with knee OA after resistance training⁸. Therapeutic exercise programs as a treatment for knee OA are frequently used in

clinics. However, it is not yet known which type of exercise is most beneficial for patients with knee OA. Recent guidelines for the management of knee OA are emphasizing on the central role of exercise⁹ and majority of the studies only investigate on the effectiveness of regular exercises and aerobic training for knee OA. Literature review shows that, there are not many studies carried out on the effect of Isokinetic resistance training in this group of patients. Therefore, the aims of this study are to investigate the effectiveness of the isokinetic resistance training programme, and to find out the effective angular velocity which could be prescribed for the treatment of patients with knee OA. In this study, isokinetic strength will also be tested using isokinetic equipment (Biodex dynamometer). Angular velocities chosen for testing are 90°.sec⁻¹ and 180°.sec⁻¹.

The main objectives of the present study were to evaluate the effectiveness of isokinetic resistance training programme in knee osteoarthritis patients, (i) in reducing pain score; (ii) on thigh circumference, and (iii) on physical functional ability.

2. METHOD

Thirty knee OA patients aged between 40 and 65, with moderate bilateral knee OA (Altman grade II) were recruited from the physiotherapy unit of Universiti Sains Malaysia Hospital, Kubang Kerian. The subjects were randomised into three groups; a control group and two intervention groups, each consisting of 10 subjects. Each subject was given an explanation on the objectives and protocol of the study. The study was approved by the Universiti Sains Malaysia Research and Ethical Committee. The complete methodology followed in this project has been described in a flow chart (Figure 1).

2.1 Sample Size Calculation

The sample size was calculated using PS Power and Sample Size Calculation version 2.1.30 with the power of the study was set at 80% with 95%

confident interval while standard deviation (σ) observed is 1.8 and difference in population means (δ) is set at 2.2⁷. The sample size calculated for each group was 7; however, considering the possibility of drop out of the subjects, the researcher set the size at 10 in each group.

2.2 Randomisation into Intervention and Control Group

Subjects were age and gender matched before they were randomly assigned to an intervention groups and control group (Table 1). A simple randomisation method of drawing lots was carried out. Subjects in the control group followed the existing physician prescribed physiotherapy treatment programs which consisted of heat treatment, (either treated with hot pack or shortwave diathermy - SWD) for 12 sessions. The first intervention group were

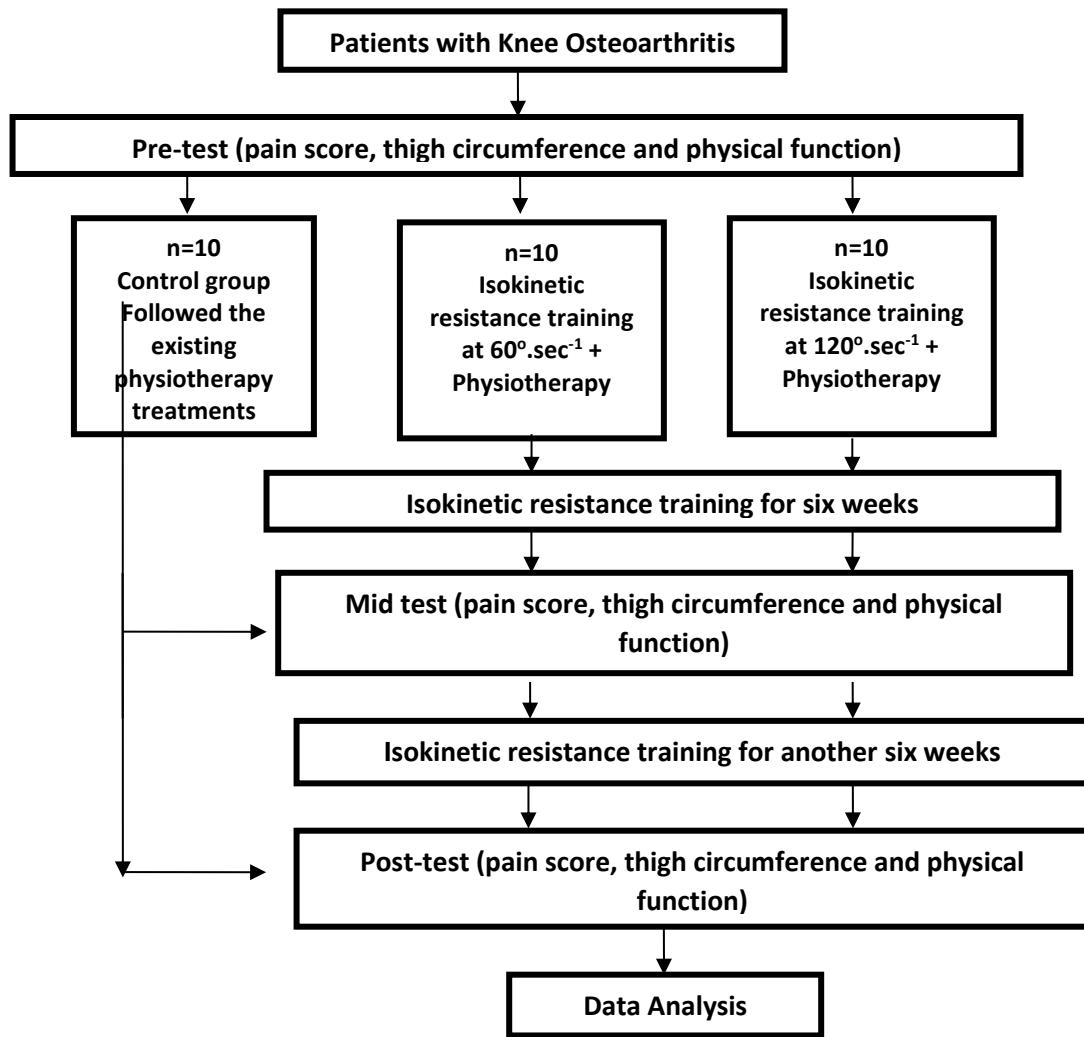


Figure 1
The methodology followed in this study

prescribed with a training programme which involved isokinetic resistance training at $60^{\circ}.\text{sec}^{-1}$ angular velocity while the second intervention group were prescribed with isokinetic resistance

training at $120^{\circ}.\text{sec}^{-1}$ angular velocity. All subjects in both groups were required to attend training 2 times per week for consecutive 12 weeks (24 sessions), besides continuing with pre-existing

physiotherapy treatment two times per week for six weeks. Isokinetic strength assessments were carried out on the control group at the same time intervals as for the intervention groups at pre, mid and post training sessions.

2.3 Inclusion criteria

- All patients who are diagnosed with primary knee osteoarthritis.
- No significant knee stiffness or reduction in active knee range of motion.
- No previous surgery to the tested knee.

2.4 Exclusion criteria

- Patients with severe knee pain restricting active range of motion
- Patients with previous history of knee injuries which involve either extra-articular or intra-articular structures.
- Patients with history of medical illnesses causing poor effort tolerance
- Patients with severe pain requiring analgesics other than NSAID e.g., opioids

2.5 Anthropometric Data

A wall-mounted stadiometer (Seca Corporation, USA) was used to measure standing height and standing weight to the nearest 0.1 cm and 0.1 kg respectively. Participants were shoeless and lightly clothed during anthropometric measurements. Thigh circumference was measured using tape measure at 12cm from superior border of patella pre, mid and post training in both knees.

2.6 Pain Score Assessment

A numeric rating visual analogue scale (VAS) was used to quantify knee pain ¹⁰ (Langley and Sheppard, 1985). Subjects were asked to verbally rate the pain in and around the knee joint on scale ranged from 0 to 10, where 0 represented no pain and 10 represented the most severe pain. Measurements are taken at pre (before training session), mid (after 12 session of training) and post (after 24 session of training) test intervals.

2.7 Physical Functional Ability

Physical function is usually measured by grading the degree of difficulty in performing activities of daily living such as stairs climbing. The WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index (physical activities subscale) addresses 17 such activities with five responses in each question was used. The measurement was taken at pre, mid and post training. The lowest the score, the less difficulties were encountered by the patients in doing their daily physical activities.

2.8 Data Analysis

The data were analysed using Statistical Package for Social Science (SPSS) version 14.0 software. Normality of data was determined through histogram where the normality curve was used as an indication whether the data was normally distributed or not. Non-parametric test was utilised if the data was not normally distributed. If the data was normally distributed, one-way ANOVA repeated measure was utilised to analyse the main effects of time (pre, mid and post) differences, while two-way ANOVA was used to analyse between group differences in isokinetic strength, pain score, thigh circumference and physical functions score. For within-group differences, Bonferroni adjustment for multiple comparisons was used to determine the differences when one-way ANOVA repeated measure showed a significant main effect of time. Significance level was set at $p < 0.05$, and all data were presented as means \pm SD.

3. RESULTS

The age, height and weight of the participants are illustrated in Table1.

Table 1**Physical characteristic data for intervention and control groups of Knee Osteoarthritis patients**

Parameters	Control	$60^{\circ}\text{sec}^{-1}$	$120^{\circ}\text{sec}^{-1}$
Age (years)	54 ± 5	52 ± 6	54 ± 6
Height (m)	155.3 ± 5.3	154.4 ± 5.3	155.3 ± 6.3
Weight (kg)	67.7 ± 14.2	61.0 ± 10.7	69.7 ± 8.7
Gender	8 females & 2 males	8 females & 2 males	8 females & 2 males

Values shown as mean \pm SD

3.1 Pain Score (Visual Analog Scale)

Visual analogue pain score of the control and intervention subjects during pre, mid and post is

illustrated in figure 2. Two-way ANOVA repeated measure revealed that there was no significant

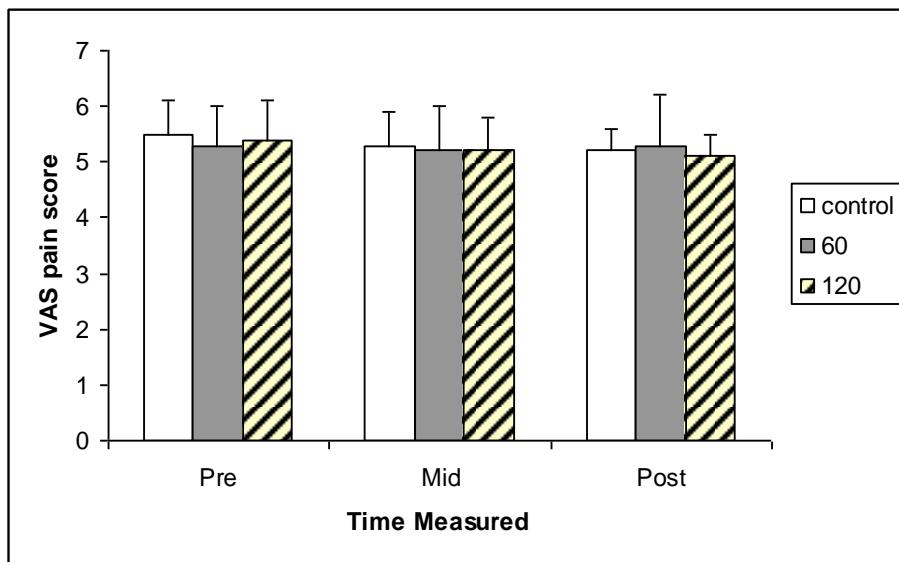


Figure 2
VAS pain score in each group pre, mid and post training

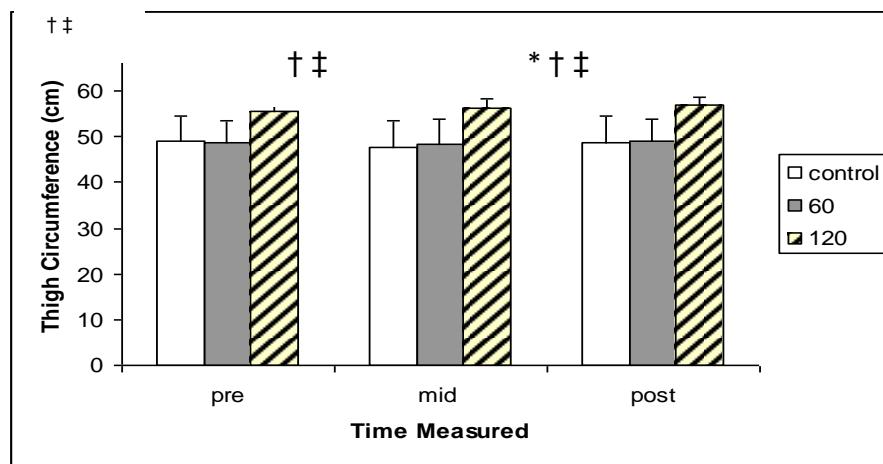
Interaction ($p > 0.05$) between time and group. In terms of within group analysis, there was also no significant main effect of time on knee VAS pain score ($p > 0.05$) in control and both intervention groups at all time points.

illustrated in figure 3. Two-way ANOVA repeated measure revealed that there was a significant interaction ($p < 0.05$) between time and group. Simple effect test found that there was a significant difference ($p < 0.05$) of right thigh circumference at pre, mid and post training measurement compared to control and 60° trained group. There was a significant main effect of time in 120° training group, but no significant main effect of time in control and 60° trained group at all 3 times points.

3.2 Thigh Circumference

3.2.1 Right Thigh Circumference

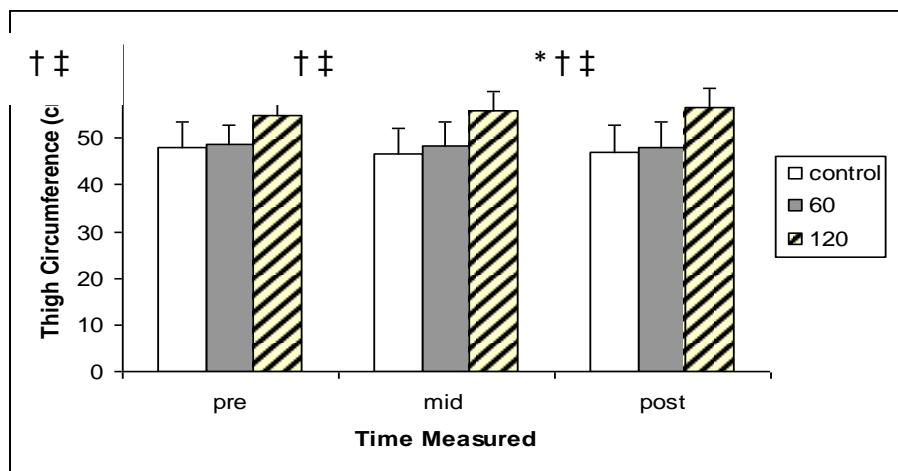
Right thigh circumference of the control and intervention subjects during pre, mid and post is

**Figure 3***Right Thigh circumference measurement in each group pre, mid and post training** Significant different from pre-test ($p<0.05$); † Significant different from control group ($p<0.05$)‡ Significant different from other intervention group ($p<0.05$)

3.2.2 Left Thigh Circumference

Left thigh circumference of the control and intervention subjects during pre, mid and post is illustrated in figure 4. Two-way ANOVA repeated measure revealed that there was a significant interaction ($p<0.05$) between time and group. Simple effect test found that there was a significant

difference ($p<0.05$) of left thigh circumference at pre, mid and post training measurement compared to control and 60° trained group. There was a significant main effect of time in 120° training group at post-test measurement, however, there was no significant main effect of time in control and 60° trained group at all 3 times points.

**Figure 4***Left Thigh Circumference measurement in each group at re, mid and post training** Significant different from pre-test ($p<0.05$); † Significant different from control group ($p<0.05$)‡ Significant different from other intervention group ($p<0.05$)

3.3 WOMAC Osteoarthritis Index Physical Activities Subscale Score

Two-way repeated measure ANOVA revealed that there was a significant interaction between time and group in the physical ability scale (Figure 5). Simple effect test showed that there was significant different ($p < 0.05$) at post-test in both

intervention group compared to control. However, there was no significant difference between both the intervention groups. There was significant main effect of time ($p < 0.05$) in both the intervention groups at mid and post training level, but no significant main effect of time in control group at all 3 time points.

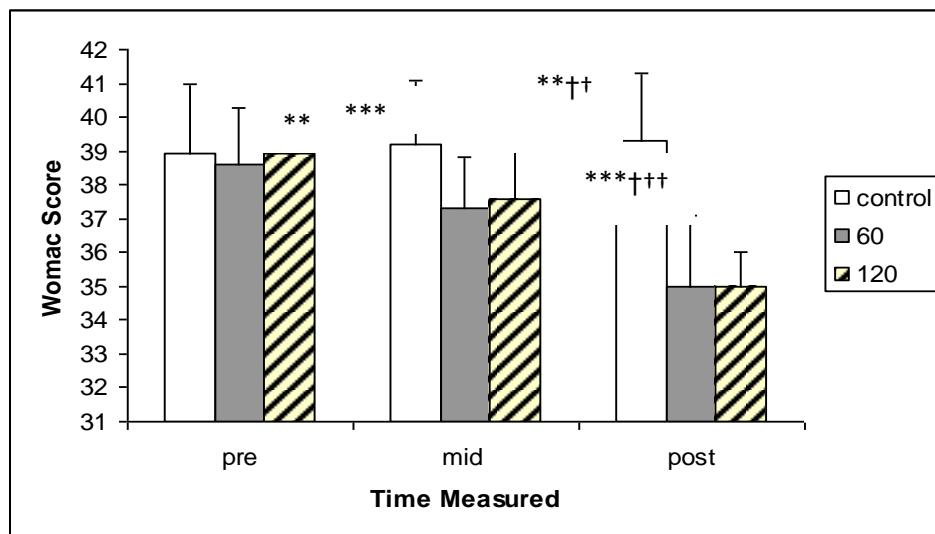


Figure 5

WOMAC Physical Activities Subscale Score in Each Group at pre, mid and post training

** Significant different from pre-test ($p < 0.01$); *** Significant different from pre-test ($p < 0.001$)

†† Significant different from control group ($p < 0.01$); ††† Significant different from control group ($p < 0.001$)

4. DISCUSSION

Pain and functional disability were evident as the most common symptoms of patients of OA. Because of the lack in curative therapy, most of the treatments were aimed to reduce the symptoms and to prevent further deterioration of the knee joint. Treatment of knee OA includes pain relief with analgesics and non-steroidal anti-inflammatory drugs (NSAIDs), surgical correction, and conservative physical interventions⁶. Weight control, physical therapy and weak analgesics were suggested as initial treatment for knee OA patients. Fransen et al.¹¹ found that drugs, physical modalities, and the role of exercise were beneficial in reducing pain and increasing muscle power of the affected knee.

