EFFECT OF CORE TRAINING ON PHYSICAL & TECHNICAL CHARACTERISTICS OF NOVICE RHYTHMIC GYMNASTS

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KUALA LUMPUR

2019

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THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

CENTRE FOR SPORT AND EXERCISE SCIENCES
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

UNIVERSITI MALAYA

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Registration/Matric No: VHA110008

Name of Degree: Doctor of Philosophy

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

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EFFECT OF CORE TRAINING ON PHYSICAL AND TECHNICAL CHARACTERISTICS OF NOVICE RHYTHMIC GYMNASTS

ABSTRACT

Enhancing certain characteristics among rhythmic gymnastics (RG) is helpful in the early stages of RG training process. Using descriptive analysis in study 1, the physical & technical characteristics of 100 female Malaysian Rhythmic Gymnasts (6-9 years old) from two gymnastic clubs of Kuala Lumpur were examined. The results of study 1 showed that the mean score of the physical characteristics of the participants in the current study including power, balance, flexibility & strength placed in the range of average compared to the provided norm by Sheerin (2012). For technical characteristics, the results of study 1 showed the essential technical characteristics including jump, balance & pivot skills in this study need to improve since the scores are below 1.00. Gymnastic Federation allow scores of maximum in all level of RG is 1.00 & minimum mark of 0.50. Study 2 (Quasi-experiment), is aimed to assess the effect of the core training program on enhancing the physical & technical characteristics of the Malaysian Rhythmic Gymnasts. From the participants in study 1, 40 rhythmic gymnasts were randomly selected for study 2 which divided in intervention & control groups. Participants in the intervention group received eight weeks of the core training program as the intervention program & control group carried out their normal training without any additional training. The results of Mix within-between ANOVA on the physical variables showed that there was a significant difference in mean of: 1) vertical jump between two groups ($F=56.66$, $p<0.001$, $\eta^2=0.50$) & within three stages of time ($F=36.97$, $p<0.001$, $\eta^2=0.49$); 2) right leg balance between two groups ($F=15.93$, $p<0.001$, $\eta^2=0.30$) & within three stages of time ($F=52.26$, $p<0.001$, $\eta^2=0.58$); 3) left leg balance between two groups ($F=4.75$, $p=0.03$, $\eta^2=0.11$) & within three stages of time ($F=2.95$, $p=0.05$, $\eta^2=0.07$). There was no significant difference in the mean value of sit

& reach between two groups (F=0.17, p=0.67) & within three stages of time (F=2.85, p=0.06).Furthermore, The results of Mix within-between ANOVA on the technical variables showed that there was a significant difference in mean of 1) sit-up test between two groups (F=10.15, $p<0.001$, η^2=0.21) & within three stages of time (F=27.70, $p<0.001$, η^2=0.42); 2) scissors jump between two groups (F=14.93, $p<0.001$, η^2=0.28) & within three stages of time (F=33.69, $p<0.001$, η^2=0.47); 3) right leg balance between two groups (F=18.74, $p<0.001$, η^2=0.33) & within three stages of time (F=36.97, $p<0.001$, η^2=0.49); 4) st& erect on toes test between two groups (F=8.13, $p<0.001$, η^2=0.18) & within three stages of time (F=9.11, $p<0.001$, η^2=0.19), 5) pivot passé scores between two groups (F=10.82, $p<0.001$, η^2=0.22), within three stages of time (F=11.64, $p<0.001$, η^2=0.23). Overall, the results of the study showed the intervention program can be introduced as an effective program for improving the physical & technical characteristics of the Malaysian Rhythmic Gymnasts. The findings of the study can be used by Malaysian gymnastics coaches & gymnastics trainers to design & implement a core training program to improve the performance of Malaysian Rhythmic Gymnasts.

Keywords: Physical Characteristics, Technical Characteristics, Rhythmic Gymnastics, Core training.

EFFECT OF CORE TRAINING ON PHYSICAL AND TECHNICAL CHARACTERISTICS OF NOVICE RHYTHMIC GYMNASTS

ABSTRAK

Peningkatan ciri-ciri gimrama yang tertentu dapat membantu proses latihan pada peringkat awal dan proses pemilihan sukan ini. Kajian 1 menggunakan analisis deskriptif untuk mengkaji penentuan penguasaan ciri fizikal dan teknikal telah dilakukan kepada 100 gimnas perempuan berumur antara 6 hingga 9 dari dua kelab gimnastik di Kuala Lumpur. Skor min bagi Peserta-peserta tersebut dalam Kajian1 menunjukkan penentuan penguasaan ciri bagi kategori fizikal yang termasuk kekuatan, imbangan, lenturan dan ketangkasan adalah dalam lingkungan purata norma yang ditentukan oleh Sheerin (2012). Bagi kategori teknikal, hasil Kajian1 menunjukkan skil melompat, skil imbangan dan skil pivot yang merupakan ciri-ciri penting bagi teknikal harus diperbaiki kerana skornya adalah di bawah 1.00. Berdasarkan norma yang ditentu oleh Malaysian Gymnastics Federation, skor tertinggi untuk setiap ciri pergerakan bagi semua tahap gimrama ialah 1.00 manakala skor untuk lulus ialah 0.50. Oleh yang demikian, program latihan tambahan seperti latihan teras mungkin dapat membawa kesan kepada ciri teknikal.Kajian 2 (Eksperimen Kuasi) terhadap latihan teras dengan menjalankan ujian sebelum-selepas dan susulan dilakukan untuk menilai keberkesanan program latihan teras bagi peningkatan ciri-ciri teknikal dan fizikal terhadap ahli gimnas tersebut.Daripada sejumlah peserta gimnas dalam kajian 1, 40 orang telah dipilih secara rawak dan dibahagi kepada kumpulan intervensi dan kumpulan kawalan.Kumpulan intervensi menjalani latihan teras selama 8 minggu manakala kumpulan kawalan menjalani latihan mereka mengikut jadual latihan tanpa sebarang latihan tambahan.Hasil kajian deugan teknikANOVA ulangan mendapatipembolehubah fizikal menunjukkan perbezaan yang signifikan dari segi min: 1) Lompatan vertikal antara dua kumpulan ($F=56.66$, $p<0.001$, ñ2=0.50) dalam 3 peringkat masa ($F=10.15$, $p<0.001$,

η^2=0.21; 2) Imbangan Kaki kanan antara 2 kumpulan (F=14.93, p<0.001, η^2=0.28) dalam 3 peringkat masa (F=33.69, p<0.001, η^2=0.47; 3). Imbangan kaki kiri antara 2 kumpulan (F=18.74, p<0.001, η^2=0.33) dalam 3 peringkat masa (F=36.97, p<0.001, η^2=0.49).Min bagi duduk dan jangkau antara dua kumpulan menunjukkan tiada perbezaan yang ketara (F=0.17, p=0.67) dalam 3 peringkat masa (F=2.85, p=0.06). Menakala, hasil kajian deugan teknik ANOVA ulangau mendapatipembolehubah teknikal menunjukkan perbezaan yang signifiken dari segi min: 1) ujian bangkit tubi antara dua kumpulan (F=10.15, p<0.001, η^2=0.21) dalam 3 peringkat masa (F=27.70, p<0.001, η^2=0.42); 2) lompatan gunting antara dua kumpulan (F=14.93, p<0.001, η^2=0.28) dalam 3 peringkat masa (F=33.69, p<0.001, η^2=0.47); 3) keseimbangan kaki kanan antara dua kumpulan (F=18.74, p<0.001, η^2=0.33) dalam 3 peringkat masa (F=36.97, p<0.001, η^2=0.49); 4) berdiri tegak menggunakan jari kaki antara dua kumpulan (F=8.13, p<0.001, η^2=0.18) dalam 3 peringkat masa; 5) markah pivot passé antara dua kumpulan (F=10.82, p<0.001, η^2=0.22), dalam 3 peringkat masa (F=11.64, p<0.001, η^2=0.23).Secara keseluruhannya, kajian ini dapat dirumuskan bahawa program intervensi ini boleh diperkenalkan kepada ahli gimnas muda Malaysia bagi membantu meningkatkan ciri pergerakan fizikal dan teknikal mereka.Hasil kajian ini juga boleh digunakan oleh jurulatih gimnastik Malaysia sebagai p&uan untuk mereka dan mengaplikasikan latihan teras yang berterusan bagi meningkatkan prestasi gimnas Malaysia dalam sukan gimnastik.

Katakunci: ciri- ciri fizical, ciri- ciri teknikal, Gimnastik berirama, Latihan teras.

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest sense of gratitude to my supervisor Dr. Lim Boon Hooi who offered his continuous advice & encouragement throughout the course of this thesis. I thank him for the systematic guidance & great effort he put into training me in the scientific field. Like a charm! His challenge brought this work towards a completion. It is with his supervision that this work came to fruition. For any faults I take full responsibility. I must express my gratitude to my friend Dr Marjan Mohamadi for her continued support & encouragement, & by the patience of my mother, father & brother, sister who experienced all of the ups & downs of my research. I am extremely grateful to my parents for their love, prayers, caring & sacrifices for educating & preparing me for my future.

I am so grateful to the Sports Centre, University of Malaya for making it possible for me to study here. I give deep thanks to the professors & lecturers at the Sports Centre, the librarians, & other workers of the faculty. My special & heartily thanks to Dr Balbir, who encouraged & directed me.

Finally, I would like to thank the Serdang & Bukit Jalil National Sports Council,Gymnastics Clubs,Managements, juries, coaches, students, parents & special thanks to Ms Patrina the head coach at National Sport Council for her countless support during my research at the gymnastics club.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Introduction

Rhythmic Gymnastics (RG) is essentially a sporting procedure developed through modification of techniques & adaptations inclusive of level of competiveness, age, & many other categories of assessment. For athletes seeking to excel in RG, passionate dedication to improve their abilities becomes an increasing requirement in order to succeed in reaching personal goals (Zisi, Giannitsopoulou, Vassiliadou, Pollatou, & Kioumourtzoglou, 2009).

The RG technique was developed in the 20th Century in Central Europe. Many modes of RG were introduced into the development including four primary circuits - Dance, Scenic Arts, Music, as well as Pedagogy (Zisi et al., 2009).

Guidetti, Baldari, Capranica, Persichini, & Figura (2000) identified an increase of interest towards RG once it was introduced into the Los Angeles Olympic Games of 1984. RG mixes an exclusive range of the dance, art, and sport. With the incorporation of ballet, modern dance, basic acrobatic skills and manipulation of five hand apparatus including rope, hoop, clubs, ball and ribbon, the beauty of RG is the unlimited possibilities of an individual to deliberate one's self through artistic and polished movements. This elegance of motion is obtained from the beauty of RG. The athletes' accurate precision, choreography, flexibility, and presentation obtain high attraction from spectators which are rare to see in other variations of sport. Females practicing RG gain incredible benefits in terms of self-development. Females undertaking an RG program prove in demonstrating increasing progress over a range of important developmental areas, inclusive of flexibility, grace, balance, strength, agility, as well as hand-eye coordination (Guidetti, Baldari, Capranica, Persichini, & Figura, 2000).

RG ultimately is a feminine sporting mode requiring high levels of development towards a specific physique as well as large development demands towards technical perfection of complex movements' execution of the body with apparels (Menezes, 2006). RG is considered an artistic sport, executed with technical apparatus (rope, hoop, ball, clubs & ribbon). The use of leaps is fundamental to a gymnast's movement demanding technical motor coordination of both the upper and lower body (Ashby & Heegaard, 2002). For increased complexity, leap performances are in most cases followed up with an extra manipulation with the inclusion of one of the following apparatus: Ball, Rope, Hoop or Ribbon). The required manipulation requires the performer to include throws or passing of body through an apparatus, depending on the choice of apparatus (Mkaouer, Amara, & Tabka, 2012).

The above explained requirements of manipulation support why the demands of performing in RG are highly complex, as the gymnast is constantly required to perform with multiple task situations including jumping, twisting or balancing whilst still handling an apparatus. For this level of complexity, we can't only take into consideration the quantitative aspect, but we must also include the quality of execution directly dependent on the level of coordination, technical competence, and physical performance of the gymnast (Mkaouer et al., 2012).

RG includes the performance of dance like movements similar to that of women's artistic floor routines, although additionally working together with the use of a rhythmic apparatus and music. With the use of rope apparatus, gymnasts are required to include a large number of leaps into their routine. Utilizing the ball apparatus, the gymnast must demonstrate impressive flexibility. Using the rope, the gymnast is required to demonstrate a spectrum of balance. In ribbon, the gymnast is expected to perform pivots and turns, and in hoop the expectation is a combination of all of the above movements (Kerr, 2010).

A range of characteristics including technical skills, physical and psychological characteristics may influence a gymnast's performance (Russel, 1987). The ability of Leaping is an essential component of RG performance (Hutchinson, Tremain, Christiansen, & Beitzel, 1998). Studies carried out previously have come to the conclusion that jump ability is highly associated with power and body composition Muscle strength and leaping ability have been identified as associated with low body fat (Claessens, Lefevre, Beunen, & Malina, 1999). Relationships between anthropometric measures and performance are keys in the preliminary stages of RG training & selection process of gymnasts (Cagnoa et al., 2009).

It is useful to determine basic motor abilities and morphological characteristics on RG performance throughout the training process as well as in the sport selection process to begin with. This will assist in the motor teaching and learning process to provide the gymnasts with a sense of direction suited to their characteristics (Cagnoa et al., 2009). It is a preference for elite girl's gymnasts to have a strong development of the muscular system, enhanced flexibility of the inferior articulation, as well as high energy and the mobility. Apart from physical fitness, after a controlled training period, the nervous system control and the psychological resistance becomes an important factor in the gymnast's performance (Menezes, 2006). Laffranchi (2001) identified that the selection of gymnasts should be developed through this genotype, instead of favoring girls based on hereditariness, who which even if entered into an efficient training system, may struggle to achieve exceptional performances (Laffranchi, 2001).

Elite rhythmic gymnastics athletes require a specific body physique; maintain low body fat and have certain physical abilities including flexibility, explosive strength, and coordination to achieve a successful performance. Successful performance in rhythmic gymnastics endures years of practice and training from the gymnast, commencing from an early age of 6 years and is requires full dedication throughout adolescence (Hume, Hopkins, Robinson, Robinson, & Hollings, 1993).

Dedicated athletes that reach a high competitive level train with high intensity, adding stress to their cardiovascular and musculoskeletal systems throughout the developmental period. During this development period, the athletes' growth includes changes in body size, as well as other physiological characteristics. As well as the interaction and combination of natural development and the highly specific training, knowledge on distinctive morphological and physiological characteristics of young elite rhythmic gymnastics athletes proves highly informative and valuable Hume, Hopkins, Robinson, Robinson, & Hollings, 1993).

Weigand and Broadhurst (1998) identified that perceived competence was significantly related with multiple years of athletic experience in football, while Boyd and Yin (1996) identified that significant levels of enjoyment of a sport related to high competence and ongoing dedication and participation in such sport (Boyd & Yin, 1996; Weigand & Broadhurst, 1989).

Performances in RG competitions are evaluated by a final score composed from 2 sub-scores: 1) Difficulty, including both body difficulty (D1) and 2) Apparatus Difficulty (D2), artistic, and execution. The RG performance requirements of the Federation International Gymnastics (FIG) are closely tied to the Code of Points (CP). As the CP is revised every Olympic cycle, so do the routine requirements, which historically prove higher demands and difficulty. The increasing difficulty levels of RG competition exercises are key to characterizing the development of RG (Lisitskaya, 1995).

Based on group exercises, Ávila, da Luz Palomero, Klentrou, and Lebre (2012) state that success and high scores are achieved when there is a high amount of movement synchrony, proper distribution of movement in space, and a balanced conceptual as well as emotional expression throughout group formations (Ávila, da Luz Palomero, Klentrou, & Lebre, 2012).

1.2 Core Training and Performance of Rhythmic Gymnasts

Gymnastics is a specifically skilled sport demanding exceptionally high levels of athlete conditioning. As a consequence of the demands, Gymnasts are among the fittest, mentally composed, strongest and most flexible of all athletes, as presented by their capabilities of bodily movement and control over a large variety of positions (Bassett & Leach, 2011). The lumbo-pelvic muscles (core) provide an essential platform in order to assist in control of these movements (Willson, Dougherty, Ireland, & Davis, 2005).

The core of the human body can be simulated as a box for conceptual understanding. Abdominal muscles are located in front of this box, with the diaphragm as the roof. Para-spinal and gluteal muscles are locating at the rear of the box, with the pelvic floor and hip girdle muscles making up the floor. Lastly, rotator muscles make up the side parts of the box. The core region consists of 29 pairs of muscles that are responsible for supporting the lumbo-pelvic-hip system as a means of stabilizing the spine and kinetic chain throughout motion (Faries & Greenwood, 2007).

Core muscles are responsible for day to day general living activities of the human, athletic performance, as well as the treatment / rehabilitation of lower back pain. Training of the core muscles of the body is essential to maintaining musculoskeletal health, especially with regards to the prevention of lower back (Behm, Wahl, Button, Power, & anderson, 2005). Core training is utilized for the treatment and rehabilitation phase of trunk-related musculoskeletal problems after injury (McGill, 1998). Training of the core muscles is not only an essential parameter for prevention from injury, but is also linked to the enhancement of athlete performance. Well trained core muscles ensure a solid foundation to the limbs for torque generation (Behm et al., 2005). Just about all movements begin in the core region of the body. The core muscles are activated to play a role as a stabilizer to ensure the body maintains an upright position even before movement in the limbs is initiated (Hodges & Richardson, 1997). The abdominal region also provides a bridge between the upper and the lower extremities. During physical activity, movements are constantly transferred up and down the abdominal region. Greater neuromuscular control and stabilization allow for effective posture during kinetic chain movements. Efficient core muscle control ensures efficient acceleration, deceleration and stabilization (Ebenbichler, Oddsson, Kollmitzer, & Erim, 2001).

The majority of strength and conditioning programs include exercises to enhance the strength of the core muscles, yet a large proportion of these exercises fail to differentiate between the recruitment of the stabilizing muscles and the global mobilizing muscles. By following instruction for abdominal exercises, this may over facilitate the development of the mobilization of the muscles, in results neglecting the recruitment of the stabilizing muscles (O'Sullivan, Twomey, & Allison, 1998).

Core stabilizer muscles are activated more so by unstable than by stable exercise. Therefore, the exercise program should also ensure a destabilizing segment for strengthening and enhancing the endurance of the core stabilizer muscles (Behm et al., 2005). The spine is permanently unstable; the body requires to maximize spine stability for functional demands as well as to maintain spinal stability (Faries & Greenwood, 2007). Swiss ball exercises are recommended for the core region of the body. As for the reasons for this recommendation, core stabilizer muscles are activated more on unstable rather than stable surfaces. Core muscles can be classified into two categories: global and local. Global muscles inclusive of the erector spinal, external oblique, rectus abdominals, and quadratus lumborum have long levers and large moment arms responsible for developing torque output, essentially generating movement in a larger range of motions (Cholewicki & Vanvliet, 2002).

A strong core musculature stabilizes the pelvis dynamically during functional movements. Although it has been identified that focused core training has positive effects in numerous sports, far less is understood about the effect on gymnasts. The aim of this study is to evaluate core training programs on the physical and technical characteristics of rhythmic gymnastics performance in Malaysia.

1.3 The Problem Statement

The level of performance among the female rhythmic gymnastics in the gymnastic development program of National Sports Council of Malaysia was improving at a slow rate based on the scores awarded in the gymnastics championships they participated locally. It has also been observed that their training hours were solely on training gymnastics skills. Previous studies give us the information that some studies started to identify and describe the determinants of a rhythmic gymnastics performance. Some of them (Di Cagno et al., 2009; Douda, Avloniti, Kasabalis, and Tokmakidis, 2007) explained only the relationship between anthropometric and technical characteristics of the rhythmic gymnastics performance. Others added the psychological factors and the training process in the first parameters (Hume et al., 1993; Rutkauskaitė & Skarbalius, 2009, 2011, 2012).

Numerous studies have provided information on the Physical and Technical characteristics and successful performances in multiple types of sports but few studies have been completed on RG. Not many studies explain a good proposal which determinate the physical and technical characteristics in RG and a useful model of training for successful performance. There is no published article in this specific area of study in Malaysian Rhythmic Gymnastics, as well as no available data related to these characteristics in Malaysia. Based on the previous studies investigating the significant relationship between RG characteristics and performance, the first part of the current study is to investigate the physical and technical characteristics of RG to determine the scores of physical and technical characteristics in novice RG. The knowledge of the scores in these characteristic maybe will be helpful for researchers and coaches to focus on the weakness of the gymnasts to promote them to the higher levels. In the second part of this current study, the aim is to utilize a protocol of training which can help to enhance the performance of the RG. Previous studies give us some information about the benefit of core training on various sports and athletics performance.

Many health professionals focus on core training in a variety of environments. Strength and conditioning coaches realize the benefits of obtaining a strong core in enhancing sport performance. Fitness professionals communicate to the general population the benefits of core training or core health and the effects this has on activities of daily living, injury prevention, and aesthetic benefits. Rehabilitation professionals are known to have excelled in the training of trunk muscles both for treatment of injury as well as prevention of re-occurrence of injuries related to sub optimal trunk muscle development. Trunk strength is highly critical for enhanced performance because all movements either originate in or are related through the trunk (Thompson, 2009).

For a high number of strength and conditioning professionals, core stability is understood as a true key component in training individuals for improving sport performance (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004). The core provides a pathway for the transfer of forces from the lower extremities to the upper extremities (Behm et al., 2005).

High numbers of studies have examined the effectiveness of core training programs on athletic performance levels (Scibek, Guskiewicz, Prentice, Mays & Davis, 2001); each of these studies measured the core stability before and after training. In the case of occurrence of low-back pain, the coaching staff and the medical staff of the gymnasts reported to researchers that there were no additional incidences of low-back pain. Following the completion of the training, an informal briefing provided communication between gymnasts and coaches. The gymnasts reported that they experienced greater general stamina in their gymnastic performances, which proved direct link to the core training intervention based on the studies (Durall et al., 2009).

Durall et al. (2009) concluded that the 10 week training program proved highly effective in providing confident information that stimulation increases in trunk muscular capacity has a direct positive effect on gymnastic performances (Durall et al., 2009).

Professionals in the field of strength and conditioning continuously provide an emphasis on training the musculature of the core; specific researchers have provided conflicting findings from studies as to the effectiveness of core training programs on athletic performance (Durall et al., 2009).

Kolba (2005) highlighted the importance of core training for gymnasts, due to the various components of spin and rotation required in many gymnastic movements. Durall et al. (2009) studied the effects of a pre-season trunk muscle training programs on the occurrence of low-back pain in Division III female collegiate gymnasts, although further research is required to evaluate the effects of core training and whether it should be an inclusion to all gymnasts' conditioning programs (Durall et al., 2009; Kolba, 2005; Thompson, 2009).

There are differing reports covering the effects of core training programs on various sports performance. The majority of studies were carried out on athletes, and a certain variety of sport training accompanied the core training program on elite athletes. In view of this differentiation of reports, the importance of core training on the gymnasts 'performance, as well as no published study in Malaysia covering this specific area, and also no study on the novice RG in Malaysia. Current study particularly refers to the rhythmic gymnastics (RG) novices, which they characterized by an enormous amount of skills that they are expected to attain. They have to learn as many RG elements as possible at the beginning of systematic training. The level of expertise to which they are expected to master these skills is not very high at the beginning, more accurate and skillful performance is the goal of training phases that are yet to come.

Therefore, RG in beginning stages such as gymnasts in grade 1 could be a more appropriate sample for investigation and differential of the influence of particular core training program on physical and technical characteristics in RG than experienced rhythmic gymnasts. Furthermore, the strong purpose of this study is to evaluate the effect of core training program on the physical and technical characteristics of novice Malaysian Rhythmic Gymnasts in Klang Valley, Malaysia.

1.4 Significant of Study

Improving the physical and technical characteristics among the female rhythmic gymnastics (RG) has significant impact on their level of performance. The importance of enhancing certain characteristics among RG may be very helpful in the early stages of RG training process as well as in the sport selection process. Therefore, physical and technical characteristics play a significant role in successful performance of RG.

Adopting a core training protocol based on requirements of Malaysian RG has significant effect on improving physical abilities and technical performance. The protocol used in current study focuses on Malaysian novice RG based on their requirements on successful performance as well as using the experience and knowledge of experts in this area.

As a purposive study, this study involves 2 rhythmic gymnastics clubs which selected from 7 total RG clubs in the study location. The current study investigates the effect of 8 week core training on the characteristics of rhythmic gymnastics performance in Malaysia with the aim of investigating their physical characteristics, namely power, balance, flexibility, strength and technical characteristics, namely jump skills, balance and rotation, the findings of the current study could be used at the beginning of rhythmic gymnastics training to enhance the level of performance.

The findings of the current study enhance the knowledge and information about the characteristics of rhythmic gymnastics performance and the importance of training of core among gymnasts in Malaysia. Furthermore, it encourages researchers, coaches and athletes to extend their plans using this protocol as an additional training which they can use to achieve the potential benefits of core training and enhance physical abilities and technical performance among Malaysian young female RG.

1.5 Objective of Study 1

This study aimed to investigate the Physical and Technical Characteristics among Novice Rhythmic Gymnasts participating in this study.

1.6 Objectives of Study 2

The main objective of this study was evaluating the effects of the core training program on the physical and technical characteristics among the Malaysian Novice Rhythmic gymnasts.

1.6.1 Specific objectives

- To adopt and implement the core training program to improve the physical and technical characteristics among the participants in the among the Malaysian Novice Rhythmic gymnasts;
- To investigate the effects of the adopted core training program on the physical characteristics among the participants between (intervention and control groups) and within (pre-post and follow-up test) groups;
- To investigate the effects of the adopted core training program on the technical characteristics among the participants between (intervention and control groups) and within (pre-post and follow-up test) groups.

1.7 Research Questions of Study

a) What are the characteristics of physical and technical of Malaysian Novice Rhythmic Gymnasts?

b) Is there any significant difference on Physical characteristics between intervention and control groups in pre-post-test and follow-up test?

c) Is there any significant difference on Technical characteristics between intervention and control groups in pre- post-test and follow-up test?

1.8 Definition of terms

1.8.1 Physical Characteristics

Various physical factors might influence the gymnast performance. The physical characteristics in this study are classified into power, balance, flexibility, strength and endurance (Bradshaw & Rossignol, 2004).

1.8.2 Power

The power is considered the main component of strength in RG, and several skills, as jumping or plyometric exercises, have been used to improve this capacity. Power is the ability to generate muscular work in a short time, and the rate of force production is the basis for most sport actions (Santos, Lebre, & Carvalho, 2016).

Power is a vital factor for majority of sports especially at the highest level. Therefore, in gymnasts, it is important to analyze the relationship between power and gymnastics success (Burkett, Phillips, & Ziuraitis, 2005).

1.8.3 Flexibility

Flexibility is an essential element of gymnastics training and performance that frequently included in talent identification and screening measures for gymnasts, divers, and dancers (Sands & McNeal, 2000).

