THE EFFECTS OF POST-ISOMETRIC RELAXATION AND STATIC STRETCH TRAINING ON HAMSTRING FLEXIBILITY AND ITS RELATIONSHIP TO TIGHTNESS AMONG 9-11 YEAR OLD SCHOOL CHILDREN

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by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
BSSR	Back Saver Sit and Reach Test
BSSRD	Back Saver Sit and Reach Test Dominant Side
BSSRND	Back Saver Sit and Reach Test Non-Dominant Side
PA	Physical Activity
PAQ C	Physical Activity Questionnaire for Children
PIR	Post Isometric Relaxation
PSLR	Passive Straight Leg Raise Test
PSLRD	Passive Straight Leg Raise Test Dominant Side
PSLRND	Passive Straight Leg Raise Test Non-Dominant Side
SBJ	Standing Broad Jump
SCF	Subcutaneous Fat
SCFA	Subcutaneous Fat Arms
SCFL	Subcutaneous Fat Legs
SCFT	Subcutaneous Fat Trunk
SKM	Skeletal Muscle Mass
SKMA	Skeletal Muscle Mass Arms
SKML	Skeletal Muscle Mass Legs
SKMT	Skeletal Muscle Mass Trunk
SS	Static Stretching

KESAN RELAKSASI ISOMETRIK DAN LATIHAN REGANGAN STATIK KE ATAS KELENTURAN OTOT HAMSTRING DAN HUBUNGANNYA DENGAN KETEGANGAN OTOT DALAM KALANGAN KANAK-KANAK BERUMUR 9 – 11 TAHUN

ABSTRAK

Kajian ini dibahagikan kepada dua fasa. Fasa Satu bertujuan untuk mengenal pasti tahap ketegangan otot hamstring dan menilai hubungan diantara kelenturan otot hamstring, tahap aktiviti fizikal, BMI dan antropometri dalam kalangan kanak-kanak berumur 9-12 tahun daripada Malaysia dan Sri Lanka. Fasa Dua pula bertujuan untuk mengkaji kesan pelongaran isometrik dan regangan statik terhadap ketegangan hamstring, tahap aktiviti fizikal dan penguasaan motor dalam populasi yang sama. Fasa Satu melibatkan seramai 385 (Purata umur 10.1 ± 0.7) peserta daripada Malaysia dan 389 (Min umur 9.9 ± 0.8) daripada Sri Lanka. Pengukuran antropometri, kelenturan otot hamstring dan tahap aktiviti fizikal dijalankan bagi semua peerta dan dapatan menunjukkan tahap ketegangan otot hamstring seramai 43.3% dan 44.1% bagi peserta daripada Malaysia (melalui ujian passive straight leg raise); dan 32.5% dan 33.2% (menggunakan ujian back saver sit and reach) masing-masing bagi otot dominan dan tidak dominan. Dalam kalangan peserta daripada Sri Lanka, peratusan yang diperolehi adalah 51.2% dan 51.9% (bagi ujian passive straight leg raise) dan 40.6% dan 41.1% (dengan ujian back saver sit and reach). Dapatan kajian juga menunjukkan tahap korelasi positif yang sederhana bagi kelenturan hamstring diantara kedua-dua kaedah pengukuran bagi kedua-dua sample kajian Malaysia (r = 0.40-0.42) dan Sri Lanka (r = 0.52-0.54),

($p < 0.001$). Dapatan kajian juga menunjukkan tahap terdapat korelasi signifikan positif yang lemah di antara kelenturan otot hamstring dan tahap aktiviti fizikal bagi peserta kajian Malaysia ($r = 0.31$-0.33) dan Sri Lanka (0.21-0.31), ($p < 0.001$). Peserta yang menunjukkan tahap aktiviti fizikal "tinggi" mempunyai skor kelenturan otot hamstring yang lebih tinggi berbanding peserta dalam kategori "rendah" di kedua-dua Negara ($p < 0.05$). Peserta kajian daripada Malaysia yang mempunyai berat badan normal menunjukkan skor kelenturan hamstring yang jauh lebih tinggi berbanding kanak-kanak dengan berat badan berlebihan dan obese ($p < 0.001$). Fasa Dua pula melibatkan seramai 120 peserta 60 lelaki dan 60 perempuan dengan ketegangan hamstring yang dikenal pasti dari fasa satu. Peserta menjalani program intervensi 6 minggu dengan kesemua parameter diukur pada tahap pemulaan, minggu ke-3 dan minggu ke-6. Kedua-dua kumpulan senaman menunjukkan tahap kelenturan otot hamstring yang lebih tinggi berbanding kumpulan kawalan bagi sampel Malaysia dan Sri Lanka. Bagi sampel daripada kedua – dua negara, dapatan kajian menunjukkan peningkatan yang signifikan dari segi kemahiran motor bagi kedua-dua kumpulan senaman dan tidak terdapat perbezaan bagi kumpulan kawalan. Dapat dirumuskan bahawa kaedah relaksasi isometrik lebih baik dari kaedah regangan statik dalam meningkatkan kelenturan otot hamstring dalam kalangan peserta kajian Malaysia dan Sri Lanka yang terhasil melalui peningkatan aktiviti fizikal dan kemahiran motor di kalangan kanak-kanak berusia 9-11 tahun yang bukan atlit elit di kedua-dua negara.