Three randomized control in knee OA patients showed strengthening of Quadriceps

muscle group either isometric or isotonic resistive exercise was associated with significant improvement in muscle strength, reduction of pain and improvement in daily living activities. Moreover, a well-controlled trial involving 8 weeks of isokinetic resistance training showed significant improvement in functional status of patients with OA of the knee joints¹².

4.1 Pain Score (Visual Analogue Scale)

Based on the results, there was no significant different between control and intervention groups in VAS pain score. In terms of pain, both the intervention groups were not directly benefited much from isokinetic resistance training, however, the trend showed that there was still some improvement in terms of pain in the control group and 120° trained group, while, the pain remained constant in 60° trained group.

Huang et al.⁷ reported that there was significant difference in pain score in isokinetic group and isotonic trained group compared to the control group. The possible explanation why the present study showed different from other study is since most of the subjects are having chronic OA knee in which their pain score is considered mild started from the beginning of the testing, therefore the reduction of pain is not that obvious compared to their counterpart who are suffering from severe knee OA.

The other reason might probably be due to the characteristics of the subjects. Subjects in Huang et al.⁷ received the training three time per week for eight weeks, whereas, in present study, the subjects undergone the training two time per week for 12 weeks. In their study, four subjects from isokinetic group stopped the exercises due to intolerable pain induce by the isokinetic training. This may be the reason why the results of present study are different from their study, since the subjects of present study did not withdraw from the exercises prescribed even though their pain was increasing, therefore their VAS score showed slight increment or no changes at the end of the study. However, 120° trained group still managed to show some improvement in their pain score although statistically not significant.

When compared, 120° sec⁻¹ training group showed better score than 60° training group when pain was taken into consideration. However, in terms of knee strength based on isokinetic peak torque, and in terms of physical functions on the basis of WOMAC OA Index physical function subscale, both the interventions groups showed no significant difference. Therefore, it is recommended that patients with acute pain are not advisable to receive isokinetic resistance training initially; instead, they are recommended to be treated with physiotherapy and isotonic exercise at the beginning, and then followed by isokinetic resistance training at a higher angular velocity (120°.sec⁻¹), to improve muscle strength, functional abilities and joint stability.

4.2 Thigh Circumference

The present study revealed that isokinetic resistance training at fast angular velocity did result in thigh muscle hypertrophy, as compared to 60° trained group and control group where no significant main effect of time differences was observed. Increase in muscular strength are often attributed to muscle hypertrophy¹³. In their study, however, strength gains were not accompanied by measurable changes in muscle mass, this would suggest that increases in torque output were due to other muscular or possible neuromuscular adaptations. Farthing and Chilibeck¹⁴ investigated the effects of eccentric and concentric isokinetic training at different velocities (30°.sec⁻¹ and 180°.sec⁻¹) on muscle hypertrophy and found that eccentric fast training (180°.sec⁻¹) resulted in greatest increase in strength and hypertrophy of the muscles tested.

A study by Coyle et al.¹⁵ comparing fast and slow concentric training and muscle hypertrophy found that only the fast concentric (300°.sec⁻¹) training group significantly increased type II muscle fibre area by 11%. The present study also supported the previous findings. However, when all velocities were combined, eccentric training was more effective than concentric training for increasing muscle hypertrophy. The latter is supported by several studies comparing the effectiveness of eccentric and concentric training for muscle hypertrophy¹⁶⁻¹⁸. In their experiment, only eccentric training resulted in significant muscle hypertrophy, but in all cases, there was a trend for concentric training groups to be better than the control group.

Several other studies have also reported significant hypertrophy after concentric training^{16, 19, 20}, but variations in training duration and volume, and muscle group make it difficult to directly compare with the results of present study. O'Hagan et al.²⁰ also trained the elbow flexors but imparted a much longer training duration (20 weeks), while other studies have applied more similar training durations, but with a greater training volume per session^{15, 19}.

4.3 Physical Functions

After 12 weeks of prescribed isokinetic resistance training programme, there was significant difference in both intervention groups at post training compared to the control group. In 60° trained group, there was 9.3% reduction of WOMAC OA index score compared to pre-test, and in 120° trained group, there was 10% reduction of WOMAC OA index score compared to pre-test. Whereas, there was an increment of 1% in WOMAC OA index score in the control group which indicated there was slight deterioration in physical functions in the control group. This showed that both intervention groups have been benefited from isokinetic resistance training in terms of physical functions.

These findings supported the previous studies which used isokinetic resistance training as their training programme. A Study by Schike et al.¹² found that there was a significant decrease in pain and stiffness, and also significant increase in mobility in the intervention group who was administered isokinetic resistance training at 90°.sec⁻¹. Fisher et al.²¹ identified that functional performance, such as a decrease in difficulty climbing stairs, was improved following isokinetic resistance training.

Huang et al.⁷ reported that their patients with knee OA showed a significant decreased in disability index after treatment, which further decreased at follow up. The most importantly, the reduction of disability in the isokinetic group was significantly greater than that in other treated groups, which may be the result of improvement of knee stability through more strengthening of type II (fast twitch) muscle fibres during isokinetic resistance training²². These findings are evident as in agreement with the present study.

5. CONCLUSIONS

The present study highlighted the following:

1. In terms of pain relieving, isokinetic resistance training did not help in reducing pain.

2. Six weeks of isokinetic resistance training combined with existing physiotherapy treatments was sufficient to improve the thigh muscle circumference.
3. Isokinetic resistance training was effective in inducing muscle hypertrophy, especially training with high angular velocity (120°.sec⁻¹).
4. Isokinetic resistance training improved the physical functions of patients with knee osteoarthritis, such as stairs climbing, and other daily living activities.

6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

AkG, MaA

Collected data and performed the experiments:

AkG, MaA

Contributed with materials/analysis tools:

AkG, MaA

Analysed the data: AkG

Wrote the paper: AkG

Checked and edited the format of the paper:

AkG

Final approval: AkG

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FACILITATIVE IMPACTS OF BIOFEEDBACK INTERVENTION ON PSYCHOMOTOR ABILITIES IN IMPROVING SOCCER JUGGLING SKILLS

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1. INTRODUCTION

Efficacy of biofeedback practically is determined by effective regulation over feedback loop. The advancement of self-regulation or self-control is based upon one individual's capacity to use the feedback and divulges individual differences. This is more obvious in sport science research, as some of the players are observed as capable of decreasing their Skin conductance and EMG indices far more easily compared to their

ABSTRACT

The present study was carried out to identify whether differential types of biofeedback training regimes have beneficial influences on minimizing motor skills related problems, which might in turn facilitate in soccer ball juggling performance. Forty-five young male soccer players selected by qualified coaches as consistently players were recruited. Evaluation of motor learning ability; motor skills; transfer of training abilities; steadiness related to dexterity and coordination pertaining to bidirectional and bilateral coordination were carried out in different (pre- to mid-term and post intervention) phases to identify core areas of perceptual-motor efficiencies. Basic soccer skill tests were also performed to evaluate their pre-existing status of soccer performance ability. Thereafter they were equally categorised into three groups, in which one no-intervention control group was existed. Players were introduced to frontalis EMG and skin-conductance biofeedback intervention regimes. Post-intervention analyses revealed facilitative impacts of biofeedback intervention training, while role of motor skills and coordination abilities as predictor of higher-order juggling performance was confirmed.

counterparts, and hence tend to follow the autosensory processes requiring monitoring their own conditions and the same time also trying to reduce their Sc indices.¹⁻⁵

The autosensory process demands cognitive-emotional competence and optimal body awareness; motor skill and coordinative movement ability as well.^{2,5,6} Motor skill based on cognitive chunks or schema developed in the CNS neural network⁷⁻⁸ could be either gross (e.g. catching, throwing,

running etc.) or fine motor (precision task) skills, generally suggests that the representation of motor control in the central nervous system provides opportunities for skills to be performed in many different ways which could be both serial motor skills (either discrete or continuous), or could be open or closed.⁹

Motor skills in sports basically involve ipsilateral and contralateral movement dominance, which could be optimally understood based on finger force and dexterity (Park and Turvey, 2008). Dexterity; motor learning ability; motor skill and movement coordination were thoroughly studied on ASEAN athletic population^{3,4,5,10,11,12,13,14}, which revealed a gross problem in (directional constraint).¹⁶⁻¹⁸ This directional constraint, which is predominantly regulated by kinematic force mobilization, is prominent when the players move upper and lower limbs ipsilaterally (e.g., right hand and right foot: "ipsilateral" combination).¹⁸⁻¹⁹ This directional constraint is less prominent when moving an upper limb and a contralateral lower limb (e.g., right hand and left foot: "contralateral" combination).²⁰⁻²⁶

With such a background we intended to see whether in performance of juggling task, which demands both ipsilateral and contralateral movement efficiency, this issue of directional constraint impair the performance or not. Further to that, as numerous researchers worked on both Sc and EMG BF intervention techniques, employed in sports performance set-ups to assist the elite and promising players and reported to observe performance enhancement followed by introduction of both Sc and EMG BF^{3,4,5,10,11,12,13,14,18,19} we intend to see how far BF techniques can resolve the problems of psychomotor crises in mediating performance excellence in juggling task.

With such a background, this study purports

- 1) To study the effect of EMG biofeedback training on juggling performance mediated by different motor performance abilities observed among soccer players.
- 2) To investigate the effect of Sc biofeedback intervention on juggling skill of the soccer players, mediated by differential motor performance ability.

- 3) To compare the relative efficacy of EMG biofeedback and Sc biofeedback intervention on mediating motor performance abilities observed among soccer players, in modulating juggling performance.

2. METHODOLOGY

2.1. Participants

Forty-five high-performing (based on consistency in high-performance) soccer players of Kelantan province of Malaysia, aged between 20 – 23 years (Mean age – 21.43 yr.s and SD – 1.23) volunteered as participants. The sample size was calculated using G power 3.1.7 in which the power of the study is set at 95% with 95% confident interval and the effect size F at 0.2523.

2.1.1 Inclusion Criteria of the Present Participants

- Players faced with substantial extent of feeling of apprehension for at least 3 to 4 months – are communicated through registered clubs.
- Participants having high level of soccer skills (judged by licensed coaches and by the notational analysis procedure of soccer performance level analysis).²⁷
- Players who were not previously subjected to any sort of biofeedback and/or neurofeedback intervention program.
- Academic qualification at least up to the secondary level which may range maximum up to Under -Graduate level education
- No pre-existing medical as well as psychopathological complication.

2.1.2 Exclusion Criteria of the Present Participants

- Players who could not be present for at least 90% of the therapeutic intervention sessions.²⁸⁻²⁹
- Participants remained absent from therapeutic intervention for three consecutive sessions.²⁸⁻²⁹
- Participants who could not learn the basic components of intervention techniques within 4 sessions.

- Any incidence of major illness during
- Any occurrence of injury during training period and follow-up session.
- Participants with significant change in their lifestyle, example, death of a person in family during training period and follow-up session – which can influence their mental status and can increase their stress level which in turn may hinders their performance.

2.2. Materials Used

1. Mirror-Tracing Apparatus (Figures-1) – was administered to evaluate motor learning ability of the participants.

2.3. Procedure

Ethical approval from the Human Research Ethics Committee (HREC) USM (No: - USM/JEPeM/14070266), of the institution, was obtained, and thereafter all of the participants were provided with the detailed information concerning the experimental procedure. Thereafter all of the participants were subjected to evaluation of bilateral symmetry in motor coordination and hand–eye coordination by employing the Mirror Drawing/Tracing Apparatus; Two-arm Coordination Test Apparatus. Thereafter evaluation of dexterity (employing neuromuscular steadiness tester) was done. Here we need to confirm that, participants were selected as having right handedness (diagnosed by Edinburgh inventory).³⁰⁻³¹ Experimental procedure of the aforementioned evaluation techniques are detailed in previous researches.³²

2.3.1 Test of Soccer Ball Juggling

The standard procedure for juggling task was kept constant for all of the players. They were instructed to keep the knees slightly bent (certainly without locking the knees) to maximise the control over the ball, while the non-kicking foot was supposed to remain flat and firmly planted on the ground. Since in this present study, bilateral coordination has been given prime importance, juggling consistently with the dominant and non-dominant foot were considered as the key index of coordinated bilateral juggling ability of the participants. All of the participants were given three

- training period and follow-up session.
- 2. Two-arm Coordination Test Apparatus (Figure-2) – was used to evaluate bilateral coordination ability of the players.
- 3. Neuromuscular Steadiness tester or Dexterity Apparatus (Figure-3) – was used to assess level of dexterity or steadiness evident amongst the players.
- 4. Skin Conductance Apparatus (Udyog 2000) was used for the Sc biofeedback training, while MegaTrac ME 6000 surface EMG biofeedback apparatus was used for frontalis EMG biofeedback intervention training.

chances to practice over this bilateral juggling skill activity, in which they were supposed to kick and control the ball by alternatively controlling and juggling the ball using both of their feet only. Use of other parts of the body was restricted, and hence the maximum number of times they could juggle the ball by virtue of alternative use of dominant and non-dominant feet, were considered as their 'juggling ability' score. After the three chances of practice, once they confirmed that, they were ready to take up the test, they were subjected to the assessment of 'juggling ability'. For this test three-trials were taken (intermittent rests for 30 seconds were provided to them), and the best of the three was considered as the score. This test was carried out on one-to-one basis (to avoid contamination from any extraneous variables). Similarly following standard procedures, tests of 'bilateral shooting ability' and 'with the ball agility' were also carried out.^{5,33}

After the baseline analysis, participants were equally categorised into three groups (i.e., Control group; and two Experimental groups, who received skin conductance & frontalis EMG biofeedback training – for 15 min.s/day; 2 days/week for 12 weeks). Mid-term evaluation (after 6th week) and post-intervention analyses (at the end of 12th week) were carried out on all of the afore-mentioned variables.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

Descriptive statistics (Table 1) however revealed that indices were mostly free from dispersions and observed identical features in the obtained pre-

intervention data mostly revealed that, participants finding however implied that, the observed improvements in juggling scores during the mid-intervention and post-intervention assessment

did not have any pre-existing differences. This phases could be attributed to the interventions introduced to the participants.

Table 1**Descriptive Statistics of Performance Parameters Analysis on Soccer juggling score Across the Groups**

Variables	Control Mean (SD)	EMG Biofeedback Mean (SD)	Sc Biofeedback Mean (SD)
Soccer juggling score at pre-intervention level	46.2667 (± 2.86523)	47.7333 (± 3.86313)	49.4667 (± 3.44065)
Soccer juggling score at mid-intervention level	46.4000 (± 2.72029)	62.5333 (± 2.50333)	63.5333 (± 5.18055)
Soccer juggling score at post-intervention level	47.4667 (± 5.48852)	72.3333 (± 4.89412)	69.8667 (± 5.19432)

3.2 Multiple Linear Regression Analyses

Table 2**Model a - Summary of multiple linear regression analysis on Juggling Ability in EMG Biofeedback group (based on emotionality variables)**

Dep. Variable - Juggling Ability	Unstandardized Coefficients		Standardize d Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero- order	Partial	Part	Tolerance	VIF
(Intercept)	82.094	15.274		5.375	.000					
Two Arm Coordination ability Counter Clockwise pre-intervention	.213	.092	.442	2.305	.027	.002	.363	.279 (.078)	.398	2.511
Motor learning ability Clockwise Right post- intervention	.978	.282	1.359	3.475	.001	-.147	.506	.420 (.176)	.096	10.462
Motor learning ability Counter Clockwise Left post-intervention	-1.068	.271	-1.473	-3.936	.000	-.189	-.554	-.476 (.227)	.104	9.590

^a(F (2, 13) = 3.716, P < 0.002), Adj.R² = 35.7%

In Table 2 the model **a** emerged significant as the post-intervention outcomes of the psychomotor measures such as, two arm coordination ability in anti-clockwise direction (obtained during pre-intervention phase), motor

learning ability both in clockwise (right-handedness) and anti-clockwise directions (left-handedness) together could explain 35.7% variance of changes in the extent of juggling performance outcomes observed amongst the players.

Model **a** explained the inverse relationship among motor learning ability in counter-clockwise directions (left-handedness) and the extent of juggling ability observed in the athletes. Apart from that, two arm coordination ability and motor learning abilities were found directly associated with higher extent of juggling ability. Thus, findings however revealed that the athletes having lower motor learning ability while performing in

counter-clockwise direction (left-handedness) were evidently having better juggling performance score. Observed semi-partial correlation index (part correlation – table 2) revealed that without the influence of any other factors, modification in (probably due to the EMG biofeedback training) the contralateral motor coordination ability (using left-hand) of the right-handed players resulted in observed improvement in bilateral juggling ability

(22.7% extent of improvement could be explained). Contrary to that, post-intervention improvement in contralateral, followed by ipsilateral motor learning ability (17.6%) in clockwise directions (right-handedness) and the pre-existing ability to perform counter-clockwise direction bilateral (both contralateral and ipsilateral bimanual coordination task) two arm coordination ability (7.8%), were evident to contribute in producing higher extent of juggling ability.²

Model **a** also clarified that, for every 1% increment in post-intervention improvement in bimanual coordination ability, .442% improvement in juggling ability could be observed (tolerance index was 39.8%). This finding further implied that, the frontalis muscle EMG biofeedback intervention, perhaps resulted in substantial improvement in cerebrovascular mechanism in the central nervous system (CNS) information-processing system, which might led to reduction in peripheral muscle tension and enhanced neuromuscular adaptation in the lower extremities of the players.³⁴⁻³⁶

Table 3

Model b - Summary of multiple linear regression analysis on Juggling Ability in Sc Biofeedback group (based on emotionality variables)

Dep. Variable – Juggling Ability	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partia l	Part	Tolerance	VIF
(Intercept)	96.843	13.949		6.943	.000					
Motor learning ability Clockwise Right post	.295	.105	.881	2.814	.008	.254	.415	.377 (.142)	.184	5.449
Motor learning ability Clockwise Left post	-.339	.157	-.985	-2.162	.037	.154	-.331	-.290 (.084)	.086	11.561

^b(F (3, 11) = 3.532, P < 0.010), Adj.R² = 22.7%

In Table 3 the model **b** emerged significant as the health parameters such as, agility shuttle run test and post-intervention outcomes of motor learning tasks performed in clockwise direction (both right-handed and left-handed) and anger as the measure of mood, together could explain 22.7 % variance of changes in the extent of juggling ability observed amongst the players who received Sc BF training.