1.8.4 Strength and Endurance

Strength is a physical ability reflecting in prevailing or countering the resistance and primarily used in the muscle strain. Endurance, as another important physical skill, is the ability of better performance any movement without decrease in efficiency (Kocić, Tošić, & Aleksić, 2013).

1.8.5 Technical Characteristics

Many different factors as technical skills might influence the gymnast performance. The technical characteristics in this study are classified into three major categories: jumps, balances and rotations (Bradshaw & Rossignol, 2004).

1.8.6 Jump Skills

Jumping ability is an essential component of RG performance. Previous investigations determined predictors of jump ability as power and body composition (Di Cagno et al., 2009).

1.8.7 Balance

The term balance is defined as the state of an object when the resultant load actions (forces or moments) acting upon it are zero. The ability of an object to balance in a static situation is related to the position of the center of mass (also referred to as the center of gravity) and the area of the base of support of that object (Ragnarsdóttir, 1996).

1.8.8 Rotation

Rotation is part of the body difficulties in RG (Posture in RG). The rotation difficulties are used in the most elements of the movement which have the highest scores. In addition, rotation in RG consists of both single and multiple pivots (Pluemthanom, HirunratI, and LimroongreungratI, 2015).

1.8.9 Core Training Program

The Core region functions as a "muscle belt" that stabilizes the lumbo pelvic region, with or without the presence of upper and/or lower limbs movements. The training of this region has been adopted by the community in order to increase athletic performance (Kavcic, Grenier, & McGill, 2004).

1.8.10 Grade One Rhythmic Gymnastics

This Level is designed to give gymnasts an introduction into competitive rhythmic gymnastics and the focus should be on introducing fundamental moves with correct posture and basic apparatus technique so as to give a good grounding for more difficult movements to be introduced at the higher levels and the age of the gymnasts are under 10 years old (Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2017).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The current chapter includes a summary of the study background and the previous studies that related to the study objectives and population, such as reviewing Rhythmic Gymnastics performance, anatomy of the different core muscles, core training exercises (in general and with specific focus on the current study core training), as well as a brief review of the studies on core training among athletes including gymnasts. The chapter finally is closed with the summary of the above issues.

2.2 Characteristics of Rhythmic Gymnastics Performance

Several studies have provided focus on morphological and physiological characteristics related to successful performance and talent detection in many sports. The success of talent identification and development programs relies on a true understanding of specific performance requirements of the sport. Available information on these requirements, based on a variety of morphological, physiological, and physical fitness measurements, is valuable in any sport inclusive of rhythmic gymnastics, a critically specialized discipline involving the use of 5 hand apparatuses (hoop, rope, ball, clubs, and ribbon (Douda, Toubekis, Avloniti, & Tokmakidis, 2008).

Elite rhythmic gymnastics athletes require appropriate body physique, the maintaining of low body fat, and obtain specific physical abilities (i.e. flexibility, explosive strength, coordination) in order to ensure a high ability or likelihood of success in their performance. To obtain this successful performance in rhythmic gymnastics, years of hard dedication made up of practice and training starting at a recommended age of 6 years is recommended and continuing this process throughout adolescence. By following the above recommendation, athletes have a higher likelihood of reaching a high competitive level by training intensively and stressing their cardiovascular and musculoskeletal systems during the developmental period. During this period, growth involves changes in body size, as well as in other physiological characteristics (Douda et al., 2008).

Previous investigations, specific for rhythmic gymnastics, presented that genetic pre-disposition of growth is not only preserved but also exceeded in elite rhythmic gymnast's successful performance. Rhythmic gymnastics depends highly on the delicate interplay of balance between strength and flexibility. The range of movements required by rhythmic gymnastics overpowers the limits of physiological displacement. As a consequence, gymnasts with long and strong lower limb and high segmental lengths but light in weight, can achieve outstanding results (Miletić, Katić, & Maleš, 2004).

Rhythmic gymnastics (RG) is a specific discipline that adopts a highly trained body able to respond to the demands of the training process. Training in RG includes the systematic use of five different hand apparatus (hoop, rope, ball, clubs, ribbon) and progressive body exercises in order to enhance the multiple components of physical fitness including speed, muscular strength, jumping ability, and flexibility. Such attributes have been related with successful performances, as RG routines are judged partly on the range of motion exhibited by the gymnasts in a variety of movements as well as explosive jumps (Douda et al., 2008). Throughout gymnastic routines, the spectrum of movement surpasses the limits of physiological displacement of limbs, and this extensive range of motion requires to be performed aesthetically, smoothly, and efficiently. The majority of completed studies support the above observation, as well as the development of flexibility coinciding with the development of strength in order to support joints. Therefore, balance between muscular strength and flexibility, in both limbs, is highly essential for ensuring a higher quality of performance. This quality of gymnastics performance requires years of practice and training, which starts at the early age of 6 years and continues throughout adolescence as mentioned previously in this report. Athletes have an increasing likelihood of achieving a high competitive level when they train intensively during the developmental period. In a Study by Douda et al. (2008) the examination of the specific effects of a 6-month program on various physical abilities of rhythmic gymnasts is completed and points out the most appropriate characteristics among athletes of different age and training levels, leading to successful performance (Douda et al., 2008).

Investigations carried out previously have determined predictors of jump ability as power and body composition (Ugarkovic, Matavulj, Kurolj, & Slobodan, 2002). Relationships between anthropometric measures and performance are highly useful in the preliminary stages of RG training and the selection process (Markovic & Jaric, 2004).

Joch and Ückert (2001) identified that RG is an artistic sport performed with technical apparatus (rope, hoop, ball, clubs, & ribbon). Ultimately, the objective of a successful performance is to obtain a high score in competition from the judges. The collective evaluation of the routines are based on precision, originality, coordination to music, technical difficulties including jumps and leaps, balance, turns, flexibility elements, and waves (Joch & Ückert, 2001).

A successful gymnast aims and achieves a high score from judges during competition. The evaluation of the routine is based on precision, originality, coordination to music as mentioned above and must contain certain degrees of technical difficulty. It can be stated that several factors such as technical skills and several physiological factors might influence the performance of a gymnast. In essence, a deficit of strength, flexibility and movement precision can promote seriously failed performances with low scores. Flexibility, explosive strength, floor reaction time and anthropometric characteristics amount for 41% of the success in performing rhythmic gymnastics basic body elements of difficulty, while the frequency of movement and non-adipose voluminosity accounts for around 26% of rhythmic gymnastics manipulations with the apparatus. Muscle strength and leaping ability are affected positively by low body fat. A training program may be characterized and developed by specific preparation to improve all of these above factors in the correct way. An important relationship among physical attributes (obtained by anthropometry), leg power, flexibility and attainment has been identified. Many sports can be categorized into a title of high, medium or a low leaping demanding sport. Rhythmic gymnastics can be described as a high leap demanding sport. The ability of obtaining quality leaping is an essential component of rhythmic gymnastics performance, as athletes are requested to execute both leaps with high difficulty with the addition of choreographic elements. Based on analysis of rhythmic competitions, a predominance of difficulties of the jump / leap group has been noted (Di Cagno et al., 2009).

A large number of authors have reported that attentional resources are required for postural steadiness, and also required even when the tasks are considered automatic and involving lower order operations. Balancing capacity is related to genetic factors, however, postural control ensures to develop during an athletes' lifetime. Between the ages of 11 and 13, children athletes are capable of utilizing strategies that substantially resemble those utilized by adult athletes for maintaining equilibrium under static or dynamic conditions. Postural skill can also be influenced by sport or training in dance. Postural steadiness is certainly necessary in RG for balancing positions, as well as pirouettes and jumps. This is why RG physical training is very much common like to that of ballet training although also establishes training in pre-acrobatic movements. RG also includes the utilization of a small apparatus (rope, hoop, ball, clubs and ribbon) whose movements, which often involve throws, must be coordinated strictly with those of the gymnast. As a result, in RG performances, there are certain aspects of both ballet and artistic gymnastics, but also attentional demands directly related to the apparatus (Calavalle et al., 2008).

2.3 Anatomy of the Core

The core is identified as a highly important component for functional athletic performance in the field of sports science (Dendas, 2010). The core is the region of the body that provides the required support for upper and lower extremity movements during athletic performance (Dendas, 2010). Athletes with a strong and efficient core produce optimum force, including transfer and control force and movement in the integrated functional athletic performance (Dendas, 2010; Kiblerj, Press, & Sciascia, 2006).

The core's basic foundation originates from more than 20 muscles attached to the lumbo-pelvic-hip complex (Clark, Fater, & Reuteman, 2000; Dendas, 2010). Although previously researchers have reported the importance of a few specific core stabilizers, primarily the transverses abdomens and multifidus, all core muscles work in unity to provide high stability and mobility of the spine in order to achieve optimum athletic performance (Prentice & Kaminski, 2004).

Albeit, the complexity and integrated function of the lumbo-pelvic-hip complex causes misunderstanding regarding the definition of the core; differences among core stability, core strength, and core power; valid assessment of the core stability; and its application to functional athletic performance. It is therefore highly important to obtain a strong understanding of core anatomy and hold a clear definition of core strength, stability and power in order to accurately assess the functional athletic performance (Dendas, 2010; Hibbs, Thompson, French, Wrigley, & Spears, 2008). The anatomical core can be defined as the axial skeleton and all soft tissues with a proximal attachment originating on the axial skeleton irrespective of whether the soft tissue terminates on the axial or appendicular skeleton (Behm, Drinkwater, Willardson, & Cowley, 2010). Achieving sufficient spinal stability is represented by the complex interaction of passive (i.e., spinal ligaments, intervertebral discs, and facet articulations) as well as active muscle and neural subsystems; therefore, we cannot identify a single muscle or structure as the most essential spinal stabilizer.

The combination of core muscles utilized is dependent on the demands of the activity at hand (i.e., posture, external forces). The global axial skeleton stabilizers are inclusive of the large, superficial muscles (e.g., rectus abdominis, external oblique abdominis, erector spinae group) in which provide multi-segmental stiffness over a larger range as well as acting as prime movers during dynamic activities (Behm et al., 2010). Other core muscles may be considered axial-appendicular transfer muscles that link the trunk (i.e., axial skeleton) to the upper and lower extremities (i.e., appendicular skeleton) via the pelvic girdle and shoulder girdle, respectively during the performance of integrated kinetic chain activities, for example, throwing (Behm et al., 2010). These above core muscles function by transferring torques and angular momentum or kicking (Kiblerj et al., 2006; Willardson, 2007). Weakness in the core musculature can hinder the transfer of torques and angular momentum, with an end result of decreased athletic performance. Spinal stability is dependent on the appropriate combination and intensity of muscle activation and the generation of intra-abdominal pressure. Abdominal bracing bears to be more effective than abdominal hollowing as a way of optimizing spinal stability. There are specific training techniques and programs aimed at targeting the spinal stabilizing muscles (core) and are an important consideration for maintaining activities of healthy daily living as well as athletic performance (Behm et al., 2010).

Lehman (2006) reported specific muscles that are important for consideration when analyzing core stability and core strength. These muscles include the transverse abdominis (TrA), rectus abdominis (RA), external oblique (EO), internal oblique (IO), erector spinae (ES) and quadratus lumborum (QL) muscles (Lehman, 2006).

Willson et al. (2005) identified that the gluteus medius (GMe) and gluteus minimus (GMi) muscles engage an essential role in core stability (assisting hip extension and external rotation) by assisting in properly positioning and stabilizing the pelvis (Willson et al., 2005).

The working contribution of these abdominal muscles in support of stability is a result of their ability to produce flexion, lateral flexion, and rotation movements and control external forces that cause extension, flexion and rotation of the spine (Hodges & Richardson, 1996).

Comerford and Mottram (2006) focus in on the essence of the RA muscle and conclude that this muscle has a high recruitment limit and is vital for bracing the spine for high-load activities such as pushing and lifting heavy loads. The QL and multifidus (MF) muscles have a lower limit of recruitment and primarily contribute towards posture and stability (Comerford & Mottram, 2006).

McGill (2007) found that the psoas muscle (the largest muscle in the lower lumbar spine) is not associated in supporting core stability. This psoas muscle has a stability responsibility through axial compression and it is suggested that it was involved with lateral flexion, rotation and extension in addition to hip flexion. Core stability and core strength are essentially required to protect the lumbar spine from excessive loading and rotational movements which could certainly lead to substantial levels of injury of the spine (McGill, 2007).

Akuthota and Nadler (2004) summarized into to a break down into seven components, the processes that act towards the stabilization of the lumbar spine:

2.3.1 Osseous and Ligamentous Structures

The ligaments and osseous structures combine to supply passive stiffness to the spine. The posterior osseous elements of the spine are made up of the zygapophyseal (facet) joints, pedicles, lamina, and pars interarticularis (Akuthota & Nadler, 2004). Such structures have a limit to flexibility and it is clear knowledge that these structures can fail with repetitive loading through excessive lumbar flexion and extension. The area of the spine that is anterior to the spinal cord is made up of the vertebral bodies, the intervertebral disks, and the anterior and posterior longitudinal ligaments. The intervertebral disk is a composition of the annulus fibrosis, which surrounds the nucleus pulposus (Kennedy & Noh, 2011). The end plates form a boundary between the disk and vertebral body. The disk is at risk to injury through both compressive and shearing loads that cause injury initially to the end plates and finally to the annulus, thereby permitting disk herniation.

The spine includes ligaments such as the supraspinous, interspinous, and intertransverse ligaments posteriorly; the elastic ligamentum flavum; and the anterior and posterior longitudinal ligaments on the anterior and posterior sides of the vertebral body. The anterior and posterior longitudinal ligaments have potential to allow support and protection from disk herniation. The combined strength of the anterior longitudinal ligament and limited lumbar extension reduces the risk of anterior disk herniation. The posterior longitudinal ligament allows some protection from a posterior herniation, and most herniation occurs in the posterolateral direction where the ligament thins out and blends with the annulus fibrosis. To summarize, these ligaments appear to provide minimal inherent stability. As a matter of fact, it has been clearly demonstrated that a cadaver with bones and ligaments intact but muscles removed buckles under about the weight of 9kg. The role of these ligaments is to provide some kinesthetic awareness as well as to serve as attachments and extensions of the back musculature and fascial planes (Kennedy & Noh, 2011).

2.3.2 Thoracolumbar Fascia

The Thoracolumbar Fascia provides a relationship between the lower and upper limb operating as a retinacular strap of the muscles of the lumbar spine as a result of their orientation around the spine and also acts as an activated proprioce. The thoracolumbar fascia is a development of three layers consisting of; anterior, middle, and posterior layers. The posterior layer holds the most essential role in supporting the lumbar spine and abdominal musculature (Akuthota & Nadler, 2004).

2.3.3 Para spinals

The Para Spinals consist of the lumbar extensor muscles, inclusive of two main groups; the erector spinae and local muscles such as the rotators and multifidus. The erector spinae muscles (longissimus & iliocostalis) are mainly thoracic muscles which have long momentum arms that pose ideal for lumbar spine extension. The responsibility of the local muscles is to position sensors for the spinal segment and work as segmental stabilizers (McGill, Grenier, Kavcic, & Cholewicki, 2003).

2.3.4 Quadratus Lumborum

The Quadratus Lumborum is made up of large, thin, quadrangular muscle that has direct insertions to the lumbar spine acting as an important stabilizer of the spine (McGill et al., 2003). Akuthota and Nadler (2004) state that the Quadratus Lumborum consists of three main components; the internal oblique, external oblique and longitudinal fascicles (these have obtained far less attention than the transverse abdominal muscle). The external oblique muscle acts eccentrically in lumbar extension and lumbar torsion. Akuthota and Nadler (2004) reported that several fitness programs fail to focus in on and operate the external oblique, resulting in an imbalance. Performing exercises such as isometric or eccentric trunk twists can be utilized to assist with strengthening this muscle and supporting stability (Akuthota & Nadler, 2004).

2.3.5 Abdominals

Taking a view from a functional anatomy perspective, trunk muscles are classified as either global or local muscles. The global muscles, including the rectus abdominis (RA) and external oblique's (EO) are responsible for the production of torque and have the ability to transfer the load directly between the thoracic cage and the pelvis. The local muscles, such as the transverse abdominis (TrA) and lumbar multifidus (MF), hold a more direct or indirect attachments to the lumbar vertebrae. They are related to the segmental stability of the lumbar spine throughout whole body movements and postural changes. Therefore, the functions of local muscles are required to enhance segmental stability of the spine. Trunk stability can be described as a co-activation of global and local muscles (Imai et al., 2010).

2.3.6 Hip Girdle Musculature

The hip girdle area holds an important role within the kinetic chain in sending force from the lower extremities to the pelvis and spine (Lyons, Perry, Gronley, Barnes, & Antonelli, 1983). Studies on humans suffering lower back pain have been identified as struggling with poor endurance and delayed firing of the hip extensor (gluteus maximus) and abductor (gluteus medius) muscles, strongly suggesting that these muscles also have a role in spinal stability (Beckman & Buchanan, 1995).

2.3.7 Diaphragm and Pelvic Floor

The diaphragm and pelvic floor muscles are responsible for spinal stability. O'Sullivan et al. (1998) studies indicate that inspiration and expiration during breathing as well as the subsequent movement of the diaphragm is highly important for obtaining spine stability (as contraction of the diaphragm increases intra-abdominal pressure which subsequently increases the stability of the surrounding area which is then imparted on to the lumbar spine) (O'Sullivan et al., 1998).

Leetun et al. (2004) suggested that hip muscle activation certainly influences the ability of the human body in producing force in the upper leg muscles and it has also been reported by Leetun that hip muscle activation is essential to achieving core stability and/or core strength (Leetun et al., 2004).

One of the primary core muscles previously researched is the transverse abdominal muscle (TrA). Due to this research, there are many published reviews related to the contribution of this muscle to core stability. In contrast of the focused research towards this muscle, other muscles and their characteristics are far less understood. Due to this, the TrA muscle will not form a large part of this thesis as other important unanswered questions requiring further detailed investigations remain for the other core muscles and their involvement in core stability (Wilson, 2005).

The transverse abdominis arises from the thoracolumbar fascia positioned at the lateral raphe, the internal aspects of the lower six costal cartilages, where it is inserted with the diaphragm, the lateral third of the inguinal ligament as well as the anterior two thirds of the inner lip of the iliac crest. Its fiber orientation creates limitations for its ability to produce motion but does emphasize its relationship to increasing intra-abdominal pressure, which is considered to have major effects on lumbopelvic stability. The anticipatory contraction of the transverse abdominis has also been identified to precede extremity movement in healthy humans and is also delayed in activation in patients experiencing lower back pain (Martuscello, 2012).

Similar to Bergmark's, "box model" of the core Comerford and Mottram, (2001) it is suggested that the core is suitably representable as a double walled cylinder built up of the lower and upper back, abdomen and chest (the trunk). Comerford and Mottram (2001) additionally suggest that the pelvic and shoulder girdles are essentially required to be included in any analysis of the core musculature. This recommendation is due to the shoulder girdle (the scapula) providing the links between the arm and trunk as well as the pelvis as the connection between the legs and the trunk (Comerford & Mottram, 2001).

2.4 Anatomy of the Core during Sport

Roetert (2001) studied and reported that core stability and balance are essential factors for achieving quality performance in most sports and physical activities. This is related to the three dimensional nature of most sports. Physical movements that hold high demands on athletes require the athletes to be equipped with high strength in the hip and trunk muscles to provide effective core stability. Roetert (2001) suggested that some sporting activities require effective balance from athletes, or high force production, consistent body symmetry, which as a whole, all require a stable (Roetert, 2001).

Historical research suggests that poor core strength and stability can produce inefficient sporting techniques and puts athletes to high possibilities of minor or serious injury (Jeffreys, 2002).

Willardson (2007) made conclusions that de-conditioned core muscles would likely not act effective in sending forces through the body, with a result of higher compensatory stress on the body's muscles, joints, and connective tissues, which increasingly adds injury risk to athletes (Willardson, 2007). A significantly low amount of research has been undertaken throughout the subject of sporting, with minimal research carried out on focusing towards the effectiveness of core training programs in enhancing healthy athletes' core ability and enhancing such athlete's performance in sports (Willardson, 2007).

Abt et al. (2007) carried out studies of the effect of core stability on the mechanics of cycling. The observation was that following a fatiguing core stability program session, the lower extremity mechanics (essentially the knee joint alignment), core endurance and core strength significantly reduced. On the basis of these findings of the cited study, it could be suggested that a strong core stability and core strength are essentially required as a means of keeping efficient posture of the athlete to enable force production as well as optimal technique and that it is also highly important to train both of these processes regularly to increase the athletes performance and core stamina (Abt et al., 2007).

Hodges and Richardson (1998) carried out a series of tests involving the TrA superficial muscles in planned and unplanned movements to understand how subjects responded to such stimuli. The results showed that TrA response time was constant but the superficial muscle response time was inconsistent, thus supporting the suggestions that the TrA is responsible for a general, stabilizing role to the core, whilst the superficial muscles are responsible for a more precise role in specific limb movement. Hodges and Richardson (1997) identified that the TrA muscle was consistently the first muscle to be initiated before limb movement (when rapid unilateral arm and leg movements are performed). This was supported by Hodges et al. (1999) who utilized a kinematic movement system to analyze body movement prior to trunk movements being performed. It was found that prior to rapid bilateral shoulder movements; there was a minor but consistent motion of the spine created in the opposite direction to the movement, essentially supporting the understanding that the CNS activates muscles prior to movement to reduce the forces (Hodges, 1999; Hodges and Richardson, 1997, 1998).

Hodge (1999) reported that the alternative influence of preparation for limb movement on the initiation of the trunk muscles provides suggestions that the central nervous system (CNS) manages with segmental stability of the spine in many ways. This has a certain implication on how the TrA and the other abdominal muscles are trained in athletes. An example of this covered by Hodges (1999) suggests that the TrA muscle is managed independently of the other trunk muscles and is required to be trained separately from the other muscles at a continuous and consistently low level activation range. Hodges (1999) reported that alternative movements travelling in a range of directions can apply several differing forces on the human body and this can result in changes to the direction of forces applied on the spine. This variance of forces on the spine results in different activation patterns of the trunk muscles, all dependent on the movement of the limb. For example, the ES muscle is activated significantly earlier throughout shoulder flexion rather than shoulder abduction or extension and a converse relationship exists for the flexing abdominal muscles (Hodges, 1999).

Comerford and Mottram (2006) reported that core stability model identifies local and global muscles as well as the concept of stabilizer and mobiliser muscles. The responsibility of stabilizing muscles is posture and the distribution and absorbing of force throughout the body (Comerford & Mottram, 2006). Mobilizing muscles (due to multi-joint positioning and large moment arms) provide strong input to the increased movement, force, and power of the limbs (Bergmark, 1989). This contribution assists in identifying three categories that the muscles can be identified under, depending on their functional role; local stability role (increases segmental stiffness, is responsible for the control of excessive intersegmental movement and also controls low-load challenges), global stability role (provides stability across joints) and global mobility role (produces movement and controls high-load challenges) (Bergmark, 1989; Comerford & Mottram, 2006).

There is a variety of core stability and core strength exercises that are performed as normal practice in core training programs involving a large range of exercises such as static, dynamic, symmetrical, and asymmetrical, mixed with and without external resistance as well as using stable and unstable bases. This variety of exercises results in differing demands on the body and differing muscle activation levels of the core musculature (Viitasalo & Komi, 1975), with some activating the muscles to a higher extent compared to others (Panjabi, 1992). Identifying the type of exercise that is most effective in improving an athlete's core stability and core strength is highly dependent on the resultant muscle activation level and which muscles are the most sport-specific to sporting performance (Morrissey, Harman, and Johnson, 1995).

This has important implications for subsequent training programs, as ideally, an individual should perform exercises that produce the same muscle activation each time and elicit the same level of muscle activation as in training. An exercise that sometimes produces high activation and other times low activation would not be as effective as an exercise that produces high muscle activity each time that it is performed. Therefore, it is important to establish the muscle activation repeatability of such exercises on the major core muscles involved during these exercises, something which is yet to be established to any extent in published literature but something which this thesis hopes to begin to answer (Morrissey et al., 1995).

2.5 Core Training

"The Core region functions as a "muscle belt" that stabilizes the lumbo pelvic region, with or without the presence of upper and/or lower limbs movements" (Kavcic et al., 2004). Apart from carrying the responsibility for the lumbar and thoracic spine stabilization, the core region allows mobility and more effective upper and lower limb force production and transfer (Akuthota & Nadler, 2004). The core region also takes responsibility for the center of the bio kinematic chain in the majority of daily living and sporting activities. The training of the core region has been accepted by communities at large in order to increasing athletic performance as well as for clinical purposes aiming at preventing and rehabilitating orthopedic injuries (Tse, McManus, & Masters, 2005). The term "stabilization exercise" is utilized to indicate any form of exercise that challenges stability of the spine, whilst muscle recruitment patterns, static and dynamic postures are trained (Akuthota & Nadler, 2004).

Training the core region is a systematical, progressive, and functional procedure (Piegaro, 2003). It is important to focus on the plane of motion, range of motion, loading parameters (physio ball, medicine ball, body blade, power sports trainer, weight vest, dumbbell, tubing), body position, amount of control, speed of execution, amount of feedback, duration (sets, repetitions, tempo, time under tension), and frequency (Piegaro, 2003).

An abundance of leading health professionals emphasizes the importance of core training in a variety of configurations. Strength and conditioning coaches understand the positives of a strong core in enhancing sport performance. Fitness professionals indicate to communities the benefits of core training and core health and the effects this has on daily activities, injury prevention, as well as the aesthetic benefits. Rehabilitation professionals are understood to have excelled in the training of the trunk muscles both for the objective of treating injuries or prevention of re-occurrence of injuries as a result of poor trunk muscle development (Britton, 1986).

Trunk strength is essential for performance as all movements either originate in or are related to the trunk. In saying this, to develop an athlete's full potential, it is essential that an athlete's core strength must be as a minimum, equal, if not greater, to that of the rest of the body. If the core is weak, this will negatively affect the entire body strength due to this close relationship (Britton, 1986).

The core allows increased force output when sufficient strength is available to the athlete. The trunk connects movements of the lower body to the upper body. Force vectors are constantly transmitted up and down the body when movements are performed. Ground reaction forces and forces generated by the lower body muscles are sent up the body to the upper extremities when used in an activity (Hedrick, 2000). In addition, the weight and forces applied at the upper extremities travel through the body down to the ground. In both cases, all of the forces travel through the core. The core musculature is also responsible for producing a range of movements of the trunk in many planes of motion. A poorly developed core is likely related to poor posture. As force is most efficiently transferred through a straight line, poor posture can lead to less efficient movements and decreased force output. This may reduce the power output of the upper extremities and promote inconsistent, uncoordinated movements (Brittenham & Brittenham, 1997).

Studies suggest that a poorly developed core may be related to lower back pain. It is clearly understood that core muscles provide an important role in stabilizing the spine (Cholewicki & McGill, 1996). As the spine is permanently unstable, a critical role of the musculature is to control the stiffness of the spine during movements that create instability (McGill et al., 2003).