THE EFFECTS OF POST-ISOMETRIC RELAXATION AND STATIC STRETCH TRAINING ON HAMSTRING FLEXIBILITY AND ITS RELATIONSHIP TO TIGHTNESS AMONG 9-11 YEAR OLD SCHOOL CHILDREN

ABSTRACT

The present study was divided into two phases. Phase one aimed to identify the prevalence of hamstring tightness and to assess correlation of hamstring flexibility with physical activity, BMI and anthropometry among 9-11 years old Malaysian and Sri Lankan children. Second phase aimed to investigate the effects of post isometric relaxation and static stretch training on hamstring tightness, physical activity level and motor proficiency in same populations. The number of subjects recruited in phase one was 385 (Mean age 10.1 ± 0.7) Malaysian and 389 (Mean 9.9 ± 0.8) Sri Lankan subjects. All the subjects were assessed for anthropometry, hamstring flexibility and physical activity level revealing hamstring tightness in 43.3% and 44.1% Malaysian subjects (by passive straight leg raise test); and 32.5% and 33.2% (by back saver sit and reach test) on dominant and non-dominant side respectively. Among Sri Lankan subjects the percentage was 51.2% and 51.9% (by passive straight leg raise test) and 40.6% and 41.1% (by back saver sit and reach test) on dominant and non-dominant side respectively. There was a significant positive moderate correlation between the findings of hamstring flexibility obtained by the two test methods among Malaysian ($r = 0.40–0.42$) and Sri Lankan ($r = 0.52–0.54$) subjects ($p < 0.001$). There was a significant positive weak to moderate correlation between hamstring flexibility and

physical activity level among Malaysian ($r = 0.31–0.33$) and Sri Lankan (0.21-0.31) subjects ($p < 0.001$). Subjects in the "high" physical activity category obtained significantly higher scores of hamstring flexibility compared to "low" physical activity subjects in both countries ($p < 0.05$). The normal weight subjects obtained significantly higher hamstring flexibility scores when compared to overweight and obese children among Malaysian subjects ($p < 0.001$). Phase two involved 120 subjects with 60 males and 60 females with hamstring tightness identified from phase one of this study recruited in both countries for 6 weeks intervention with all parameters measured at baseline, on 3rd and 6th week. Both exercise groups showed significantly higher values for hamstring flexibility scores when compared to the control groups in Malaysian and Sri Lankan populations. Among subjects of both countries there were significant improvements in both exercise groups at the end of six weeks in motor proficiency with such difference not seen in control group. It is concluded that the post isometric relaxation stretch method was superior to static stretching in improving hamstring flexibility among Malaysian and Sri Lankan subjects which reflected in enhanced physical activity and motor proficiency in both countries among 9-11 years old sedentary children who were not elite athletes.

CHAPTER 1

INTRODUCTION

1.1 Background and Scope of the Study

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity, as defined by World Health Organization in 1946 and the definition has not been amended ever since (World Health Organization, 1947). There are many factors like- behavioural, genetic and environmental that influence health. They are present from before conception and continue throughout an individual's life time. Many countries have developed screening methods to measure and improve the health and health related components of fitness for individuals in various domains, which also covers physical fitness at all age groups including children and adolescents (Pillsbury, Oria, & Pate, 2013).

The daily activities of children of the present age and genetics are determinants of their growth and development. Advances in technology have contributed to a more sedentary life style and has led to children being less active (Ogden, Carroll, Kit, & Flegal, 2014). The realities of the way of living these days are such, that children spend most of their school time in different class activities like reading, writing, drawing etc. and are at a higher risk of adapting poor postural habits because of sitting for long hours (Bettany-Saltikov et al., 2019). Since the hamstring muscles bend the knee, this long hours of sitting can lead to shortening of this muscle group (Vadivelan & Priyaraj, 2015). Previous research has shown that hamstring tightness is common among adolescents, 40 % of girls and 75 % of boys who were of the 10 years age group in the

Danish population (Reimers, Brodersen, & Pedersen, 1993). There is a natural rise in hamstring tightness, mostly just before the start of pubertal growth spurt, it might be associated with the natural evolution of lumbar lordosis and pelvic tilt and quick growth of bone ends compared to soft tissues (Alter, 2004).

In both adults and children hamstring muscle flexibility is important to maintain correct body posture and gait. Hamstring tightness can cause reduced mobility in the pelvis and thus leads to gross amount of biomechanical variations in the pressure distribution along the spine (Mayorga-Vega, Merino-Marban, Sánchez-Rivas, & Viciana, 2014). It clearly shows that reduced flexibility of hamstring is associated with postural problems and high risk to musculoskeletal injuries (Jenkins, 2005).