Model **b** explained the inverse relationship between the outcome of motor learning tasks performed in clockwise direction (left-handed) and the extent of improvement observed in the juggling ability amongst the players. Interestingly identical type of motor learning tasks (performed in clockwise direction) using right-hand was evident as directly associated with enhancement in juggling scores. Observed semi-partial correlation index (part correlation – table 3) revealed that without the influence of any other factors, modification in (perhaps by virtue of Sc biofeedback training) the right-handed motor learning ability resulted in observed improvement in bilateral juggling ability

(14.2% extent of improvement could be explained). Contrary to that, left-handed motor learning performance at the post-intervention evaluation revealed that without the influence of any other factors, 8.4% (Table – 3 – part correlation) reduction in left-handed motor learning performance might result in heightened juggling performance in the soccer players. Perhaps this perplexing evidence hints upon to the fact that the players were extremely prone to right-handed dominance.^{31, 32}

Model **b** also clarified that, for every 1% increment in post-intervention improvement in right-handed motor learning ability, .881% improvement in juggling ability could be observed (tolerance index was 18.4%). This finding confirms the efficacy of Sc biofeedback intervention, which revealed the role of Sc biofeedback in minimising directional constraint¹⁶⁻¹⁸ and in facilitating higher-order cognitive-emotional competence in neural information processing, which could lead to enhanced juggling performance.³⁷

Table 4

Model c - Summary of multiple linear regression analysis on 'Juggling Ability' in Control group (based on emotionality variables)

Dep. Variable - 'With the ball agility'	Unstandardize d Coefficients		Standardize d Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero- order	Partial	Part	Toleranc e	VIF
(Intercept)	1.239	.339		3.655	.001					
Two Arm Coordination Percentages	.012	.003	.633	3.442	.001	.300	.483	.448 (.201)	.503	1.990
Clockwise post										

^a(F (1, 13) = 4.979, P < 0.002), Adj.R² = 27.0%

In Table 4 the model *c* emerged significant as the fitness parameter measure of back and leg strength and psychomotor measure two arm coordination ability in clockwise direction (obtained during post-intervention phase) together could explain 27.0 % variance of changes in the extent of 'juggling ability' observed amongst the soccer players of the control condition.

Model *c* explained the direct relationship between two arm coordination ability in clockwise direction and 'juggling ability'. Outcomes however revealed that the players, who were evident as having higher extent of bimanual coordination ability in performing clockwise direction tasks, were evident as having higher extent of bilateral juggling skill. Observed semi-partial correlation index (part correlation – table 3) revealed that without the influence of any other factors, bimanual coordination ability of the players of the control group, could display slightly better juggling performance (20.1% extent of improvement could be explained).

Model *c* also clarified that, for every 1% increment in post-intervention observation of bimanual coordination ability, .633% improvement in juggling ability could be observed (tolerance index was 50.3%). This finding however revealed that, though the players of control group could not display improvement in juggling performance, they also did not display poorer performance. Thus the observed relationship could be only attributed to the practice or habituation effect or pre-existing awareness concerning the required task and also confirm the question of right-handed dominance.³⁰⁻³¹ To be more precise on this phenomenon, in bilateral juggling task, once the players get habituated, since the task demands movement of an

upper limb and a contralateral lower limb (e.g., right hand and left foot: "contralateral" combination), the magnitude of directional constraint may reduce.²⁰⁻²⁶

Here before summing up the question may be raised as to habituation effects on minimising the directional constraints amongst the players of intervention groups too. To clarify that question it could be discussed that, with practice of contralateral combination of upper and lower limb movements, juggling task performance may get improved but without optimal enhancement in neuromuscular adaptation; reduction in peripheral muscle tension and in somatic perception of arousal (by virtue of EMG biofeedback) and without improved task-focussing mediated through cognitive-motivational and emotional regulation (Sc biofeedback), substantial improvement in juggling performance may not occur.

4. CONCLUSIONS

- Frontalis EMG biofeedback intervention training was observed as beneficial for reduction in peripheral neural tension and for the enhancement in neuromuscular adaptation at the lower limb of the players, which in turn resulted in better juggling performance.
- Skin Conductance biofeedback intervention on the other hand had beneficial impact on the cognitive-emotional adaptation leading to enhanced bimanual coordination, and the enhanced autonomic adaptation helped the players to remain task-focussed, which perhaps led to enhanced juggling performance.

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6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

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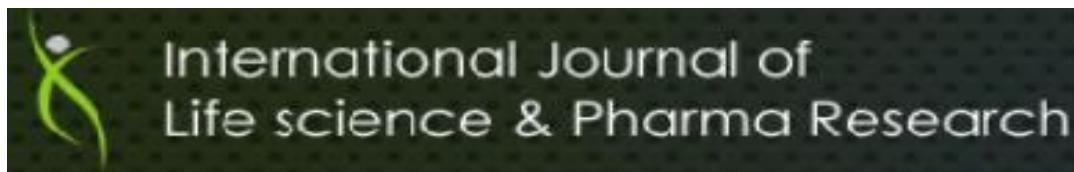
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IMPACT OF AUTONOMIC COMPETENCE AND MOOD FACTORS IN REGULATION OF OUTCOMES OF BIOFEEDBACK TRAINING ON REACTION PERFORMANCE EVIDENT AMONG MALAYSIAN PROMISING SOCCER PLAYERS

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ABSTRACT

This study was conducted to investigate the role of biofeedback interventions carried out in different modalities, with an objective to improve reaction ability among the soccer players. Sixty-nine young male promising soccer players (matched in anthropometric, cardiovascular and performance status) identified as having moderately high trait anxiety and debilitative mood states were recruited as participant. Participants were subjected to assessment of evaluation dispositional as well as transient anxiety; mood states; psychobiological (skin conductance or Sc orienting reflex activity judged by ERP of autonomic and peripheral measures of arousal) and psychomotor attributes (visual modality simple muscular reaction activity) in relation to performance excellence in soccer. Thereafter, the participants were categorised into three groups, viz. Group A – no-intervention control group, Group B – experimental group I (received Sc biofeedback training) and Group C – experimental II (received electromyography or EMG biofeedback training). Interventions followed for 15 minutes/ session, 2 sessions/week for 16 weeks. After the eighth week of intervention, mid-term analysis on all the parameters was carried out, and the post-intervention analyses were done after the 16th week of intervention. Furthermore, to evaluate the level of sustainability, post follow-up analysis of all the parameters of the baseline assessment as conducted to the participants. Two-way repeated measure of ANOVA revealed that both Sc and EMG biofeedback were found to facilitate in simple muscular reaction performance, while Sc biofeedback training appeared as better effective technique in improving reaction performance. Findings however clarified impact of favourable and facilitative mood states, lower dispositional anxiety and enhanced psychobiological competence on improvement in reaction ability evident among Malaysian promising soccer players.

KEYWORDS: Soccer; Biofeedback; Mood States; Trait Anxiety; Sc orienting activity

1. INTRODUCTION

Soccer performance is essentially characterised by split-second timing, fast decision making, alert and agile movements. One of the best indicators of these aspects of speed and effectiveness of decision making, is reaction time (RT). Like in any other challenging motor task situations, in sports particularly in any ball-game situation, high performance could be considered as resultant of successful interaction between quite a few relevant psychological and psychobiological aspects resulting in peak reaction ability. Sustainability in peak reaction ability definitely depends on multiple level of cognitive and cortical activation, and unique coordination between the sensory and motor processes involved in that.¹⁻³

The use of reaction time as an index of cognitive performance change due to an exercise conditioning treatment was selected because it reflects a number of CNS conditioning theoretically influences as well by exercise – induced physiological adaptation⁴⁻⁵ are a few amongst many sport scientists who have directed their efforts toward examining this aspect. In cognitive schema concerning any motor coordinated performance is already established, optimum cortical arousal initiated by ascending reticular activating system (ARAS) leads to faster sensory-motor information processing.⁶ The descending tract of RAS influences motor functions and can ensure improvement in the speed and coordination of reactions under higher levels of arousal.⁷ Optimum excitatory ARAS would facilitate in faster reactions, but cognitive overload leads to a state of over stimulation wherein his ARAS can't accept further excitement. This leads to a tendency to reject or to reduce the level of newer excitements, which is more common in introverted people, while extroverts remain relatively more excitement-hungry.⁸⁻¹⁰ This arousal leads to a state of readiness, enabling to process more information with further accuracy, efficiency and integration with memories or schemata stored in the brain. Finally, because of the activated pre-motor and motor cortex¹¹, they get prepared to make an appropriate response both rapidly and accurately.

Any promising soccer player or high-average skilled soccer player should be able to read and interpret complex situations quickly and to initiate decisive action. The faster the simple muscular reaction and movement time of the individual, the quickly will be responses to

complex situations.²⁻³ Here the subject of concern for the sport psychology researchers in the fields of soccer, appear with the question of intricate psychological and psychobiological processes influencing and in consequence ensuring excellent reaction performance. Numerous studies pointed out the importance of ARAS only in controlling excellent reaction performance⁷, while a lot of others pointed out the need for consideration into movement related motor coordination¹²⁻¹³ and others considered role of involvement of cortical activation as cognitive component as more important factor for concern.²⁻³ This present study on the contrary, are trying to point out to their concern over the methodological issues related to the assessment and analyses of the reaction performances in the field of soccer, along with the simultaneous assessment of other correlated and influencing psychobiological mediators.

A relevant issue of concern in measuring emotionality among soccer players is the determination of inherent features underlying dispositional and transient anxiety indicators arising out of competitive situations. Researches in the field of emotional crises and sport performance relationships are highly concerned with anxiety-performance relationships, as emotional and cognitive-emotional contributory factors have largely been ignored.¹⁴⁻¹⁶ Apart from that, underlying factors such as the anxious apprehensions resulting from high aspiration level^{3,17}, diminished self-esteem¹⁰, lack of self-confidence¹⁸, phobia of failure and fear of success phobia^{15,19} are of concern for the development of severe negativity in the players.

Of concern in this current research, is the psychophysiological aptitude of soccer players. Psychophysiological aptitude includes basic regulation of cortical and autonomic activation, which serve as precursors for vigilant monitoring on movements of opponents²⁰; alert split-second reactions.²¹ Kicking a soccer ball requires optimal perceptual – motor coordination and speedy positioning²⁰; vigilant actions and change of directions.²² Hence the excellence in psychomotor coordination performance requires unique autonomic adaptation²³⁻²⁴ and strong regulation over monoamine neurotransmitters²⁵, which could be aptly evaluated by psychobiological markers.^{3,11,23-24,26-27} Thus, the current research has been conducted to investigate on the impacts of psychological skill training (hereafter, biofeedback training) on emotional and psychobiological mediators of reaction ability

evident among Malaysian promising soccer players.

2. METHODS

2.1 Participants

For the present experiment sample size was calculated using G power 3.1.7.²⁸ The power of the study is set at 95% with 95% confident interval and the effect size F at 0.20. Total required sample size was calculated as 69 and hence sixty-nine young adult high-performing soccer players were recruited as participants (mean age = 22.31 and SD = 1.4446). They were selected based on the psychological evaluation of dispositional anxiety; kinanthropometric and cardiovascular status of the players and moderately high level of soccer performance skill levels.

2.2 Materials Used

For this experiment, some self-report inventories were administered along with psychobiological and psychomotor evaluations. Further to that, soccer performance related parameters were also assessed, and for all these evaluations following equipment and test materials were required.

- 1) State-Trait Anxiety Inventory (STAI)²⁹
- 2) Brunel Mood Scale³⁰
- 3) Electronic Reaction Timer Apparatus (Udyog, India 2000).
- 4) Skin Conductance Biofeedback Apparatus (Udyog, India 2000 and ProComp Infinity5 equipment of Thought Technology, USA, 2014).
- 5) Electrical Muscle Potentiality (EMG Apparatus) (ME6000, 2008).
- 6) Materials for Performance Test: – Soccer Ball; 14 cones; Stopwatch; Marker; PVC box and Measuring tape

2.3 Procedure

After the participants agreed to participate in the study and after they signed the consent form, they were subjected to evaluation dispositional as well as transient anxiety, employing the subjective self-report assessment tool, State-Trait Anxiety Inventory (STAI).²⁹ Thereafter they were also subjected to assessment of mood states, by using Brunel Mood Scale.³⁰ At the next step, participants were introduced to evaluation of visual modality simple muscular

reaction time (SRT - reaction activity), following the standardised protocol.^{3,17,31-32} Thereafter, they were subjected to assessment of Basal Skin conductance (Sc) as well as basal Electrical Muscle Potentiality of (SEMG) by employing surface Sc and electromyography (SEMG) assessment systems, for which they had to remain in reclining position and some surface EMG disposable electrodes were attached to the frontalis muscle (forehead muscle), and Sc electrodes were attached to the phalange of the fingers of the participants, and they were supposed to remain in reclining position with eyes closed and in relax composure. At this phase, they were prompted with a white noise as novel and benign stimulation to record phasic or habituation paradigm psychobiological responses (ERP).

Thereafter, based on randomized sampling formula (employing Research Randomizer Software³³, participants were equally categorized into following groups – 1) Group A – No-intervention or control group (n = 23); 2) Group B – Experimental Group I, who received EMG Biofeedback intervention training (n = 23), and 3) Group C – Experimental Group II, who received Sc Biofeedback training (n = 23).

Participants selected for intervention regimes were subjected to the training sessions for 15 - 20 minutes per session/ two sessions per week for 16 weeks (32 sessions in total). Control Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating the performance disaster amongst soccer players.

2.4. Statistical Analysis

The data were treated with SPSS 24.0, and analysis of descriptive statistics and a two-factor ANOVA with repeated measures was carried out to compare data on reaction performance obtained from the two intervention experimental conditions observed across different phases of analyses. Simple main-effects analyses and Bonferroni post

hoc tests were undertaken when ANOVA revealed a significant interaction. Further to that, outcomes of multiple linear regression analyses were critically observed to identify whether various corroborative relationships between mood states and inner psychopathological make-up as derived by employing the mood factor analysis and the

direct psychobiological measures (autonomic indices obtained by the skin conductance measures under habituation paradigm), which could reveal the intricate processes involved in catastrophic or disruptive emotionality observed in highly skilled but under-performing Malaysian Soccer players.

3. RESULTS

Outcomes of this study are presented based on the descriptive information (refer to tables 1 to 4),

pairwise comparison (table 5) and multiple linear regression reports (Tables 6 to 8).

Table 1

Descriptive Statistics of Skin conductance Parameters Analysis on Consistency of Skin conductance Across the Groups

Variables	Control Mean (SD)	EMG Biofeedback Mean (SD)	Sc Biofeedback Mean (SD)
Consistency of skin conductance at pre-intervention level	14.72 (± 4.96)	4.00 (± 6.86)	10.37 (± 11.80)
Consistency of skin conductance at mid-intervention level	68.83 (± 24.95)	32.03 (± 18.86)	29.31 (± 24.34)
Consistency of skin conductance at post-intervention level	72.92 (± 22.66)	9.51 (± 6.14)	16.23 (± 24.15)
Consistency of skin conductance at follow up-intervention level	45.32 (± 22.13)	29.93 (± 35.09)	15.05 (± 13.21)

Table 2

Descriptive Statistics of Skin conductance Parameters Analysis on Amplitude Across the Groups

Variables	Control Mean (SD)	EMG Biofeedback Mean (SD)	Sc Biofeedback Mean (SD)
Amplitude at pre-intervention level	2.43 (± 1.80)	1.27 (± 1.63)	1.58 (± 2.08)
Amplitude at mid-intervention level	2.10 (± 1.35)	2.90 (± 1.74)	2.45 (± 2.02)
Amplitude at post-intervention level	1.73 (± 1.45)	3.17 (± 1.35)	1.75 (± 1.22)
Amplitude at follow up-intervention level	6.18 (± 7.30)	5.42 (± 5.80)	3.07 (± 1.33)

Table 3

Descriptive Statistics of Skin conductance Parameters Analysis on Spontaneous Fluctuations (SF) Across the Groups

Variables	Control Mean (SD)	EMG Biofeedback Mean (SD)	Sc Biofeedback Mean (SD)
SF at pre-intervention level	5.67 (± 8.19)	3.47 (± 4.85)	6.93 (± 6.42)
SF at mid-intervention level	3.80 (± 3.88)	3.20 (± 3.92)	4.33 (± 4.84)
SF at post-intervention level	2.87 (± 3.58)	3.93 (± 3.24)	3.93 (± 3.17)
SF at follow up-intervention level	3.40 (± 4.75)	1.67 (± 1.23)	3.20 (± 2.98)

Table 4

Descriptive Statistics of Psychomotor Parameters Analysis on Reaction Ability Across the Groups

Variables	Control Mean (SD)	EMG Biofeedback Mean (SD)	Sc Biofeedback Mean (SD)
Reaction Ability at pre-intervention level	.36 ($\pm .02$)	.36 ($\pm .01$)	.37 ($\pm .03$)
Reaction Ability at mid-intervention level	.36 ($\pm .04$)	.35 ($\pm .02$)	.35 ($\pm .02$)
Reaction Ability at post-intervention level	.34 ($\pm .02$)	.32 ($\pm .02$)	.34 ($\pm .02$)
Reaction Ability at follow up-intervention level	.35 ($\pm .03$)	.32 ($\pm .01$)	.34 ($\pm .02$)

Tables 1 and 2 were conceived to represent phase wise alterations observed in the physical performance parameter and soccer performance parameters, which were observed amongst participants of three different groups. Observations based on the shapiro-wilk test for normality however revealed that indices were mostly free from huge dispersions and identical

features in the obtained pre-intervention data mostly revealed that, participants did not have any pre-existing differences. Hence, whatever differences were observed in the mid-term as well as in the post-intervention and post-follow-up phases could be attributed to the interventions introduced to the participants.