McGill et al. (2003) identified that the stability of the spine likely results from highly coordinated muscle activation patterns utilizing many muscles and that recruitment patterns must alter continuously, depending on the task being performed by the human. It has also been identified that poor timing of muscle activation in response to sudden trunk loading is related to patients with lower back pain (McGill et al., 2003).

As per the above findings, implications exist to both the prevention and treatment of patients susceptible of sustaining unstable events. This is based on the fundamental principle that load bearing tissue will produce stiffness losses and an increased risk of unstable behavior when the mechanical integrity of these tissues is decreased or eliminated. Spine instability can be related to both the cause and result of injury. Reports suggest that it takes one muscle only with inappropriate activation amplitude to create instability (McGill et al., 2003).

A substantial number of professionals conclude that a strong, endurable, and healthy human core is important for overall general health, performance, as well as prevention of injury and treatment. However, there is a lack of compatibility in the programming methods by which this conclusion is achieved, which causes a large range of variables and little concerning support for a confident training method to be fixed and accepted by all professionals. Research that has been completed detailing core stability in the area of rehabilitation has generally focused mainly on spine pathology and LBP research (Hodges & Richardson, 1996; Richardson, 2002).

Reports by a number of researchers on the sporting sector state that there is a lack of research focused on the effects of core stability training producing improvements in athletic performance (Comerford & Mottram, 2006; Lehman, 2006; Tse et al., 2005). Research suggests that there is an effect on performance by improving core stability but such statements are assumptions taken from basic testing (Cholewicki & McGill, 1996). A summary of a selection of these studies are represented in table 2.1.

Table 2.1: Examples of published sport specific core training program and their effectiveness on enhancing sporting performance

Study	Subjects	Training	Exercises	Performance measures	Findings
1)Stanton, Reaburnand Humphries (2004)	18 male athletes	6 weeks - 2 times per week	Swiss ball	Core stability EMG (abdominals and back) VO2 max, Running economy	Core stability improved No effect on EMG activity No effect on VO2 max or running economy
2) Tse, McManus Masters (2005)	45 rowers	8 weeks – 2 times per week	Trunk endurance	Flexion / extension tests Vertical jump Shuttle run, 40 m sprint overhead medicine ball throw2000 m max ergo row	Improvements in trunk extension test No differences for any functional performance tests
3)Cosio, Reynolds, Winter, and Paolone (2003)	15 nonAthletic women	5 weeks	Curl-ups andback extensions	EMG abdominals and erectorspinae Cybex strength measures Balance tests	Higher EMG activity Improved balance scores No change for strength measurements
4) Myer et al.(2005)	41female athletes	6 weeks	Core strength Balance Resistance training Speed training	1RM squat and bench press Single leg hop Vertical jump Sprint time	Increased squat (92%) and bench press (20%) lifts Single leg hop distance increased (9cm) Speed improved by 0.07sec
5) Nadler et al. (2002)	NCAAcollegeathletes	30-45mins during season: 4-5times perweek Off season:2-3times perweek	Sit ups Pelvic tilts Squats, Lunges Leg press Free weights	Injury occurrenceExtensor strengthHip strength	No significant reduction of injuries Extensor strength no different Hip strength was effected and improved
6) Cressey (2007)	19 male soccer players	10 weeks-27 sessions	Deadlifts Lunges, Squats Single leg balances	Bounce drop jump Countermovement jump 40 and 10yard sprints Agility tests	Improved drop jump (3.2%) and countermovement jump height (2.4%) for stable group Improved sprint times (40yd: Stable 3.9%; unstable 1.8%)

There are variety of core exercises that affect the torso muscles from several angles and planes of motion. An effective core exercise should be dynamic rather than static targeting functional key movements. Using exercise ball helps individuals to reach the required functional, dynamic movements in order to better reinforcement in core area ("Core-strength-exercises," 2015).

Overall, there are several benefits of using exercise ball among core training such as increasing flexibility, balance, versatility, and active sitting. In the following, the core activities using in the current study are briefly introduced:

Abdominal Crunch (on a Stability Ball): Among the many abdominal activities in order to strengthen the core, different kinds of crunch exercises might be the most familiar. Abdominal crunches are planned to give greater strength to the core muscles. Targeting the core muscles, abdominal crunch improves the posture, and improve the muscles' mobility and flexibility (Figure 2.1).

Figure 2.1: Abdominal Crunch (Photo from the training session)

Performing abdominal crunches, the rectus abdominus and the oblique muscles are tightened. These exercises enhance the muscles' mass and density. As well, abdominal crunches help body to burn fat efficiently. However, these exercises should be done along with some other core activities to maximum effect ("The 7 Minute workout health benefits of abdominal crunches," 2014).

Overall, doing abdominal crunches regularly is a highly efficient way to enhance body balance by strengthening the abdominal muscles. Improving posture is the other important effect of doing abdominal crunches. Optimizing body posture is also effective on preventing back pain and back injuries.

Furthermore, it found that athletes who performed abdominal crunches on a stability ball, as opposed to a mat, activated their transverse abs more and developed greater core stability relative to the mat group. So, doing crunches on a stability ball may give your abs a more balanced workout by hitting more muscles that make up the core ("Abdominal Crunches Stability Ball Effective," 2015).

Swiss Ball Wall Squat: According to Mike Mejia (strength and conditioning coach), “lower-body strength is essential for sports performance and injury prevention”. During Swiss ball wall squat exercise, lower body muscles (the quadriceps, glutes and hamstrings muscles) are strengthened. As well, this activity engages the core muscles to improve stability ("Best New Move Swiss Ball Wall Squat," 2016).

Using the stability ball helps to improve balance and good posture. Selecting the accurate size of ball (based on the individual height) is important. Swiss Ball Wall Squat is an efficient leg-strengthening exercise making the quadriceps (one of the biggest muscles in human body muscles) stronger. As well, during this exercise, all the muscles responsible for extending legs and flex thighs (such as the rectus femoris, vastus lateralis, vastus medialis, vastus intermedius) are strengthened ("Benefits of Wall Squats," 2017) (Figure 2.2).

Figure 2.2: Swiss Ball Wall Squat

Overall, Swiss ball wall squat exercises make the body functions better and more effective in athletes and also normal people. The final outcome of a powerful core can lead to an increase in the capability of transfer power associated with many activities such as throwing, jumping, running, lifting, striking, and several gestures used by human body to provide power in an infinite number of movement patterns ("Wall Squat Stability Ball," 2018).

Superman on Swiss Ball: “The superman on Swiss ball” strengthens the core, lower back, glutes, hips, hamstrings, and shoulders. Compare with doing this activity on the on the floor, performing the superman exercises on a stability ball is more difficult (https://www.exercise.com/exercises/swiss-ball-superman). Some of the benefits of the Superman exercises included ("Benefits of Supermans Exercise," 2018):

- ✓ **Practical for Gymnastic Movements:** This exercise is a basic movement skill vital to understand some gymnastics positions. Training the extension stability and positional consciousness trough the exercise can have a vigorous transfer to gymnastic skills in the several movements (such as kipping movements, muscle ups, and static holds). Eventually, by improving the ability to preserve the torso rigid flexion and extension through powerful muscle contractions can enhance the strength in several dynamic gymnastic and fitness moves.

- ✓ Improving lower back and Glute muscle groups: Doing the superman exercises help to develop several essential skills required for more advanced movements and postures (Figure 2.3).

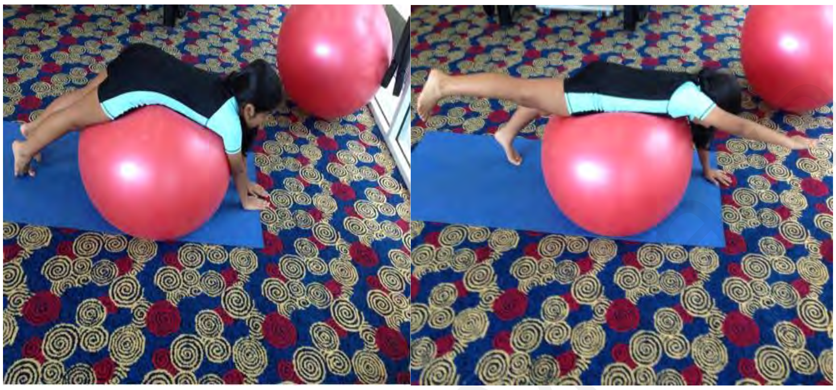

Figure 2.3: Supermen on Swiss Ball

- ✓ **Comparable Bodyweight Exercise:** the movement can be very helpful for strength, power, and fitness athletes. As well this exercise has an extra privilege that it is a very primary level, scalable and low skill exercise, making the Superman exercise so ideal for beginners ("Benefits of Supermans Exercise," 2018).

Kneeling Ball Roll: Using a stability ball, this functional and effective exercise strengthens the core, shoulders and upper-back muscles. There are several similarities between Kneeling Ball Roll and Planck's movement, but the main difference between these two exercises is the location of the hand/arm (in the plank arm or hand is placed on the floor). Therefore, overall, more muscles are engaged in the Kneeling Ball Roll adding the instability factor using exercise ball. As well compared with the Plank, this movement increases the intensity more.

Figure 2.4: Kneeling Ball Roll

The Kneeling Ball Roll is an excellent exercise for having a strong core. This exercise is highly functional and effective and can be performed by almost anyone. It is notable that intensity can be decreased by using a “too big” ball ("Benefits of Supermans Exercise," 2018) (Figure 2.4)

The Hamstring Curl on the Swiss Ball: The hamstring curl performing on the Swiss ball is one of the effective and challenging exercises isolating the hamstring muscles (on the back of the thighs). It is a fundamental body-weight exercise, suitable for almost every fitness level.

Maintaining balance on the ball (whilst doing the curl) is the most important factor in this movement. Without a doubt, compared with the regular exercise (on the floor), performing the hamstring curl on a ball is more challenging and enhance balance and coordination more effectively. In other words, the advantages of the hamstring curl are reinforced due to performing the exercise on the ball (as the unstable surface). The instability given by ball makes the exercise more reflexive and difficult to control. Therefore, several small stabilizing body muscles are recruited in the lower-body (Assuming the movement is performed correctly) ("The Swiss Ball Curl Bridge Hamstring to Target Muscles," 2018) (Figure 2.5).

Figure 2.5: The Hamstring Curl on the Swiss Ball

The hamstring curls is an efficient exercise for strengthening the hamstrings, the gastrocnemius, the calf, the popliteus, the gracilis and Sartorius. As well, performing the hamstring curls stabilizing the torso, hips and ankles. Though several movements in lower-body focusing the bigger muscles, strengthening the body's small muscles is also significant due to having a great support in the joints as well as increasing control (" Add Hamstring Curls to Your Routine Like Celebrity Trainer Ashley Borden," 2019).

2.6 Review of the studies on Core training among athletes

For the purpose of this thesis, what is referred to as the core, core stability and core strength needs to be clearly established. The core musculature will refer to all the musculature from the neck down to the knees (including shoulder stabilization muscles and the upper leg muscles). Core stability will refer to the production of muscle stiffness by the elastic components and ligamentous structures within the muscles which aids in the ability to minimize postural sway and spinal movement during loading and force production. Core strength refers to the increase of force generation to aid movement brought about by creating active stiffness in the muscles and force production through the core muscles. The core varies greatly from study to study, with only a few specific studies including upper and lower sections of the body (i.e. the shoulders, hips and upper leg) as well as the trunk muscles (Lehman, 2006).

Kibler et al. (2006) concluded core stability in a sporting environment as the ability to control the position and motion of the trunk over the pelvis to allow optimum force production, transfer and control of force as well as motion control to the terminal segment in combined athletic activities (Kiblerj et al., 2006). Akuthota and Nadler (2004) concluded core strength as the muscular control required around the lumbar spine to maintain an athlete's functional stability (Akuthota & Nadler, 2004).

Faries and Greenwood (2007) provide clearer statements as to the differentiations between core stability and core strength for the rehabilitation sector by stating that core stability refers to the ability to maintain stabilization of the spine as a successor of muscle activity, with core strength referring to the ability of the musculature to produce force through contractile forces as well as intra-abdominal pressure (Faries & Greenwood, 2007).

Carter, Beam, McMahan, Barr, and Brown (2006) Studies performed with low back pain sufferers as well as the general population can't be extended to the athletic and elite sports performer as generic information. This inability to generalize findings together with the inconsistency of definitions of the core creates difficulty in the collection and application of meaningful data.

Consequently, study results specific to the effect of core training remain inconclusive and inconsistent. It has however been suggested of the importance to have sufficient strength and stability for the body to function optimally in both every day and sporting environments and that by having sufficient stability and strength, enhancement of athletic performance can be achieved (Carter, Beam, McMahan, Barr, & Brown, 2006).

2.6.1 Studies on Relationship between Athletic Performance and Components of Core Stability

There are a few studies focused on the investigation of the relationship between athletic performance and components of core stability, core functions, including core strength, core endurance, core power, and core fitness (Dendas, 2010; Nesser, Huxel, Tincher, & Okada, 2008; Wagner, 2010)

A study carried out by Nesser et al. (2008) was the first known study focused on examining the relationship between core stability and athletic performance in athletes of Division 1 football. The examination of the core stability was carried out using McGill Protocol consisting of back extension, trunk flexion, and left and right bridges. The investigations performance variables included three strength variables; one-repetition maximum and 40-yard sprints, plus a 10 yard shuttle run. The data that was obtained demonstrated that core stability is neutrally related to strength and performance (Nesser et al., 2008).

Wagner (2010) identified the relationship between the function of the core and athletic performance; although conclusions were not consistent of that within the context of core stability and its effect on athletic performance. Wagner stated that "a 30-second or 60-second sit-up test is the best field test of core stability currently available" in measuring athletic performance of college level football players (Wagner, 2010).

Sharrock et al. (2011) investigated the relationship between a core stability test and performance tests with the use of the double-leg lowering test (DLLT) as a way of measuring the core strength and stability of college athletes in a range of sports. The performance tests included the forty-yard dash, the T-test, vertical jump, and a medicine ball throw. The results of the correlated data presented a low relationship between the DLLT as a measure of core stability with regards to the medicine ball throw. No significant correlations between abdominal strength and the T-test (r = 0.052), forty-yard dash (r = 0.138), and the vertical jump (r = 0.172) were reported (Sharrock et al., 2011).

Okada, Huxel, and Nesser (2011) studied the relationship between core stability, functional movement, and performance. Twenty-eight healthy individuals were evaluated on three core-stability movements, the seven movements of the Functional Movement Screen, and three performance tests. The purpose of this evaluation was to identify any relationships between the three variables. The core stability measures comprised flexion, extension, and right and left lateral. The Functional Movement Screen measures the deep squat, left and right hurdle step, left and right in-line lunge, left and right shoulder mobility, left and right active straight leg raise, trunk stability push -up, and left and right rotary stability. The performance tests comprised a backward medicine ball throw, the T-run, and a single-leg squat. The study exposed weak but significant relationships between the performance test and the core stability movements. No significant correlations were found between the core-stability movements and Functional Movement Screen scores. The results of this research suggest that the FMS may not be a strong predictor of performance (Okada, Huxel, & Nesser, 2011).

Researchers formed a team and Dendas (2010) investigated the relationship between core stability and athletic performance in a sport. The research team made the test assumption that selecting core tests specific to performance capabilities is key to successfully investigating the relationship between two variables. Through estimating the tests of core stability having similar movement patterns of the specified athletic performance, researchers were able to analyze the core muscular contributions in dynamic movement. The team successfully observed relationships between the function of the core and athletic performance; although their conclusions conflicted with the conditions of core stability and its effect on athletic performance (Dendas, 2010).

Dendas (2010) examined the relationship between athletic performance and core stability in Division II football players where core strength with the use of the Medicine Ball Explosive Sit-up Throw Test (MBESTT) as well as a 60 second maximum sit-up test including a built-in 30 second test, and core endurance using McGill protocol were utilized. Investigation performance variables included 3RM for the power clean, back squat, and bench press, as well as vertical jump height, and 40m sprint time with a 20m split time (Dendas, 2010). The results of the test presented that there was a substantial relationship between athletic performance and 60 second and 30 second maximum sit-up tests, as well as the McGill trunk flexion test. The 60s maximum sit-up test was substantially related with the relative power clean ($r = 0.836$), relative squat ($r = 0.608$), relative bench press ($r = 0.590$), vertical jump height ($r = 0.721$), 40-m sprint time ($r = -0.680$), and 20-m sprint time ($r = -0.803$). The MBESTT was only related to the absolute bench press ($r = 0.496$). Even though Dendas (2010) hypothesized that MBESTT was responsible for the delivery of the core power, test scores on the MBESTT were not related to scores on any other measures of core stability in the study. The researcher concluded that most of core stability measures held acceptable field-based test reliability. Dendas (2010) reported the results that “the isometric tests had a much larger load placed on them”, which elicited a greater muscular activation and also explains why there was a greater correlation with tests of soccer sport performance (Dendas, 2010).

Wagner (2010) investigated the relationship between core fitness and tests on performance in female soccer players. He defined core fitness as “the combination of isometric core stability and concentric core strength to perform a task of sport performance”. As per the researcher’s findings, isometric core strength was utilized to evaluate the ability of the core to provide a stable base of support with use of an isokinetic dynamometer throughout movements of trunk flexion and bi-lateral rotation, while concentric functional core strength was utilized in the evaluation of the ability of the core to produce and transfer forces to the limbs by performing front abdominal power test (FAPT) and side abdominal power test (SAPT) (Wagner, 2010). The researcher has compared these two core tests with the soccer kick and throw-in to see which core function held a larger responsibility in soccer athletic performance. The researchers assessed isometric core strength while assessing concentric functional core strength. The conclusion of the research was that the isometric core strength correlated more strongly with tests of soccer sport performance than concentric functional core strength, as opposed to other previous studies and their own hypothesis (Wagner, 2010).

Although both researchers Dendas, (2010) and Wagner (2010) have established valid assessments of core and athletic performance, their research findings promote the question, which type of core function has a greater contribution to athletic performance (Dendas, 2010; Wagner, 2010).

2.6.2 Studies on relationship between core stability and athletics' risk for injury

It is theorized that by having a good core stability and core strength, there is a beneficial impact on actual sporting performance (Scibek et al., 2001). This is a result of the optimum recruitment of the core musculature to prevent one muscle from taking over the control of the movement and preventing the co-ordination of recruitment in the core muscles (Cressey, West, Tiberio, Kraemer, & Maresh, 2007). As a result, this would increase injury risk to the core muscles and result in the inhibition of the normal muscle activation patterns for that movement and therefore have the potential to decrease the sporting performance (Hetu, Christie, & Faigenbaum, 1998).

Abt et al. (2007) investigated the relationship between core stability and cycling mechanics of the lower extremity. The results of this investigation reported that core fatigue resulted in altered cycling mechanics that could place the lower extremity at risk for injury due to increased forces on the knee. However, no major differences were observed in pedaling forces. Due to fatigue affecting the lower extremity alignment and mechanics, the authors reported that core stability and endurance may improve both these measures. According to the authors, these are the only studies that have specifically focused on quantifying the relationship between core stability and athletic performance, leaving many unanswered questions (Abt et al., 2007).

Some studies have suggested that there is an advantageous effect on performance by improving core stability and strength, such conclusions are merely assumptions based on basic strength testing and not actually related to sporting performance measurements (Akuthota & Nadler, 2004; Cholewicki & McGill, 1996). For example, Heidt, Sweeterman, Carlonas, Traub, and Tekulve (2000) studied the effects of implementing a core training program on reducing injury risk. The authors found that they were able to gain an injury prevention effect through a speed and agility protocol. The authors found a reduction of lower extremity injuries of 19% in those that completed the training program but failed to establish whether sporting performance was substantially heightened as an effect of the program protocols (Heidt, Sweeterman, Carlonas, Traub, & Tekulve, 2000).

Nadler et al. (2002) examined the influence of core strengthening on hip-muscle imbalance and low-back pain of Division I athletes. In one year, the occurrence of reported lower-back pain and pre-season hip-strength measures were recorded and compared to the results of the following year. Male and female athletes were intervened by a structured core strengthening program that consisted of abdominal, Para spinal, and hip extensor strengthening. The results reported that after the intervention, right hip-extensor strength improved significantly in comparison to the left extensor (P = 0.009). Females specifically reported a higher incidence of lower-back pain when they had weaker left hip abductors. Although there was no significant relationship between the occurrence of lower-back pain and increased core strength, the authors reported that hip-extensor strength "balance" could possibly be increased with a core-strengthening program (Nadler et al., 2002).

2.6.3 Studies Related to Core Training Effectiveness/Effects on Athletics' Performance

Historically, the body of literature concerning the effects of core training on athletic performance has significantly increased. However, this relationship has still not been defined, and relatively few studies have attempted to quantify a relationship between the two variables.

Even with the strong theoretical link between core stability and strength ability and sporting performance, Thompson, Cobb, and Blackwell (2007) conclude that there has been highly limited research based on studies of the effectiveness of functional training programs on the improvement of sports performance or functional fitness (Thompson, Cobb, & Blackwell, 2007).

These positive findings following a core training program are supported by Cressey et al. (2007) who observed improvements in male soccer players' performance measurements. Cressey et al. (2007) observed that at the end of a ten week training program involving free weight core strength exercises including deadlifts, squats and lunges with added resistance, where one group performed the exercises on the floor and another on an inflatable rubber disc to provide an unstable floor surface, both groups resulted in improvements in drop jump and countermovement jump height along with sprint times. However, the group that trained on the stable surface resulted in greater improvements in performance. It was suggested that this was due to the greater force that can be produced during more stable movements which increases the demands on the core musculature and increases the training load which would result in a greater training adaptation (Cressey et al., 2007).

A larger number of researchers have evaluated the effects of core training on sports performance. Tse et al. (2005) analyzed the effectiveness of an 8-week core endurance exercise protocol on college aged male rowers. The authors concluded that although their program did improve core endurance, it did not improve functional performance in tests such as the vertical jump, broad jump, shuttle run, and 40 m sprint. This led the researchers to state that core strength and power may be more influential in functional performance (Tse et al., 2005).

Myer et al. (2005) reported that core training programs are effective in improving sporting performance. The benefits include increased power, agility and speed and are achieved by increasing active joint stabilization, reducing muscle imbalances, improving functional biomechanics, increasing strength of structural tissues (bones, ligaments and tendons) and by reducing subsequent injury risk. He also identified improvements in performance following a core training program with significant performance improvements in; vertical jump height, single leg hop distance, speed, bench press and squat strength and improved biomechanical motion (range of motion) (Myer et al., 2005).

However, Tse et al. (2005) implemented and evaluated a core endurance intervention programme on college-age rowers which proved less effective. The core training took place two days a week for eight weeks (16 days total) on 45 rowers (each session was approximately 30 – 40 minutes long) and measured core endurance (flexion, extension and side flexion tests). Functional performance tests included; vertical jump height, shuttle run and 40 m sprint speed, overhead medicine ball throw distance and a 2000 m ergo maximum rowing test. The results displayed significant improvements in the side flexion tests of the core group, however there were no significant differences observed in the functional tests between the two groups (Tse et al., 2005).

Tse et al. (2005) suggested that these findings above may have been due to the margins for improvement in the subjects being relatively small in such a high-conditioned group of athletes. It could also be due to the exercises performed in the program not being functional enough to improve performance to result in a significant difference. The frequency of intervention (two sessions a week) may also have not been enough to result in a performance enhancement (Tse et al., 2005).

Aggarwal, Zutshi, Munjal, Kumar, and Sharma (2010) investigated the comparison of core-stability training and balance training on balance performance outcomes (static, dynamic, and functional) of active individuals. Thirty recreationally active participants were split into three groups: core training, balance training, and a control. The core-stability training group met three times a week for six weeks, working through a series of core exercises during each 40-to-50 minute session. The results suggested that both the core-stability group and the balance-training group increased scores significantly when evaluated by the Star excursion balance test (SEBT) and the stork balance test. Both methods delivered effectiveness, however, the core-stability training group displayed more improvement in all the assessed variables (Aggarwal, Zutshi, Munjal, Kumar, & Sharma, 2010).

Mahlow (2003) studied the effects of core-stability exercises and hamstring stretches on hip range of motion of a sample of college baseball players. Four groups were assessed: a hamstring-stretching group, a core-stability exercise group, a combination hamstring stretches and core group, and a control. The intervention ran for six weeks and results were assessed weekly to determine if there was an effect related to time. Upon completion, the results suggested that there was no significant interaction between the groups. However, test week on impact on degrees of hip flexion was significant. Although not significant, the largest range of improvement occurred between the second and third week of the intervention (Mahlow, 2003).

Some studies have identified that targeted training programs do improve core ability (stability, endurance and/or strength) but not sporting performance. For example, Stanton et al. (2004) observed a significant difference in core stability following a Swiss ball core training program but did not observe improvements in VO2 max or running economy performance. They suggested that the Swiss ball training was not specific enough to transfer the improvements in core stability to sporting performance. Other studies have reported improvements in core ability and sporting performance following core training programs (Stanton et al., 2004). For example, Thompson et al. (2007) observed that following an eight week progressive functional core training program (three sessions of 90 minutes per week) inclusive of exercises such as; squats, lunges and trunk rotations and included core stabilization, static and dynamic and muscular strength exercises, club head speed during the golf drive was increased along with improvements in functional fitness (Thompson et al., 2007).

Sato and Mokha (2009) studied the results of six weeks of participation in a core strengthening program on running kinetics, lower-extremity stability, and 5000 meter performance in runners. Although the researchers provided evidence of a significant effect on running time in three experimental groups after six weeks of training, the core stability test did not particularly influence ground force production and lower-leg stability functions. The researchers concluded that core strength training may be an effective training method for improving performance in runners due to the effect of effect on running time (Sato & Mokha, 2009).

Tse et al. (2005) examined the effect of a core endurance program on college-age rowers. They found that subjects in the core endurance training group improved core endurance variables when tested using specific measuring parameters that related to their training program, however, did not show any improvement in comparison to the control group during functional testing. This study compared the performance during a large range of functional tasks following 8 weeks of core endurance training. Repeating this study design with a core training program that followed a more functional approach could however lead to a different conclusion (Tse et al., 2005).

Kolba (2005) in their case-control study investigating core stability and gymnasts identified a positive link between core stability training and balance during gymnastic poses. Their statistical analysis would require to be strengthened for their findings to gain wider acceptance. Their findings are supported by strength of anecdotal support however more investigative studies are required to understand the relationship between core stability and balance performance. Kolba stressed the importance of core stability training for gymnasts, because of the various components of spin and rotation involved in several gymnastic movements (Kolba, 2005).

Kim (2010) identified that specialized training programs including core training have been applied to golfers with positive results. The trunk of a golfer is the most prone part to injury, typically attributable to poor posture and improper swing technique, or weakened trunk muscle strength due to lack of exercise. Strengthening of the core muscles could protect against injury while also improving golfing performance and results (Kim, 2010).