In a wider scheme of things, lumbar extensibility and hamstring protect the spine from various risks and allow people to perform daily activities and social functioning and are well recognized as health related fitness marker (Roth-Isigkeit, Thyen, Stöven, Schwarzenberger, & Schmucker, 2005). In addition to the other studies that identified the relationship between tight hamstring and lower back pain, a follow up study to study this association confirmed that tight hamstrings may lead to back pain (Feldman, Shrier, Rossignol, & Abenhaim, 2001). Hamstring flexibility is a very important physical and health related fitness component. It is also a modifiable risk factor that can be amended to reduce the risks of injury and disorders to the lower limb and back which could occur later in life as a result of daily living activities, physical activity or sport involvement (Pate, Oria, & Pillsbury, 2012).

Physical activity is defined as a bodily movement produced as a result of muscle contraction and involves some amount of energy expenditure. It is well accepted that physical activity has benefits on the psychological, social, behavioural aspect of life

and enhances quality of life (LaCaille, 2013). Physical activity is an important health related component and is thought to be decreased in children since the past few decades and hence, increases risks of diseases related to overweight and obesity among children as they enter adulthood (Ebbeling, Pawlak, & Ludwig, 2002).

Reduced physical activity levels among children are leading to excess body weight or obesity. It is stated that reduced physical activity, excess energy intake along with unhealthy eating patterns, also a combination of both leads to resultant excess energy (Güngör, 2014). Findings suggest that high levels of obesity have a negative influence on physical fitness parameters (Abel et al., 2018).The lack of participation in physical activity is leading to problems such as- paediatric obesity and also a decrease in fitness that leads to altered flexibility, strength and cardiorespiratory capacity (Eisenmann, 2003; Steele, Brage, Corder, Wareham, & Ekelund, 2008).

Reduction in hamstring flexibility is considered to cause muscle damage (Cabry & Shiple, 2000), reduced pelvic mobility brings about alterations in lumbopelvic rhythm (López-Miñarro, Muyor, & Alacid, 2012) sometimes leads to conditions such as lower back pain (Feldman et al., 2001). This indicates that decreased flexibility in the hamstring muscles might have a negative impact on individuals' health. There is need to address the issue of decreased flexibility among school children in school settings through physical education classes.

Stretching can be used as an effective manoeuvre to lengthen muscles and the adjoining soft tissue structures; this in turn can reduce tension and improve the alignment of joint and thus, help improving posture. Studies have shown that hamstring muscles flexibility can be improved by stretching exercises (Kang, Jung, An, Yoo, &

Oh, 2013; Lim, Nam, & Jung, 2014; Meroni et al., 2010). Many stretch methods are available and are used, which include ballistic stretching, static stretching, proprioceptive neuromuscular facilitation and muscle energy technique (López-Miñarro, Muyor, Belmonte, & Alacid, 2012; Mottram & Comerford, 2006; Smith & Fryer, 2008; Zakas, Galazoulas, Grammatikopoulou, & Vergou, 2002). Muscle energy technique is a form of manual therapy technique that is utilized to stretch or lengthen muscles. While performing this stretch the individual uses his/her own muscle energy in the form of gentle isometric contractions to relax muscles (Dhargalkar, Kulkarni, & Ghodey, 2017). Static stretching is the technique of lengthening muscles by moving the muscle to a point of stretch at low force and the position is held for few seconds. There is no additional movement in this form of stretch (Alter, 2004).

It has been established that static stretching and muscle energy technique (MET) are both effective in improving joint flexibility when compared to the control group, who do not receive any stretching programme (Ballantyne, Fryer, & McLaughlin, 2003). It is shown that static stretching as well as muscle energy technique improves muscle flexibility by improving the viscoelastic properties of the muscle. However, there is ongoing debate about which is the most effective way to be used by practitioners (Ahmed & Abdelkarim, 2013). Post isometric relaxation is a form of muscle energy technique used to improve flexibility. Post isometric relaxation is a method that involves taking the muscle to a point of stretch and it is followed by isometric contraction, which leads to subsequent reduction in stiffness (Chaitow & Crenshaw, 2006).

1.2 Conceptual Definitions

(a) Flexibility

Flexibility is the ability to move as single joint or series of joint through an unrestricted pain free range of motion. It is dependent on the flexibility of muscle which allows the muscle that crosses a joint to relax, lengthen and yield to a stretch force (Patni et al., 2013).

(b) Muscle tightness

Muscle tightness is the decrease in the ability of the muscle to elongate, resulting in decrease in range of motion at the joint on which it acts. The movement in the direction of the elongating muscle is limited (Akinpelu, Bakare, & Adegoke, 2009).