In the next sub-section, differential impacts of both EMG and Sc biofeedback intervention training on physical performance parameter, i.e., the reaction ability of the players were considered for assessment of optimal physical performance conditions required for performance of soccer skills. Impact of both the biofeedback intervention techniques have been evaluated, and the pairwise comparison tables are presented to clarify the differences in outcomes evident, if any, on the aforementioned

performance parameters tested. Table 5 revealed the observed differences amongst the three groups of participants. Further to that, relative impacts of both EMG and Sc biofeedback intervention were also evaluated based on regression analyses (Tables 6 to 8), in which beneficial impacts of intervention training on psychological, psychophysiological and emotional factors and the additive and moderative contributions of those variables on reaction performance were evaluated.

Table 5

Pairwise Comparisons of outcomes of Reaction Ability Scores Across the Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b
Control group	EMG Biofeedback	.029**	.006	.000
	Sc Biofeedback	.016**	.005	.007
	EMG	-.029**	.006	.000
	Biofeedback	.021**	.006	.009
Sc	Control group	-.016**	.005	.007
	Biofeedback	-.021**	.006	.009

*p<0.05; **p<0.01

Outcomes of the pairwise comparisons represented in the Table 5, depicted that at the post-intervention assessment with respect to the Reaction Ability, differences amongst the participants were evident. Findings however implied that, compared to the participants of the no-intervention group or the players of control condition, their counterparts both in the EMG and Sc Biofeedback intervention groups had significantly faster reaction ability (p<0.01; p<0.01). Apart from that, compared to the participants of EMG BF group, the Sc BF group players were observed to have significantly faster reaction ability (p<0.01).

Since the outcomes of the pairwise comparisons represented from Table 5 clarified

that the both EMG and Sc biofeedback intervention were effective in enhancing the level of reaction ability performance parameter, the post-intervention outcomes clarified that, players of both experimental conditions could display faster reaction ability. Here, at this stage, it was felt necessary to get ensured regarding the impacts of intervention technique employed. This was done precisely, to evaluate the additive and mediating factors, such as the roles of the biofeedback interventions induced modifications in the psychomotor, physiological, psychophysiological and emotional factors, and the summated or regressed contributions of those variables interacting on the reaction performance parameter.

Table 6

Model a - Summary of multiple linear regression analysis, explaining changes in Reaction Ability as predicted by modifications in emotionality and in psychomotor parameters observed at the post-intervention phase of analyses amongst the EMG Biofeedback trainee players

Dep. Variable - Reaction Ability	Unstandardized Coefficients		t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error			Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	.372	.014	27.412	.000***					
Adaptation level post	.000	.000	.816	.5.176	.000***	-.198	.693	.382	.220
Latency post	-.003	.001	-.430	-4.922	.000***	-.077	-.675	-.364	.716
Facilitative mood	-.000	.000	-.268	-2.851	.008**	-.185	-.468	-.211	.618
Trait anxiety	.001	.000	.404	4.457	.000***	.158	.638	.329	.665

^a(F (5, 17) = 10.279, P < 0.000), Adj.R² = 76.0%

In Table 6 the model *a* emerged significant as the psychophysiological measure of Sc adaptation

level, latency obtained during post-intervention phase and psychological measures such as –

facilitative mood and trait anxiety together could explain 76.0 % variance of changes in the extent of reaction ability.

Model **a** explained the inverse relationship among facilitative mood and post-intervention observations of latency and the extent of reaction ability observed in the athletes. Apart from that, trait anxiety (TA), along with post-intervention observations of adaptation level were found to

contribute directly on reaction ability. Therefore, findings implied that after having the EMG BF training, players those who had relatively higher level of facilitative mood, could enjoy the efficacy of delayed autonomic latency, facilitated in displaying faster reaction ability. Outcomes of psychological assessments however revealed that the players having relatively lower dispositional anxiety (TA), performed faster in reaction tasks.

Table 7

Model b - Summary of multiple linear regression analysis, explaining changes in Reaction Ability as predicted by variables of emotionality observed at the post-intervention phase of analyses amongst the Sc Biofeedback trainee players

Dep. Variable – Reaction Ability	Unstandardized Coefficients		Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	.334	.017		20.174	.000***					
Sc Mean post	.000	.000	.825	4.357	.000***	.396	.588	.466	.319	3.138
Adaptation Level post	.000	.000	.429	2.354	.024*	-.198	.365	.252	.344	2.903
Latency post	-.003	.001	-.317	-2.780	.009**	-.077	-.420	-.297	.878	1.139
Recovery Time post	.001	.000	.402	3.161	.003**	.090	.466	.338	.707	1.414
Trait anxiety	.001	.000	.261	2.374	.023*	.158	.368	.254	.945	1.058

^b(F (4, 18) = 10.531, P < 0.000), Adj.R² = 30.2%

In Table 7 the model **b** emerged significant as the post-intervention outcomes of the psychophysiological measure of tonic Sc level, adaptation level, latency and recovery time, along with the psychological measures such as, trait anxiety together could explain 30.2 % variance of changes in the extent of reaction ability. Model **b** explained the inverse relationship among post-intervention outcomes of autonomic latency and the extent of reaction time performance outcomes observed in the athletes. Apart from that, tonic Sc level, adaptation level and Sc recovery time

observed in the post-intervention phase, and trait anxiety were found directly associated with the extent of reaction ability observed amongst the participants.

Therefore, findings revealed that the players having relatively delayed latency, performed poorly in reaction performances. Direct relationships however revealed that, those who had relatively lower tonic Sc level; and lower adaptation level and faster recovery time along with lower level of trait anxiety could display faster reaction ability.

Table 8

Model c - Summary of multiple linear regression analysis on Reaction Ability in Sc Biofeedback group (based on emotionality variables)

Dep. Variable – Reaction Ability	Unstandardized Coefficients		Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	.243	.047		5.178	.000					
Tension	.001	.000	.357	2.468	.018*	.331	.363	.355	.989	1.011

^c(F (3, 19) = 2.781, P < 0.053), Adj.R² = 11.1%

In Table 8 the model **c** emerged significant as tension as the measure of mood state could explain 11.1 % variance of changes in the extent of reaction time. Model **c** explained that tension

has direct association with lower extent of reaction time. Henceforth, findings revealed that the soccer players having lower extent of tension were evident as having faster reaction time.

4. DISCUSSION

Based on the results obtained, we intended to revisit the reasons behind those outcomes. The prime objective of this study was to investigate the facilitative impacts of biofeedback intervention training regimes on enhancement in psychobiological conditioning and resultant improvement in psychomotor factors associated with soccer performance, hereafter simple reaction ability evident among the players. Outcomes of this study revealed that both the intervention techniques (viz., Sc and EMG biofeedback intervention) were effective in bringing about the improvements in reaction performances, in which compared to that EMG BF intervention, the Sc BF was evident as better effective in inducing desired modifications in reaction tasks performed by the soccer players.

Findings in this context revealed that compared to the players of the EMG BF participants Sc BF participants were observed to display faster reaction performance. This observed beneficial impact of Sc biofeedback training over EMG BF training however got supported by several of the previous findings.^{17,23,34-38} Findings reported by Saha et al.^{3,39}, however contradicted this finding. Precisely, improvements evident in reaction ability could be resulted from enhancement in autonomic processing in the ascending reticular tract²⁶⁻²⁷ and excitatory potentials generated in the basal ganglion and in the mid-brain.¹¹

The comparative better edge of Sc biofeedback encouraged us to investigate into the aspects such as, psychobiological and psychological factors, which could possibly mediate differentially among players of different groups, who were exposed to differential biofeedback training. Out of the two intervention techniques, Sc biofeedback training appeared better effective in improving reaction performance. With such a background, we intended to pay attention to the outcomes of multiple regression reports, which provided us with the information on predictive contribution of relevant mediator variables. At first, attempts have been made on explaining roles of predictors variables associated with emotional make-up of the players who received EMG BF training. An account of contribution of emotional make-up (both psychological and autonomic or psychobiological factors were considered) of EMG BF group of players on their reaction time performance was analysed.

Higher tolerance index observed in collinearity statistics (Table 6) suggested that – in explaining reaction ability very high extent of variances (71.6%) in latency was not predicted by other measures. Similarly, high extent of (61.8 %) variances in facilitative mood and (66.5 %) in Trait Anxiety were not predicted by other measures of emotionality. Model *a* also explained that for every 1% delay in autonomic latency, .430% increment in faster reaction ability would occur, whereas for every 1% reduction in autonomic Sc adaptation, .816% increment and for every 1% increment in facilitative mood, .268% increment in faster reaction ability would be evident. Furthermore, relationships also implied that, for every 1% reduction in trait anxiety, .404% faster reaction ability would be displayed.

Outcomes of this model however revealed that, at the post-intervention phase of assessment, the EMG BF group participants were observed as having faster reaction ability, which was influenced by lower extent of dispositional anxiety; relatively higher facilitative mood; relatively delayed latency and reduced autonomic adaptation, evident amongst majority of the players, who received EMG BF intervention training.

Thereafter, emotional make-up of the Sc BF group players, and the relative impact on reaction performance was analysed. Collinearity analyses here revealed that, higher extent of tolerance indices was observed in Table 7, which however suggested that – in explaining reaction ability very high extent of variances (87.8 %) in latency was not predicted by other measures. Similarly, very high extent of variances (94.5 %) in trait anxiety; (70.7 %) variances in Sc recovery time were not predicted by other measures of emotionality. Model *b* also explained that for every 1% increment in autonomic latency, 317% increment in faster reaction ability would occur, whereas for every 1% reduction in trait anxiety and in recovery time respectively, .261% and .402% faster reaction ability would occur. Higher tolerance index was also evident in collinearity statistics in Table 8, in which the model *c* suggested that – in explaining reaction ability very high extent of variance (98.9%) in tension was not predicted by other measures. Model *c* also explained that for every 1% reduction in tension, .357% faster reaction ability would be evident.

Outcomes of the previous models however revealed that, at the post-intervention phase of assessment, out of the Sc BF group participants those who were observed as having relatively delayed autonomic latency; relatively lower level of dispositional anxiety and faster autonomic (Sc) recovery, they were observed to have faster reaction ability. Outcomes also revealed that those who had relatively lower level of tension had faster reaction ability.

Thus, the outcomes of multiple regression analyses clarified that, obtained improvement in reaction ability evident among the EMG biofeedback trainees were facilitated by lower extent of dispositional anxiety accompanied by relatively higher facilitative mood. These players

were also observed to have relatively delayed latency and reduced autonomic adaptation, perhaps which have put some deleterious impacts on their reaction performance, and hence they did not have maximum improvement in reaction time. As for the Sc biofeedback trainees, relatively delayed autonomic latency was evident. But that delay in Sc latency, perhaps helped them in having adequate appraisal of visual stimuli, and hence the relatively lower level of dispositional anxiety and relatively lower level of tension accompanied by faster autonomic (Sc) recovery, might have mediated in displaying best reaction performance outcomes.

5. CONCLUSIONS

Present study revealed efficacy of both EMG and skin conductance biofeedback intervention techniques in improving reaction performance among Malaysian promising soccer players. In producing faster reaction performance, compared to the EMG biofeedback training, skin conductance biofeedback intervention was appeared as better effective technique. Overall enhancement in mood states, reduction in anxiety and enhanced psychobiological processes, especially autonomic competence in inducing faster recovery was evident to facilitate in reaction performance.

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7. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

SrS, SoS

Collected data and performed the experiments:

SrS, SoS

Contributed with materials/analysis tools:

SrS, SoS

Analysed the data: SrS, SoS

Wrote the paper: SrS, SoS

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BIOFEEDBACK INTERVENTION REGIMES AND ROLE OF DIFFERENT MEDIATORS IN ENHANCING SOCCER BALL JUGGLING PERFORMANCE

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ABSTRACT

Purpose of this present study was to identify intricate relationships between emotional mood states and psychobiological mediators in moderating or in influencing impacts of differential biofeedback intervention training on performance of soccer skills, which were observed among promising soccer performers. Eighty-one young male intermediate level soccer players were recruited as participants, who were subjected to evaluation of mood states; projective emotionality; autonomic skin conductance (Sc) and EMG indices. Bilateral soccer ball juggling ability was assessed as one of the basic soccer skill ability. Thereafter they were equally categorised into three groups, in which one no-intervention control group was existed. Players were introduced to frontalis EMG and skin-conductance biofeedback intervention regimes. Post-intervention analyses revealed facilitative impacts of biofeedback intervention training, while role of mood states; emotionality; EMG and Sc indices as predictors of higher-order juggling performance were confirmed.

KEYWORDS: *Biofeedback, soccer juggling, emotionality, autonomic competence*

1. INTRODUCTION

Emotional overloading and crises are known to put deleterious impacts on performance. In soccer, alike what may happen to all other sport performance, emotional crises put immense inhibiting impacts. Resolution of those emotional crises are definitely essential for successful performance of soccer skills. Among numerous ways of self-regulation and resolution of emotional crises, biofeedback intervention techniques are universally accepted therapeutic systems, which can aptly regulate emotional upheavals. Biofeedback trainings employ, non-invasive therapeutic

techniques, and hence those are gaining popularity among researchers and therapists. These biofeedback trainings could be employed using different sense-modalities, which are based on auto-sensory observations provided to the individual seeking therapeutic assistances.

Auto-sensory observations of peripheral and autonomic indices facilitate in self-regulation techniques and thus biofeedback training emerged as viable options for performance enhancement.¹⁻⁵ Our previous research attempts on ASEAN population also revealed that, different types and levels of biofeedback intervention, helps in

conscious engagements in psychomotor dependent soccer performance skill.^{2,6,7}

Since the auto sensory process demands cognitive-emotional competence,^{2,3,5} enhancement in bodily awareness; cognitive schemas required for skilful motor performance⁸⁻⁹ could be viewed as potential contributors mediating improvement in coordinated gross motor functioning. Role of biofeedback interventions though have already been studied in a few of our previous studies^{3,6,7} and of other relevant sport psychobiology researchers too,^{1,4,5,10,11,12} additive or moderating contribution of potentially significant predictors are not yet confirmed.^{1,3,4,6,10,12}

With such a background, the study was conducted:

- 1) To investigate the impact of EMG biofeedback intervention training, on the role of differential mediators, on improvements in juggling performance, if any, observed among soccer players.
- 2) To evaluate the effect of Sc biofeedback intervention on juggling skill of the soccer players, mediated by differential other factors.
- 3) To compare the relative efficacy of EMG biofeedback and Sc biofeedback intervention on differential mediators, observed among soccer players, in modulating juggling performance.

2. METHODOLOGY

2.1. Participants

Eighty-one intermediate level of (based on inter-rater concordance between three qualified coaches in rating the level of consistency in high-performance) soccer players of Kelantan province of Malaysia, aged between 18 – 21 years (Mean age – 20.06 yrs. and SD – 2.15) volunteered as participants. The sample size was calculated using G power 3.1.7 in which the power of the study is set

2.2. Materials Used

1. The Brunel Mood Scale (BRUMS) was administered for assessment of mood states of the participants;¹³
2. Rorschach Ink – Blot (RIB) Test was administered for Projective analysis of Emotionality;¹⁴
3. MegaTrac ME 6000 surface electromyography (EMG) biofeedback apparatus was used for frontalis EMG biofeedback intervention training;
4. Skin Conductance (Sc) Apparatus (Udyog 2000) was used for the Sc biofeedback training.

2.3. Procedure

After approval from the Human Research Ethics Committee (HREC) USM (No:- USM/JEPeM/14070266), of the institution was obtained, all of the participants were invited by sending opaque-sealed envelopes, with detailed information with regard to the experimental procedures. Thereafter, upon their arrival they were provided with the detailed information concerning the experimental procedure. Once they agreed upon to participate in the experiment and given signed consent, all of them were subjected to evaluation of mood-states and evaluation of projective emotionality by employing BRUMS and Rorschach (RIB) tests. Thereafter psychobiological indices, such as different facets of SEMG were evaluated by using the ME 6000 SEMG analysis system (Fig. 1), followed by evaluation of autonomic indices of emotionality using skin conductance apparatus (Fig. -2 & 3 - viz., latency; amplitude; recovery time & adaptation level etc.).



Figure 1: ME 6000 EMG apparatus for Biofeedback



2.3.1 Test of Soccer Ball Juggling

Juggling skill of the participants was evaluated following the standard procedures. For this purpose, players were given three chances to practice over this bilateral juggling skill activity, since in this experiment players were supposed to kick and control the ball by alternatively controlling and juggling the ball using both of their feet only (please refer to Figure 4). Use of other parts of the body was restricted (Figure 5), and hence the maximum number of times they could juggle the

ball by virtue of alternative use of dominant and non-dominant feet, were considered as their 'juggling ability' score. After the three chances of practice, once they confirmed that, they were ready to take up the test, they were subjected to the assessment of 'juggling ability'. For this test three-trials were taken (intermittent rests for 30 seconds were provided to them), and the best of the three was considered as the score. This test was carried out on one-to-one basis (to avoid contamination from any extraneous variables).



After the baseline analysis, participants were equally categorised into three groups (i.e., Control group; and two Experimental groups. While apart from regular soccer skills performance training, control group players were not introduced to any other training, their counterparts in groups 2 and 3 were subjected to training of frontalis EMG and skin conductance biofeedback training respectively following an identical protocol (for 15 min.s/day; 2

days/week for 12 weeks). Mid-term evaluation (after 6th week) and post-intervention analyses (at the end of 12th week) were carried out on all of the afore-mentioned variables.

3. RESULT & DISCUSSION

3.1 Descriptive Statistics

Descriptive statistical tests were conducted on the bilateral juggling skills scores of the participants,

which are represented in the Table 1. Observations however revealed that indices were mostly free from huge dispersions and observed identical features in the obtained pre-intervention data mostly revealed that, participants did not have any pre-

existing differences, and hence whatever differences were observed in the mid-intervention; post-intervention and post-follow-up interventions could be attributed to the interventions introduced to the participants.