2.6.4 Studies Related to Core Training Studies Unstable Equipment

The utilization of unstable equipment in training core stability has increased in popularity among healthy athletes. This is due to some studies which have reported advantageous performance effects following core training programs completed on unstable surfaces which improved the individual's power and strength. It is understood that the unstable surface creates a more specific sporting movement for the athletes (i.e. the swimming stroke has no stable surface where force can be generated against when in the water) and ultimately any improvements in core ability are then transferable to actual sporting performance (Boyle, 2004).

Research has identified that when exercising utilizing unstable exercises, the force output and rate of force development is reduced from the athlete (McBride, Cormie, & Deane, 2006). This could be a case of muscles having a greater role in stabilization in maintaining balance rather than producing and transferring forces through the body (anderson and Behm, 2004). For example, McBride et al. (2006) observed that peak force was reduced by 45.6% and the rate of force development by 40.5% throughout unstable exercises (McBride et al., 2006). The authors of the above research observed a reduction in muscle activation during the unstable exercises of 37.3% in the VL and 34.4% in the VM muscles. This reduction in force output and muscular activation would reduce the effectiveness of the exercise for athletes who are training for strength and power improvements and therefore questions the effectiveness of these exercises for the athletic community (due to higher levels of muscle activation being needed to result in adaptations to the muscles to bring about strength gains). Activation of over 60% of maximal strength has been reported to be required to result in strength benefits from a training program (Häkkinen, Kraemer, & Newton, 1997).

Research has suggested that there is higher muscle activity (e.g. TrA and oblique muscles) during unstable exercises compared to the same exercise performed on stable surfaces. As an example, when a sit-up is performed with a Swiss ball, muscle activation of 50% MVC is observed compared to 21% MVC when the sit-up is performed on the floor (Vera-Garcia, Grenier, & McGill, 2000). However, Willardson

(2007) points out that these findings along with other similar findings anderson and Behm (2004) only observe muscle activation levels of below 60% MVC which is not sufficiently high enough to lead to enhancements in muscle strength as previously highlighted (anderson & Behm, 2004; Willardson, 2007).

Utilization of free weights has been increasingly popular within the highest level of athletes. Free weight exercises demand moderate levels of instability (due to the weight of the load / resistance) with high levels of force production resulting in potential improvements to core stability as well as core strength (Burden & Bartlett, 1999; Kraemer et al., 2002). These types of lifts however, (e.g. deadlifts, squats and overhead press) are only performed in the sagittal plane and such exercises require to be progressed to include rotation and unilateral movements to mimic the actual sporting movement which usually occurs in all three planes of movement (Willardson, 2007).

Stanton et al. (2004) studied the effects of a short-term Swiss-ball training program on core stability and running economy. Eighteen male athletes were assessed on stature, body mass, treadmill VO2 max, running economy, running posture, core stability, as well as electromyography activity of the abdominal and back muscles. A pretest-posttest program design was utilized over a six-week span to determine the effects of a twice-weekly Swiss-ball training program. The results suggest that a Swiss-ball core-training program may positively affect core stability without eliciting improvements in physical performance measures, as there was a significant effect of the training program on core stability, yet no other measures were significant (Stanton et al., 2004).

Hamlyn, Behm, and Young (2007) report that greater muscle activation levels can be achieved by performing exercises with heavy ground-based free weights. Therefore, to develop core strength, exercises performed on a stable base with free weights may be more effective (Hamlyn, Behm, & Young, 2007).

The utilization of instability devices and exercises to train the core musculature is an important method of many training centers and programs. It was the intent of this position stand to provide recommendations regarding the role of instability in resistance training programs designed to train the core musculature. The definition of the core is the axial skeleton and all soft tissues with a proximal attachment originating on the axial skeleton, disregarding whether the soft tissue terminates on the axial or appendicular skeleton. Core stability is achievable with a combination of muscle activation and intra-abdominal pressure. Abdominal bracing has been proved to be more effective than abdominal hollowing in optimizing spinal stability. When similar exercises are carried out, core and limb muscle activation are reported to be higher under unstable conditions, rather than under stable conditions. However, core muscle activation that is similar to or higher than that achieved in unstable conditions can also be achieved with ground-based free-weight exercises, including Olympic lifts, squats, and dead lifts. Since the inclusion of unstable surfaces to resistance exercises can decrease force, power, velocity, and range of motion, they are not recommended as the primary training mode for athletic conditioning (Behm et al., 2010).

Unstable exercises utilizing equipment such as a Swiss ball may still be useful for core training by improving core musculature endurance and stability opposed to strength or power (Carrière & Tanzberger, 1998). As a summary, these unstable exercises could be included for during a maintenance phase of a core training program or when processes such as core endurance are being targeted (Carrière & Tanzberger, 1998).

The researchers assessed core stability using Sahrmann's core test and observed electromyography (EMG) activity of abdominal and back muscles, VO2max, and running economy. Since there were no significant differences observed for EMG activity of the abdominal and back muscles, treadmill VO2max, running economy, or running posture, researchers reported that Swiss ball training may positively affect core stability without concomitant improvements in physical performance (Stanton, Reaburn, & Humphries, 2004).

Marshall and Desai (2010) identified muscle activity of upper body, lower body, and abdominal muscles during advanced Swiss ball exercises with use of EMG analysis. The researchers concluded that performing higher complicated Swiss ball exercises could reduce potential benefits due to the practical difficulty and risk. However, this study provided sure evidence that advanced Swiss ball exercise produces a significant whole body stimulus (Marshall & Desai, 2010).

A similar study to the current investigation was conducted by Nesser et al. (2008) which evaluated the relationship between isometric endurance core exercises and performance measures in Division I college football players. The authors reported weak to moderate relationships between measures, with inconsistent results. It was reported by the researchers that the tests used to evaluate the core focused further on endurance over strength and that the latter may be more critical to athletic performance (Nesser et al., 2008).

Scibek et al. (2001) studied the effects of therapy ball training on swimming performance. It was reported that therapy ball training significantly improved core stability measurements but did not transfer to improved swim performance (Scibek et al., 2001). Kline, Krauss, Maher, and Qu (2013) studied the effects of core strengthening programs in pre-professional ballet dancers utilizing traditional core strengthening exercises such as an unsupervised home program combined with a supervised core strengthening program using a dynamic surface sling system. The results gathered from the programs support the concept that dynamic strengthening can be performed by ballet dancers without adverse effects. Dynamic sling training may offer dancers a valuable strengthening ability, although it is costlier than a home floor exercise program and at this point in research, is only hypothetically more beneficial than a traditional HEP of core strengthening exercises. The authors concluded that core strengthening is considered essential in pre-professional ballet dancers. Strong muscles around the trunk, pelvic girdle, and hips are essential in the training of ballet students as they form the foundation for the balance, stability, and muscle coordination required to perform the simple base movements at the barre and more complex movements during center work. Additionally, improved core strength has the potential to significantly reduce performance injuries and prolong the dancer's career (Kline, Krauss, Maher, & Qu, 2013).

Basset and Leach (2011) investigated the effects of an eight week training program regarding core stability in elite female junior gymnasts. The results gathered displayed that the core stability training group was able to hold five of the eight test positions significantly longer than the controlled durations applied in the program. This confidently suggests that core stability training enhanced the gymnasts' ability to hold an isometric plank position longer. In conclusion, the authors stated that traditional core stability training is far more beneficial to gymnasts in respect to enhancing core endurance times for up to 20 second intervals, which may be beneficial to performance (Bassett & Leach, 2011).

2.7 Conclusion

Research carried out to date has highlighted benefits of training core stability and core strength for taking out everyday activities (Häkkinen, 1993; Leinonen et al., 2000). However, far less research has been completed focused on the benefits of core training in elite athletes and how this training should be carried out to optimize sporting performance with many reporting contradictory findings and conclusions (Faries & Greenwood, 2007; Lehman, 2006). Therefore, further research is required to evaluate the effects of core stabilization training and whether it should be included in all gymnasts‟ conditioning programs (Arokoski et al., 1999; Cholewicki & Vanvliet, 2002).

Despite this statement above, many elite athletes continue to undertake core stability and core strength training as part of their overall training program. To establish whether training core stability and core strength are important in enhancing sporting activities, research is required to establish the impacts training these areas may have on resultant performance. What is termed as performance (as with the definitions of core stability and core strength) differs between the rehabilitation and sporting sectors? In the rehabilitation sector, an improved performance for a LBP sufferer would be the ability to perform everyday tasks sufficiently (Hides, Richardson, & Jull, 1996). Where as in the sporting sector, an improved performance may be defined by improving technique in order to run faster, throw further or jump higher, reducing an individual's injury risk may therefore expand to a greater ability and productivity during their sporting performance (Myer, Ford, Palumbo, & Hewett, 2005).

CHAPTER 3: METHODS

3.1 Introduction

This chapter includes methods employed in the study such as study location, study design, sampling technique, participants' recruitment, intervention strategy and statistical tests. The current Quasi-experimental study containing two different studies included intervention and control groups in 3 points of pre-post and follow-up test in interventional study. Several actions were taken before the main study such as multi-stage extensive literature review and developing and designing the intervention module and implication of training programs.

3.2 Study Design

The current study is a quasi-experimental study with pre-post and 4 week follow-up test, in which participants were randomly selected to receive the training program (intervention group). Participants in the control group were exposed to the same conditions as intervention group expect for the core training plan. Pre-post and follow up tests were performed in both intervention and control groups before and after the training program (8 weeks) as well as 4 weeks later for the follow-up test.

3.3 Study Population

The population of this study was all female young rhythmic gymnasts attaching with the sport clubs in the Klang Valley in 2014. Seven gymnastic clubs were identified in the study area including Sarina's Rhythmic Gymnastics Club, Bukit Jalil National Sport Complex Club, Total Rhythmic Gymnastics Club, Serdang Rhythmic Angels Club, Pink Clubs Rhythmic Gymnastics Training Center, Rhythmic Gymnastics Training Center, and Carolyn's School of Rhythmic Gymnastics.

3.4 Sampling Unit

The sampling unit of the study was a female young rhythmic gymnast attaching with the selected sport clubs that fulfilled all the inclusion criteria at the time of study.

3.5 Sampling Technique and Recruitment

The sampling technique of the current was purposive sampling (Saunders, Lewis, &Thornhill, 2009). The purposive sampling is a non-probability method selecting based on factors of a certain population or the objectives of the study, also known as judgmental, selective, or subjective sampling. It can be a suitable sampling method in situations when the researchers need to asses a targeted sample in a short time or when sampling for proportionality is not an important issue including: Sampling to achieve representativeness or comparability, Sampling special or unique cases, Sequential sampling and Sampling using multiple purposive techniques (Etikan, Musa, & Alkassim, 2016).

In this study, a non-probability sampling (purposive sampling-availability sampling) method was used due to the limited number of sports clubs as well as the low number of the volunteer athletes who were eligible for the study. However, in the second study, the participant in the intervention and control groups selected randomly to avoid selecting bias.

The purpose of the first study was to investigate the physical and technical characteristic of rhythmic gymnasts participating in the study. To achieve this purpose, list of all sport clubs in the study area that have a gymnastics club for 6 to 9 years old gymnasts was prepared. A total of 7 sport clubs including Sarina's Rhythmic Gymnastics Club, Bukit Jalil National Sport Complex Club, Total Rhythmic Gymnastics Club, Serdang Rhythmic Angels Club, Pink Clubs Rhythmic Gymnastics

Training Center, Rhythmic Gymnastics Training Center, Carolyn's School of Rhythmic Gymnastics.

In the next step, the permission of conducting the study was asked from each club. Only 2 clubs (Bukit Jalil National Sport Complex Club and Serdang Rhythmic Angels Club) approved to cooperate in the study. Therefore, for having appropriate number of participants, all female young rhythmic gymnasts attaching with these two clubs that fulfilled all the inclusion criteria were selected for study 1 (58 and 42 participants from Bukit Jalil National Sport Complex Club and Serdang Rhythmic Angels Club respectively).

It is notable that in this study, all participants were female because Olympic Rhythmic Gymnastics is only for females. Furthermore, all subjects were selected in grade 1 (minimum age for this level was 6 and maximum was 9 years old). The reasons for selecting gymnasts in grade 1 were:

a) The appropriate number of gymnasts in this level;
b) The gymnasts in this level require more attention and practice to promote to the higher levels.

The second study was to investigate the effects of core training program on physical and technical characteristics of the participants. For study 2, only 40 participants from study 1 were recruited to join to the interventional study (23 and 17 participants from club 1 and 2 respectively).

Therefore, these 40 participants were randomly divided to intervention (n=20) and control (n=20) groups using a random sampling with a draw session. Each participant was asked to pick up a number from a box containing no.1 or 2 randomly. No.1 represented intervention group and no.2 was control group. Finally, from club number 1, 13 and 10 participants (13 participants as intervention group and 10 participants as control group) and from club number 2, 7 and 10 participants (7 participants as intervention group and 10 participants as control group) selected respectively. It is notable that although in current study the number of participants was not determined using sample size formulas, a review of similar previous studies has confirmed the adequacy of the number of participants. For example, the sample size of a related study by Bassett and Leach (2001), was 22 (7 and 15 in intervention and control groups respectively).

Prior to these steps, a meeting was scheduled with participants in each club to give them some information about the study and ask them about their willingness to participate in the study. The details of the training sessions were fixed in a meeting or by phone calls with their parents.

3.6 Inclusion and Exclusion Criteria

3.6.1 Inclusion Criteria

- ✓ Participants who were active in rhythmic gymnastics clubs in grade 1
- ✓ Participants who never had core stability training
- ✓ Age: 6-9 years old

3.6.2 Exclusion Criteria

- ✓ Participants who have physical disability that enables them to participate in study.

3.7 Developing and Designing the Intervention Program

The aim of the interventional program was improving participant's core region among Malaysian rhythmic gymnasts. The training of this region has been adopted by the previous researches in order to increase rhythmic gymnast's performance.

The intervention protocol was adapted from Stanton's protocol Swiss Ball training program in the form of "Training guideline for trainer's booklet" through a process of consultation with the experts in the study field and according to Stanton intervention core training program (Stanton et al., 2004).

The steps of protocol's devolvement are represented below:

Current study was conducted among 40 young female Rhythmic gymnasts aged 6 to 9 from the rhythmic gymnastics' clubs of Kuala Lumpur. Searching for the best resources and references based on the study adjectives through online searching (literature review) and getting the experts recommendations through several meetings with gymnastic coaches and instructors were done in this stage.

Finally, putting all the sources, references and data together, 5 preliminary activities were adopted from some available core training activity guideline and Stanton's protocol Swiss Ball training program (Stanton et al., 2004). To use the documents, the required permissions were obtained from the publishers or organizations. Study objectives, the skill level of the participants (grade one gymnasts), and time limitations were some of the important considerations during adopting the activities.

In the next step, based on the research goals and objectives, the duration of the project, study limitations and after some major changes, 5 activities were rewritten for intervention sessions. These activities were gathered in a single set as the intervention protocol "Trainer Guideline" and pictures were attached to the protocol. Both content and face validly as well as reliability of the activities was checked to finalizing the activities.

The Swiss-ball core training protocol used in the current study was planned to provide the co-activation of the core global and local muscles (Sekendiz, Cug, & Korkusuz, 2010). This protocol can be carried out in isolation or integrated into other training programs in order to strength the core musculature. The exercises used in this protocol can be gradually modified to complement for the individual differences and needs (Lehman, Gordon, Langley, Pemrose, & Tregaskis, 2005; Sekendiz et al., 2010).

In this protocol, four of the activities have been adapted from a study by Sekendiz (2010) investigating the effects of Swiss-ball core training on women strength, endurance, flexibility, and balance that included seven core training exercises. Three of the core exercises in Sekendiz's study were excluded due to the similarity in the target muscles with other exercises (Sekendiz et al., 2010). The last activity is the protocol in the current study was adopted from Stanson's protocol (2004), including six core training exercise (Stanton, Reaburn, & Humphries, 2004). Most of the exercises in the Stanson's protocol were target same muscles with Sekendiz protocol. So they were not used in the study in order to save time. Finally, the five exercises selected to activate the core region muscles affecting the planned assessments in the current study.

Objectives, the skill level of the participants (grade one gymnasts), and time limitations were some of the important considerations during adopting the activities. In the next step, based on the research goals and objectives, the duration of the project, study limitations and after some major changes, these five activities were rewritten for intervention sessions. These activities were gathered in a single set as the intervention protocol and some guidance pictures were attached.

Both content and face validly as well as reliability of the activities was checked to finalizing the activities. In order to assess the content validity of the interventional protocol, the initial version of the protocol was reviewed by 9 experts in fitness training and gymnastic trainers. As well, Inter-Rater Reliability (Cohen's kappa for two raters) was used to assess reliability of the training exercises protocol. Each of the activities was classified as Strong, Moderate and Poor regarding to their reliability and rated by 2 gymnastic trainers. The results of the reliability of activities rating is presented in table 3.4.

3.8 Pilot study

Two different pilot studies were held in the sport clubs that were not included in intervention and control groups. The results of these studies were presented in section 3.15.

a) The first pilot study was done in order to check the inter-rating reliability of the study's physical and technical tests using Cohen's Kappa (Altman, 1991) among Malaysian rhythmic gymnasts using fifteen female rhythmic gymnasts, aged (6-9) years old were participated in the study in juries' point of view. It is notable that the reliability of the study's physical and technical tests already confirmed in the previous studies (section 3.12). The results of the reliability test will represent in table 3.6.

b) The second pilot study was done as the internal validity of the core training program in order to finalizing the training program. Ten female rhythmic gymnasts (about 10% of the main study's sample size) (Lancaster, Dodd, & Williamson, 2004), aged 6-9 years old participated in this study. After pre-test, the training program was hold for 3 weeks (each week 2 sessions, same as the test in main study) and followed by the post-test. From 5 activities in the main study 2 activities were selected randomly for the training sessions in the pilot study.

   Using T-test (after checking data normality using the Skewness ratio between (-2 and 2), the results showed that in duration of the pilot study the physical and technical characteristics were improved among the participants but not significantly (Table 3.8). Therefore, it is likely that the participants' physical and technical characteristics to be improved significantly by the core training program in the duration of main study.

All participants were able to perform the exercises without injury. The participants reported that the exercises were challenging. Another purpose was to identify any modifications that had to be made to the testing and/or training procedures. No modifications were made to the procedures.

In order to selecting the research assistants (RAs), After several purposeful interviews with the applicants, two local research assistants (RAs) was selected to contribute in different stages of this study: 1) A top fitness trainer with more than 10 years of experience in fitness and strength training, 2) A postgraduate student in sport coaching field and several experiences in work at gymnasium fitness clubs.

In order to conduct the interventional sessions, the training sessions for local RAs had begun before the starting of core training sessions and Swiss ball familiarization movement was conducted for 2 weeks. More specifically, after finalizing the interventional protocol, each single activity was discussed step by step and the demonstration of training sessions was hold over and over. The possible questions and situations were analyzed. Overall, more than 10 hours training was hold for research assistants before starting the intervention program. The training sessions and discussion meeting were continued during intervention period for checking the quality of the intervention program.

The first session contained introducing the program and benefits of core training sessions. Intervention sessions were held twice weekly; exercises were conducted 2 days (Monday-Saturday) per week for core muscles strength. Each participant was given a Swiss ball in accordance to her height. The size of the Swiss balls were conducive to accomplishing >90° angle at both the hip and knee while sitting on the Swiss ball (Norris, 2001).

Table 3.1: Core Training Program Adapted from (Sekendiz et al., 2010; Stanton et al., 2004)

Exercise	Week	1	2	3	4	5	6	7	8
	Time Duration	30 min	30 min	35 min	35 min	40 min	40 min	45 min	45 min
	Date	Sep, 7th and 9th	Sep, 14th and 16th	Sep, 21th and 23th	Sep, 28th and 30th	Oct, 5th and 7th	Oct, 12th and 14th	Oct, 19th and 21th	Oct, 26th and 28th
Abdominal Crunch	**Sets**	2	2	2	2	3	3	3	3
	Repetitions	6	8	10	12	6	8	10	12
Swiss Ball Wall Squat	**Sets**	2	2	2	2	3	3	3	3
	Repetitions	6	8	10	12	6	8	10	12
Superman on the Ball	**Sets**	2	2	2	2	3	3	3	3
	Repetitions	6	8	10	12	6	8	10	12
Kneeling Ball Roll	**Sets**	2	2	2	2	3	3	3	3
	Repetitions	6	8	10	12	6	8	10	12
Hamstring Curl	**Sets**	2	2	2	2	3	3	3	3
	Repetitions	6	8	10	12	6	8	10	12

3.9 Core Training program

Five core training exercises (abdominal crunch, Swiss Ball wall squat, superman on an Exercise Ball, kneeling ball roll, and hamstring curl) were included in the study's interventional training protocol. A brief explanation of each exercise is presented below:

3.9.1 Abdominal Crunch

Crunches or abdominal crunches work the rectus abdominis muscle in the midsection of body. Ab curls may also engage the external or internal oblique muscles, especially when rotation is added to the movement. Abdominal crunches are an effective way to strengthen the front of torso or core region of body.

3.9.2 Swiss Ball Wall Squat

The quadriceps, or front of thigh are the targeted muscles during this exercise but many other muscles get a workout also. The butt, hip, calf, back of thigh, low back, abs, and side abs are all used during this exercise
Muscles Used in Squat with Ball Exercise:

Major muscle groups utilized during this leg exercise are: Gluteus maximus, Gluteus medius, Gluteus Minimus, Quadriceps, and Hamstrings. Special emphasis is placed on the quadriceps muscles as these control the motion both eccentrically and concentrically.

3.9.3 Superman on an Exercise Ball

The Superman is one of the best exercises to strengthen upper and lower back muscles. If done regularly, the Superman may help alleviate back pain that is related to weak back muscles. In addition to strengthening back muscles, the Superman works glutes and hamstring muscles. The Superman Exercise is a great bodyweight core move that works the stabilizing muscles of back as well as your gluteus, hamstrings and shoulders.

3.9.4 Kneeling Ball Roll with the Hands on The Ball Which Ended in a Push up Position

The kneeling ball roll is an excellent exercise for activating the inner-unit or “core” musculature.

The inner-unit is a term for the core muscles that stabilize the spinal column, rib cage and pelvis so that the bigger outer-unit muscles (prime movers) are not recruited in faulty substitution patterns.

3.9.5 Hamstring Curl

The exercise ball hamstring curl is a leg curl variation used to build and strengthen the muscles of the hamstring complex. The exercise ball hamstring curl provides several unique challenges. For example, it challenges the core to stabilize the spine as you contract your hamstrings to bring the exercise ball towards the body.

The Swiss balls were either 55 or 65 cm in height. The volume of the exercise program (Table 3.1) gradually increased by increasing the repetitions and duration of the activities. Before each session, participants performed 6-8-minute warm-up, and then stretching. The rest interval between the sets and circuits was approximately 30 seconds. Exercise session lasted 30 minutes for week 1 and gradually increased up to 45 minutes in progress of the time. All of the sessions were instructed and supervised by the same (RA) assistants. In each session and movement, participants were reminded to focus on the specific muscles which were activated while performing movement (for example abdominal muscles during Abdominal Crunch).

The experimental group underwent regular training with additional core training program during 2 period including 8 weeks (2 sessions, per week) before the post-test as well as additional 4 weeks before the follow-up test (Tse, McManus, & Masters, 2005). Control groups on the other hand, received only regular RG training during this period. Before each activity the purpose, details and steps of the activity was explained completely for participants.

3.10 The Study Assessments (Pre, Post and follow-up tests)

Requirement of follow-up assessments were decided according to the changes from pre to posttest. Basically, the results of the post-test in compared with pre-test can show the effects of the training program on the physical and technical characteristics among the participants. However, in order to increase the internal validity of the study and checking the sustainability of the results, the training program was continued after post-test for more 4 weeks. The results of follow-up test also showed the increasing trend of improving technical and physical abilities among participants in the intervention group compared with the participants in control group.

The pre-test (physical and technical tests) was done before the intervention protocol for all participants (control and experimental group). The first post-test was done immediately after the last session of 8-week intervention program and the follow-up test was done immediately after the last session of one month (4 weeks) interventional training. The intervention protocol “Trainer Guideline” was given to the coaches to perform the same intervention protocol to the participants in that duration of time.

Participating in a deliberative meeting before starting the pretest assessments, all those responsible for conducting the tests (including the main researcher, the research assistants, and juries) took a thorough review of the manner in how tests will be carried out and the rating methods. In this meeting the juries came to agreement on the details of the correct tests and how to score.

Physical test (including vertical Jump, stork stand balance test, sit and reach test, sit up) and tests conducted by the main researcher and two local research assistants (a top fitness trainer with more than 10 years of experience in fitness and strength training and a postgraduate student in sport coaching field and several experiences in work at gymnasium fitness clubs). All the participants had a warmup before performing tests with their gymnastic coach in about 20 minutes. The warmup contained:

a) 5-min run around the spring floor with intermittent skipping and jumping.
b) Walk on high toe with knees straight across floor.
c) Walk on high toe with knees bent across floor.
d) Walk on heels across floor.

e) Static stretching on panel mats.

All participants in both clubs did the physical tests in a single day. Each RAs assistant was responsible for performing specific tests for all participants. Main researcher conducted 2 tests for all participants. In each club the participants (n=20) divided into 3 groups for performing physical tests. Group 1, vertical jump test with 7 participants and one assistant, group 2, sit and reach test with 7 participants and one assistant and group 3, sit up test and stork stand balance test with 6 participants and the main researcher (Figure 3.1). After performing each test, participants were leaded to another group to perform next tests.

Each Assistant wrote the name of participants in each test to make sure all 20 participants performed all the tests. All the process performed in another club with the same assistants with the rest of participants (n=20)

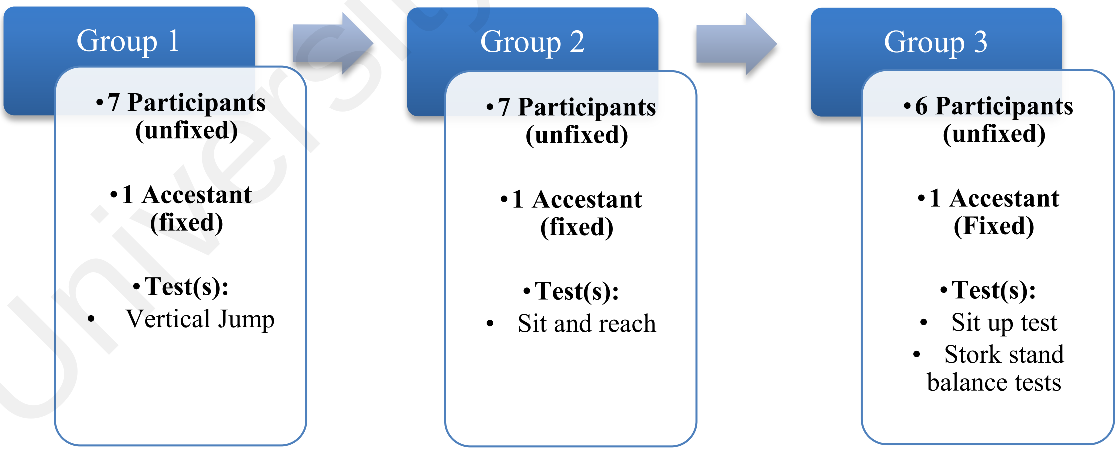

Figure 3.1: Performing physical tests

Technical tests were conducted by 2 top female Malaysian juries in two different days for each club. Participants performed each test under the supervision of juries. Each participant started and ended each test with the signal of the juries. Right-leg balance with free leg in front/side at horizontal from all participants, erect on toes with successive arm waves, half bent leg and other stretched forward ,scissors jump with arm circles and pivot passé 360 in a passé position to the right with arms at side were conducted by all participants respectively. The exact same post-test and follow-up test was done immediately after the last session of each period of intervention programs by the same juries.