(c) Physical activity

Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure (Caspersen, Powell, & Christenson, 1985).

(d) Obesity

Children are categorised for obesity based on Body Mass Index. Accordingly World Health Organization has defined obesity and overweight as BMI Z-score > 2 and > 1 SD respectively (World Health Organization, 2017).

(e) Stretching

Stretching is a general term used to describe any therapeutic manoeuvre designed to increase extensibility of soft tissues, thereby improving flexibility and range of motion by elongating structures that have adaptively shortened (Saunders, 2007).

(f) Static Stretching

Static stretching is a type of stretching exercise where a specific position is held with the muscle on tension to a point of a stretching sensation. The stretch force is low, such that it does not elicit stretch reflex and long duration (usually 30 sec). Static stretching has a relaxation, elongation effect on muscle, improving range of motion (ROM), decreasing musculo-tendinous stiffness and also reduce the risk of acute muscle strain injuries (Clark & Lucett, 2010).

(g) Post Isometric Relaxation

Post Isometric Relaxation (PIR) is the effect of the decrease in muscle tone leading to relaxation in a single or group of muscles, after a brief period of submaximal isometric contraction of the same muscle. This technique involves stretching as well as isometric contraction (Chaitow & Crenshaw, 2006).

(h) Agility

Agility is the ability to move and change direction and position of the body quickly and effectively while under control (Paul, Gabbett, & Nassis, 2016).

(i) Leg power

Leg power is the ability to exert force with the lower extremities quickly (Power=Force x Velocity) (Md et al., 2002).

1.3 Objectives of the study

The objectives of the study were divided into general and specific.

General Objectives:

1. To assess the prevalence of hamstring tightness in 9-11 years old Malaysian and Sri Lankan children.
2. To assess the association of hamstring flexibility with physical activity level in 9-11 years old Malaysian and Sri Lankan children.
3. To study the association of hamstring flexibility with BMI and body composition variables in 9-11 years old Malaysian and Sri Lankan children.
4. To compare the effectiveness of Post Isometric Relaxation and Static Stretch training in eliminating hamstring tightness among 9-11 years old Malaysian and Sri Lankan children on physical activity and motor proficiency.

Specific Objectives:

1. To assess the prevalence of hamstring tightness measured by the passive straight leg raise test.

2. To assess the prevalence of hamstring tightness measured by the back saver sit and reach test and study the association between the two assessment methods.

3. To assess the correlation between hamstring flexibility and physical activity level.

4. To compare hamstring flexibility between subjects of different physical activity levels.

5. To assess the correlation between hamstring flexibility, BMI and body composition variables.

6. To compare hamstring flexibility between subjects of different obesity levels.

7. To assess the effects of Post Isometric Relaxation and Static Stretch training in eliminating hamstring tightness in Malaysian and Sri Lankan children.

8. To investigate the effects of the intervention methods on physical activity level in differently trained groups.

9. To investigate the effects of the intervention methods on motor proficiency in differently trained groups.

1.4 Hypotheses

To achieve the objectives of the study the following hypotheses were formulated:

Null Hypothesis ($H_0$1): There is no significant difference in prevalence of hamstring tightness measured by the passive straight leg raise test and by the back saver sit and reach test.

Alternative Hypothesis (H_A1): There is a significant difference in prevalence of hamstring tightness measured by the passive straight leg raise test and by the back saver sit and reach test.

Null Hypothesis ($H_0$2): There is no significant correlation between hamstring flexibility measured by passive straight leg raise test and back saver sit and reach test.

Alternative Hypothesis (H_A2): There is a significant correlation between hamstring flexibility measured by passive straight leg raise test and back saver sit and reach test.

Null Hypothesis ($H_0$3): There is no significant correlation between hamstring flexibility and physical activity.

Alternative Hypothesis (H_A3): There is a significant correlation between hamstring flexibility and physical activity.

Null Hypothesis ($H_0$4): There is no significant difference in the hamstring flexibility among subjects of different physical activity levels.

Alternative Hypothesis (H_A4): There is a significant difference in the hamstring flexibility among subjects of different physical activity levels.

Null Hypothesis ($H_0$5): There is no significant correlation between hamstring flexibility, BMI and body composition.

Alternative Hypothesis (H_A5): There is a significant correlation between hamstring flexibility, BMI and body composition.

Null Hypothesis ($H_0$6): There is no significant difference in the hamstring flexibility among subjects of different obesity levels.

Alternative Hypothesis (H_A6): There is a significant difference in the hamstring flexibility among subjects of different obesity levels.

Null Hypothesis ($H_0$7): There is no significant difference between the effects of Post Isometric Relaxation and Static Stretch training in eliminating hamstring tightness in Malaysian and Sri Lankan children.

Alternative Hypothesis (H_A7): There is a significant difference between the effects of Post Isometric Relaxation and Static Stretch training in eliminating hamstring tightness in Malaysian and Sri Lankan children.