Table 1
Descriptive Statistics of Performance Parameters Analysis on Soccer juggling score across the Groups

Variables	Control Group (N = 27) Mean (SD)	EMG Biofeedback (N = 27) Mean (SD)	Sc Biofeedback (N = 27) Mean (SD)
Soccer juggling score at pre-intervention level	56.67 (\pm 16.92)	53.61 (\pm 21.63)	54.63 (\pm 17.41)
Soccer juggling score at mid-intervention level	55.24 (\pm 18.20)	62.45 (\pm 19.83)	59.33 (\pm 15.05)
Soccer juggling score at post-intervention level	56.17 (\pm 11.32)	70.13 (\pm 14.12)	63.71 (\pm 14.45)
Soccer juggling score at follow up-intervention level	56.87 (\pm 13.47)	71.41 (\pm 10.56)	65.26 (\pm 12.45)

3.2 Repeated Measure of ANOVA

Table 2 Mauchly's Test of Sphericity (performance parameter)

Measure: Soccer juggling						
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^b	
					Greenhouse-Geisser	Huynh-Feldt
Phase	.185	68.677	5	.000	.493	.531

Reports from the Table 2 revealed the results of Mauchly's test of sphericity, which indicated that for the main effect of phase differences violated the

assumption of sphericity and therefore the F-value\|s for that effect was required to be corrected.

Table 3 Tests of Within- Subjects Effects on Soccer juggling

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Soccer juggling Phase	2823.644	1.479	1909.228	84.681	.000
Greenhouse-Geisser	1400.467	62.116	22.546		
Greenhouse-Geisser					

Thus, the output (result of ANOVA with corrected F-value) is represented in the Table 3 (table of tests of within subjects' effects). We can report the results as for the participants of this experiment, 'there was a significant main effect of phase difference, $F(1.48, 62.12) = 84.68, p < .000$, which

implied that, if effects of other variables are ignored, performance outcomes pertaining to the soccer juggling task was different from each other (Table 3).

Table 4 Pair wise Comparisons Soccer juggling Across the Groups observed at the post-intervention analysis phase

Groups	Compared between	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	-8.533**	.866	.000	-10.932	-6.134
	3	-4.222**	.643	.000	-6.001	-2.443
2	1	8.533**	.866	.000	6.134	10.932
	3	4.311**	.412	.000	3.171	5.451
3	1	4.222**	.643	.000	2.443	6.001
	2	-4.311**	.412	.000	5.451	3.171

* $p < 0.05$; ** $p < 0.01$

In the Table 4, the post-intervention assessment outcomes in terms of the pair wise comparisons revealed that differences amongst the participants were evident. Outcomes of the pair wise comparisons represented in the Table 2.3 depicted that, at the post-intervention assessment, differences amongst the participants were evident. Detailed scrutiny of the comparisons however revealed that, compared to the participants of the control group, players who received the interventions were capable of displaying better juggling performance scores (See Figure 6).

Further to that, post-intervention comparisons also revealed that the amongst participants of the experimental group, those who received frontalis EMG biofeedback intervention, could display better improvement in juggling performance compared to their counterparts who received Sc biofeedback intervention. Here we wanted to find out reasons behind relative higher impact of EMG biofeedback over Sc biofeedback intervention, and therefore, multiple linear regression analyses were conducted to realise the predictive influence of differential contributing factors.

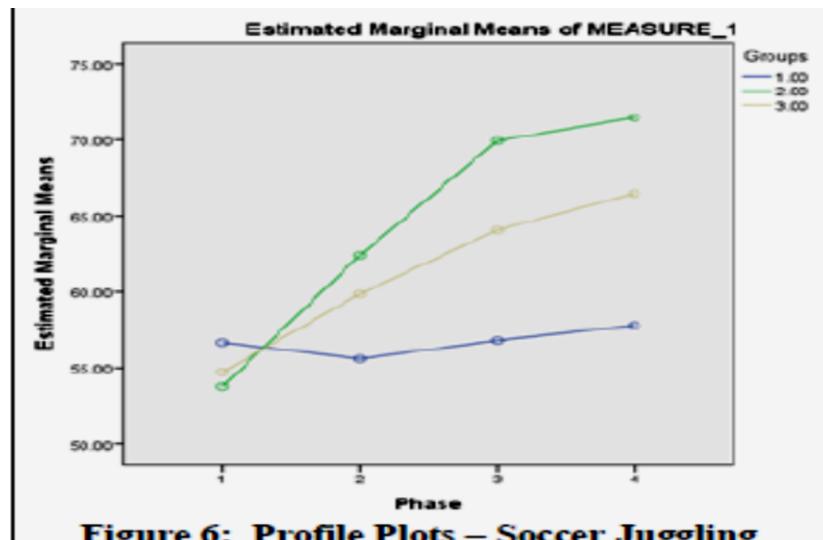


Figure 6: Profile Plots – Soccer Juggling

3.3 Multiple Linear Regressions

Table 5

Model a - Summary of multiple linear regression analysis on Juggling Ability in Control group (based on emotionality variables)

Dep. Variable – Juggling Ability	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partia l	Part	Tolerance	VIF
(Intercept)	66.416	3.570		18.605	.000					
Self-esteem	-1.266	.538	-.350	-2.354	.024	-.279	-.349	-.338 (.114)	.933	1.072

^a(F (3, 23) = 2.827, P < 0.051), Adj.R² = 11.3%

In Table 5 the model *a* emerged significant as the psychological measure of self-esteem could explain 11.3 % variance of changes in the extent of juggling ability of the players. Model *a* explained the inverse relationship between self-esteem and the extent of juggling ability observed in the players during post-intervention phase of assessment. Hence, findings revealed that the players having lesser self-esteem were evident as

having higher extent of juggling ability. As the players of control group could not display higher extent of juggling skill, observed inverse relationship, did not imply any critical concern for the lowering of self-esteem of the players. This outcome of lowering of emotional regulation goes on line with some of the previous outcomes.¹⁵⁻¹⁷

Table 6

Model b - Summary of multiple linear regression analysis on Juggling Ability in Control group (based on emotionality variables)

Dep. Variable – Juggling Ability	Unstandardized Coefficients		Standardized Coefficients		t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	237.953	30.918			7.696	.000					
Basic Average EMG	.791	.241	2.200	3.284	.003	.321	.508	.283 (.080)	.017	60.315	
Single Spectrum Average EMG	.110	.023	1.437	4.806	.000	.271	.653	.415 (.172)	.083	12.009	
Average Spectrum Zero-crossing Rate	.434	.109	.992	3.992	.000	-.087	.583	.344 (.118)	.121	8.298	
Average Spectrum EMG	.104	.037	.735	2.826	.008	.240	.453	.244 (.059)	.110	9.079	
Fatigue Relative Mean Power Frequency	-.087	.029	-.404	-3.026	.005	-.052	-.478	-.261 (.068)	.417	2.399	
Average EMG Peak	.161	.026	2.229	6.151	.000	.380	.741	.531 (.282)	.057	17.645	
Shuttle Run Agility Test Score	-10.403	2.062	-.584	-5.045	.000	-.330	-.671	-.435 (.189)	.555	1.802	

^b(F (3, 24) = 9.152) (p < 0.000), Adj.R² = 67.3%

In Table 6 the model **b** emerged significant as the peripheral electrophysiological EMG indices and performance parameters together could explain 67.3% variance of changes in the extent of juggling best. Model **b** explained the inverse relationship among lowering of Fatigue Relative Mean Power Frequency and faster agility shuttle run test score and the extent of improvement in juggling performance observed in the players of control group. Apart from that, it was also observed that players those who had higher Basic Average EMG; Single Spectrum Average EMG; Average Spectrum Zero-crossing Rate; Average Spectrum EMG; Average EMG Peak power were found to display better juggling performance. Observed semi-partial correlation index (part correlation – table 6) revealed that without the

influence of any other factors, higher Average EMG Peak power and faster agility could explain 28.2% and 18.9% improvement respectively in bilateral juggling ability (based on semi-partial correlation only higher scores are explained). Perhaps this perplexing evidence hints upon to the fact that the players were having pre-existing differentially higher electrical muscle potentiality, which however revealed that, the players who were able to recruit more motor neurons; and motor neuronal firing were higher, and also had comparatively lower fatigability, were having higher juggling performance skills.^{4,10,11,18}

Table 7

Model c - Summary of multiple linear regression analysis on Juggling Ability in EMG Biofeedback group (based on emotionality variables)

Dep. Variable - Juggling Ability	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	82.094	15.274		5.375	.000					
Autonomic Adaptation Level	-.225	.073	-.996	-3.064	.004	.220	-.460	-.370 (.137)	.138	7.230
Skin Conductance Recovery Time	1.061	.261	.751	4.066	.000	.231	.566	.491 (.241)	.428	2.335

Positive mood	-.611	.261	-.326	-2.342	.025	-.088	-.368	-.283 (.080)	.753	1.328
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^a(F (2, 23) = 6.317, P < 0.000), Adj.R² = 45.3%

In Table 7, the model **c** emerged significant as the post-intervention outcomes of the psychobiological measures and emotional aspects together could explain 35.7% variance of changes in the extent of juggling performance outcomes observed amongst the players. Model **c** explained the inverse relationship among post-intervention observations of Sc adaptation level and positive mood and the extent of juggling ability observed in the athletes. Apart from that, recovery time was found directly associated with higher extent of juggling ability. Thus, outcomes implied that the athletes having relatively lesser extent of Sc adaptation level and lower extent of positive mood were evidentially

having better juggling performance score. Contrary to that, players having relatively delayed Sc recovery time were evident as having higher extent of juggling ability.

Observed semi-partial correlation index (part correlation – table 7) revealed that without the influence of any other factors, lower extent of Sc adaptation level (13.7%); lack of positive mood (8%) and delayed Sc recovery time (24.1%) could explain reasons behind higher extents of juggling ability. These observed lack of autonomic as well as emotional competence as predictor for higher juggling performance, contradicts outcomes of several of previous empirical evidences.^{3,6,7,17}

Table 8
Model d - Summary of multiple linear regression analysis on Juggling Ability in Sc Biofeedback group (based on emotionality variables)

Dep. Variable – Juggling Ability	Unstandardized Coefficients		Beta	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error				Zero-order	Partial	Part	Tolerance	VIF
(Intercept)	96.843	13.949		6.943	.000					
Shuttle Run Agility Test Score	-3.766	1.203	-.457	-3.131	.003	-.267	-.453	-.420 (.176)	.843	1.186
Anger	-.271	.117	-.340	-2.318	.026	-.132	-.352	-.311 (.096)	.836	1.196

^a(F (3, 11) = 3.532, P < 0.010), Adj.R² = 22.7%

In Table 8 the model **d** emerged significant as the performance parameters such as, agility shuttle run test and post-intervention outcomes of anger as the measure of mood, together could explain 22.7 % variance of changes in the extent of juggling ability observed amongst the players who received Sc BF training. Model **d** explained the inverse relationship among the outcomes of agility shuttle run test score and anger and the extent of improvement observed in the juggling ability amongst the players. Therefore, findings revealed that the athletes who had improvement in agility, and who could lower their extent of state of anger could display better juggling ability. Semi-partial correlation indices (part correlation – table 8) revealed that without the influence of any other factors, faster agility (17.6%) and lowering of anger (9.6%) could explain reasons behind having higher extents of juggling ability. This outcome of higher order emotional regulation and higher agility as facilitated by Sc biofeedback were

evidenced in earlier studies conducted on similar population.^{6,12,16,17,19}

In sum, outcomes were discussed under the purview of the heightened ability of the participants in autonomic and peripheral arousal modulation and emotional regulation, which could have contributed in juggling performance. EMG parameters were observed as associated with control condition players, whereas those were not evidenced as significant predictors for experimental group players. Similarly, though Sc indices were observed as predictors for juggling task in case of EMG BF group players (who could display maximal improvement in juggling skill), perhaps frontalis EMG BF was not adequate enough in enhancing positive mood and autonomic adaptation, and hence were not capable of resulting in faster Sc recovery.^{3,6,7,17}

4. CONCLUSIONS

- 1) Frontalis EMG biofeedback intervention facilitated in juggling performances observed among soccer players, although specific roles of the mediators could not be confirmed.
- 2) Skin Conductance biofeedback intervention was also evident as having beneficial impact on juggling performance skills performed by the soccer players.
- 3) Compared to the Sc intervention, frontalis EMG biofeedback intervention was observed as more facilitative in enhancing juggling performance.

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6. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

SrS, SoS

Collected data and performed the experiments:

FaS, SrS, SoS

Contributed with materials/analysis tools:

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Analyzed the data: SrS, SoS

Wrote the paper: SoS, SrS

Checked and edited the format of the paper:

FaS, SrS, SoS

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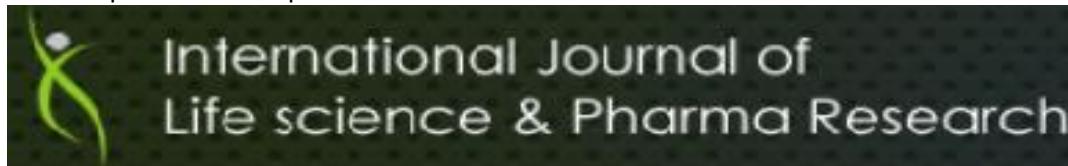
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COST-EFFECTIVE EXERCISE PROGRAMS ON HEALTH-STATUS OF MALAYSIAN DIABETIC INDIVIDUALS - A SOCIO-PSYCHOLOGICAL ANALYSIS

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ABSTRACT

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Lifestyle-related diseases like Type 2 Diabetes Mellitus (T2DM) induces humongous amount of global health and economic burden. This study purports to compare the efficacy of aerobic and combined exercise intervention programs evident amongst T2DM individuals in Kelantan, Malaysia to assess the cost-effectiveness of those exercise interventions. 75 middle-aged T2DM individuals from middle-income population of Kelantan, Malaysia were recruited as participants, and hence they were assessed with HbA1c for evaluation of stability in regulation of blood-glucose level; EuroQol 5D-5L questionnaire for evaluation of perceived health-status; Brunel Mood States (BRUMS) for assessment of changes in mood states and Bender-Gestalt II (BG- II) for evaluation of cognitive competence. After the baseline assessment, they were randomly categorized into 3 groups – control group, and two experimental groups, such as - aerobic exercise training and combined introduction of aerobic and strength-training exercises. Protocol for the exercise interventions was scheduled as 20-50 minutes/day; 3-4 days/ week; for 14 weeks. Thereafter to assess the effectiveness of the intervention programs, post-intervention analyses were carried out after 14 weeks. Finally, incremental cost effectiveness ratio (ICER) was calculated to determine the most cost - effective exercise program for the diabetic population. Post-intervention analyses revealed significant improvement in the level of HbA1c; mobility and in overall perceived health status. Further to that, participants of the combined intervention Group had significant improvement in cognitive comprehension and working memory levels. Finally, cost effectiveness analysis showed that combined exercise program has been observed to be the most cost-effective program having the lowest ICER among aerobic and no exercise program in Malaysia.

KEYWORDS: *Type 2 Diabetes Mellitus, Exercise regimes, EuroQol 5D-5L, Cognitive competence, Mood States, Cost Effectiveness Analysis*

1. INTRODUCTION

In last few decades, the world has seen radical changes in global lifestyles, owing to demographic transition, combined with

urbanization and industrialization. Type 2 diabetes mellitus (T2DM) has emerged as major public health problem putting a humongous amount of health and economic burden on people worldwide.

2. METHODOLOGY

2.1 Participants

For this study, based on the standardised inclusion and exclusion criteria, 75 participants were invited from the Diabetic clinic (outpatient), Hospital Universiti Sains Malaysia (HUSM) and from the community centre of Gunong (Kawasan Rukun Tatangga, Gunong, Bachok, Kelantan). Ethical approval for this study was obtained from the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPem/15060229).

After the baseline assessment, participants were randomly categorized (following concealed allocation) into three different groups, namely Group A: Control group (N = 25, received no intervention); Group B: Experimental Group I (N = 25, received aerobic exercise training i.e. walking) and Group C: Experimental Group II (N = 25, received combined exercise, i.e. aerobic exercise training and resistance/strengthening exercise training).

2.2 Assessment Protocol

Glycosylated haemoglobin was evaluated by analysis of HbA1c. EQ-5D-5L questionnaire created by the EuroQol group¹⁰, was used to assess mobility, anxiety/depression, usual activities, self-care and pain/discomfort. Brunel Mood Scale (BRUMS)¹¹ was used to measure alterations in mood-states followed by physical activity.¹²⁻¹⁴ Bender-Gestalt II test was employed for optimal diagnosis of the cognitive competence, pertaining to comprehension ability, working memory¹⁵ of the T2DM participants.¹⁶⁻¹⁷

2.3 Intervention Technique

In this research two different exercise interventions were introduced following standardised protocol. These two-exercise interventions were:

1. Aerobic Exercise Training (supervised walking followed by stretching exercises).
2. Combined Exercise Training (supervised walking and strengthening exercises were incorporated to target strength gain in the major muscle groups).

The intervention sessions were outlined based on the Joint Position Statement prepared by

the ACSM and ADA.¹⁸ Protocol for the exercise interventions was scheduled as 20-50 minutes/day; 3-4 days/ week for 14 weeks. All the intervention sessions were supervised by qualified exercise trainers, and to prevent methodological bias, the participants, researcher and the trainers for the study were blinded.

2.4 Data Analysis

In this study analyses of mean differences were carried out following Wilcoxon signed-rank test and Two-way repeated measures of ANOVA/ Mixed factorial ANOVA. The significance level for all the analysis was set at $p < .05$. The cost-effective analysis perspective adopted in this research was mainly the provider's perspective which referred to the direct costs of setting up and running a programme. All the costs were expressed in the Malaysian currency (Malaysian Ringgit – MYR). The unit of health was measured based on change in health status resulting from the differential exercise interventions by the direct elicitation method of Visual Analogue Scale (VAS) of EuroQol-5D-5L(EQ-5D-5L). Simple accounting of costs over a short period of time

was considered, hence no consideration for asset depreciation was required. Besides, the health outcome (EQ-VAS) was taken from randomized controlled trial, so no synthesis of diverse epidemiologic and clinical studies required to be modelled.