On the other hand, participants in control group received only the routine exercises in the duration of studies. The pre-post tests were done for both participants in the intervention and control groups in the same days. Ethically, after finishing the follow-up assessments, the same training program was held for the participants in the control group (by the trained assistants).

3.11 Dependent and Independent Study Variables

An independent variable refers to how participants are treated (Lodico, Spaulding, & Voegtle, 2010). So, the independent variables of the current study were: Initial physical and technical characteristics (height and weight) (study 1) as well as the intervention program (study 2).

Furthermore, the dependent variables are the output of the independent variable(s) (Lodico et al., 2010). Therefore, in the current study the dependent variables were all the physical and the technical characteristic included:

The physical characteristics: power (vertical jump test), balance (stork stand balance test), flexibility (sit and reach test) and strength and endurance (sit up test).

The technical characteristics: jump skill (scissors jump), balance skill (right leg balance with free leg in front/ side at horizontal and stand erect on toes with successive arm waves, half bent leg and other stretched), and pivot skill (pivot passé 360).

3.12 Measuring Details of the Study Variables

The study variables were divided into 2 categories: 1) Physical characteristics including power, balance, flexibility as well as strength and endurance; 2) Technical characteristics including jump skill, balance skills, and pivot skill. The definition, importance, performance methods, validly and reliability (from previous studies) of the related tests are presented below:

3.12.1 Physical Characteristics

High level of physical abilities is needed for Women's competitive gymnastics to success. Strength, Endurance, Agility, Flexibility, Balance and Power are some of the most important physical skills that play a vital role in the success of a competitive gymnast (Bradshaw & Rossignol, 2004). A system of competitive levels ranging (from 4 to 10) is utilized by the United States Association of Gymnastics (USAG) to rank the skills and abilities of individual gymnasts. For moving to up from a competitive level to another, a gymnast must reach to a "specific all-around score". The difficulty of each skill is normally increased, in parallel with increasing the competitive level.

Flexibility, strength, endurance, and power tests have been suggested as useful tools to gauge gymnastic potential (Bajin, 1987). These physical characteristics are mentioned by the USAG Talent Opportunity Programs (TOPs) Test, a multi-test battery designed to measure gymnasts' abilities (Sleeper, Kenyon, & Casey, 2012).

The details of the physical characteristics are represented below:

3.12.1.1 Power: Vertical Jump

Description

Power is a vital factor for majority of sports especially at the highest level. Therefore, in gymnasts, it is important to analyze the relationship between power and gymnastics success. Lower limb power can be measured through some factors such as vertical jump and running vertical jump task (Burkett et al., 2005; Hamilton, Shultz, Schmitz, & Perrin, 2008; Vanezis & Lees, 2005). The ability to do vertical jump is very important in many sports such as basketball, volleyball, diving, and gymnastics. Enhancing lower limb power can increase vertical jump height which can improve the outcome during gymnastics performance (Cochrane & Stannard, 2005; Vanezis & Lees, 2005).

Lower limb power is a vital factor for the sport of gymnastics. Generally, power is directly related to the muscle size. Larger leg muscles generally equal higher lower limb power, but larger leg muscles might be less aesthetically pleasing and aesthetics have been found to be necessary at the elite level of gymnastics (Ackland, Elliott, & Richards, 2003; French et al., 2004). Vertical jump is an essential assessment to test the explosive strength of the leg musculature among gymnasts to determine power (Burkett et al., 2005). Lower limb power is a important characteristic in gymnastics (Figure 3.2).

Figure 3.2: Vertical Jump Test (Burkett et al., 2005).

Reliability and Validity of Vertical Jump

Vertical jump height was measured by the Stand and Reach test (Chu, 1996). This test was selected because it has high validity (r = 0.80) and reliability (r = 0.93) coefficients (Safrit & Wood, 1995) and because it allows arm movement and a squat motion before the jump, such as those performed in sports. Also Johnson and Nelson, (1974) reported a reliability of (r = 0.93) and an objectivity of (r = 0.93) for this test.

Procedure and Equipment

The Vertex Vertical Jump Meter was used as a variant of the traditional sergeant jump. It is the vertical jump-testing device that many college and professional teams. It comprises plastic swivel vanes arranged in half-inch increments attached to a telescopic metal pole that was adjusted for each subjects' reach height (Buckthorpe, Morris, & Folland, 2012).

The test requires subjects to use their dominant hand to displace the highest possible plastic vane with an overhead arm swinging motion at the apex of their jump. Jump height was determined as the number of vanes displaced above the metal pole and converted from inches to centimeters. All jumps were performed from a standardized position with the participant stood facing the vanes at a distance of 10 cm from the Vertex, with their dominant shoulder aligned with the end of the vanes. The test was repeated three times (Buckthorpe et al., 2012).

Scoring

The highest displaced horizontal swivel vane determines the maximum jump height (cm). To calculate vertical jump height, the difference between standing reach measurement and the highest displaced horizontal swivel vane is measured. According to the norm of (Sheerin et al., 2012) the scores with the range of <6.4 cm are very, (6.4 - 11.8) poor, (11.9 - 17.2) below average, (17.3 - 28.2) average, (28.3 - 33.7) Above Average, (33.8 - 39.1) good and >) 39.1 are excellent (Table 3.2).

Table 3.2: Norms of Performance on Each Physical Test for Gymnasts Aged 6-9 Years Adapted by (Sheerin, Williams, Hume, Whatman, and Gleave, 2012).

Performance	Vertical jump (cm)	Stork Stand Balance (s)	Sit and Reach(cm)	Sit-up(s)
Very Poor	<6.4	<1.56	<15.5	<10
Poor	6.4 - 11.8	1.56 - 1.68	15.5 - 20.5	10 - 14
Below Average	11.9 - 17.2	1.69 - 2.32	21.0 - 25.5	16 - 22
Average	17.3 - 28.2	2.33 - 6.11	26.0 - 37.0	24 - 36
Above Average	28.3 - 33.7	6.12 - 9.93	37.5 - 42.5	38 - 44
Good	33.8 - 39.1	9.94-12.78	43.0 - 47	46 - 50
Excellent	>39.1	>12.78	>47.5	>50

3.12.1.2 Balance: Stork Stand Balance Test

Description

Balance is the process of sustaining the of the body's position center of gravity (CoG) vertically over the base of support and relies on rapid, continuous feedback from visual, vestibular and somatosensory structures and then executing smooth and coordinated neuromuscular actions. The balance skill is an important factor in the shaping and enhancing specialized motor habit, as it is the foundation of the complex technical factors mastery to reach significant sport results (Hrysomallis, 2011).

Balance is a factor of technique among rhythmic gymnastics belonging to the basic group of body elements. With or without props, all gymnasts need to show their skills to manage keeping the complex balances as characteristic structural group during each movement. Furthermore, the skills of maintaining balance seems to be an important element in the technique of doing other movements, which do not include the balances in the narrow sense, such as turns or similar. Composition must necessarily have balances, which are visibly kept on the reduced surface of support, with high legs opening, (over 180°). Turns of 720°, performed as triple turns in pass (180°) require fantastic ability to keep the balanced position of a gymnast (Kocić et al., 2013).

Reliability and Validity Stork Stand Balance Test

The stork stand test has acceptable face validity, a test-retest reliability (r = 0.87), and an inter-rater type of reliability (objectivity; r = 0.99) (Johnson & Nelson, 1969). (Stork Stand test has a reported concurrent validity of (r=0.86) and test-retest reliability of (r=0.94) (Suni et al., 1998).

Procedure and Equipment

The equipment of this test was flat, non-slip surface and stopwatch. The subjects were asked remove the shoes and place the hands on the hips, then position the non-supporting foot against the inside knee of the supporting leg. The subjects were given one minute to practice the balance. The subject raises the heel with examiner signal to balance on the ball of the foot. The stop watch was started as the heel was raised from the floor. The stopwatch was stopped if any of the follow occurs (Figure 3.3):

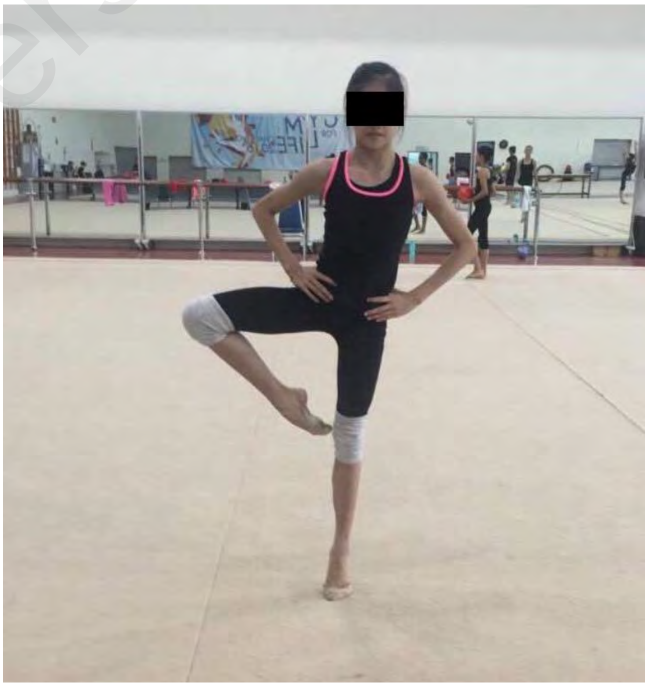

Figure 3.3: Stork Stand Balance Test

- ✓ The hands come off the hips;
- ✓ The supporting foot swivels or moves (hops) in any direction;
- ✓ The non-supporting foot loses contact with the knee;
- ✓ The heel of the supporting foot touches the floor;
- ✓ The participants were first instructed to familiarize themselves with the balance position, and they were advised to stand as long and as quietly as possible. Three trials were allowed, and the best was recorded.

Scoring

The maximum time which participants hold the body in the right position record in second and the best of three attempts will be the final score, according to the norm of (Sheerin et al., 2012), scores with range of <1.56 (s) is very poor balance, (1.56 - 1.68) (s) poor, (1.69 - 2.32) (s) below average, (2.33 - 6.11) (s) average, (6.12 - 9.93) (s) Above Average, (9.94 - 12.78) (s) good and >12.78 are excellent balance (Table 3.2).

3.12.1.3 Flexibility: Sit and Reach Test

Description

Flexibility is an essential element of gymnastics training and performance that frequently included in talent identification and screening measures for gymnasts, divers, and dancers (Sands & McNeal, 2000). The Sit and Reach (SR) test is a field test measuring hamstring and low back flexibility. This test is included in many health related fitness test batteries due to its role in maintaining hamstring and low back flexibility that potentially prevent the different kind of musculoskeletal injuries and low back problems, postural deviations, gait limitations, and risk of falling (Hui and Yuen, 2000) (Figure 3.4). The objective of this test is to monitor the development of the athlete's lower back and Hamstring flexibility.

Figure 3.4: Sit and Reach Test

Reliability and Validity of Sit and Reach Test

Many studies on the validity and reliability of SR test protocol have been reported, and a number have been proposed (Jones, Rikli, Max, & Noffal, 1998). Mosher, Carre, and Schutz (1982) they found validity coefficients of r =0.64 between the SR test and a criterion measure for hamstring flexibility. All SR test protocols yield moderate validity for hamstring flexibility and poor validity for lower back flexibility (Jackson & Baker, 1986; Mosher, Carre, & Schutz, 1982). Sit and Reach test has demonstrated a moderate criterion related validity for estimating hamstring flexibility measured in different populations: children and adolescents (Castro-Piñero et al., 2009; Cornbleet & Woolsey, 1996; Hartman & Looney, 2003).

Procedure and Equipment

The equipment of this test was Sit and Reach Box. A standardized Sit and Reach Test was performed. The subjects were asked to sit on the floor with legs stretched out straight ahead. Shoes should be removed. The soles of the feet are placed flat against the box. Both knees should be locked and pressed flat to the floor. The tester assisted by holding them down, with the palms facing down wards, and the hands on top of each other or side by side, the subject reached forward along the measuring line as far as possible. The tester checked to ensure that the hands remained at the same level, not one reaching further forward than the other. After some practice reaches, the subject reached out and holds that position for at two seconds while the distance is recorded (Davis, 2004).

Scoring

The sliding ruler that is centered on the top of the box was used to obtain the SR scores. The markings on the ruler were positioned so that the 35-cm mark represented the point at which the subjects' fingertips were in line with their toes. This device permitted a scoring range from 0 cm to 50 cm. According to the norm of Sheerin et al., (2012) suggesting the scores with <15.5 very poor flexibility, (15.5 - 20.5) poor, (21.0 - 25.5) below average, (26.0 - 37.0) average, (37.5 - 42.5) above average, (43.0 - 47.5) good and >47.5 excellent flexibility (Table 3.2).

3.12.1.4 Strength and endurance: 60 Second Maximum Sit-Up Test (60s MSUT)

Description

Strength is a physical ability reflecting in prevailing or countering the resistance and primarily used in the muscle strain. Analyzing movements in rhythmic gymnastics show that they are characterized by a large number of various jumps. Furthermore, the explosive strength of legs and the repetitive strength of body trunk have a significant relationship with judging the specific level of well-trained features in gymnasts (Kocić et al., 2013).

Endurance, as another important physical skill, is the ability of better performance any movement without decrease in efficiency, for example, to perform activities with unabated intensity, for longer time. In rhythmic gymnastics, the minimum estimation error throwing of a prop, or a shorter endurance in balance, can imperil the placement.

Aerobic skills affect the gymnasts' recovery process by enhancing its speed and facilitate it (Kocić et al., 2013).

In rhythmic gymnastics, the endurance is not the primary physical skill, but its importance increases at the beginning of the nineties. In respect of the fact that endurance has just recently gained an important place in the model characteristics of gymnasts, as well as that it has its specificities in this sport branch, it is necessary for it to become more treated both in theory (research) and practice (training) of rhythmic gymnastics (Kocić et al., 2013).

Strength and endurance was measured by the maximum sit-ups in 60 seconds. The 60s MSUT was adopted from similar tests described by (Dendas, 2010) (Figure 3.5 and 3.6). The objective of this test is to monitor the development of the athlete's abdominal strength and endurance (Dendas, 2010).

Reliability and Validity of Sit-Up test

Reliability for the timed sit-up test has previously been established. Ryman Augustsson et al. (2009) reported that test-retest reliability coefficients for 60 Second timed sit-up test was statistically significant (r = 0.86) (Dendas, 2010; Ryman Augustsson et al., 2009). Ryman Augustsson et al. (2009) also reported Interclass correlation coefficients (ICC) of 0.93 with a 95% confidence interval of 0.77. Each up-down cycle was counted as a successful repetition of the sit-up (Ryman Augustsson et al., 2009).

Figure 3.5: Starting position of Sit-Up Test

Figure 3.6: Ending position of Sit-Up Test

Procedure and Equipment

Stopwatch, partner to hold subject's ankles, Mat or towel to lie on (optional) was the test's equipment. The subject had to flex the trunk up until the elbows touched the thighs and then lower the trunk back until the scapulae came into contact with the floor for a successful sit-up (Dendas, 2010).

Scoring

The test was scored as maximal number of correct sit-ups within the 60-second time period. The completion of one complete curl up (up and back) counts as one. According to the norm of Sheerin et al., (2012) suggesting the scores with <10 very poor, (10 - 14) poor, (16 - 22) below average, (24 - 36) average, (38 - 44) above average, (46 - 50) good and >50 excellent (Sheerin et al., 2012) (Table 3.2).

3.13 Technical Test

In the current study, all of the technical tests were adopted from National RG classification program. Four elements were selected from grade 1 freehand activities Figure (3.7 to 3.10). Table 3.2 shows all 10 elements of the technical tests for grade 1 in RG recommended by the National RG classification program.

Table 3.3: National Rhythmic Gymnastics Classification Program (Grade 1, freehand)

NO	Elements
1)	Vertical jump, one leg in front, with arm swings
2)	Scissors jump with arm circles
3)	Vertical jump in a passé wit a half turn, and arm swings forward-upwards
4)	Right-leg balance with free leg in front/side at horizontal
5)	Stand on flat floor, the leg behind not lower than 45 passing to the side and forward successively with the arms, stretched to the sides (hold 1 sec on each side)
6)	Balance on left toes in passé position with arms stretched to the sides
7)	Stand on flat feet, arch back with arms and trunk parallel t the floor
8)	Chain turn 360 to the left with arm swings to the sides
9)	Pivot passé 360 in passé position to the right with arms at sides
10)	Stand erect on toes withy successive arm waves, half bent leg and other stretched forward with rounded arms

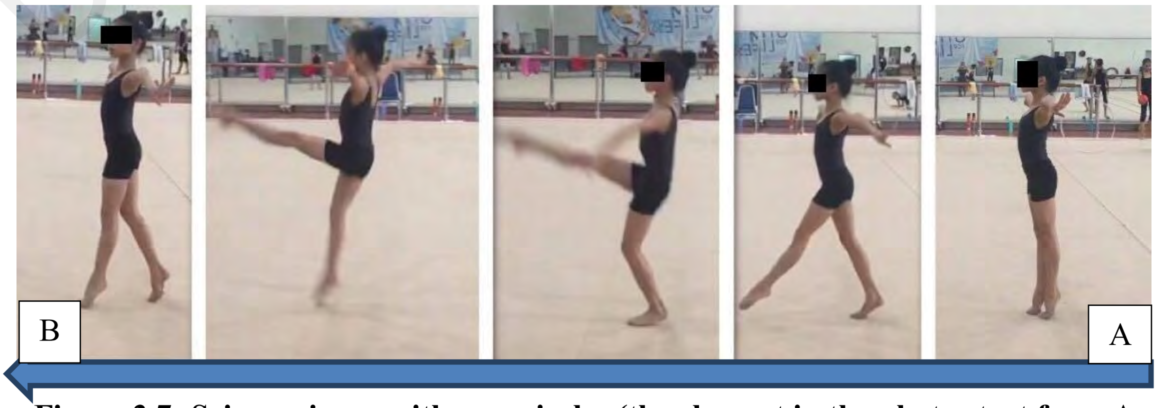

Figure 3.7: Scissors jump with arm circles (the element in the photo start from A and end at B position).

Figure 3.8: Right-leg balance with free leg in front/side at horizontal

Figure 3.9: Stand erect on toes with successive arm waves, half bent leg and other stretched forward with rounded arms and trunk

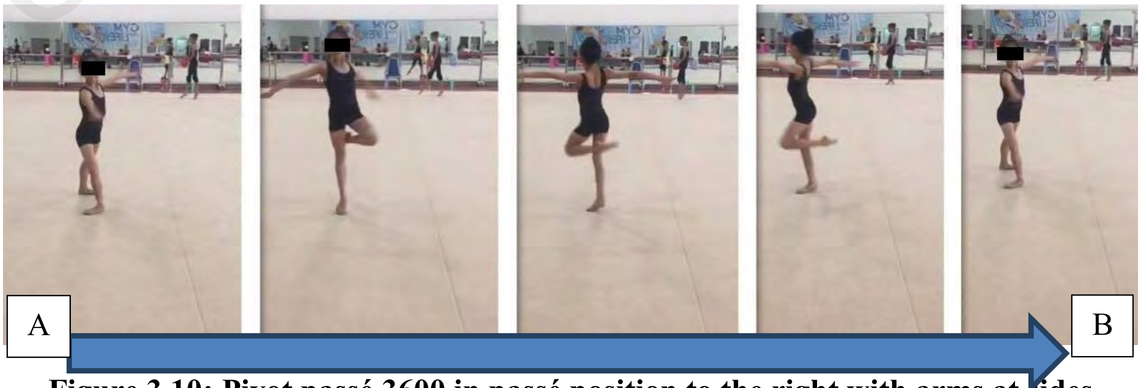

Figure 3.10: Pivot passé 3600 in passé position to the right with arms at sides (open) (the element start from A position and end at B position)

3.13.1 Scoring of technical test

Four Malaysian female juries including 2 main and 2 reserved members (the involvement of the 2 reserved members was not required) evaluated the 4 technical elements according to the Code of Points of RG. The participants performed all 4 elements three times, and only the best performance was evaluated. The average of juries' scores considered as the final score of each test. Prior to this, the juries had a discussion session to reach an agreement on the tests' scoring along with the main researcher. The main researcher simplified the judging procedure; therefore, the standard RG judging score, which is more suitable for compositions compared with evaluating single elements, was avoided.

Basically, they evaluate execution (body technique) for all of the elements. The score of each element was based on 0.0–1.0-point scale. When the movement deviates from the perfect prototype, the judge deducted a penalty from the starting score of 1 point for each element.

Penalties range from 0.10 to 0.50 according to the severity of the error. For example, if a jump routine is executed with a lack of amplitude in its form, the judge would deduce 0.10 points from the execution score, maximum mark for passing of each element was 1.00 and minimum mark was 0.6 and 0.5 in accordance with the Code of Point criteria (Table 3.4). Each Jury scored to each element in one score sheet and total mark reported.

Table 3.4: Code of Points for Little Gymnasts to Grade 3 Execution (Body Technique)

Grade	LG	**G1**	G2	G3
Balance				
Incorrect body segment (elbow, hand, knee etc.)	0.1	0.1	0.1	0.1
Insufficient amplitude	0.1	0.1	0.1	0.1
Not visibly held (min 4 seconds)	0.1	0.1	0.1	0.1
Shape not defined well or fixed	0.1	0.1	0.1	0.1
Jumps/Leaps				
Heavy landing	0.1	0.1	0.1	0.1
Incorrect body segment (elbow, hand, knee, etc.)	0.1	0.1	0.1	0.1
Insufficient amplitude	0.1	0.1	0.1	0.1
Insufficient elevation	0.1	0.1	0.1	0.1
Shape not defined well or fixed	0.1	0.1	0.1	0.1
Pivots				
Axis or body not at vertical	0.1	0.1	0.1	0.1
Shape not defined well or fixed	0.1	0.1	0.1	0.1
Incorrect body segment (elbow, hand, knee, etc.)	0.1	0.1	0.1	0.1
Incomplete rotation	0.1	0.1	0.1	0.1
Flexibility				
Shape not defined well or fixed	0.1	0.1	0.1	0.1
Incorrect body segment (elbow, hand, knee, toe etc.)	0.1	0.1	0.1	0.1
Insufficient amplitude	0.1	0.1	0.1	0.1

3.14 Data analysis

Data analysis was done using SPSS software (version 21). The Skewness ratio and its standard error were taken to check the normality (between -2 and 2) (Bai and Ng, 2005). All interval and ratio data were also checked by graphical method such as histograms and scatter plots (Tabachnick & Fidell, 2007). Confidence interval and the level of significant alpha were set at 95% and 0.05 respectively.

A Mix between-within subjects ANOVA was done to investigate the differences in the mean of the continuous variables among the 3 stages of pre- and post and follow up test in intervention and control groups. Normality (Skewness & Kurtosis) and Homogeneity of Variance (Levene's test), Sphericity (the variances of the differences between the related groups of the within-subject factor for all groups of the between-subjects factor of variables), and Outliers significance was assessed before doing the main the test (Pallant, 2007). Partial eta square used as a value of effect size. According to Cohen (1988), 0.01, 0.06 and 0.14 represent small, moderate and large effect size respectively (Bakeman, 2005).

3.15 Exploratory Data Analysis (Results of the Validity and Reliability Tests)

3.15.1 Results of the Reliability of the Study Protocol Activities

In order to check the inter-rater reliability of the protocol's activities, a Cohen's Kappa test was done among 15 RG. According to (Altman, 1991), Cohen's Kappa is ranged between -1 and +1: 0.01 to 0.20 slight agreement; 0.21 to 0.40 fair agreement; 0.41 to 0.60 moderate agreement; 0.61 to 0.80 substantial agreement; 0.81 to 1.00 perfect agreement (Altman, 1991; West, Welch, & Galecki, 2014). Based on the results represented in (Table 3.5) the reliability test for the activities was moderate to perfect. It is notable that 8/10 (80%) of the rates were moderate reliability and strong reliability.

Table 3.5: Reliability Test (Protocol Activities)

Test	Cohen's Kappa (K)
Abdominal Crunch	0.64
Swiss Ball Wall Squat	0.82
Superman on an Exercise Ball	0.60
Kneeling Ball Roll with the Hands On The Ball	0.63
Hamstring Curl	0.82

3.15.2 Results of the Content Validity of the Tests

The content validity of the study's selected tests was checked and approved by a panel of experts including university lectures and judges and coaches in the related area. The internal validity was done as a pilot study among 10 female rhythmic gymnasts (aged 6-9). The results showed that the selected physical and technical characteristics were enhanced after finishing the core training program although it was not a significant improvement. Therefore, doing the exercises in a longer period may improve the physical and technical characteristics significantly. The results of the pilot study are represented in table 3.6 and 3.8.

Table 3.6: The mean scores of physical and technical characteristics before and after intervention (pilot study, n=10)

Characteristics	Before Intervention	After Intervention	t-value	P-value
Physical Characteristics				
Vertical Jump	23.50 ±4.89	24.17 ±5.15	-2.00	0.10
Stork Stand Balance Right Leg	4.88±2.19	5.27±1.99	-1.76	0.14
Stork Stand Balance Left Leg	4.56±2.72	4.90±1.78	-1.73	0.15
Sit and Reach	30.83 ± 5.11	31.00 ± 5.29	-1.00	0.36
Sit Up	29.50±7.89	30.00±7.95	-2.23	0.07
Technical Characteristics				
Scissors Jump	0.60 ± 0.09	0.68 ± 0.11	-2.07	0.09
Right-leg balance	0.53 ±0.24	0.68 ± 0.08	-1.80	0.13
Stand Erect on Toes	0.63 ± 0.10	0.69 ± 0.12	-2.23	0.07
Pivot Passé 360	0.58 ± 0.7	0.65 ± 0.5	-1.58	0.17

*Significant at level p<0.05

3.15.3 Results of the Judges Inter-Rater Reliability for the Tests

In order to check the inter-rater reliability of the study's tests, a Cohen's Kappa test was done among 15 RG. Based on the results represented in Table 3.7 the reliability test for the physical tests was substantial to perfect. As well, the reliability test for the technical tests was substantial to moderate strong.