Null Hypothesis ($H_0$8): No significant changes are expected in the effects of the intervention methods on physical activity level in differently trained groups.

Alternative Hypothesis (H_A8): Significant changes are expected in the effects of the intervention methods on physical activity level in differently trained groups.

Null Hypothesis ($H_0$9): No significant differences are expected between the stretch methods of intervention on motor proficiency.

Alternative Hypothesis (H_A9): Significant differences are expected between the stretch methods of intervention on motor proficiency.

In order to increase the scope of the study and have a wider research impact, 9-11 years old children in Malaysia and Sri Lanka were included to the study. It was thought that conducting the descriptive study to analyse correlations between important health fitness markers among children and identification of the better stretch method for the study group in two countries will be beneficial for the children and thus, benefit the future of both countries. The subjects of both countries were not compared in order to avoid any concerns or issues that could arise in the instance of presence of any inferiority/ superiority and not to speculate any differences in the findings.

The study involved two phases- descriptive study and intervention study. The descriptive phase of the study aimed to assess percentage of hamstring tightness and the

correlation of hamstring flexibility with physical activity level, BMI and body composition parameters. The intervention phase of the study was aimed to compare the effectiveness of two stretching methods of improving hamstring flexibility and the effects of stretching intervention on physical activity level, lower leg power and agility among Malaysian and Sri Lankan school children.

1.5 Significance of the Study

Hamstring tightness has shown to have negative influence of pelvic alignment, which in turn leads to spinal problems and lower back pain. Children in the age group of growth spurt during pre-pubertal, pubertal and adolescence phase are shown to be at a higher risk of hamstring tightness. Thus, in the present study prevalence of hamstring tightness was measured among 9-11 years old children to identify and address it, to prevent ill effects of hamstring tightness and thus, provide better health for children.

Hamstring flexibility, physical activity and body composition are identified to be important health markers in children that influence children's health. Also, there is evidence that physical activity level and BMI may influence hamstring flexibility. Thus, the association between these parameters was assessed among the subjects in the present study because the findings would be helpful in providing information essential to be considered while planning exercise programmes for children to address these parameters.

Hamstring tightness is proven to adversely affect pelvic mobility and place the children at a risk of developing lower back pain. This is a modifiable risk factor. Hence, it is essential to identify and treat it at an early age, such that with the help of stretching

performance the children would be able to maintain and have adequate hamstring flexibility. In order to have best benefits, two stretch methods- post isometric relaxation and static stretching were compared. The aim was to assess stretching methods of low duration, which would be easy and quick to perform, so that if proven beneficial to improve hamstring flexibility they would be feasible to be incorporated in school schedules without disturbing regular school academic activities.

Stretching exercises performed just before sports activities are incidentally blamed to cause detrimental effects on power and performance. Thus, the effects of stretching exercises used in this study over a period of six weeks on leg power, speed and agility were assessed, to identify its effects on motor proficiency. It is believed the findings of this study will be beneficial for future studies and may provide valuable information to be considered while planning exercise programmes for children.

CHAPTER 2

LITERATURE REVIEW

2.1 Health and wellness issues in children

It is well known that health is defined as a state of complete physical, mental and social well- being and not merely the absence of disease or infirmity (World Health Organization, 1947) and there are many factors like- behavioural, genetic and environmental that influence health. They are present from before conception and continue throughout an individual's life time. It is understandable that childhood health predicts adult morbidity and mortality; it is necessary to attain, sustain and monitor health from childhood till adulthood (Pillsbury et al., 2013).

Wellbeing and the lifestyle of current generation has changed a lot. The present generation is taken over by 'screen', in various forms: computer, mobile phone, tablet, television etc. It has become a major part of contemporary life. There is increasing concerns rising on this matter, since the impact of screens on children and adolescent's health is dangerous (Marsh, Mhurchu, & Maddison, 2013). There is sufficient evidence that increased screen time is linked with obesity. The suggested mechanism being increased energy intake and decrease in the time spent on sports or activities requiring physical involvement. Decreased participation in physical activities reduce metabolic rate, leading to increase in body weight (Chaput et al., 2011).

Various changes occur in the musculoskeletal system, and particularly in musculo-tendinous junction through childhood as children grow into early adolescence and adolescence. That includes an increase in muscle thickness and cross-sectional area,

fascial length etc. (Kubo, Kanehisa, Kawakami, & Fukunaga, 2001a; O'Brien, Reeves, Baltzopoulos, Jones, & Maganaris, 2010b). In addition to this, adaptations to the muscle and tendinous structures occurs, that leads to changes in musculo-tendinous length and stiffness (Kubo, Teshima, Hirose, & Tsunoda, 2014; O'Brien, Reeves, Baltzopoulos, Jones, & Maganaris, 2010a; Waugh, Blazevich, Fath, & Korff, 2012).