3. RESULTS

Statistical analyses were carried out based on findings from Wilcoxon Matched Pairs Signed Ranks Test (in case of analysis of EuroQoL-5D) and Two - way repeated measure of ANOVA. Participants from Kelantan, Malaysia basically represented the middle-income range with a mean monthly income of MYR 3407.81. Comparative efficacy of the intervention programs is detailed hereafter.

Table 1 clarifies significant improvement in HbA1c values in both the aerobic and combined intervention groups, which was evident out of the differences observed between control and combined group ($p = .000$) and between control and aerobic group ($p = .000$).

Table 1
Pairwise Comparisons for HbA1c values across different groups based on phases

Phases	Groups	MD (95% CI)	p-value
Pre	Control - Aerobic	-.35 (-1.42,.72)	1.00
	Control - Combined	.02 (-1.05,1.08)	1.00
	Aerobic – Combined	.37 (-70,1.43)	1.00
Post	Control - Aerobic	4.26 (-3.26, 5.26)	.000**
	Control - Combined	4.86 (-3.88,5.87)	.000**
	Aerobic – Combined	0.72 (-1.73, .29)	.258

* $p < .05$; ** $p < .001$

The following table (Table 2) displays that after 14 weeks of aerobic exercise (supervised walking) intervention, significant improvement in state of mobility ($p = .001$) and pain or discomfort ($p = .011$) was observed. In case of the participants of

the combined exercise (supervised walking combined with resistance exercises) group, post-intervention improvement in perceived sense of mobility ($p = .001$) was evident

Table 2
A comparison of pre-and post-exercise intervention effect on self-reported descriptions of health problems using five dimensional EuroQoL-5D health state scores GroupWise (Wilcoxon Matched Pairs Signed Ranks Test)

EQ-5D Individual Dimensions	Pre-Intervention		Post intervention	P value (Pre-Post)
	n	n	n	
CONTROL GROUP				
Mobility	25	24	24	.741
Self-care	25	24	24	.101
Pain/discomfort	25	24	24	1.00
Activity	25	24	24	.667

Anxiety/depression	25	24		.301
AEROBIC EXERCISE GROUP				
Mobility	25	22		.001**
Self-care	25	22		.100
Pain/discomfort	25	22		.011**
Activity	25	22		.292
Anxiety/depression	25	22		.101
COMBINED EXERCISE GROUP				
Mobility	25	24		.001**
Self-care	25	24		.100
Pain/discomfort	25	24		1.00
Activity	25	24		.661
Anxiety/depression	25	24		.567

*p<.05; **p<.001

Table 3
Pairwise Comparisons for EQ-VAS Score across different groups based on phases

Phases	Groups	MD (95% CI)	p-value
Pre	Control - Aerobic	9.00 (-1.88,19.88)	.138
	Control - Combined	-3.25(-14.13,7.63)	1.000
	Aerobic – Combined	-12.25(-23.13, -1.38)	.062
Post	Control - Aerobic	-1.70(-7.67,4.27)	1.000
	Control - Combined	-10.00 (-15.97, -4.03)	.000**
	Aerobic – Combined	-8.30 (-14.27, -2.33)	.003**

*p<.05; **p<.001

Table 3 depicts significant improvement in the health status revealed through the outcomes of the EQ-VAS Score followed by the combined intervention, which was evident out of the

differences observed between control and combined group ($p = .000$) and between aerobic and combined group ($p = .003$).

Table 4
Pairwise Comparisons for Comprehension score and Working Memory score across different groups based on phases

	Phases	Groups	MD (95% CI)	p-value
Comprehension score	Pre	Control - Aerobic	-.50(-1.14,.14)	.182
		Control - Combined	-.55(-1.19,.09)	.119
		Aerobic – Combined	-.05(-.69,.59)	1.00
	Post	Control - Aerobic	1.90(1.20,2.60)	.000**
		Control - Combined	.70(.00,1.40)	.050
		Aerobic – Combined	-1.20(-1.90, -.50)	.000**
Working Memory score	Pre	Control - Aerobic	-.40 (-1.17,.37)	.617
		Control - Combined	-.70(-1.47,.07)	.087
		Aerobic – Combined	-.30(-1.07,.47)	1.00
	Post	Control - Aerobic	-.95 (-1.73, -.18)	.011
		Control - Combined	-1.15 (-1.93, -.38)	.002**
		Aerobic – Combined	-.20 (-.98,.58)	1.00

*p<.05; **p<.001

Table 4 reveals significant improvement in cognitive comprehension amongst participants of combined intervention and control group, which was evident out of the comparative improvements observed in the participants of control group (p

=.000), and in the combined group ($p = .000$). In case of Working Memory however, improvement was only evident followed by the combined intervention ($p = .002$).

Table 5
Ranking of Incremental Cost Effectiveness Ratio (ICER) (lowest to highest value)

Intervention	Net Cost (MYR)	Incremental Cost (Δ Cost)	EQ-VAS Score (Health Status - HS)	Incremental EQ-VAS Score (Health status - Δ HS)	ICER (Δ Cost / Δ HS) (MYR)
1. Control (no exercise) (Group A)	1205.98	n/a	80	n/a	-
2. Combined Exercise program (Group C)	3567.16	75.00	90	8.3	9.04
3. Aerobic Exercise program (Group B)	3492.16	2286.18	81.7	1.7	1344.82

Table 5 shows the ranking of the different exercise intervention programs based on the Incremental Cost Effectiveness Ratio (ICER) values from lowest to highest. The exercise intervention program which incurred lowest ICER value was ranked first in the table and followed accordingly. Here, combined exercise intervention program had

the lowest ICER of positive MYR 9.04/Health Status with highest cost and most effective health status. After that the ICER value of aerobic exercise intervention program was MYR 1344.82/Health Status.

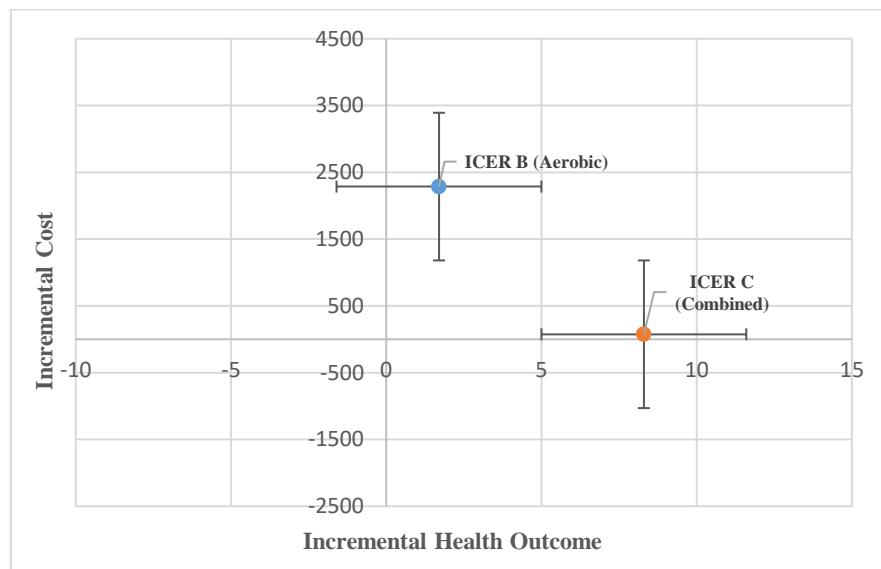


Figure 1
Cost-Effectiveness Plane (CEP) with mean ICER values for aerobic exercise and combined exercise program in Malaysia

The above figure demonstrates the mean Incremental Cost Effectiveness Ratio (ICER) values for aerobic exercise intervention program (ICER B) and combined exercise intervention program (ICER C). Mean of ICER B and the mean of ICER C both fell in the north-east quadrant of CE plane stating that both the intervention programs were more effective and costlier compared to no exercise group. In

addition, the mean ICER C positioned itself much lower than the mean ICER B in the north-east quadrant of CE plane. Thus, it shows that the combined exercise is more effective and less costly compared to aerobic exercise program.

5.DISCUSSION

Participants in the aerobic and combined exercise groups had improvements in the perceived level of mobility, as majority of the T2DM individuals reported to 'no problem' in mobility. Reason behind the evident perceived improvement in mobility could be attributed to the exercise interventions introduced to them. This evidence of beneficial impacts of exercise have been supported by Aoki and colleagues¹⁹ who acknowledged, individuals with T2DM may

experience limited joint mobility due to glycation of joint structures, and hence flexibility training such as stretching activities are extremely essential for maintenance of full range of motion (ROM) of joints. Apart from that, both the exercise regimes perhaps escalated the range of movement at the joints, and consequently more synovial fluid was released into the joints, which perhaps finally improved the level of mobility of the T2DM individuals.²⁰

Diabetes and Lifestyle modification

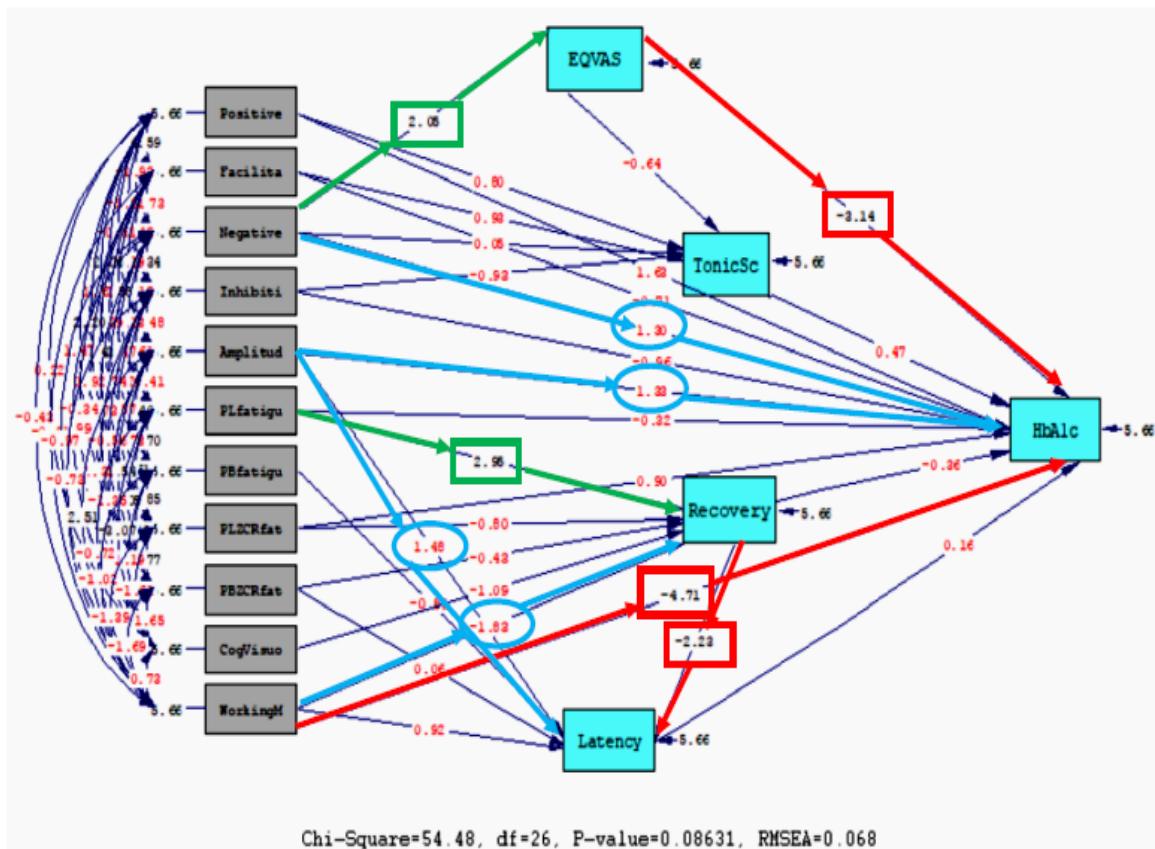


Figure 2
Representing outcomes of structural equation explaining inter-dependent and additive roles of multiple mood states; emotional aspects; psychobiological and muscle fatigue factors and cognitive factors on modification in HbA1c levels evident among middle-aged Malaysian T2DM patients

Further to that, effectiveness of combined exercise intervention was also supported by Herriott et al.²¹ who emphasized on improvement in the level of flexibility. Apart from the observed improvements in mobility, perceived improvement in the levels of self-care, usual activities, pain in aerobic and combined exercise group were also evident, which were supported by the findings of the study done by Myers et al., in 2013²².

Findings of beneficial impact of combined training on cognitive comprehension score

revealed higher-order cognitive comprehension, in the form of visual motor integration¹⁶⁻¹⁷ and configurational ability¹⁵, which was evident amongst participants in Malaysia. Combined exercise participants were required to engage in both aerobic as well as resistance training, which perhaps improved level of mobility²³ and visual-motor engagement and integration¹⁵ in those T2DM individuals. Combined exercise was also evident as effective in improving working memory score of the participants, which Cipolotti

and Warrington¹⁵ postulated, as improvement in elaborative encoding and probable development in the own encoding strategy of those T2DM individuals, in enhancing their level of working memory.²⁴⁻²⁵ The structural model (Figure 2) however clarified the significance of improvement in working memory (denoted by red line) and in perceived health-status (denoted by green line) in reducing level of HbA1c. Apart from those direct influences, mediating contribution of mood changes and autonomic indices of emotionality were also evident, which implied that the T2DM participants who had higher negative mood-states, reported to have better health status, and also higher working memory which finally contributed behind improvement in glycaemic regulation (HbA1c).

Now, the most interesting part in the CEA was the point estimate showed that incremental cost per health status for combined group compared to aerobic exercise group had positioned in a place in the cost effectiveness plane where it clearly indicates that combined exercise program is more effective and less costly than aerobic exercise program. This has happened because the incremental health status score for combined group was higher than aerobic group. As a result, the higher cost of combined exercise program was soaked up by the higher rate of improvement in health status over the time. Hence, in this set up, combined exercise program was the most cost effective compared to other alternative. This outcome was supported by another study done to measure the cost effectiveness of exercise interventions in T2DM population in Canada.²⁶

6.CONCLUSIONS

This research revealed efficacy of both aerobic and combined exercise intervention in improving overall health status of T2DM individuals from a socio-psychological perspective. Combined exercise program was evident as the most cost effective and best effective intervention program.

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8. CONTRIBUTION OF AUTHORS

Conceived and designed the experiments:

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Collected data and performed the experiments:

FaS, SrS, SoS

Contributed with materials/analysis tools:

FaS, RoM, SrS, SoS, WmI

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Wrote the paper: FaS, SoS, SrS

Checked and edited the format of the paper:

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Final approval: FaS, SrS, SoS, MsI

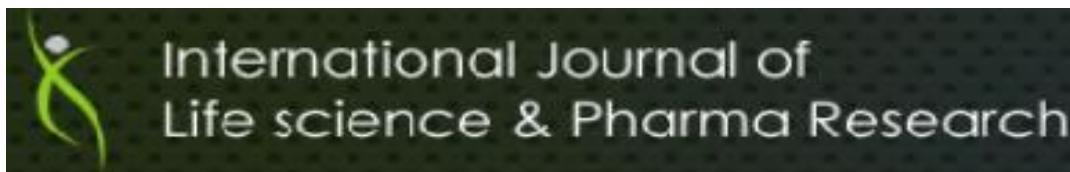
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IMPACT OF COORDINATION TRAINING REGIMES ON PREDICTORS OF DEXTERITY IN MODULATING COORDINATION IN YOUNG RECREATIONAL PLAYERS

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ABSTRACT

Present study intended to compare the efficacy of conventional coordination training (CCT), electromyography (EMG)- assisted perceptual motor training (PMT) and combination of both interventions (CI) in improving ideomotor processes in young-adult recreational athletes identified as having coordination deficiency (CD). This study was carried out in the experimental laboratory of the Dept. of Exercise & Sport Science, in Univ. Sains Malaysia, Kelantan, Malaysia. 80 young-adult eighty participants (18 - 24 years) from Kelantan province of Malaysia were screened following identical selection criteria and were matched according to extent of CD. Thereafter participants were subjected to pre-intervention analyses were carried out based on evaluation of bilateral & cross-lateral coordination and analysis of precision motor efficiency based on dexterity performance carried out both in lower and higher difficulty levels. After that, participants were randomly categorized into 4 groups (1 control and 3 experimental groups, with n = 20/group). Control group (Gr. I) participants did not receive any intervention, Group II participants received CCT; Group III received training of EMG-PMT and Group IV participants received CI. Thus, participants of the experimental groups were introduced to their respective intervention training, following a protocol for 15-20 minutes/day; 2 days/ week; for 16 weeks. Intensity and frequency of intervention training were gradually increased (e.g., 15 minutes/session first two levels, 20 minutes/session for 3rd and 4th difficulty-levels). Mid-term evaluation was carried out after 8th week, and at the end of 16th week, post-intervention assessment was carried out. After 12 weeks of no intervention, post follow- up assessment was done to verify the extent of sustainability of the interventions. Two-way repeated measure of ANOVA revealed no improvement in dexterity tasks performed under higher difficulty level, while only EMG-PMT intervention was evident as effective in improving dexterity tasks performed under lower difficulty level.

Keywords: Movement coordination; Laterality; Dexterity

1. INTRODUCTION

Human being in life-endeavour matures through abundant processes of modifications,

which eventually brings forth relatively permanent changes in behaviour. Alike other developmental learning, in physical activity set-ups, motor educability or learning is significantly relevant,

which comprises a set of cognitive processes. These enhancements in motor efficiency bring forth subsequent relatively stable modifications in motor behaviour.¹ Genetic predispositions may be required to perform efficient motor activities, which determine the motor ability of any individual performer.² The genetic predispositions may obviously vary among individuals, but those alone cannot ensure excellence in coordinated performance. Higher-order of motor ability leads to enhancement in motor skills and coordination, which enable an individual to engage in performance of day-to-day essential chores and active daily living conveniently and without any hindrance.