Table 3.7: Reliability of the Test

Tests	Kappa (K)
Physical	
Vertical Jump	0.809
Stork Stand Balance Right Leg	0.630
Stork Stand Balance Left Leg	0.731
Sit and Reach	0.636
Sit Up	0.817
Technical	
Scissors Jump	0.598
Right-leg balance	0.565
Stand Erect on Toes	0.659
Pivot Passé 360	0.683

3.15.4 Results of the Reliability of the Study's Tests

In order to check the reliability of the study's tests, a test-retest reliability coefficient was done among 10 female rhythmic gymnasts (aged 6-9). The results showed for all tests the Pearson Correlation was higher than 0.7 (between 0.72 and 0.88) (Table 3.8). Reviewing literatures, the Test-retest reliability coefficients vary between 0 and 1, where: 1, ≥ 0.9, $\geq 0.8 < 0.9$, $\geq 0.7 < 0.8$, $\geq 0.6 < 0.7$ mean perfect reliability, excellent reliability, good reliability, acceptable reliability and questionable reliability respectively. It is notable that due to the low number of the participants the power of the results might be low.

Table 3.8: Test-Retest Reliability

Tests	Pearson Correlation
Physical	
Vertical Jump	0.843
Stork Stand Balance Right Leg	0.765
Stork Stand Balance Left Leg	0.720
Sit and Reach	0.880
Sit Up	0.861
Technical	
Scissors Jump	0.810
Right-leg balance	0.739
Stand Erect on Toes	0.765
Pivot Passé 360	0.795

CHAPTER 4: DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter summarizes the results of the study and the analytical method. Using descriptive analysis in the study 1, the physical and technical characteristics of 100 young Malaysian Rhythmic Gymnasts (all female) participating in the study was examined.

The effect of 8 weeks core training program 40 female young rhythmic gymnasts (randomly selected from respondents in the study 1) was investigated in the study 2. Generally, several statistical methods including descriptive and multivariate analysis techniques used to study the effectiveness of intervention program.

4.2 Results of the Study 1

4.2.1 Age, Height and Weight of the Participants in Study 1

The purpose of the first study was to investigate the physical and technical characteristics of the participants. One hundred female young rhythmic gymnasts (from 6 to 9 years old) were recruited from two gymnastic Clubs of Kuala Lumpur, Bukit Jalil National Sport Complex Club and Serdang Rhythmic Angels Club. Table 4.1 represents the mean score of age, height and weight of the participants in the study 1.

Table 4.1: The mean score of age, height and weight of the participants in the study 1 (n=100) and study 2 (n=40)

Characteristics	Study 1 Mean±SD	Study 2 Mean±SD
Age	7.27±0.89	7.55±1.01
Height	127.93±13.92	126.45±12.83
Weight	26.41±7.46	25.55±7.43

According to the results, the mean age of participants was 7.27±0.89 furthermore; the mean score of the participants' height and weight were 127.93±13.92 and 26.41±7.46, respectively.

4.2.2 Physical Characteristics of the Participants

The mean and standard deviation of the physical domains are reported in Table 4.2. The mean score of Vertical Jump, Stork Stand Balance Right Leg and Stork Stand Balance Left Leg were 23.43±4.36, 5.32±2.04 and 4.32±1.74, respectively. Furthermore, the mean score of Sit and Reach and Sit-Up were 35.22± 4.68 and 33.36 ± 6.07, respectively.

Table 4.2: Means and standard deviations (SD) of the participants' physical characteristics

Characteristics	N	Mean	SD
Vertical Jump	100	23.43	4.36
Stork Stand Balance Right Leg	100	5.32	2.04
Stork Stand Balance Left Leg	100	4.32	1.74
Sit and Reach	100	35.22	4.68
Sit Up	100	33.36	6.07

4.2.3 Technical Characteristics of the Participants

The mean and standard deviation of technical test components reported in Table 4.3. According to this table the mean score and standard deviation for scissors jump with arm circles, right-leg balance with free leg in front/side at horizontal were 0.57 ± 0.26 and 0.61 ± 0.22, respectively. Furthermore, the mean score of stand erect on toes with successive arm waves, half-bent and Pivot passé 360 in passé position to the right with arms at sides were 0.69 ± 0.94 and 0.66 ± 0.59, respectively. According to the norms provided by Malaysian Gymnastic Federation, scores of maximum mark of each element in all level of RG gymnasts is 1.00 and minimum mark for passing is 0.50, therefore, result of all elements in the selected technical test in this study need to improve since the scores is below than 1.00.

Table 4.3: Means and standard deviations (SD) of the participants' technical Characteristics

Characteristics	N	Mean*	SD
Scissor Jump	100	0.57	0.26
Right- Leg Balance	100	0.61	0.22
Stand Erect on Toes	100	0.69	0.94
Pivot Passé 360	100	0.66	0.59

*Range point value: 0.04-1.00

4.3 Results of the Study 2

The purpose of this study was to investigate the effect of the 8 weeks core training as intervention program (2 sessions per week) and 4 weeks follow up test (1 session per week) on the physical & technical characteristics of Malaysian Rhythmic Gymnasts participating in the study. From the participants in the first study, forty participants were selected randomly and divided into two groups, the intervention group (n = 20) and the control group (n = 20). The experimental group received regular training as well as the additional core training (intervention program) before their regular training. Participants in the control group, on the other hand, they did not receive any special training program apart from their regular rhythmic gymnastics.

4.3.1 Age, Height and Weight of the Participants in Study 2

Table 4.1 represented the mean score of age, height and weight of the participants in the study 2 (n=40). According to the results, the mean age of participants was (7.55±1.01). Furthermore, the mean score of the participants' height and weight were (126.45±12.83) and (25.55±7.43), respectively.

4.3.2 Results of the Assumptions

Normality (Kolmogorov-Smirnov test) and Homogeneity of Variance (Levene's test) and Homogeneity of Co-variance (using Box'M), and Outliers significance were assessed before doing the main test. Mauchly's assumption using Sphericity (the variances of the differences between the related groups of the within-subject factor for all groups of the between-subjects factor of variables) was checked for reading the right results (Pallant, 2007).

The normality distribution of participants in both intervention and control groups was tested using Kolmogorov-Smirnov test. Tables 4.4 shows the results of normality test for intervention and control groups.

Table 4.4: The results of the normality test for intervention and control groups

Tests	Asymp. Sig. (2-tailed) *		
	Pre-test G1-G2**	**Post-test G1-G2**	**Follow-up test G1-G2**
Physical Test			
Vertical Jump	0.49-0.31	0.61-0.52	0.92-0.38
Stork Stand Balance Right Leg	0.92-0.85	0.82-0.90	0.83-0.98
Stork Stand Balance Left Leg	0.86-0.60	0.65-0.72	0.67-0.75
Sit and Reach	0.97-0.56	0.62-0.52	0.46-0.88
Sit Up	0.73-0.30	0.49-0.63	0.34.0.67
Technical Test			
Scissors Jump	0.07-0.06	0.28-0.04	0.08-0.10
Right-leg balance	0.22-0.12	0.51-0.05	0.28-0.10
Stand Erect on Toes	0.51-0.07	0.40-0.35	0.07-0.69
Pivot Passé 360	0.29-0.06	0.53-0.10	0.23-0.27

*One-Sample Kolmogorov-Smirnov test; **G1: intervention group, G2: control group

According to the results of one-simple Kolmogorov-Smirnov test, the p.value for mostly physical and technical test was higher than 0.05. Therefore, there was a normality distribution for all physical and technical tests in intervention and control groups.

Table 4.5: The results of the homogeneity of variance and covariance tests

Tests	P.value*			
	Pre-test	Post-test	Follow-up test	Homogeneity of Co-variance**
Physical Test				
Vertical Jump	0.73	0.96	0.42	0.003
Stork Stand Balance Righ Leg	0.62	0.96	0.37	0.01
Stork Stand Balance Lef Leg	0.53	0.74	0.19	0.002
Sit and Reach	0.97	0.87	0.70	0.03
Sit Up	0.34	0.05	0.08	0.001
Technical Test				
Scissors Jump	0.05	0.07	0.11	0.01
Right-leg balance	0.17	0.88	0.26	0.48
Stand Erect on Toes	0.30	0.67	0.26	0.17
Pivot Passé 360	0.61	0.67	0.68	0.04

*Levene's test; **Box's test (significant level: 0.001)

Furthermore, the results of the Levene's and Box'M test (for assessing Homogeneity of Variance and Homogeneity of Co-variance respectively) represented in table 4.5. Due to the sensitivity of Box's test, the test's level of significance was 0.001(Pallant, 2007).

4.3.3 Effect of the Intervention Program on the Physical and Technical Characteristics

Table 4.6 represented descriptive statistic (Mean scores, SD) of the study physical and technical characteristics in 3 different stages of time for intervention and control groups. The mean scores of each characteristic between the intervention and control groups and in the 3 study's time-point were shown in this table. Although the mean differences can be reviewed in this table, the significance and other details of the data analysis is explained in the next section.

Table 4.6. Descriptive statistic (Mean, SD) of physical and technical characteristics scores in 3 different stages of time for intervention and control groups

Variable	TEST	Group	Mean±SD
Vertical Jump	Pre-test	Intervention	23.75±3.75
		Control	22.65±4.00
	Post- test	Intervention	26.70±4.00
		Control	22.80±3.98
	Follow-up	Intervention	28.20±5.00
		Control	23.05±3.96
Stork Stand Balance Right Leg	Pre-test	Intervention	3.63±1.07
		Control	3.89±1.24
	Post- test	Intervention	4.61±1.52
		Control	3.87±1.31
	Follow-up	Intervention	4.95±1.48
		Control	3.76±1.20
Stork Stand Balance Left Leg	Pre-test	Intervention	6.77±1.72
		Control	6.61±1.48
	Post- test	Intervention	7.45±1.36
		Control	6.30±1.24
	Follow-up	Intervention	7.77±1.59
		Control	6.35±1.23
Sit and Reach	Pre-test	Intervention	35.95±4.12
		Control	36.19±4.03
	Post- test	Intervention	35.10±4.17
		Control	36.85±4.58
	Follow-up	Intervention	35.50±4.49
		Control	36.20±4.12
Sit Up	Pre-test	Intervention	35.95±5.01
		Control	32.60±5.93
	Post- test	Intervention	38.65±3.86
		Control	32.90±6.01
	Follow-up	Intervention	39.50±3.83
		Control	33.15±6.05
Scissors Jump	Pre-test	Intervention	0.62±0.17
		Control	0.50±0.30
	Post- test	Intervention	0.82±0.13
		Control	0.51±0.27
	Follow-up	Intervention	0.88±0.12
		Control	0.53±0.29
Right-leg balance	Pre-test	Intervention	0.54±0.25

		Control	0.57±0.19
	Post- test	Intervention	0.74±0.14
		Control	0.64±0.20
	Follow-up	Intervention	0.80±0.15
		Control	0.72±0.24
Stand Erect on Toes	Pre-test	Intervention	0.61±0.16
		Control	0.54±0.25
	Post- test	Intervention	0.77±0.15
		Control	0.57±0.20
	Follow-up	Intervention	0.83±0.17
		Control	0.61±0.24
Pivot Passé 360	Pre-test	Intervention	0.59±0.23
		Control	0.55±0.25
	Post- test	Intervention	0.76±0.13
		Control	0.54±0.19
	Follow-up	Intervention	0.84±0.13
		Control	0.58±0.21

Overall, based on the norm represented by Sheerin et al. (2012), the mean score of all the current study participants' physical characteristics was identified as average. These findings showed that regarding to the physical characteristics; there was still a lot of room for improvement among participants.

Furthermore, according to the norms provided by Malaysian Gymnastic Federation, scores of maximum marks of each element in all level of RG is 1.00 and minimum mark for passing is 0.50. Therefore, result of all elements in these technical tests in this study need to improve since the scores is below than 1.00.

As well, interaction effect, main effects as well as within and between effects were considered reporting the results. Partial eta square used as a value of effect size. According to Cohen (1988), 0.01, 0.06 and 0.14 represent small, moderate and large effect size respectively (Bakeman, 2005).

An interaction effect is a change in the simple main effect of one variable over levels of the second. If the interaction effect is significant ($p>0.05$), determining the main effect of each level on each factor could be done by ding simple mean effect as the additional analysis. As well, the changes of each variable in each level in the plots could be reviewed another to understand the interaction effect.

This point also needs to be explained why the p value of some tests (in Bonferroni post-hoc is equal to 1. According to International Business Machines (IBM) "SPSS offers Bonferroni-adjusted significance tests for pairwise comparisons. When the product of the Least Significant Difference (LSD) p-value and the number of comparisons exceeds 1, the Bonferroni-corrected p-value reported by SPSS will be 1.000. The reason for this is that probabilities cannot exceed 1 (Pallant, 2007).

Vertical Jump

The results of Mix between-within subjects ANOVA on vertical jump scores showed that there was a significant difference in mean of vertical jump between two groups with large effect ($F=7.13$, $p<0.001$, $\eta2=0.16$), among 3 stages of time with large effect ($F=36.97$, $p<0.001$, $\eta2=0.49$) and interaction between group and time also with large effect ($F=26.36$, $p<0.001$, $\eta2=0.41$) (Table 4.7). With $p=0.55$, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

The result of Bonferroni test revealed that the difference of the vertical jump score between control and intervention groups in pre-test was not significant (Δmean=1.10, $p=0.38$) while the differences between intervention and control groups was significant for vertical jump in post-test (Δmean=3.90, $p<0.001$) with large effect ($\eta^2=0.20$) and follow-up test (Δmean=5.15, $p<0.001$) and effect size was large ($\eta^2=0.25$). Therefore, the null hypothesis was rejected and it can be concluded that the intervention program was effective on vertical jump in intervention group (Table 4.8).

To show the efficacy of the core training program, the mean score of vertical jump in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in vertical jump score in intervention group was significant (Δmean=-2.95, $p<0.001$) with a large effect (η^2=85). There was also a significant difference between vertical jump mean between post-test and follow-up test (Δmean=-1.5, p=0.01). Meanwhile, there was no significant difference in vertical jump between pre-test and post-test (Δmean=-0.51, p=1.00) and between post-test and follow-up test (Δmean=0.14, p=1.00) in control group (Table 4.9).

The simple main effect was done to investigate the interaction between groups and time points. The results of the univariate test showed that the educational protocol has positive effect on the vertical jump mean score in post-test (F=9.54, p=0.004) and follow-up test (F=13.2, p=0.001). However, the interaction between groups and time points was not significant in pre-test (F=0.80, p=0.38). Figure 4.1 shows the mean plot in intervention and control groups across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the vertical jump mean score between 2 groups in post and follow up tests.

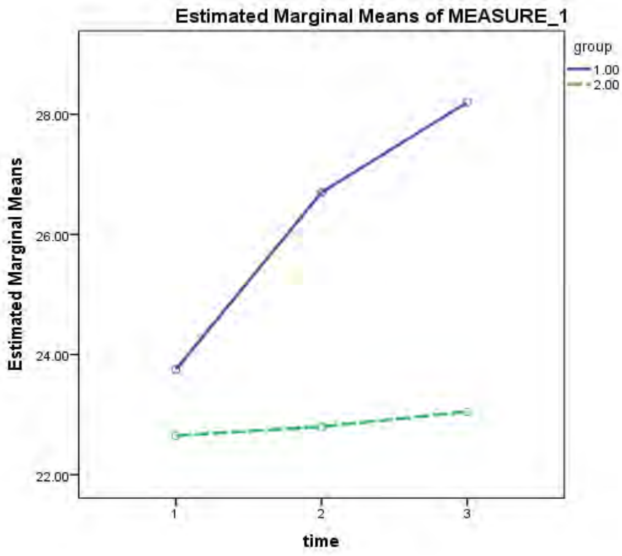

Figure 4.1: The mean plot of vertical jump in intervention (Group1) and control (Group2) across the 3 stages of time

Stork Stand Balance (Right Leg)

The results of Mix between-within subjects ANOVA on right leg balance scores showed that there was a significant difference in mean of right leg balance between two groups with large effect ($F=15.93$, $p<0.001$, $\eta2=0.30$), among 3 stages of time with moderate effect ($F=52.26$, $p<0.001$, $\eta2=0.58$) and interaction between group and time also with large effect ($F=54.99$, $p<0.001$, $\eta2=0.55$) (Table 4.7). With $p=0.58$, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

Table 4.7: Result of ANOVA within – between subject effects for physical

Variable		df	Mean Square	F-Value	P-Value.	Partial Eta Squared
Vertical Jump	Time	2	60.32	36.97	<0.001*	0.49
	Group	1	343.41	7.13	0.01*	0.16
	Time * Group	2	62.25	26.36	<0.001*	0.41
Stork Stand Balance (right leg)	Time	2	30.12	52.26	<0.001*	0.58
	Group	1	108.01	15.93	<0.001*	0.30
	Time * Group	2	26.47	54.92	<0.001*	0.55
Stork Stand Balance (left leg)	Time	2	1.37	2.95	0.05*	0.07
	Group	1	24.89	4.75	0.03*	0.11
	Time * Group	2	4.40	8.21	0.001*	0.18
Sit and Reach	Time	2	3.41	2.85	0.06	0.07
	Group	1	9.07	0.17	0.68	0.00
	Time * Group	2	1.16	0.77	0.44	0.02
Sit-up	Time	2	45.03	27.70	<0.001*	0.43
	Group	1	795.67	10.15	0.003*	0.21
	Time * Group	2	33.42	15.50	<0.001*	0.30

*Significant at level p<0.05

The result of Bonferroni test revealed that the difference of the right leg balance score between control and intervention in pre-test was not significant (Δmean=0.32, p=0.50) while the differences between intervention and control groups was significant for right leg balance in post-test (Δmean=2.57, p<0.001) with large effect (η^2=0.39) and follow-up test (Δmean=2.80, p<0.001) and effect size was large (η^2=0.44). Therefore, the null hypothesis was rejected, and it can be concluded that the intervention program was effective on right leg balance in intervention group (Table 4.8).

To show the efficacy of the core training program, the mean score of right leg balance in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test & post-test in right leg balance score in intervention group was significant (Δmean=-2.25, p<0.001) with a large effect (η^2=75). There was also a significant difference between right leg balance mean between post-test and follow-up test (Δmean=-0.34, p=0.03). Meanwhile, there was no significant difference in right leg balance between pre-test and post-test (Δmean=-0.01, p=1.00) and between post-test and follow-up test (Δmean=-0.11, p=1.00) in control group (Table 4.9).

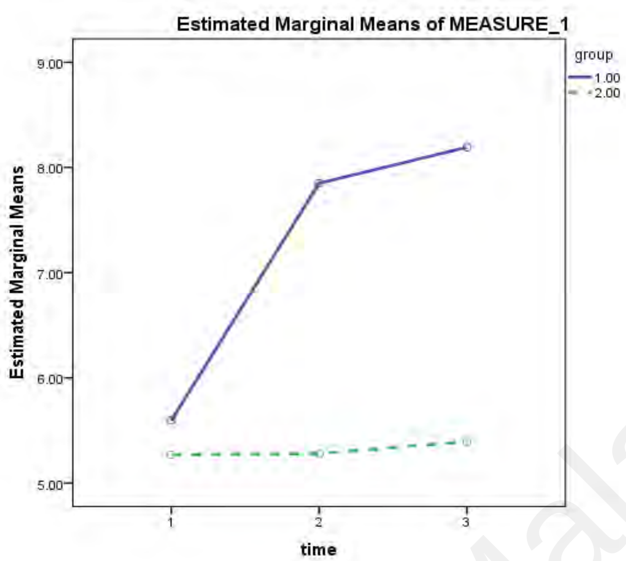

Figure 4.2: The mean plot of Stork Stand Balance (right leg) in intervention (Group1) and control (Group2) across the 3 stages of time

The results showed that the educational protocol has positive effect on the stork stand balance (right leg) mean score in post-test (F=23.87, p<0.001) and follow-up test (F=30.21, p<0.001). However, the interaction between groups and time points was not significant in pre-test (F=0.47, p=0.49). Figure 4.2 shows the mean plot of intervention and control groups across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the stork stand balance (right leg) mean score between 2 groups in post and follow up tests.

Stork Stand Balance (left leg)

The results of Mix between-within subjects ANOVA on left leg balance scores showed that there was a significant difference in mean of left leg balance between two groups with moderate effect (F=4.75, p=0.03, η2=0.11), among 3 stages of time with moderate effect (F=2.95, p=0.05, η2=0.07) and interaction between group and time also with large effect (F=8.21, p<0.001, η2=0.18) (Table 4.7). With p=0.35, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

Table 4.8: Holistic mean difference between intervention and Control Groups in pre-test, post-test and follow-up test for physical characteristics

Variable	time	Intervention group (I)	Control group (J)	Mean Difference (I-J)	S.E	p. value	95% CI		Partial η²
							Lower Bound	Upper Bound	
Vertical Jump	1	23.75	22.65	1.10	1.23	0.38	-1.39	3.59	0.1
	2	26.70	22.80	3.90	1.26	<0.001*	1.34	6.45	0.20
	3	28.20	23.08	5.15	1.43	<0.001*	2.26	8.04	0.25
Stork Stand Balance (right leg)	1	5.59	5.27	0.32	0.47	0.50	-0.63	1.28	0.1
	2	7.85	5.28	2.57	0.53	<0.001*	1.50	3.36	0.39
	3	8.19	5.39	2.80	0.51	<0.001*	1.76	3.83	0.44
Stork Stand Balance (left leg)	1	6.70	6.61	0.16	0.51	0.75	-0.87	1.19	0.003
	2	7.46	6.30	1.15	0.41	<0.001*	0.32	1.98	0.17
	3	7.77	6.35	1.42	0.45	<0.001*	0.50	2.33	0.20
Sit and Reach	1	35.95	36.15	-0.20	1.29	0.88	-2.81	2.41	0.001
	2	35.10	35.85	-0.75	1.39	0.59	-3.56	2.06	0.01
	3	35.50	36.20	-0.70	1.36	0.61	-3.46	2.06	0.01
Sit-up	1	35.95	32.60	3.35	1.53	0.06	-0.16	6.86	0.05
	2	38.65	32.90	5.75	1.61	<0.001*	2.49	9.01	0.25
	3	39.50	33.15	6.35	1.60	<0.001*	3.11	9.59	0.29

*Significant at level p<0.05

The result of Bonferroni test revealed that the difference of the left leg balance score between control and intervention in pre-test was not significant (Δmean=0.16, p=0.75) while the differences between intervention and control groups was significant for left leg balance in post-test (Δmean=1.15, p=0.01) with large effect (η^2=0.17) and follow-up test (Δmean=1.42, p=0.003) and effect size was large (η^2=0.21). Therefore, the null hypothesis was rejected, and it can be concluded that the intervention program was effective on left leg balance in intervention group (Table 4.8).

To show the efficacy of the core training program, the mean score of left leg balance in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in left leg balance score in intervention group was significant (Δmean=-0.69, p=0.04) with a large effect (η^2=32). There was also a significant difference between left leg balance mean between post-test and follow-up test (Δmean=-0.31, p=0.01). Meanwhile, there was no significant difference in left leg balance between pre-test and post-test (Δmean=-0.30, p=0.80) and between post-test and follow-up test (Δmean=-0.04, p=1.00) in control group (Table 4.9).

The simple main effect was done to investigate the interaction between groups and time points. The results showed that the educational protocol has positive effect on the left leg balance mean score in post-test (F=7.86, P=0.008) and follow-up test (F=9.94, P=0.003). However, the interaction between groups and time points was not significant (F=0.09, P=0.75). Figure 4.3 shows the mean plot of intervention and control group across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the left leg balance mean score between 2 groups in post and follow up tests.

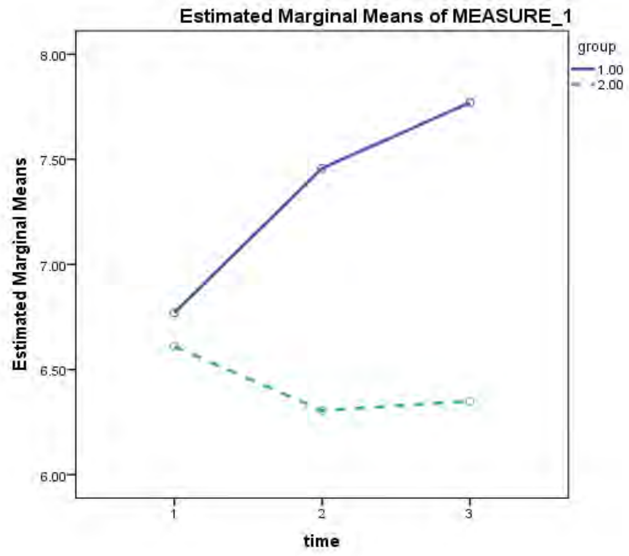

Figure 4.3: The mean plot of Stork Stand Balance (left leg) in intervention (Group1) and control (Group2) across the 3 stages of time

Sit and Reach Test

The results of Mix between-within subjects ANOVA on sit and reach scores showed that there was not a significant difference in the mean value of sit and reach between two groups (F=0.17, p=0.67), among 3 stages of time (F=2.85, p=0.06), and interaction between group and time (F=0.77, p=0.44) (Table 4.7). With p=0.75, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, the intervention program had no effect on sit and reach scores among participants. Figure 4.4 shows the mean plot of intervention and control group across the 3 stages of time.