Reduced flexibility and muscle tightness among children during the growing phase is postulated to be a result of tightness in the muscles and tendons, the reason for this being the bones growing faster than the muscles grow and stretch (Alter 2004). Childhood is the phase of life that represents the developmental period corresponding to the end of infancy to the start of adolescence. The term adolescence refers to a period of life between childhood and adulthood. Although, adolescence is a difficult period to be defined in terms of chronological age (because of different maturation rates) it can be said to be between 12-18 years for girls and 14-18 years for boys (Malina, Bouchard, & Bar-Or, 2004; Radnor et al., 2018). Preadolescence is stated to be between the age group 9-11 years (Radnor et al., 2018) and ages 10 and 11 are classified as adolescences by World Health Organization. Thus, the 9-11 years reference range in which children are in a growing phase into adolescence and early adolescence and tend to have muscle tightness was selected in the present study.

During the stage of transition from childhood to adolescence and early stage of adolescence, the participation in physical activity begins to decline which adversely affects the physical fitness of the individuals (Duncan, Duncan, Strycker, & Chaumeton, 2007). Regular involvement is physical activity is stated to be associated with adequate levels of flexibility. The reason explained for this association is that physically active children and adolescents tend to have better developed skeletal muscle, tendon and

ligament elasticity; this is true specifically when they engage in activities that move joints through greater range of movements (Dorneles, Oliveira, Bergmann, & Bergmann, 2016). These findings suggest that there is an association between physical activity and flexibility that influence health.

Among overweight children there is an increase in fat tissue concentration around joints, which in turn leads to decreased range of motion and flexibility (Minatto, Ribeiro, Junior, & Santos, 2010). These findings suggest that reduced physical activity level leads to excess body weight which in turn may lead to reduced flexibility. Research suggests that health related fitness parameters such as BMI, body composition parameters and flexibility may vary in different obesity and physical activity levels (Deforche et al., 2003; Minck, Ruiter, Van Mechelen, Kemper, & Twisk, 2000; Ogden et al., 2014).

2.2 Importance of flexibility

An individual with reduced muscle flexibility is placed at a higher risk of musculoskeletal injuries and his/ her level of functions is markedly affected because muscle flexibility is an important parameter for normal human functions (Hreljac, Marshall, & Hume, 2000). Flexibility is defined as a muscle's ability to lengthen and thus, allow one or more joints to move through a range of movement (Bandy & Sanders, 2007). Flexibility by definition is also the mobility of a body segment, which is dependent on the tolerance of soft tissue to movement and the ability of the soft tissue to work with forces applied to it (Houglum, 2018).

Inadequate flexibility is a causative factor that leads to muscle injury, and this statement is true in particular for the hamstring group of muscles (Funk, Swank, Adams,

& Treolo, 2001). Flexibility is an important fitness parameter for normal biomechanical functioning among sports participants (Houglum, 2018). There is lot of researches being conducted which state the several benefits of hamstring flexibility to include- enhanced performance among athletes, reduced risk to sustain an injury, reduction of the risk and postponement of post-exercise soreness, and improved dynamic skills like coordination (Andersen, 2005; Porcari, Bryant, & Comana, 2015).

The muscles situated in the posterior aspect of the thigh, the hamstring group of muscles have a higher tendency to shorten if they are not conditioned properly; if there is lack of flexibility in this muscle group it leads to lower back pain in adults and adolescents (van Middelkoop et al., 2011). Inadequate flexibility and shortening of the hamstrings is related to musculoskeletal injuries (Micheo, Baerga, & Miranda, 2012).

Tight hamstrings are stated to be associated with acute injuries like sprains and strains and also with chronic conditions like groin injuries (Grace & Graves, 2019). In addition tight hamstrings lead to an increase in pelvic tilt and thus, an increase in lumbar and/ or thoracic kyphosis; this alteration in the spinal curvatures is prominent during trunk flexion movements (Muyor, Alacid, & López-Miñarro, 2011). These changes in the pelvic tilt and spinal curvature can cause back pain, spinal problems, spondylolisthesis, disc herniation etc. (Hasler, 2013).

As the elasticity or the ability of a muscle to lengthen is reduced, there is also reduction in the ability of elongation of the muscle; this then leads to lowered range of movement and restrictions in soft tissue excursion (Doral, Tandoğan, Mann, & Verdonk, 2011). The reduction in joint range of motion can cause faulty body alignment, improper body mechanics and higher risk of injury. In addition if not attended to it may lead to

chronically tight muscles (Decoster, Scanlon, Horn, & Cleland, 2004; Wallmann, Gillis, Alpert, & Miller, 2009).

This could be attributed to the lifestyle practiced in the present age, with busy daily routines and less or no time for physical activity. People thus, neglect flexibility and it becomes a concern only when the joints become stiff and the muscles are shortened (Holt, Pelham, & Holt, 2008). Studies and reports have published about muscle shortening among children and in adolescent age group. This shortening is reported to be a result of growth acceleration and sedentary lifestyle that prevails in the present age. These studies emphasize the importance of normal hamstring flexibility in maintaining normal posture and gait. Tightness in hamstrings is related to spinal deformity, disk herniation and lower back pain too (Alter, 2004; Coelho et al., 2014).