In the field of sport activities, motor coordination abilities are considered as overt manifestation of motor control and regulation of motor processes of the central nervous system.² Up to the recreational level of sports performance, motor coordination may refer to an ability to accomplish some considerably tough spatio-temporal movements faster and with adequate accuracy.³ Unless a player gets conditioned or habituated with majority of the sub-components of movement coordination, deficiencies in coordination tasks become obvious in almost all the activities.⁴⁻⁵ Previous researches although confirmed that coordination deficiency affect performance of sports and especially in activities requiring both gross and fine motor skills, this inhibitive impact of deficiency in coordination however is not universally accepted phenomena.⁶⁻¹¹ Numerous other researches contradicted these aforementioned phenomena, and those researches evidenced that precisely, coordination deficiency may appear subtle in gross-motor skills activities, associated with balance, gait¹²⁻¹³, reaction ability¹⁴⁻¹⁸ and laterality¹⁷⁻²⁰ and with fine-motor skills deficits, such as, dexterity¹⁹ etc. precision tasks²¹⁻²² as well.

In order to clarify the intricate processes involved in motor coordination in sports, Koch and colleagues²³ proposed the concept of embodied cognition that explains how the perceptual and motor systems of a player interacts with the external environment. Based on the embodied cognition, the ideomotor process regulates the cognitive mechanisms to select the voluntary action.²³ As Thomaschke²⁴ hypothesized, the cognitive mechanism associated with ideomotor process involves motor-visual priming, which signifies that the response to one perceptual pattern is influenced by another

previously exposed stimulus. This priming could be both positive, which speeds up processing, and negative that lowers the speed of information processing²⁵ and perceptual²⁶ and conceptual²⁷ in nature.

Apart from that, other researches on motor coordination related aspects revealed that, coordination training interventions enhancing posterior alpha activity in the frontal as well as parietal region²⁸ improved procedural memory, and hence resulted in higher-order bilateral symmetry in rotational coordinative activities.²⁹ Similar enhancement in bilateral symmetry and latero-spatial coordinative performances were also evident amongst Malaysian recreational players.¹⁷⁻²⁰ Thus, these two processes were conceived to explain on the processes associated with gross as well as precision motor skill and coordinated movements. Current study intends to investigate on the mechanisms involved in precision or fine motor skill activities.

The fine motor skill task or precision motor task is essentially considered as the manual dexterity task, which refers to involvement of the coordination of small muscles. Dexterity in this context involves the harmonious action simulation by hands and fingers, with visual synchronization.³⁰⁻³² We intended to focus our research on the motor-visual priming.²⁵ Thomaschke²⁴ processes involved in the neuromuscular steadiness-dependent visual-motor integration³³ associated with precision motor task. We also hypothesized role of certain latero-spatial and ipsilateral coordinative processes mediating improvement in neuromuscular steadiness-dependent dexterity task. Further to that, we wanted to explore into differential roles of coordination enhancing training regimes³⁴⁻⁴¹, which were evident to facilitate in gross motor skill performances, whether those can improve fine-motor skills as well.

These intervention techniques are designed for differential purposes, as conventional coordination training regimes are meant to enhance in the ability to perform difficult spatio-temporal movement structures, by engaging in coordination training programmes, such as – balance training symmetry-asymmetric movements, acrobatic exercises, visuo-motor (eye-hand) coordination skills training, etc.^{34,36}, EMG-assisted perceptual-motor training intended to realize specific patterns of muscle activation involved in a specific movement and integrated signals based on muscle synergies.³⁹⁻⁴¹ There is no

such available literature regarding combined effect of conventional coordination training and EMG-assisted perceptual coordination training on developing motor coordination of the sports performance in Malaysian as well as in Bangladeshi contexts. These limitations in the critical scrutiny of existing reported literatures, delimit the opportunities of methodologically compatible realistic selection of sub-components of both conventional and EMG-PMT intervention techniques in adapted development of a combined coordination intervention technique, which could be tailored for enhancement in motor and movement coordination deficiencies evident amongst Malaysian and Bangladeshi recreational athletes diagnosed as having coordination deficiencies. Hence, at this outset this research project got motivated to include another intervention plan, which would combine integrated components of conventional coordination training and EMG-assisted perceptual motor training as well, to observe whether the combined introduction can provide any differential benefits compared to the hypothesized outcomes of conventional and EMG-assisted intervention training alone.

Based on such paradigms in this study, we planned on categorizing intervention technique into three groups. Recreational players were targeted as the participants, who were assumed to get benefitted from the information received about their physiological, psychological and psychobiological status pertaining to their problems of coordination. Therefore, in this present research study three types of coordination training were used, namely, Conventional Coordination Training; EMG-assisted Perceptual Motor Training and Combined Training of Conventional Coordination Training and EMG-assisted Perceptual Motor Training. Here, we wanted to clarify further the reasons behind conducting this experiment. Previously numerous studies although hinted up on beneficial impacts of interventions on improving the gross-motor

skills activities, associated with balance, gait, reaction ability and laterality, while effectiveness of those training regimes on fine-motor skills deficits, such as, dexterity, are not yet confirmed. In understanding the reasons behind fine-motor skill deficiencies we intended to have more -depth analysis on roles of ideomotor performance processes and procedural memory processes. These two unconscious processes determine reasons behind coordination deficiency and probable ways for enhancement in coordination as well. While ideomotor process is more concerned about selection of movements and the cognitive aspects of movements, procedural memory also involves cognitive process as implicit memory, which stores information about "how to do" a skilled motor action. Thus, this study purports to investigate on differential roles of intervention techniques in modulating both ideomotor and procedural memory processes, and roles of these processes on improvement, if any, of the neuromuscular-steadiness dependent fine-motor skill involved in dexterity tasks.

2. METHODS

2.1 Participants

The present study was a confirmatory random assignment experiment involving a pre-and post-intervention design with a no-intervention control group of participants. For this experiment, sample size was calculated using G power 3.1.7.⁴² The power of the study is set at 95% with 95% confident interval and the effect size F at 0.20. Total required sample size was calculated as 80. Considering the possibility of drop-outs, one hundred and nine young adult recreational players having CD were recruited as participants (mean age = 21.47 and SD = 1.38). They were living in and around Kota Bharu and they were communicated through the student population of Health Campus of USM (in Kota Bharu, Malaysia).

[1] -- Friday, September 18, 2015 -- 17:54:18

F tests - ANOVA: Repeated measures, within-between interaction

Analysis: A priori: Compute required sample size

Input: Effect size f = **0.20**

α err prob = **0.05**

Power (1- β err prob) = **0.95**

Number of groups = **4**

Number of measurements = **4**

Corr among rep measures = 0.5

Nonsphericity correction ϵ	=	1
Output: Noncentrality parameter λ	=	25.6000000
Critical F	=	1.9211026
Numerator df	=	9.0000000
Denominator df	=	228
Total sample size	=	80
Actual power	=	0.9595017

Figure 1**Sample size calculation report**

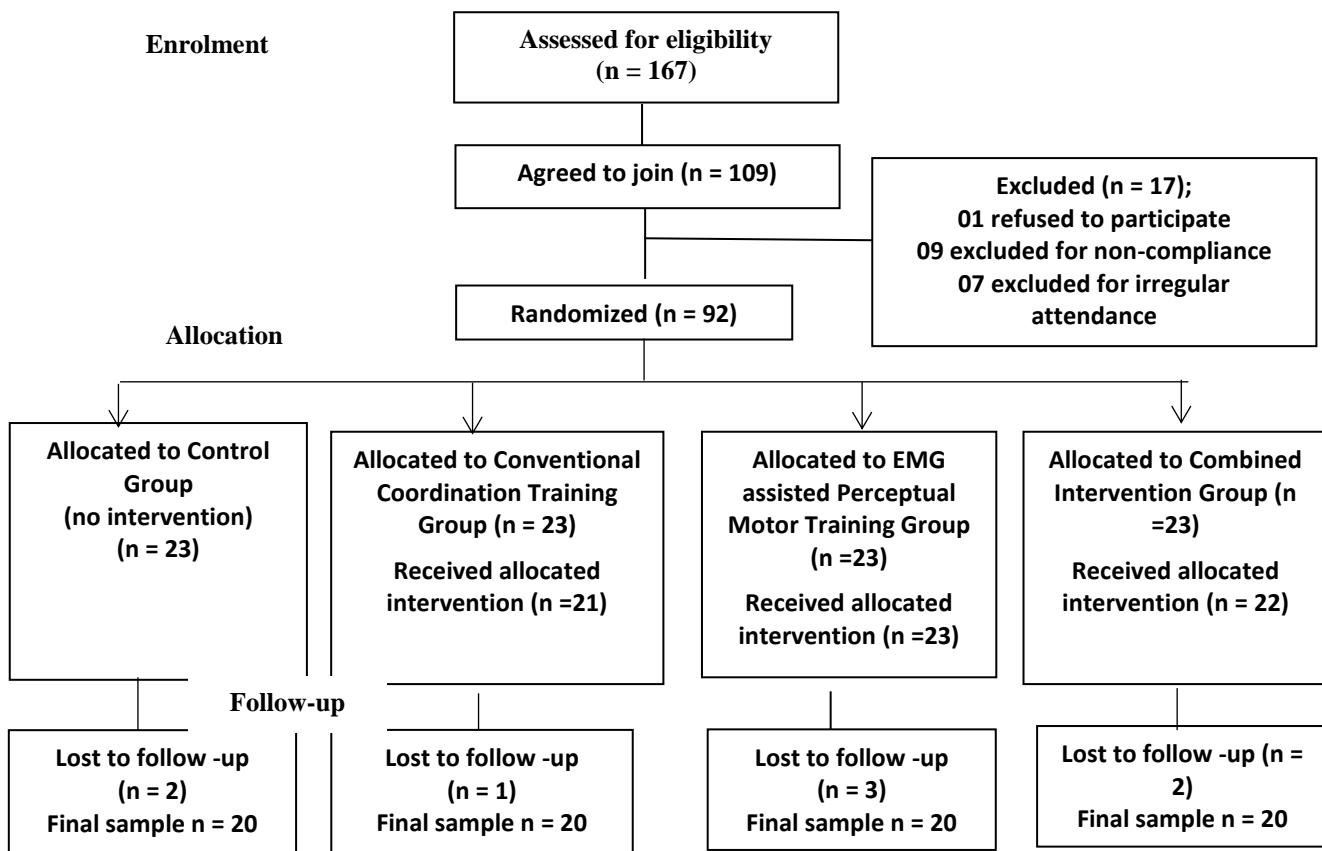
Selection of the participants was based on the Sherrill Perceptual-Motor Screening Checklist⁴³ and Adult Developmental Coordination Disorder Checklist (ADC).⁴⁴

2.2 Materials Used

For this experiment, some self-report inventories were administered along with equipment for psychomotor evaluations were required. For all these evaluations following equipment and test materials were required.

- 1) Adult Developmental Coordination Disorder Checklist (ADC) and Sherrill Perceptual Motor Screening Test, for evaluation of extent of coordination disorder evident among the participants;

- 2) Mirror Drawing Test Apparatus (Udyog, India 2013), was used for evaluation of left and right lateral motor control (both in clockwise and counter-clockwise direction);
- 3) Two-Arm-Coordination Tester (Udyog, India 2013), for evaluation of extent of bilateral symmetry in motor and movement coordination;
- 4) Neuromuscular Steadiness Tester (Udyog, India 2009), for evaluation of both lower and higher difficulty level Dexterity performance ability;
- 5) Additional materials required for test: – Stopwatch; Marker; Screens etc.

**Figure 2** CONSORT Diagram Showing Flow of Participants

2.3 Procedure

The detailed procedure which was followed to carry out this research, has been described below in the following steps –

STEP I – At first one-hundred and sixty-seven young-adult recreational athletes were invited for assessment of their ability to coordinate movements. For that, they were evaluated by the experts based on the Adult Developmental Coordination Disorder Checklist (ADC) and Sherrill Perceptual Motor Screening Test. Those who were identified as having coordination deficiency (CD), were invited to take part in this study as volunteers (n= 117). 109 individuals agreed to take part in this study (See Fig. 2 for CONSORT diagram). Finally, 92 participants agreed to take part in this experiment, and after they signed the consent form all of them were equally and randomly categorized (following the Research Randomiser Program)⁴⁵ into four groups; Group A, i.e., control group or no intervention group (n = 23); Group B i.e., experimental group I (n = 23), received conventional coordination training; Group C i.e. experimental group II (n = 23), received EMG

assisted perceptual motor training and Group D – Experimental Group III, who received combined intervention of both conventional coordination training and EMG assisted perceptual motor training (n = 23). Allocation of the groups was concealed, and all the intervention sessions were supervised by qualified exercise trainers. To prevent methodological bias, the participants, researcher and the trainers engaged in this study were kept blinded. Furthermore, participants were told by the researcher, that they had all the rights to withdraw themselves from the study whenever they felt distress and uncomfortable.

STEP II – Participants were taken to the laboratory of the exercise and sport science at Univ. Sains Malaysia for the group-wise baseline assessments. For the assessments, participants were subjected to evaluations of psychomotor parameters, such as, Motor Learning Ability, Two Arm Co-ordination test and Dexterity or Neuromuscular Steadiness, which were carried out following standard procedures.^{14,46-48} Information on these procedures and the gazettes are being provided in nut-shell.

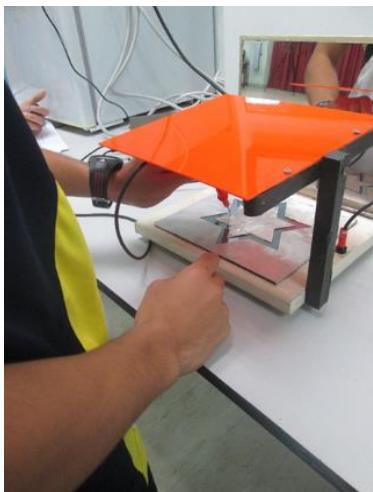


Figure 3: Motor control test using Mirror Drawing Apparatus



Figure 4: Two- Arm Coordination Test employed for evaluation of bilateral motor and movement coordination



Figure 5: Neuromuscular steadiness tester used for test of Dexterity

For assessment of motor learning ability of the participants, the Mirror Drawing or Mirror Tracing Apparatus (see Figure 3) was used. This equipment enables the researchers to avail information on the level of hand-eye coordination of the participants and their ability to reverse and motor re-education. For this assessment, participants are asked to follow the path designed like a star, with an aid of the metal stylus. This task is required to be performed by watching the mirror image of the star. There is an impulse

counter that is attached to the unit which indicates the error committed in tracking the path. The Mirror drawing apparatus used in the tracing task is mainly a measurement of visual-spatial task. Researchers⁴⁹ have identified that participant who are left handed (right cerebral hemisphere) take lesser time in completing the task compared to that of right handed (left cerebral hemisphere) participants. It was also observed that right hand dominant individuals are good in emotional, nonverbal and visual spatial task performance and

those who are left hand dominant are excellent in verbal and analytical tasks.

Next, we are providing information on evaluation of bilateral coordination, which is required to be performed employing two hands of the participants, and hence this test is also termed as two-arm coordination test, which is evaluated by using the Two-Arm Coordination Apparatus (for assessment of extent of symmetry observed in Bilateral Motor Coordination Ability). Coordination is important aspect of motor performance and is very essential for task involving both arms. The apparatus consists of two handles and the two handles are attached to a metal-tipped pointer at the centre of the handles. Participants are instructed to move the metal pointer in the path that resembles that of a star, by manipulating the handles with both the hands. An impulse counter attached to the device denotes the error committed by the participants during the performance of the task.

Finally, in this section information on the test of dexterity ability is being provided. For the assessment of dexterity ability, which is also termed as neuromuscular steadiness or precision motor performance, the Neuromuscular Steadiness Test Apparatus was used. This apparatus is used to test the extent of steadiness of the limb in performing a task. Measurement of steadiness is a measurement of the psychomotor ability of the participant. The apparatus consists of a metallic arched disc-structure consisting of nine holes of different diameter and a metal tipped pointer stylus. The biggest of the nine holes, measures as big as 1 cm diameter, which gradually gets reduced by 1mm (or .1 cm) and hence, the last hole contains only 2mm diameter. The disc is centrally affixed and hence, it can be rotated to enable the person to hold a metal tipped pointer stylus inside the holes steadily. The task of participants is to hold the stylus steadily for 10 seconds, so that it does not touch outside metallic part of the wholes. Any contact with the metallic edge around the hole is supposed to record error by the impulse counter attached to the apparatus.

After the baseline evaluations, these participants were subjected to their assigned intervention programs, as Control group (Gr. I) participants did not receive any intervention, Group II participants received CCT; Group III received training of EMG-PMT and Group IV participants received CI. Participants of the experimental groups were introduced to their respective intervention training. Protocol for the

interventions was scheduled as 15-20 minutes/day; 2 days/ week; for 16 weeks, followed by gradual and identical increment in difficulty level (15 minutes/session first two levels, 20 minutes/session for 3rd and 4th difficulty-levels). After 8 weeks of intervention, mid-term evaluation was carried out, and after 8 more weeks of intervention, post-intervention assessment was carried out at the end of 16th week. After 12 weeks of no intervention, post follow-up assessment was done to verify the extent of sustainability of the interventions.

Participants selected for intervention regimes were subjected to the training sessions for 15 - 20 minutes per session/ two sessions per week for 16 weeks (32 sessions in total). Control Group participants continued with their regular sports activities without being exposed to any of the therapeutic interventions. Participants of the experimental groups were attending such sessions for two-days per week for altogether 16 weeks. At the end of the 8th week, mid-term assessment was carried out following the protocol identical with the pre-intervention or baseline assessment protocol and again after the 16th week post-intervention assessment was carried out to evaluate impacts of therapeutic intervention, if any, in ameliorating movement coordination among the recreational players.

2.4. Statistical Analysis

The data obtained from the experimental trials were treated to obtain the descriptive outcomes of the data. A two-factor ANOVA with repeated measures were used to compare data from the four experimental trials. Simple main-effects analyses and Bonferroni post hoc tests were undertaken when ANOVA revealed a significant interaction. The significance criterion was set at $p<0.05$ and for all statistical analyses all data were analysed by employing SPSS version 24.0 software programs. Apart from that, multiple linear regression analyses were carried out to evaluate predictive relationships between the dependent and independent measures of psychological attributes associated with procedural memory and ideomotor mechanism and the resultant changes, if any on the coordinative performance observed amongst the recreational players having CD.