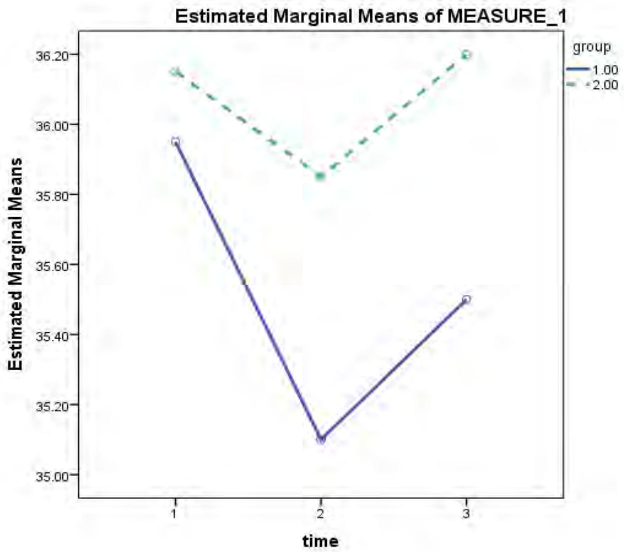

Figure 4.4: The mean plot of Sit and Reach in intervention (Group1) and control (Group2) across the 3 stages of time

Table 4.9: The difference of physical characteristics means scores between tests in Intervention and Control Groups

Variable	Intervention position	(I) time	(J) time	Mean Difference (I-J)	S.E	p. value	95% CI		Partial η²
							Lower Bound	Upper Bound	
Vertical Jump	intervention	Pre-test	Post-test	-2.95*	0.23	<0.001	-3.53	-2.36	0.85
		Pre-test	follow-up test	-4.45*	0.46	<0.001	-5.59	-3.31	
		Post-test	follow-up test	-1.50*	0.47	0.01	-2.69	0.31	
	control	Pre-test	Post-test	-0.51	0.24	1	-0.73	0.45	0.03
		Pre-test	follow-up test	-0.37	0.45	1	-1.54	0.74	
		Post-test	follow-up test	0.14	0.47	1	-1.44	0.94	
Stroke Stand Balance (right leg)	intervention	Pre-test	Post-test	-2.25*	0.21	<0.001	-2.80	-1.72	0.75
		Pre-test	follow-up test	-2.60*	0.25	<0.001	-3.21	-1.98	
		Post-test	follow-up test	-0.34*	0.13	0.03	-0.66	-0.03	
	control	Pre-test	Post-test	-0.10	0.21	1	-0.55	0.53	0.02
		Pre-test	follow-up test	-0.12	0.24	1	-0.74	0.50	
		Post-test	follow-up test	-0.11	0.13	1	-0.43	0.47	
Stroke Stand Balance (right leg)	intervention	Pre-test	Post-test	-0.69*	0.27	0.04	-1.37	-0.01	0.32
		Pre-test	follow-up test	-1.00*	0.28	<0.001	-1.69	-0.30	
		Post-test	follow-up test	-0.31*	0.10	0.01	-0.60	-0.06	
	control	Pre-test	Post-test	0.30	0.27	0.80	-0.37	0.98	0.03
		Pre-test	follow-up test	0.26	0.28	1	-0.43	0.95	
		Post-test	follow-up test	-0.04	0.10	1	-0.30	0.21	
Sit and Reach	intervention	Pre-test	Post-test	0.85	0.35	0.06	-0.o01	1.17	0.17
		Pre-test	follow-up test	0.45	0.41	0.85	-0.58	1.48	
		Post-test	follow-up test	0.40	0.26	0.39	-1.05	0.25	
	control	Pre-test	Post-test	0.30	0.35	1	-0.56	1.16	0.06
		Pre-test	follow-up test	-0.05	0.41	1	-1.08	0.98	
		Post-test	follow-up test	-0.35	0.26	0.56	-0.30	1	
Sit-up	intervention	Pre-test	Post-test	-2.70*	0.44	<0.001	-3.80	-1.60	0.60
		Pre-test	follow-up test	-3.55*	0.47	<0.001	-4.73	-2.37	
		Post-test	follow-up test	-0.85*	0.27	0.01	-1.52	-0.18	
	control	Pre-test	Post-test	-0.30	0.43	1	-1.40	0.79	0.04
		Pre-test	follow-up test	-0.55	0.46	0.76	-1.73	0.63	
		Post-test	follow-up test	0.25	0.27	1	-0.92	0.42	

*Significant at level p<0.05

Sit-Up (60 second) MSUT

The results of Mix between-within subjects ANOVA on sit-up scores showed that there was a significant difference in mean of sit-up between two groups with large effect (F=10.15, p<0.001, η2=0.21), among 3 stages of time with large effect (F=27.70, p<0.001, η2=0.42) and interaction between group and time also with large effect (F=15.50, p<0.001, η2=0.29) (Table 4.7). With p=0.67, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

The result of Bonferroni test revealed that the difference of the sit-up score between control and intervention in pre-test was not significant (Δmean=3.35, p=0.06) while the differences between intervention and control groups was significant for sit-up in post-test (Δmean=5.57, p<0.001) with large effect (η^2=0.25) and follow-up test (Δmean=6.35, p<0.001) and effect size was large (η^2=0.29). Therefore, the null hypothesis was rejected and it can be concluded that the intervention program was effective on sit up in intervention group (Table 4.8).

To show the efficacy of the core training program, the mean score of sit-up in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in sit-up score in intervention group was significant (Δmean=-2.70, p<0.001) with a large effect (η^2=60). There was also a significant difference between sit-up mean between post-test and follow-up test (Δmean=-0.85, p=0.01). Meanwhile, there was no significant difference in sit-up between pre-test and post-test (Δmean=-0.30, p=1.00) and between post-test and follow-up test (Δmean=-0.25, p=1.00) in control group (Table 4.9).

The simple main effect was done to investigate the interaction between groups and time points. The results showed that the educational protocol has positive effect on the sit and reach mean score in post-test (F=12.74, P=0.001) and follow-up test (F=15.77, P<0.001). However, the interaction between groups and time points was not significant (F=3.73, P=0.06). Figure 4.5 shows the mean plot of post-test in intervention and control group across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the sit and reach mean score between 2 groups in post and follow up tests.

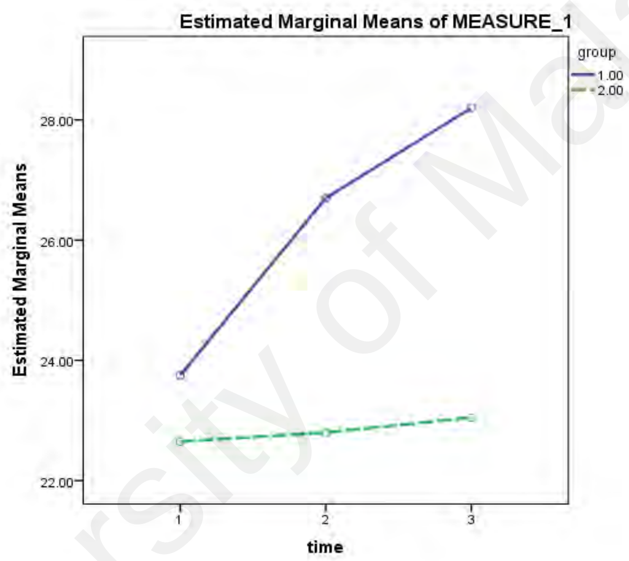

Figure 4.5: The mean plot of Sit-Up in intervention (Group1) and control (Group2) across the 3 stages of time

4.3.4 Effect of the Intervention Program on the Technical Characteristics Scissors Jump with Arm Circles

The results of Mix between-within subjects ANOVA on scissors jump scores showed that there was a significant difference in mean of scissors jump between two groups with large effect (F=14.92, p<0.001, η2=0.28), among 3 stages of time with large effect (F=33.68, p<0.001, η2=0.47) and interaction between group and time also with large effect (F=20.23, p<0.001, η2=0.35) (Table 4.10). With p=0.79, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

The result of Bonferroni test revealed that the difference of the scissors jump score between control and intervention in pre-test was not significant (Δmean=0.13, p=0.10) while the differences between intervention and control groups was significant for scissors jump in post-test (Δmean=0.32, p<0.001) with large effect (η^2=0.38) and follow-up test (Δmean=0.35, p<0.001) and effect size was large (η^2=0.38). Therefore, the null hypothesis was rejected, and it can be concluded that the intervention program was effective on scissors jump in intervention group (Table 4.11).

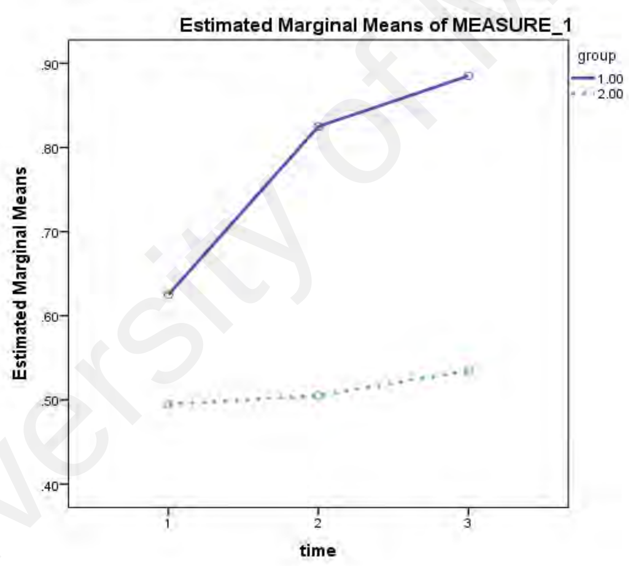

Figure 4.6: The mean plot of Scissors Jump with Arm Circles in intervention (Group1) and control (Group2) across the 3 stages of time

To show the efficacy of the training program, the mean score of scissors jump in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in scissors jump score in intervention group was significant (Δmean=-0.20, p<0.001) with a large effect (η^2=0.17). There was also a significant difference between scissors jump mean between post-test and follow-up test (Δmean=-0.6, p=0.01). Meanwhile, there was no significant difference in scissors jump between pre-test and post-test (Δmean=-0.01, p=1.00) and between post-test and follow-up test (Δmean=-0.03, p=1.00) in control group (Table 4.12).

The simple main effect (Univariate tests) was done to investigate the interaction between groups and time points. The results showed that the educational protocol has positive effect on the scissors jump mean score in post-test (F=23.07, P<0.001) and follow-up test (F=23.61, P<0.001). However, the interaction between groups and time points was not significant (F=2.78, P=0.10) in pre-test. Figure 4.6 shows the mean plot of intervention and control group across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the scissors jump mean score between 2 groups in post and follow up tests.

Right Leg Balance with Free Leg in Front/ Side at Horizontal

The results of Mix between-within subjects ANOVA on right leg balance scores showed that there was not a significant difference in mean of right leg balance between two groups (F=1.01, p=0.32), and interaction between group and time (F=2.15, p=0.12) (Table 4.10). However, a significant difference in mean of right leg balance among 3 stages of time with large effect (F=17.61, p<0.001, η2=0.31). With p=0.45, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

Table 4.10: Result of ANOVA within – between subject effects for technical characteristics

Variable		df	Mean Square	F-Value	P-Value.	Partial Eta Squared
Scissors Jump with Arm Circles	Time	2	0.24	33.68	<0.001*	0.47
	Group	1	2.13	14.92	<0.001*	0.28
	Time * Group	2	0.14	20.23	<0.001*	0.35
Right Leg Balance	Time	2	0.51	17.61	<0.001*	0.32
	Group	1	0.07	1.01	0.32	0.02
	Time * Group	2	0.05	2.15	0.12	0.05
Stand Erect on Toes	Time	2	0.26	22.15	<0.001*	0.37
	Group	1	0.87	9.11	<0.001*	0.19
	Time * Group	2	0.10	7.54	<0.001*	0.17
Pivot passé 360	Time	2	0.20	11.64	<0.001*	0.23
	Group	1	0.88	10.82	0.002*	0.22
	Time * Group	2	0.13	7.60	<0.001*	0.17

*Significant at level $p<0.05$

The mean score of right leg balance in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in right leg balance score in intervention group was significant (Δmean=-0.21, p=0.002) with a large effect (η^2=34). There was also a significant difference between right leg balance mean between post-test and follow-up test (Δmean=-0.06, p=0.08). Meanwhile, there was no significant difference in right leg balance between pre-test and post-test (Δmean=-0.08, p=0.68) and between post-test and follow-up test (Δmean=-0.02, p=0.73) in control group (Table 4.12).

Figure 4.6 shows the mean plot of intervention and control group across the 3 stages of time. The non-significant interaction between time and groups is clear in the mean plot regarding to the relative equality of the distance between each time point between the two groups.

Table 4.11: Holistic mean difference between intervention and Control Groups in pre-test, post-test and follow-up test for technical characteristics

Variable	time	Intervention Position		Mean Difference (I-J)	S.E	p. value	95% CI		Partial η²
							Lower Bound	Upper Bound	
Scissors jump	1	intervention	control	0.13	0.08	0.10	-0.03	0.29	0.001
	2	intervention	control	0.32	0.07	<0.001*	0.18	0.45	0.38
	3	intervention	control	0.35	0.07	<0.001*	0.20	0.50	038
Right Leg Balance	1	intervention	control	-0.04	0.07	0.59	-0.18	0.10	0.008
	2	intervention	control	0.10	0.05	0.08	-0.05	0.28	0.08
	3	intervention	control	0.08	0.06	0.21	0.14	0.38	0.04
Stand Erect on Toes	1	intervention	control	0.06	0.07	0.34	-0.07	0.20	0.02
	2	intervention	control	0.20	0.06	<0.001*	0.08	0.31	0.23
	3	intervention	control	0.25	0.07	<0.001*	-0.38	-0.11	0.21
Pivot passé 360	1	intervention	control	0.04	0.08	0.60	-0.11	0.19	0.1
	2	intervention	control	0.22	0.05	<0.001*	0.11	0.32	0.32
	3	intervention	control	0.25	0.06	<0.001*	0.14	0.36	0.35

*Significant at level p<0.05

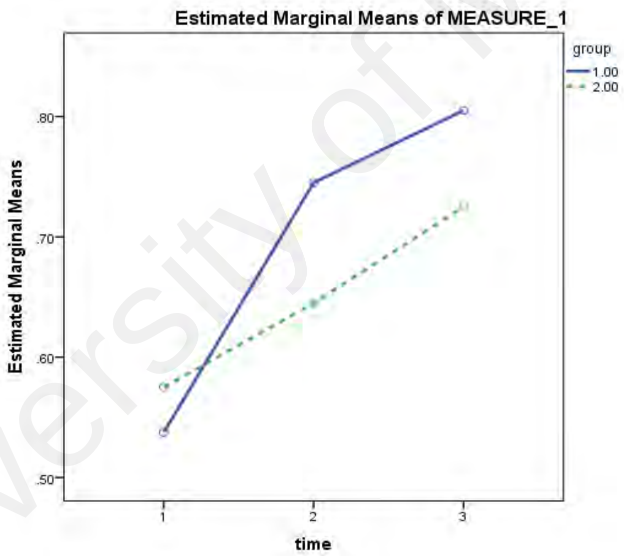

Figure 4.7: The mean plot of Right Leg Balance in intervention (Group1) and control (Group2) across the 3 stages of time

Stand Erect on Toes with Successive Arm Waves

The results of Mix between-within subjects ANOVA on stand erect on toes scores showed that there was a significant difference in mean of stand erect on toes between two groups with large effect ($F=9.11$, $p<0.001$, $\eta2=0.19$), among 3 stages of time with large effect ($F=9.11$, $p<0.001$, $\eta 2=0.19$) and interaction between group and time also with large effect ($F=22.15$, $p<0.001$, $\eta 2=0.37$) (Table 4.10). With $p=0.68$, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

The result of Bonferroni test revealed that the difference of the stand erect on toes score between control and intervention in pre-test was not significant (Δmean=0.06, $p=0.34$) while the differences between intervention and control groups was significant for stand erect on toes in post-test (Δmean=0.20, $p<0.001$) with large effect ($\eta^2=0.23$) and follow-up test (Δmean=0.25, $p<0.001$) and effect size was large ($\eta^2=0.21$). Therefore, the null hypothesis was rejected and it can be concluded that the intervention program was effective on stand erect on toes in intervention group (Table 4.11).

To show the efficacy of the core training program, the mean score of the stand erect on toes in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in stand erect on toes score in intervention group was significant (Δmean=-0.16, $p<0.001$) with a large effect ($\eta^2=42$). There was also a significant difference between stand erect on toes mean between post-test and follow-up test (Δmean=-0.10, $p=0.03$). Meanwhile, there was no significant difference in stand erect on toes between pre-test and post-test (Δmean=0.02, $p=1.00$) and between post-test and follow-up test (Δmean=-0.04, $p=0.29$) in control group (Table 4.12).

Table 4.12: The difference of technical characteristic mean scores between tests in intervention and Control Groups

Variable	intervention position	(I) time	(J) time	Mean Difference (I-J)	S.E	p. value	95% CI		Partial η²
							Lower Bound	Upper Bound	
Scissors jump	intervention	1	2	-0.20	0.03	<0.001*	-0.01	1.17	0.17
		1	3	-0.26	0.03	<0.001*	-0.58	1.48	
		2	3	-0.60	0.02	0.01*	-1.05	0.25	
	control	1	2	0.30	0.03	1	-0.56	1.16	0.06
		1	3	-0.05	0.04	1	-1.08	0.98	
		2	3	-0.35	0.02	0.56	-0.30	1	
Right Leg Balance	intervention	1	2	-0.21	0.06	<0.001*	-0.39	-0.10	0.35
		1	3	-0.27	0.06	<0.001*	-0.52	-0.22	
		2	3	-0.06	0.03	0.03*	-0.22	0.03	
	control	1	2	-0.07	0.05	0.68	-0.19	0.09	0.04
		1	3	-0.15	0.06	0.07	-0.21	0.08	
		2	3	-0.02	0.04	0.98	-0.12	0.07	
Stand Erect on Toes	intervention	1	2	-0.07	0.04	<0.001*	-0.25	-0.06	0.42
		1	3	-0.25	0.04	<0.001*	-0.35	-0.16	
		2	3	-0.10	0.03	<0.001*	-0.16	-0.03	
	control	1	2	-0.07	0.05	0.21	-0.11	0.06	0.08
		1	3	-0.15	0.06	0.25	-0.17	0.03	
		2	3	-0.08	0.03	0.29	-0.02	0.11	
Pivot passé 360	intervention	1	2	-0.17	0.05	<0.001*	-0.30	-0.04	0.48
		1	3	-0.25	0.05	<0.001*	-0.37	-0.13	
		2	3	-0.08	0.03	0.005*	-0.14	-0.02	
	control	1	2	0.01	0.05	1	-0.11	0.13	0.09
		1	3	-0.03	0.06	1	-0.15	0.08	
		2	3	-0.04	0.02	1	-0.10	0.01	

*Significant at level p<0.05

The simple main effect (Univariate tests) was done to investigate the interaction between groups and time points. The results showed that the educational protocol has positive effect on the stand erect on toes mean score in post-test (F=13.31, P=0.001) and follow-up test (F=10.41, P=0.003). However, the interaction between groups and time points was not significant (F=0.95, P=0.34) in pre-test. Figure 4.6 shows the mean plot of intervention and control group across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the stand erect on toes mean score between 2 groups in post and follow up tests.

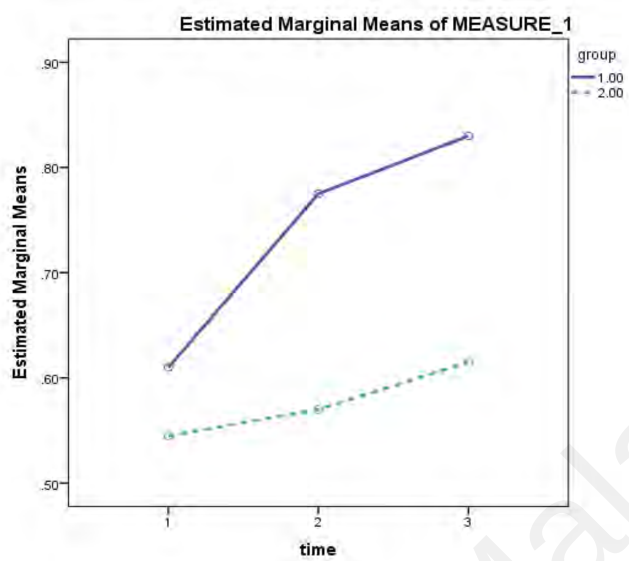

Figure 4.8: The mean plot of the stand erect on toes in intervention (Group1) and control (Group2) across the 3 stage of time

Pivot passé 360

The results of Mix between-within subjects ANOVA on pivot passé scores showed that there was a significant difference in mean of pivot passé between two groups with large effect ($F=10.82$, $p<0.001$, $\eta 2=0.22$), among 3 stages of time with large effect ($F=11.64$, $P<0.001$, $\eta 2=0.23$) and interaction between group and time also with large effect ($F=7.60$, $p=0.001$, $\eta 2=0.17$) (Table 4.10). Therefore, to test the related hypothesis post hoc test (Bonferroni) was applied to compare the mean scores.

The result of Bonferroni test revealed that the difference of the pivot passé score between control and intervention in pre-test was not significant (Δmean=0.04, $p=0.60$) while the differences between intervention and control groups was significant for pivot passé in post-test (Δmean=0.22, $p<0.001$) with large effect ($\eta^2=0.32$) and follow-up test (Δmean=0.25, $p<0.001$) and effect size was large ($\eta^2=0.36$). With $p=0.52$, the sphericity assumption was not rejected, and the uncorrected (sphericity assumed) univariate results was considered. Therefore, the null hypothesis was rejected and it can be concluded that the intervention program was effective on pivot passé in intervention group (Table 4.11).

To show the efficacy of the core training program, the mean score of pivot passé in pre-test, post-test and follow-up test were compared in both the intervention and control groups. The result of post hoc test (Bonferroni) revealed that the difference between pre-test and post-test in pivot passé score in intervention group was significant (Δmean=-0.17, $p<0.001$) with a large effect (η^2=48). There was also a significant difference between pivot passé mean between post-test and follow-up test (Δmean=-0.08, $p<0.001$). Meanwhile, there was no significant difference in pivot passé between pre-test and post-test (Δmean=0.01, p=1.00) and between post-test and follow-up test (Δmean=-0.04, p=0.1) in control group (Table 4.12).

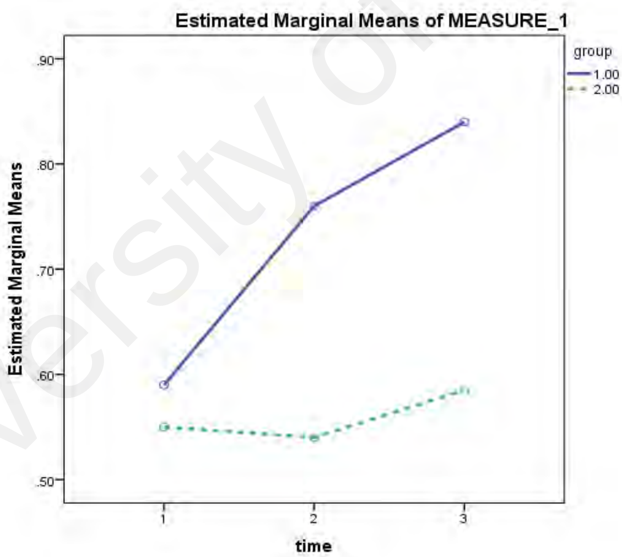

Figure 4.9: The mean plot of the pivot passé 360 in intervention (Group1) and control (Group2) across the 3 stages of time

The simple main effect (Univariate tests) was done to investigate the interaction between groups and time points. The results showed that the educational protocol has positive effect on the pivot passé mean score in post-test (F=17.75, P<0.001) and follow-up test (F=20.36, P<0.001). However, the interaction between groups and time points was not significant (F=0.28, P=0.60). Figure 4.9 shows the mean plot of intervention and control group across the 3 stages of time. The interaction between groups and post/follow up tests is also clear in the mean plot regarding to the significant distance of the pivot passé mean score between 2 groups in post and follow up tests.

CHAPTER 5: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Introduction

The purpose of the study 1 was to investigate the physical and technical characteristics of young Malaysian Rhythmic Gymnasts. To achieve this purpose, one hundred rhythmic gymnasts (all female, aged 6 to 9 years old) were recruited from two gymnastic Clubs of Kuala Lumpur including Bukit Jalil National Sport Complex Club and Serdang Rhythmic Angels Club.

In the study 2, the effects of the core training program on participants' physical and technical characteristics were investigated as the main study objective. From the participants in the study 1, forty rhythmic gymnasts were randomly selected for study 2 which divided randomly into intervention and control groups. Participants in the intervention group received 8 weeks of the core training program as the intervention program on top of their regular training and control group carried out their normal training without any additional training.

5.2 The physical and technical characteristics among participants in the study 1

The Physical characteristics investigating in this study included, jumping ability, balance skills, flexibility as well as strength and endurance. Results revealed that, the mean score of Vertical Jump (jumping ability), Stock Stand Balance Right Leg and Stock Stand Balance Left Leg were 23.43±4.36 (cm), 5.32±2.04 (s) and 4.32±1.74 (s), respectively. Furthermore, the mean score of Sit and Reach and Sit-Up were 35.22± 4.68 and 33.36 ± 6.07, respectively.

According to the study by Sheerin et al. (2012), the norm of mean score of vertical jump is between less than 6.4 and more than 39.1 cm (<6.4=Very poor, 6.4-11.18=Poor, 11.2-17.2=Below average, 17.3-28.2=Average, 28.3-33.7=Above average, 33.8-

39.1=Good and > 39.1=Excellent) (Sheerin et al., 2012). Regarding to this norm, the participants in the current study placed in the range of average (17.3 - 28.2 cm) in vertical jump.

These finding are in contrast with the results of the study by Douda et al. (2007) who showed the mean score of vertical jump test among the novice RG in Greece was 35.04±3.72. Comparing these results with the norm reported in the Sheerin et al. study, the Greece gymnasts are placed in the range of good (33.8-39.1) (Douda et al., 2007). Therefore, regarding to the vertical test, the participants in the current study with the mean score of (23.43±4.36) in the vertical jump test were in lower range in jumping ability compared with the Greece novice rhythmic gymnasts and the Malaysian Novice RG need to improve their jumping abilities.

Furthermore, results of the current study is in agreement with a study by Miletić et al. (2004) among 50 female novice rhythmic gymnasts (mean age 7.11±0.3 years) in Croatia that revealed the mean score of the participants' vertical jump test was (22.11±4.13) (Miletić et al., 2004). Regarding to the norm of Sheerin 2012, the participants in this study were placed in the average range and in compare with the mean score of the current study; they were in the same level.

Results of the current study also showed that the Stork Stand Balance Right Leg and Stork Stand Balance Left Leg 5.32±2.04(s) and 4.32±1.74(s), respectively. Furthermore, according to the norm mentioning in the study by Sheerin et al. (2012), both right and left legs stork stand balance among the participants are average (2.33-6.11). The norm of mean score of Stork Stand Balance is between less than 6.4 and more than 39.1 cm (<6.4=Very poor, 6.4-11.18=Poor, 11.2-17.2=below average, 17.3-28.2=Average, 28.3-33.7=above average, 33.8-39.1=Good and > 39.1=Excellent) (Sheerin et al., 2012).

Similarly, results of the current study also showed that the mean score of sit and reach (cm) was 35.22±4.68. According to the norm mentioning in the study by Sheerin et al. (2012), the norm of mean score of Sit and Reach test is between less than 15.5 and more than 47.5 cm (<15.5=Very poor, 2.10-25.5=Below average, 26.0-37.0=average, 37.5-42.5=Above Average, 43.0-47.5=Good, and >47.5=Excellent) (Sheerin et al., 2012). Therefore, the participants in the current study with the mean score of placed in the range of average (26.0–37.0 cm) in Sit and Reach test (cm).

According to the study by Douda et al. (2007) the mean score of sit and reach test among the Greece novice rhythmic gymnasts was 20.78±4.37 putting the participants in the below average range based on Sheerin et al. (2012) classification. On the other hand, the results of the study by Miletić et al. (2004) showed the mean score of sit and reach test of the Croatia novice rhythmic gymnasts was 55.00±7.54 (very strong according to the Sheerin et al. norm). Therefore, compared with the participants in the current study, the Greece and the Croatia novice rhythmic gymnasts were in the lower and higher levels of flexibility (Douda et al., 2007; Miletić et al., 2004).