An infant lying on the back can easily take the feet to the mouth and a young child can easily perform complex yoga techniques while seated on the floor with legs bent outwards, this is a clear indication that children are more flexible than their adult counterparts (Burns et al., 2012; Pangrazi & Beighle, 2019). Though, young children are more active, their activity level tends to decrease as their age advances and their lifestyle becomes more sedentary. This is a result of inactive behaviour of early age (Kohl III & Cook, 2013b). In the present era most individuals spend their time and lives in a sedentary manner and also, the people who involve in exercises, either do not perform it in correct manner of do not take time to stretch. This could be a possible reason that leads to shortening of hamstring muscles (Kendall, McCreary, Provance, Rodgers, & Romani, 2005).

While schooling, most of the class activities like reading, writing, listening etc. during school require children to be seated and place them at a high risk of adapting

poor postural habits of sitting for many long hours. The hamstring muscles work on bending the knee and this long hours of sitting can lead to shortening of this muscle group (Vadivelan & Priyaraj, 2015). When children are less active and spend most of the time sitting and lying on bed, the hamstring muscle that works on the bending the knee and straightening the hip gets more prone to becoming tight. The development of tightness in hamstring leads to pain and poses a higher risk to injury and can cause difficulty in walking. These discomforts or issues arising from shortened hamstrings can be avoided, if focus is made on maintaining and improving children's flexibility (Fatima, Qamar, Hassan, & Basharat, 2017; Vadivelan & Priyaraj, 2015).

Adequate flexibility of hamstrings and lumbar extensibility serve to protect the spine from various risks and allow people to perform daily activities and social tasks/ duties efficiently and thus, are important health related fitness markers (Roth-Isigkeit, Schwarzenberger, et al., 2005). Poor elasticity of hamstrings is clearly shown to be associated with postural issues, deviations in gait, increase risk of fall and as a factor to higher risk to musculoskeletal injuries (Vadivelan & Priyaraj, 2015). There is sufficient evidence that hamstring muscle flexibility is important in both adults and children for normal posture and gait because a decrease in hamstring flexibility will lead to a gross amount of biomechanical variations in the pressure distribution of the spine and cause reduced pelvic mobility (da Silva Dias & Gómez-Conesa, 2008).

2.2.1 Physiology of Flexibility

Flexibility is defined as the range of motion available in a joint or group of joints. It can also be described as the total achievable excursion of a body part through its range of motion. Also it is known as the ability to move a joint through a normal

range of motion without undue stress to the musculo-tendinous unit (Kisner & Colby, 2012). Muscle flexibility is described as extensibility, i.e., ability to elongate of the musculo-tendinous unit (Gajdosik, 2001). Flexibility of muscles is dependent on the characteristics or ability of the soft tissue structure to elongate during movement or exercise. It also comprises of the biomechanical variables such as load, energy and stiffness (Albright et al., 2000). Sarcomeres are elements of the muscle that lengthen and have the ability to deform elastically, thus, enabling the muscle to elongate. The elastic property of sarcomere is derived mainly from cytoskeletal proteins whose anatomy and flexibility lead to reversible extension. Titin is a protein which is long enough to span between M- and Z- bands, linking the thick and thin filaments longitudinally that allow changes to the sarcomere length (Tskhovrebova & Trinick, 2012). This increase in length of sarcomere leads to muscle elongation.

The neuromuscular system also influences flexibility with two main proprioceptors involved in the mechanism of stretching and flexibility. One of them is muscle spindle, it is a structure situated within the muscle fibres ad they limit changes in muscle length. The other proprioceptor is Golgi Tendon Organ (GTO), which are situated near the musculo-tendinous junction, they are sensitive to an increase in muscle tension; whenever the Golgi Tendon Organ is stimulated there is a reflexive relaxation in the muscle, which is being stretched (Baechle & Earle, 2008).

Flexibility can be explained as the mobility of the body part, which can be restricted if there is lack of flexibility of the surrounding muscles (Læssøe & Voigt, 2004). Restriction in the movement is associated with muscle extensibility, when there is reduction in muscular extensibility the body undergoes alterations in posture in order to

establish an adaptive response which will lead to an adaptive wrong posture (Veiga, Daher, & Morais, 2011). This alteration in posture due to inadequate flexibility emphasizes the importance to have normal muscle flexibility.