3. RESULTS

Outcomes of this study pertaining to descriptive information of dexterity task performed under lower and higher difficulty level

are presented in the tables 1 and 2. Apart from that, outcomes of the pairwise comparison (tables 3 and 4) and multiple linear regression report (Table 5) are also detailed.

Table 1

Descriptive statistics of dexterity performance with lower difficulty level score across the different groups and phases

Groups & Statistics Phases	Gr. - 1 - Control group Mean/SD	Gr. - II - Conventional coordination Group Mean/SD	Gr. III - EMG-PMT EMG-assisted PMT Group Mean/SD	Gr. IV - CI Combined Intervention Group Mean/SD
Pre	50.75/24.00	52.55/16.58	50.90/4.91	53.05/19.11
Mid	53.25/22.51	46.25/9.51	38.20/15.89	44.95/27.33
Post	63.50/22.37	42.15/28.24	35.45/13.07	54.40/21.47
Follow up	67.75/18.63	48.40/11.94	43.05/13.71	61.90/33.37

Table 2

Descriptive statistics of dexterity performance with higher difficulty level score across the different groups and phases

Groups & Statistics Phases	Gr. - 1 - Control group Mean/SD	Gr. - II - Conventional coordination Group Mean/SD	Gr. III - EMG-PMT EMG-assisted PMT Group Mean/SD	Gr. IV - CI Combined Intervention Group Mean/SD
Pre	56.90/24.06	54.90/23.70	55.20/20.30	53.60/31.87
Mid	54.90/23.70	47.06/16.29	45.80/27.99	54.90/23.70
Post	63.10/22.61	44.20/14.27	40.80/6.84	47.10/29.05
Follow up	68.60/19.39	56.60/18.23	47.20/14.17	68.70/28.86

Outcomes of the mean differences observed between the groups across different phases are represented in Tables 3 and 4. Pairwise comparisons for dexterity tasks performed under lower (Table 3) as well as higher (Table 4)

difficulty levels are represented across different phases and among different groups, which clarified inter-group differences evident across phases of evaluations.

Table 3

Pairwise comparisons of dexterity with lower difficulty level scores observed amongst different groups of participants across different phases

Phases	(I) Different Intervention Group	(J) Different Intervention Group	Mean Difference (I-J)	95% Confidence Interval for Difference			
				Std. Error	Sig.	Lower Bound	Upper Bound
Pre	Control Group	Conventional coordination Group	.200	5.568	1.000	-14.885	15.285
		EMG-assisted PMT Group	-.150	5.568	1.000	-15.235	14.935
		Combined Intervention Group	.700	5.568	1.000	-14.385	15.785
	Conventional coordination Group	EMG-assisted PMT Group	-.350	5.568	1.000	-15.435	14.735
		Combined Intervention Group	.500	5.568	1.000	-14.585	15.585
		Combined Intervention Group	.850	5.568	1.000	-14.235	15.935
	EMG-assisted PMT	Conventional coordination Group	11.100	6.317	.498	-6.014	28.214
		EMG-assisted PMT Group	17.800	6.317	.037*	.686	34.914
		Combined Intervention Group	8.300	6.317	1.000	-8.814	25.414
Mid	Control Group	EMG-assisted PMT Group	6.700	6.317	1.000	-10.414	23.814
		Combined Intervention Group	-2.800	6.317	1.000	-19.914	14.314
		Combined Intervention Group	-9.500	6.317	.821	-26.614	7.614
	Conventional coordination Group	Conventional coordination Group	17.250	6.945	.091	-1.565	36.065
		EMG-assisted PMT Group	25.300	6.945	.003*	6.485	44.115
		Combined Intervention Group	9.100	6.945	1.000	-9.715	27.915
	EMG-assisted PMT	EMG-assisted PMT Group	8.050	6.945	1.000	-10.765	26.865
		Combined Intervention Group	-8.150	6.945	1.000	-26.965	10.665
		Combined Intervention Group	-16.200	6.945	.134	-35.015	2.615
Post	Control Group	Conventional coordination Group	19.350	6.692	.030**	1.220	37.480
		EMG-assisted PMT Group	24.700	6.692	.003**	6.570	42.830
		Combined Intervention Group	-1.150	6.692	1.000	-19.280	16.980
Follow - Up	Control Group	Conventional coordination Group					
		EMG-assisted PMT Group					
		Combined Intervention Group					

Conventional coordination Group	EMG-assisted PMT Group	5.050	6.247	1.000	-11.874	21.974
EMG-assisted PMT	Combined Intervention Group	.300	6.247	1.000	-16.624	17.224
	Combined Intervention Group	-4.750	6.247	1.000	-21.674	12.174

*p<.05; **p<.001

Table 3 shows the interaction effect of intervention groups and various phases on the level of dexterity scores evident across phases and groups, which were performed under lower difficulty level. In the pre-intervention phase, no significant difference between the various intervention groups were observed. However, in the mid-term as well as during the post-intervention assessment phases, compared to the control group significant improvement in dexterity

performance was evident only among the participants of the EMG-PMT group. During the follow up assessment session, however, compared to the control group participants, their counterparts both in the EMG-assisted PMT and conventional coordination groups (CCT) were evident to display better dexterity performance outcomes.

Table 4

Pairwise comparisons of dexterity with higher difficulty level scores observed amongst different groups of participants across different phases

Phases	(I) Different Intervention Group	(J) Different Intervention Group	Mean Difference (I-J)	95% Confidence Interval for Difference			
				Std. Error	Sig.	Lower Bound	
Pre	Control Group	Conventional coordination Group	-16.700	10.815	.788	-46.895	13.495
		EMG-assisted PMT Group	-5.300	10.815	1.000	-35.495	24.895
		Combined Intervention Group	-3.700	10.815	1.000	-33.895	26.495
	Conventional coordination Group	EMG-assisted PMT Group	11.400	10.815	1.000	-18.795	41.595
		Combined Intervention Group	13.000	10.815	1.000	-17.195	43.195
		Combined Intervention Group	1.600	10.815	1.000	-28.595	31.795
Mid	EMG-assisted PMT	Control Group	17.900	9.355	.382	-8.220	44.020
		Conventional coordination Group	9.100	9.355	1.000	-17.020	35.220
		EMG-assisted PMT Group	14.100	9.355	.843	-12.020	40.220
	Control Group	Combined Intervention Group	-8.800	9.355	1.000	-34.920	17.320
		EMG-assisted PMT Group	-3.800	9.355	1.000	-29.920	22.320
		Combined Intervention Group	5.000	9.355	1.000	-21.120	31.120
Post	EMG-assisted PMT	Control Group	27.100	10.199	.070	-1.376	55.576
		Conventional coordination Group	8.200	10.199	1.000	-20.276	36.676
		EMG-assisted PMT Group	16.000	10.199	.753	-12.476	44.476
	Control Group	Combined Intervention Group	-18.900	10.199	.433	-47.376	9.576
		EMG-assisted PMT Group	-11.100	10.199	1.000	-39.576	17.376
		Combined Intervention Group	7.800	10.199	1.000	-20.676	36.276
Follow - Up	Control Group	Conventional coordination Group	27.400	8.981	.026*	2.324	52.476
		EMG-assisted PMT Group	-.100	8.981	1.000	-25.176	24.976
		Combined Intervention Group	21.400	8.981	.136	-3.676	46.476
	EMG-assisted PMT	EMG-assisted PMT Group	-27.500	8.981	.025*	-52.576	-2.424
		Combined Intervention Group	-6.000	8.981	1.000	-31.076	19.076
		Combined Intervention Group	21.500	8.981	.132	-3.576	46.576

*p<.05; **p<.001

Table 4 shows the interaction effect of intervention groups and various phases on the level of dexterity, which were performed under higher difficulty level of performance. In the pre-intervention phase, mid-intervention phase as well as post-intervention phase, no significant difference between the various intervention groups were observed. During the follow up assessment session, however, outcomes revealed that participants of the EMG-assisted PMT group had better improvement compared to their

counterparts in the conventional coordination training group. No other comparative differences between control group and experimental groups and also between the experimental groups were evident. Outcomes thus revealed that, in case of the recreation players having coordination deficiencies, in improving dexterity performance (performed under higher difficulty level), compared to all other techniques, EMG-assisted PMT training appeared the most effective intervention technique.

Comparative evaluation reports however clarified that, in cases of dexterity tasks performed under lower difficulty levels only, EMG-PMT intervention was evident as effective in enhancing dexterity performance. While up to the post-intervention phase of analyses, no other intervention appeared effective, although along with the EMG-PMT, impact of conventional intervention was evident only at the post-follow-up phase. Thus, outcomes for the recreational players having CD for this parameter revealed that, while dexterity tasks were performed under

lower difficulty levels, only EMG-PMT intervention technique was evident as sustainably effective in improving dexterity performance. For the dexterity tasks performed under higher difficulty levels, in improving the levels of dexterity, up to the post-intervention phase of analyses, no intervention techniques appeared effective. While impacts of CCT and EMG-PMT were evident at the post-follow-up phase, which cannot be attributed to the efficacy of those intervention techniques employed.

Table 5

Multiple Linear Regression Outcomes - explaining dexterity scores obtained under higher difficulty level, evident among EMG-PMT group of players at post-intervention phase

Model: a Dexterity Performance with Higher Difficulty level	Unstandardized Coefficients		Beta	Correlations			Collinearity Statistics			
	B	Std. Error		t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	-25.587	35.041		-.730	.470					
Left lateral motor control	.690	.226	.398	3.056	.004	.404	.464	.379	.909	1.100
Bilateral Movement	-.016	.007	-.298	-2.290	.028	-.274	-.365	-.284	.910	1.098

^aF (2, 17) = 6.177, p = .000, Adj. R² = 39.9%

In Table 5, the model *a* emerged significant as the independent factor such as, bilateral movement of the participants of the EMG-PMT group, observed in the pre-intervention phase was found to put inhibitive impacts on the dependent measure of dexterity performance with higher difficulty level perceived in the post-intervention phase. Further to that, left lateral motor control evident in the pre-

intervention phase was found directly associated to the dependent measure of dexterity performance with higher difficulty level. These predictors together could explain 39.9% variance of changes in the extent of dexterity performance evident during the post-intervention phase, among the participants of EMG-PMT group, which were performed under higher difficulty level.

4. DISCUSSION

Results of the experiment represented in Tables 1 and 2 depicted considerable extent of improvement in EMG-PMT and CCT intervention groups. Descriptive information did not reveal any improvement in the combined intervention (CI) group. Analyses of mean differences were done to investigate on impacts of the intervention techniques on the dexterity performance. Evaluation of dexterity performance however was carried out both under lower (Table 3) and higher (Table 4) difficulty levels, which revealed no beneficial impact of conventional coordination training or CCT in improving dexterity performance with higher difficulty level. But, the post-follow-up assessment however revealed that both under lower difficulty and under higher difficulty, beneficial impacts of CCT were evident. Outcomes thus revealed that, conventional training regimes were not enough in

improving precision motor skill evaluated by dexterity task, which was a neuromuscular-dependent task. This finding of no improvement in dexterity contradicts findings reported in the experiment of Erickson and Kramer.⁵⁰ Reason behind this contradiction could be traced in the neuromuscular-dependent task, which was performed in this experiment, were different compared to what was carried out in the experiment of Erickson and Kramer.⁵⁰ Thus, it should be acknowledged that, outcomes of the precision tasks performed in these two experiments were not similar, and their findings cannot be considered as convincingly decisive. Further to that, in improving dexterity performed both under lower (Table 3) and higher (Table 4) difficulty level, no impact of combined intervention technique was confirmed. This finding of no impact of combined intervention however contradicted the findings of the previous study of Schoemaker et al.⁵ who confirmed the

improvement in precision motor performance followed by combined intervention.

In case of participants of the EMG-PMT group on the contrary, outcomes of dexterity task performed under lower (Table 3) and higher (Table 4) difficulty levels, revealed differential characteristic feature. In case of dexterity tasks performed under lower difficulty level, although sustainable beneficial impact of EMG-assisted perceptual motor training was evident, while difficulty levels got increased, until the post-intervention phase, no such beneficial impact of EMG-PMT on dexterity at all was confirmed. The observed sustainable improvement in dexterity, however got supported by the findings of Schoemaker et al.⁵ who evaluated the effectiveness of Neuromotor dependent perceptual coordination training and observed improved performance in MABC and precision motor performance.

Here, at this point we wanted to investigate, as to why followed by EMG-PMT intervention, improvement in dexterity performance was evident under lower difficulty level only, and not under the higher difficulty level. For that, we intended to focus onto the in-depth analyses of the regression outcomes, which suggested combined contribution of both procedural memory and ideomotor processes involving mostly latero-spatial and ipsilateral motor coordination, which might have caused alteration in fine-motor control evident among participants of the EMG-PMT group. Regression outcome revealed that, out of all the parameters evaluated, only one valid relationship model emerged as significant, in which ipsilateral and bilateral movement coordination task related aspects were found associated with fine (viz., dexterity task) motor skill dependent aspects. Based on the shared contribution of two mediating and/or moderating predictors (viz., left lateral motor control and bilateral movement skills). Two independent predictors associated with two factors of procedural memory, viz., left-lateral motor control and bilateral movement efficacies emerged as significant contributors, which had additive contributory impacts, that explained changes in one ideomotor mechanism (viz., dexterity). In order to have a better understanding on these additive contributory relationships, we paid attention to collinearity statistics and beta coefficient of the regression outcomes.

Higher tolerance index observed in collinearity statistics suggested that – in

explaining dexterity tasks performed under higher difficulty level, very high extent of variance in left-lateral motor control (90.9%) was not predicted by bilateral movement control. Similarly, very high extent of variance in bilateral movement control (91%) was not predicted by left-lateral motor control. The model however also explained that for every 1% improvement in bilateral movement control, .298% improvement in dexterity would occur, whereas, for every 1% enhancement in left-lateral motor control, would cause .398% of reduction in dexterity among the EMG-PMT group of participants. Hence, the reasons behind poor outcomes of dexterity performance under higher difficult level evident among EMG-PMT intervention, got clarified by the outcomes of regression analysis. Outcomes finally implied that if contribution of improvement in left-lateral motor control is controlled or regressed, those who couldn't perform better in bilateral movement coordination task, as the difficulty level of dexterity task got increased, could not perform well. Precisely the outcome clarified that, those who lacked in left-lateral motor control, if they were also unable to improve their bilateral movement coordination, faced problems in dexterity tasks performed under higher difficulty levels.

Here, we paid attention to the scenario for both the CCT and CI intervention techniques, as to why those were not effective in inducing desired improvement in dexterity. The CCT, earlier in previous studies was evident as effective intervention technique in improving majority of the gross motor skills^{17-18,51} which were characteristically both procedural memory and ideomotor performance mechanisms. But this technique could not ensure any beneficial impacts in improving dexterity as measure of precision – motor skills. Dexterity being a precision task, it requires fine motor skill and optimal extents of visuo-motor integration ability³³, which is an important function for motor control and motor learning. Conventional coordination training protocol although included fine motor skill tasks, engagements in other coordinative tasks perhaps got the participants more focussed onto gross-motor control and coordination. This enhanced focus, perhaps also got them aroused. Thus, increased arousal and over-engrossing focus onto gross motor tasks, perhaps reduced the focus onto visual- motor integration, reduction of heightened emotionality and neuromuscular stability, which got them impaired to engage in better dexterity

performance. The combined intervention, which contained some of the components of CI and EMG-PMT, was also evident as not effective at all in improving dexterity. This could have happened perhaps for the reason that the recreational athletes who received both conventional and combined intervention training, were more kinematically oriented and hence they were probably more focussed onto directional issues pertaining to motor and movement control.

Here at this point, impact of EMG-PMT on post-intervention outcome of neuromuscular steadiness or dexterity performance is being given emphasis. Marked improvement in dexterity performed under lower-level of difficult tasks was observed amongst EMG-PMT trainees. The observed outcomes received supports from previous researches⁵²⁻⁵³, who pointed out to the importance of rigorous methodology of biofeedback-like intervention in EMG-PMT. Reasons behind such improvements, could be explained in terms of higher-order activation in premotor and pre-frontal cortex.⁵⁴⁻⁵⁵ In this study EMG-PMT intervention was carried out in orienting activity dependent regimes, which enhances cognitive-emotional competence⁵⁶ and results in better precision response programming.⁵⁷ Further to that, improvement in dexterity requires enhancement in neuromuscular stability and steadiness.

Apart from that, visuo-motor integration ability is also required to maintain relax yet steady dexterity of finger. Apart from kinematic focus, perhaps most of the recreational athletes had lower level of lean muscularity, i.e., they probably had more endo-meso-ectomorphic somatotype feature. While, those who got trained in EMG-PMT intervention, got training on impacts of isometric contraction and peripherally induced muscular relaxation. Furthermore, some of these participants were probably more endo-ectomesomorphic, and hence together with the benefits from EMG-PMT training, and their muscular advantages, perhaps had better neuromuscular control compared to their counterparts having endo-meso-ectomorphic features.

Apart from all these anthropometric advantages, we postulated as it was pointed out by Bar-Eli and coresearchers⁵⁸, the EMG-PMT training facilitated in higher-order neuromuscular facilitation, which worked behind enhanced performance in dexterity performed under lower difficulty. This enhancement perhaps was not

enough, as Blumenstein and colleagues⁵²⁻⁵³ cautioned, and hence could not enhance the dexterity outcomes, when the difficulty levels got increased, as those required further higher-order neuromuscular adaptation, which was not possible in the current methodological paradigm. We intend to carry out future researches to arrive at any decisive conclusion on this issue, and we also hope that, this study would encourage other researchers to carry out further replicated studies to resolve the issues highlighted in this study.

5. CONCLUSIONS

This research revealed efficacy of electromyography-assisted perceptual motor training in improving dexterity task performed under lower difficulty level, among Malaysian recreational athletes. This intervention technique was not effective in improving dexterity performed under higher difficulty level. Conventional and combined intervention techniques were not evident as effective at all in enhancement of dexterity performed under any of the difficulty levels.

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7. CONTRIBUTION OF AUTHORS

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Collected data and performed the experiments:

FaS, SrS, SoS, MaA

Contributed with materials/analysis tools:

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