According to the study by Sheerin et al. (2012), the norm of mean score of Sit Up (sec) is between less than 10 and more than 50 (<10=Very poor, 16-22 = Below average, 24-36=average, 38-44= Above Average, 46-50=Good, and >50=Excellent) (Sheerin et al., 2012). Regarding to this norm, the participants in the current study with the mean score of (33.36±6.07) were placed in the average range (24-36) in Sit Up test (sec).

Similarly, the results of the study by Miletić et al. (2004) showed the mean score of sit up test (sec) was 26.10±8.01 among the 50 female rhythmic gymnastics novices in Croatia. Referred to the norm of Sheerin et al. (2012), they were placed in the range of average, like the Malaysian participants in the current study. On the other hand, the study by Douda et al. (2007) in Greece reported that the mean score of sit up test (sec) was 39.02±3.90 among the participants, therefore, referring to the norm of Sheerin et al. (2012), they were placed in the range of above average, higher than the participants in the current study (Douda et al., 2007; Miletić et al., 2004).

Overall, based on the norm represented by Sheerin et al. (2012), the mean score of all the current study participants' physical characteristics was identified as average. These findings showed that regarding to the physical characteristics; there was still a lot of room for improvement among participants.

Regarding to the technical characteristics, the findings of the current study showed that the mean score and standard deviation for scissors jump with arm circles, right-leg balance with free leg in front/side at horizontal were 0.57±0.26 and 0.61±0.22, respectively. Furthermore, the mean score of stand erect on toes with successive arm waves, half-bent and Pivot passé 360 in passé position to the right with arms at sides were 0.69±0.94 and 0.66 ± 0.59, respectively.

According to the norms provided by Malaysian Gymnastic Federation, scores of maximum marks of each element in all level of RG is 1.00 and minimum mark for passing is 0.50. Therefore, result of all elements in these technical tests in this study need to improve since the scores is below than 1.00.

5.3 The effect on the core training on the physical characteristics among participants in the study 2

The core training protocol that used as the intervention program in this study were selected to target the body muscles which are utilized during performing the study physical and technical tests. Performing the core exercises on a Swiss ball increase the activities' effects on body's strength, endurance, and balance. As well improving posture is the other benefit of using of using ball during the core exercise. On the other hand, attempts were made to make simple exercises suitable for the age group of participants ("Reaping The Benefits of Using an Exercise Ball," 2017).

Regarding to these advantages and according to the study findings, generally, participants in the group doing core training (interventional group, n=20) showed a significant improvement in the mean score of the majority of the assessed physical characteristics after the training period, compared with the control group.

5.3.1 Vertical Jump

The results of the current study showed the core training program had a significant positive effect on the jumping ability among participants in intervention group; meanwhile, no significant difference was seen among participants in the control group. The mean score of jumping ability in intervention group at the pre-test was (23.75±3.77) which significantly ($p<0.0001$, $\eta^2=85$) increased to (26.70±4.00) in post-test. Furthermore, the results of follow-up test in intervention group showed the continuity of improving the jumping ability in follow-up test (28.20±5.00). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of vertical jump from pre-test to post-test (22.65±4.00 vs. 22.80±3.98) and post-test to follow-up test (22.80±3.98 vs. 23.05±3.96).

The mean score of jumping ability in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of jumping ability in the post-test ($\Delta=3.90$, $p=0.004$, $\eta^2=0.20$) and in the follow-up test ($\Delta=5.15$, $p=0.001$, $\eta^2=0.20$) both with a large effect size.

Therefore, we can confirm that, the interventional program had effective impact on participants' jumping ability. According to the study by Sheerin et al. (2012), at the end of training sessions the mean score of jumping ability among participants in the intervention group was improved to the borderline value between average and above average (28.20±5.00).

Previous studies approved the effect of core training on the jumping ability among different athletes. These results are in agreement with the finding of the previous studies that examined the effect of core training on jumping abilities. Using explosive strength training, the results of two different studies in 2004 and 2005 among soccer players showed that core training was significantly improve the participants jumping ability (Gorostiaga et al., 2004; Moore, Hickey, & Reiser II, 2005). Another study by Wong et al. (2010) showed that the 12-week combined strength and power training including core training for young soccer players significantly improved their explosive performance including vertical jump (Wong et al., 2010).

The results of the current study has also supported by the findings of a study by Christou et al. (2006) that showed compared with the athletes who only participated in soccer training, the participants joining in strength training (twice a week) along with their routine soccer training had a positive improvement in upper- and lower-body strength as well as vertical jump performance (Christou et al., 2006).

5.3.2 Balance Skill

The results of the current study showed core training had a significant positive effect on the mean score of balance skills among participants in the experimental group. The mean score of Right leg balance in intervention group at the pre-test was (5.59±1.45) which significantly ($p<0.0001$, $\eta^2=76$) increased to (7.85±1.77) in post-test. The results of follow-up test in intervention group showed the continuity of improving the balance ability in follow-up test (8.19±1.82). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of the right leg balance from pre-test to post-test (5.27±1.53 vs. 5.28±1.54) and post-test to follow-up test (5.28±1.54 vs. 5.39±1.35).

The mean score of right leg balance in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of Right leg balance in the post-test ($\Delta=2.57$, $p<0.001$, $\eta^2=0.38$) and in the follow-up test ($\Delta=2.79$, $p=0.001$, $\eta^2=0.44$) both with a large effect size.

Furthermore, the mean score of left leg balance in intervention group at the pre-test was (6.77±1.72) which significantly ($p=0.04$, $\eta^2=32$) increased to (7.45±1.36) in post-test. Furthermore, the results of follow-up test in intervention group showed the continuity of improving the balance ability in follow-up test (7.77±1.59). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of the left leg balance from pre-test to post-test (6.61±1.48 vs. 6.30±1.24) and post-test to follow-up test (6.30±1.23 vs. 6.35±1.23).

The mean score of left leg balance in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of left leg balance in the post-test ($\Delta=1.15$, $p=0.008$, $\eta^2=0.17$) and in the follow-up test ($\Delta=1.42$, $p=0.003$, $\eta^2=0.20$) both with a large effect size.

Therefore, in conclusion, the interventional program had effective impact on participants' both right and left leg balance. According to the study by Sheerin et al. (2012), at the end of training sessions the mean score of right and left leg balance among participants in the intervention group were improved from average (2.33-6.11) to the above average range (6.12-9.93).

The spine's position is a very important factor of the body's center of gravity, and could be helpful to regulate balance. Core training improves the spinal segments' control and deep stabilizing muscle co-contraction, which cause to better control of the body's center of gravity and optimal lumbo-pelvic control. Enhancing of the static balance performance by core stability training may also explain by improving trunk control (Hoffman & Payne, 1995).

According to anderson and Behm (2005), the proprioceptive system receives information from joints and muscles to coordinate unconscious reflexes and maintain balance. Local muscles have a greater proprioceptive function, and if the Swiss-ball stresses these muscles to a greater extent, this may form the basis for an improved balance effect after training (anderson & Behm, 2005).

The significant improvement in balance in the current study showed that the core training protocol in this study not only facilitate the global muscles but also facilitate the local muscle groups of the core. Therefore, this core training protocol can be effective as an additional training to improve balance skills in the rhythmic gymnasts that is needed to improve balance.

Training on unstable surface (such as physio-ball) and the exposure to altered sensory input stresses the musculature and activates the neuroadaptive mechanisms which lead to gains in stability and proprioceptor activity, improved sway control, and improved core stability (Cosio-Lima et al., 2003). The training of trunk musculature might also lead to improved functioning of lower extremity and thus enhanced balance control, because it will lead to more efficient neural recruitment patterns, increased nervous system activation, improved synchronization of motor units and a lowering of neural inhibitory reflexes (Gladwell, Head, Haggar, & Beneke, 2006).

A study by Sandrey and Mitzel (2013) investigated the dynamic balance and core endurance after 6 weeks core stability training program in high school track and field athletes consisting 3 levels with 6 exercises per level and lasted for 30 min each session 3 times per week. Using the Star Excursion Balance Test (SEBT) for poster medial (PM), medial (M), and anteromedial (AM) directions; abdominal fatigue test (AFT); back extensor test (BET); and side-bridge test (SBT) for the right and left sides, results showed a significant improvement for all 3 directions of the SEBT (PM, M, and AM), AFT, BET, right SBT, and left SBT with large and moderate effect size (PM and AM). Comparing the results of the current study and the study mentioned above, the SEBT in the above study is similar to the stork stand balance test that used in the current study designing to measure balance ability. The other similarity between these two studies was the core intervention program with Swiss ball (Sandrey & Mitzel, 2013).

A study by Aggarwal et al. (2010) compared the effects of 2 different training methods (stabilization training and balance training) on balance performance (static, dynamic and functional balance tests) among recreationally active individuals. Thirty male and female recreationally active participants were randomly divided into three groups: core stability training group (CSTG), balance training group (BTG), and the control group assessing at baseline and six week post-test. Static balance was measured using the Stork balance test; dynamic balance using the Star excursion balance test (SEBT) and functional balance was measured using multiple single leg hopping stabilization test (MSLHST). The results showed both training groups (BTG and CSTG) had significant ($P<0.05$) positive effect on balance performance compared to the control group, however the improvement in the mean score of the CSTG was higher than the BTG. The results of the present study is in agreement with the above study which both found the positive effect of the core training on the balance performance and the stork stand balance. However the two have some differences such as the characteristics of participants and the duration of the intervention program (Aggarwal et al., 2010).

On the other hand, some studies have not found any significant effect of core training program on the balance skills. For example, Lewarchick et al. (2003) reported that a seven-week core training program was not significantly effective footballers' balance skills. A study by Swaney and Hess (2003) also stated that nine weeks of core training did not affect balance of swimmers significantly (Lewarchick, Bechtel, Bradley, Hughes, & Smith, 2003; Swaney & Hess, 2003).

5.3.3 Sit and Reach (Flexibility)

The mean score of the sit and reach in intervention group at the pre-test was (35.95±0.91) which changed to (35.10±0.98) in post-test and (35.50±0.96) in follow-up test with no significant difference among 3 stages of time ($F=2.85$, $p=0.06$). Meanwhile, there was also no significant change in mean score of the sit and reach in control group at the pre-test, post-test and follow-up test (7.54±3.69) and (7.26±3.32) for pre-test, post-test1 and post-test 2 respectively).

Therefore, the results of the present study do not found any significant changes in the mean score of flexibility in post-test and follow-up test. In the other words, according to the finding of the current study, the core stability training was unable to enhance flexibility of the rhythmic gymnasts in intervention group.

The volume and intensity of the core training program in the current study may not enough or appropriate to improve the flexibility among the participants in the study. More focus on some specific exercises or different training design may require improving the participants' flexibility in short-term. Furthermore, our participants were young children and the phase of their physical development might also interact with flexibility levels.

Overall, reviewing literatures reported different results concerning the effects of core training on flexibility improvement. It has been suggested that resistance training (including core exercises) may significantly enhance the flexibility if the exercises are performed through the full range of motion involving both the agonist and antagonist muscle groups (Duncan, Weiner, Chandler, & Studenski, 1990; Mayer, Gatchel, Betancur, & Bovasso, 1995).

The previous studies on core training involving children and prepubescent, have reported both improvement and no changes in flexibility after strength training using programs with low to moderate volume and intensity (Faigenbaum et al., 1996).

A study by Sekendiz Cug, and Korkusuz (2010) suggested that even the Swiss-ball exercise protocol (that also was one of the current study's exercises) was effective on improving lower back muscles' flexibility, but it was possible that the results had affected by the static stretches included in the warm-up and cool-down phases of the Swiss-ball exercise intervention (Sekendiz, Cug, & Korkusuz, 2010).

The results of present study is in agreement with the findings of a study by Christou et al. (2006) that showed participation in core training including stretching exercises in the resistance program did not improve the young soccer players' flexibility (Christou et al., 2006).

5.3.4 Sit-Up test (Strength and Endurance)

Regarding to the result of the current study core training was found to be an efficient training method for improving abdominal strength and endurance in rhythmic gymnasts. Abdominal strength and endurance was measured using Sit Up test.The mean score of sit-up test in intervention group at the pre-test was (35.95±5.01) which significantly

($p<0.0001$, $\eta^2=85$) increased to (38.65±3.87) in post-test. Furthermore, the results of follow-up test in intervention group showed the continuity of improving the sit-up in follow-up test (39.50±3.83). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of sit-up test from pre-test to post-test (32.60±5.93 vs. 32.90±6.07) and post-test to follow-up test (32.90±6.07 vs. 33.15±6.03).

The mean score of sit-up test in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of sit-up test in the post-test ($\Delta=5.75$, $p<0.001$, $\eta^2=0.25$) and in the follow-up test ($\Delta=6.35$, $p<0.001$, $\eta^2=0.29$) both with a large effect size respectively.

Therefore, results of the current study revealed that, the interventional program had effectived impact on participants' strength and endurance. According to the study by Sheerin et al. (2012), at the end of training sessions the mean score of one minute sit-up among participants in the intervention group were improved from average (24–36) to the above average range (38-44).

The findings of previous studies have supported the positive effect of core training on the abdominal strength and endurance among different athletes (Sekendiz et al., 2010). For example, Sekendiz et al. (2010) showed the significant effect on strength and endurance (trunk extensor, abdominal) after 12 weeks of Swiss-ball core strength training in sedentary women. Another study among collegiate baseball players found significant enhance in flexor endurance among participants, although no significant increases reported in the Sorensen or side-bridging test (Lust, Sandrey, Bulger, & Wilder, 2009). Furthermore, a study by Tse and colleagues showed significant improvement in the side-bridging test of collegiate rowers, but failed to improve the Sorensen or flexor endurance tests (Tse et al., 2005).

Schiffer, Kleinert, Sperlich, Schulte, and Strüder (2009) reported a significant increase in the Sorensen (The Sorensen test is the most widely used test in published studies evaluating the isometric endurance of trunk extensor muscles) and 1-minute sit-up test following 10 weeks of group aerobics sessions. Similarly, a study by Stanton and colleagues showed significant improvements in Sahrmann core stability (Sahrmann test is the most common test of function. It involves the use of a pressure cuff placed under the lumbar spine to measure one's ability to maintain pelvic neutral while performing exercises) testing in high school athletes training with a Swiss ball (Schiffer, Kleinert, Sperlich, Schulte, & Strüder, 2009; Stanton et al., 2004).

The results of the present study are also similar to the findings of a study by Marshall and Murphy (2006) that found increase the activity of the rectus abdominis, transvers abdominis and the internal obliques after performing different core stability exercises (single-leg hold and press-up) on a Swiss ball, compared with exercising on a stable surface (Marshall & Murphy, 2006).

In addition, Behm, Leonard, Young, Bonsey, and MacKinnon (2005) showed a significant increase in the activation of the deep abdominal stabilizers as well as the lumbo-sacral and upper lumbar erector spinae during trunk strengthening exercises on a Swiss ball. Besides the increase in the electromyography (EMG) activity Cosio-Lima et al. (2003) also demonstrated significant increase in the static balance task performance after a 5-week functional training program with a Swiss ball compared with conventional floor exercises in untrained women. These studies also showed a significant increase in abdominal and erector spinae muscle EMG activity and duration of static balance times compared to floor exercises (Behm, Leonard, Young, Bonsey, and MacKinnon, 2005; Cosio-Lima et al., 2003).

In the study by Cosio-Lima et al. (2003) abdominal and erector spinae muscle EMG activity and duration of static balance were significantly increased following 5 weeks of physio ball core stability exercises compared to conventional floor exercises in young women. On the other hand, the results of the present study were not supported by Donahoe-Fillmore et al. (2007) that found no improvement in either abdominal strength, posture or Sorensen and flexor endurance testing after a 10-week Pilates mat program (Cosio-Lima et al., 2003; Donahoe-Fillmore et al., 2007).

5.4 The effect on the core training on the technical characteristics among participants in the study 2

The Technical characteristics that investigated in this study included: jumping ability balance skill, and pivot skill.

5.4.1 Jumping Skill (Scissors Jump)

The results of the current study showed core training had a significant positive effect on the mean score of scissors jump among participants in the intervention group. The mean score of scissors jump in intervention group at the pre-test was (0.62±0.17) which significantly ($p<0.0001$, $\eta^2=65$) increased to (0.82±0.13) in post-test.

Furthermore, the results of follow-up test in intervention group showed the continuity of improving the scissors jump in follow-up test (0.88±0.12). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of scissors jump test from pre-test to post-test (0.49±0.30 vs. 0.50±0.26) and post-test to follow-up test (0.50±0.26 vs. 0.53±0.29).

The mean score of scissors jump test in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of scissors jump test in the follow-up test ($\Delta=0.32$, $p<0.001$, $\eta^2=0.37$) and in the follow-up test ($\Delta=0.35$, $p<0.001$, $\eta^2=0.38$) both with a large effect size respectively. Therefore, in conclusion, the interventional program had effective impact on participants' jumping skill.

The reason of successful results in the scissor jump and other variables improvement might be the longer duration of the core training program and the hamstring exercise on the Swiss ball. Several previous studies investigated the effects of core training on the technical performance including jumping skills (Cosio-Lima et al., 2003; Sato & Mokha, 2009; Tse et al., 2005).

The result of the current study is in consent with a study by Battaglia et al. (2014) that studied the effect of a six-week intervention video observation and motor imagery and physical practice including core training on jumping performance among national rhythmic gymnastics. The results showed the intervention program was an effective method for improving the jumping performance in elite rhythmic gymnasts (Battaglia et al., 2014). The similarities between the current study and the study that mentioned above were the participants of the studies (RG) and the intervention program which concluded core training.

A study by Tse et al. (2005) investigated the effects of the core training protocol on core endurance and technical performance (overhead medicine ball throw, jumping skills, shuttle run, 2000 m maximal rowing ergometer test). The core training demanded participants to use the "hollowing" technique in conjunction with specific core exercises. The results showed no significant difference in technical performances after finishing the training program. The researchers recommended further studies to explain the results with more evidences (Tse et al., 2005).

On the other hand, the result of the current study is in contrast with the finding of a study by Schilling, Murphy, Bonney, and Thich (2013) who showed that core strength and endurance training program (two times per week for six weeks) led to significant enhancements in three different core endurance tests (back extensor endurance, flexor endurance, and lateral musculature endurance) in ten untrained college students. Although, no improvement was seen in agility, sprint and vertical jump abilities, the researchers suggested that core strength training may not be the only contributor to these performance markers (Schilling, Murphy, Bonney, & Thich, 2013).

5.4.2 Balance Skill

The results of the current study showed core training had a significant positive effect on the mean score of balance skills (right leg balance with free leg in front/ side at horizontal and stand erect on toes with successive arm waves, half bent leg and other stretched) among participants in the intervention group. The mean score of right leg balance in intervention group at the pre-test was (0.54±0.25) which significantly ($p=0.002$, $\eta^2=34$) increased to (0.74±0.14) in post-test.

Furthermore, the results of follow-up test in intervention group showed the continuity of improving the right leg balance in follow-up test (0.80±0.15). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of right leg balance test from pre-test to post-test (0.57±0.19 vs. 0.64±0.20) and post-test to follow-up test (0.64±0.20 vs. 0.72±0.24).

The mean score of right leg balance test in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of right leg balance test in the post-test

(Δ=0.16, p=0.01, η^2=0.18) and in the follow-up test (Δ=0.26, p<0.001, η^2=0.35) both with a large effect size respectively. Therefore, according to the study's findings, the hypothesis that core training, leads to significant improvement in balance skill was found to be true and the group doing core stability training showed greater improvement in all the assessed variables after the training period, compared with the control group.

The improvement in the Right leg balance with free leg in front and stand erect on toes with successive arm wave's conditions can be attributed to the activities and progressions in the core stability training program. Part of the training program consisted of balance-related activities that constantly increased in difficulty. The exercises progressed from balancing on the ground to balancing on a Swiss ball and added activities such as Abdominal Crunch, Swiss Ball Wall Squat, Kneeling Ball Roll and Superman on the Ball. This progression of exercises, intended to increasingly stress the motor-control system and provide greater neuromuscular control challenges, may have resulted in improved balance. In addition, the core stability training component of our program used stability-ball exercises, which have been found to improve static balance (Cosio-Lima et al., 2003).

The result of the current study is in agreement with the result of study by Cosio-Lima et al. (2003) investigating the effects of the 5-week core-stability program (sit-ups and back-extension exercises) on stability ball. The results showed the participants who did the single-limb static balance with eyes closed and the stance limb in full extension and at 60° of knee flexion on stability ball had a higher improvement than the group that did the same exercises on the floor. It was hypothesized that the neural adaptations of the stability-ball training resulted in more efficient neural recruitment patterns and improved synchronization of motor units that led to increased limb stability and balance (Cosio-Lima et al., 2003).

Similar mechanisms are likely responsible for the static-balance gains found in this investigation. Granacher et al. (2014) compared two core stability training programs on stable and unstable surfaces and observed an improvement (2-3%) in balance scores after 6 weeks in twenty seven adolescents. Iacono, Martone, Alfieri, Ayalon, and Buano (2014) reported that static and dynamic balance of soccer players improved after a four-week core training. Their training program consisted of exercises to prevent injuries in addition to soccer training five times per week (Granacher et al., 2014; Iacono, Martone, Alfieri, Ayalon, & Buono, 2014).

The result of the present study is also in agreement with the result of a study by Myer, Ford, Brent, and Hewett (2006) that reported the proprioceptive training and functional core strengthening can improve dynamic balance. Using the kinesthetic ability training (K.A.T) 2000, the balance performance of 35 female handball players assessed before and after a 7-week anterior cruciate ligament (ACL) injury-prevention program. Results showed that after finishing the program there was significant improvement in the dynamic-balance scores; although, no improvement in the static balance was seen. It is notable that the details of the intervention program, duration of intervention and the subjects in this study are different with the current study but the significant improvement in the dynamic-balance scores after proprioceptive training and functional core strengthening are similar to our findings (Myer, Ford, Brent, & Hewett, 2006).

Furthermore, study by Cosio-Lima et al. (2003) showed that abdominal and erector spinae muscle EMG activity and duration of static balance significantly increased after 5 weeks of physio-ball core stability exercises compared to conventional floor exercises in young women (Cosio-Lima et al., 2003).

5.4.3 Passé Pivot Skill

The results of the current study showed core training had a significant positive effect on the mean score scores of pivot passé 360^0 in passé position among participants in the intervention group. The mean score of right leg balance in intervention group at the pre-test was (0.59±0.23) which significantly ($p<0.001$, $\eta^2=49$) increased to (0.76±0.15) in post-test.

Furthermore, the results of follow-up test in intervention group showed the continuity of improving the pivot passé in follow-up test (0.84±0.13). On the other hand, the results of study among participants in control group showed there was no significant change in mean scores of pivot passé test from pre-test to post-test (0.54±0.25 vs. 0.54±0.19) and post-test to follow-up test (0.54±0.19 vs. 0.58±0.21).

The mean score of right leg balance test in the pre-test was not significantly different between the intervention and control groups ($p>0.05$). On the other hand, there was a significant difference between mean scores of pivot passé test in the post-test (Δmean=0.23, $p<0.001$, $\eta^2=0.32$) and in the follow-up test (Δmean=0.25, $p<0.001$), $\eta^2=0.35$) both with a large effect size respectively.

Reviewing literatures has shown that rotation is a part of the body difficulties in RG (Posture in RG). The rotation difficulties are used in the most elements of the movement which have the highest scores. In addition, rotation in RG consists of both single and multiple pivots.

The results of the present study is in agreement with the findings of a study by Pluemthanom, HirunratI, and LimroongreungratI (2015) that indicated focusing on core training among gymnasts can significantly improve rotation skills. This study also found a significant difference between single pivot and multiple pivots, which demonstrated the center of mass and center of pressure inclination angles wider when the gymnasts perform multiple pivots and increasing rotation cycles (Pluemthanom, HirunratI, & LimroongreungratI, 2015).

It is expected that it was a result from multiple pivots is difficult to maintaining balance and stability control than single pivot, the center of mass and center of pressure inclination angles wider affected to the increasing rotation cycles. Furthermore, according to this study ballet training can help the gymnasts to maintain the dynamic balance during rotation (Pluemthanom et al., 2015).

The result of the current study shows similarities with Moreside and McGill (2012) that discovered the core training included trunk muscle endurance, in addition to hip-spine disassociation exercises without receiving stretches, improved hip movement and hip rotation. In this line our core training had an improvement on passé pivot and according to Bronner and Ojofeitimi (2006) and Gordon (2002) the passé movement is accomplished with combined hip flexion and external rotation, knee flexion, and ankle plantar flexion, and with the toe of the gesture limb placed at the knee joint line of the stance limb (Bronner & Ojofeitimi, 2006; Gordon, 2002; Moreside & McGill, 2012).

5.5 Conclusion

The current study (Quasi-experimental of a training intervention with pre-post and follow up testes) aimed to assess the effect of the core training program on the physical and technical characteristics of the young female Malaysian Rhythmic Gymnasts (from 6 to 9 years old) participating in the study.

Using descriptive analysis in the study 1, the physical and technical characteristics of 100 young Malaysian Rhythmic Gymnasts from two gymnastic Clubs of Kuala Lumpur, Bukit Jalil National Sport Complex Club and Serdang Rhythmic Angels Club (all female) were examined. The results of the study1 showed that the mean score of the physical characteristics of the participants in the current study including power (vertical jump test), balance (stroke stand balance tests), flexibility (sit and reach test) and strength and endurance (sit up test) placed in the range of average referred to the study by Sheerin et al. (2012).

For technical characteristics, the results of the study 1 showed the technical characteristics including jump skill (scissors jump), balance skills (right leg balance with free leg in front/ side at horizontal and stand erect on toes with successive arm waves, half bent leg and other stretched) and pivot skill (pivot passé 360^0) in this study need to improve since the scores is below than 1.00. According to the norms provided by Malaysian Gymnastic Federation, scores of maximum mark of each element in all level of RG is 1.00 and minimum mark for passing is 0.50. Therefore, the additional training program such as core training may effective on the selected technical characteristics.

Regarding to the results of the study 2, the core training program as the interventional plan had the positive effects on all the participants' physical and technical characteristics assessed in the current study except flexibility (sit and reach test). Results of the follow-up test also showed that doing the exercises in mid-time improved the participants' performance continually.

Overall, the results of the current study showed the intervention program can be introduced as an effective plan for improving the physical and technical characteristics of the young female Malaysian Rhythmic Gymnasts. The findings of the current study could be used by Malaysian gymnastics coaches and gymnastics trainers to design and implement a continuous core training program to improve the performance of Malaysian Rhythmic Gymnasts.

5.6 Recommendations

According the finding of the current study, the core training program has a high potential for different studies in different sample sizes. For example:

- ✓ Investigating the effect of core training program on the same physical and technical characteristics among Malaysian Rhythmic Gymnasts in different population or with bigger sample sizes in the future and compare the results with the findings of the current study;
- ✓ Future studies can focus on the effect of core training program on the other performance factors Malaysian Rhythmic Gymnasts such.
- ✓ Future studies can investigate the impact of other supplementary training methods such in order to compare their results with the findings of the current study.

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