2.2.2 Flexibility and Age

Children are stated to have higher flexibility than their adult counterparts, but during the phase of growth from childhood to adolescence when accelerated growth in the bones often leads to lag in soft tissue growth causing decrease in flexibility (Hoeger, Hoeger, Hoeger, & Fawson, 2018). Various changes occur in the musculo-tendinous junction through childhood as children grow into adolescence, which includes an increase in muscle thickness and cross-sectional area, fascial length etc. (Kubo et al., 2001a; O'Brien et al., 2010b). In addition to this, adaptations to the muscle and tendinous structures happens, that leads to changes in musculo-tendinous length and stiffness (Kubo et al., 2014; O'Brien et al., 2010a; Waugh et al., 2012). Reduced flexibility and muscle tightness among children during the growing phase is postulated to be a result of tightness in the muscles and tendons, the reason for this being the bones growing faster than the muscles grow and stretch (Alter, 2004)**.**

Furthermore, sedentary lifestyle with long hours of sitting is suggested to lead to problems such as- muscle tightness, reduction in joint range of movement and reduced flexibility (Muhammad Sharif Waqas, 2016). Individuals who spend most of the time seated on desks have adaptive changes that lead to shortening of hip muscles. Prolonged sitting leads to an alteration in the pelvic position, which is more posterior and causes the hamstrings to assume a shortened position. This leads to adaptive shortening and

tightness occurring to a greater extent in the hamstring muscles (Fatima et al., 2017; Pradip, Sudhir, & Nidhi, 2018).

Through childhood and schooling years children move toward puberty, the stage of development involving physical, sexual and psychosocial maturation. It is established that there is physical growth during puberty in which there is a difference in the rate of bone and muscle growth (Alter, 2004). The pubertal growth spurt averages between 9-10 years in girls and 11-12 years in boys, however, there are differences between individuals and populations (Melmed, Polonsky, Larsen, & Kronenberg, 2015). According to WHO categorization, 9–11 year old girls and boys are in the pre-pubertal and pubertal age and also this age group belongs to preadolescence and early adolescence. Children in the pre pubertal, pubertal and adolescence age group have been stated to be prone to develop hamstring tightness due to changes in skeletal growth (Stein et al., 2016); hence 9-11 age group is the right age to diagnose and eliminate hamstring tightness. On the other hand, in order to avoid hormonal influence and related developmental issues, it is important to resolve such issues before the age of menarche in girls, which has been stated to be 11.97 among Malaysian girls (Zainuddin et al., 2018) and 11.48 for Sri Lankan girls (Salgado, Abeysuriya, & Wickremasinghe, 2008).

2.2.3 Flexibility and Physical Activity

In early stages of growth such as childhood and adolescence, reduced participation in physical activity and in turn a decline in physical fitness is seen to occur (Duncan et al., 2007). When children and adolescents are physically active they tend to have better developed skeletal muscle, higher tendon and ligament elasticity, this is true when the children involved in activities requiring greater range of movement (Prieto-

Benavides, Correa-Bautista, & Ramírez-Vélez, 2015). Physical activity among children and adolescents is stated to improve muscular fitness which comprises of muscle endurance, flexibility and strength as components and when activities are planned and structured to address it (Lee et al., 2012).

Hamstring muscles are prone to become tight during rapid growth occurring during childhood and adolescence and this tightness is related to reduction in lumbar lordosis leading to lower back pain (Kendall et al., 2005). This proportion of tightness associated with normal growth has to be countered by physical activity; and it is a reason of concern with growing decline in physical activity level among children (Arora, Souza, & Yardi, 2013). Studies among school children to implement a school based physical activity program which included flexibility exercises have shown that inclusion of flexibility training showed significant improvements in hamstring flexibility (Nelson & Bandy, 2004; Reid & McNair, 2004). Also, in a study that involved home based exercise programs for flexibility for 6 days a week for 6 week have shown to have positive influence on flexibility (Czaprowski et al., 2013).

Stretching exercises in particular must be added to physical activity in order to lengthen muscles and the adjoining soft tissue structures; this in turn can reduce tension and improve the alignment of joint and thus, help in improving posture. An important step toward preventing and managing lower back pain involves maintaining a good posture along with a normal balance between the flexibility and strength of the supporting muscles around the lower back (Donatelle, 2010; Robbins, Powers, & Burgess, 2006).

With wide and unanimous research support to importance of physical activity in order to improve flexibility, there is an obvious shortage of research on if and how improved flexibility can influence the level of physical activity of an individual.

2.2.4 Flexibility and obesity and body composition

The worldwide prevalence of obesity has been recorded to have doubled from the year 1980 till the year 2008 (10% of men; 14% of women). It is also estimated and recorded that about 40 million infants and young children, which is 6 % of the total population worldwide, are obese as defined by a weight- for- height ratio > 2 standard deviations of the WHO child growth standards median (World Health Organization, 2017).

It is stated in published research that the prevalence of overweight and obesity among children aged 6-12 years old in Malaysia has increased from 20.7 % in the year 2002 to 26.4% in the year 2008. A similar study to assess obesity and overweight among children 7-12 years old children residing in urban areas in the year 2010–2011 in six regions of Malaysia found that 14.4 % overweight and 20.1 % obese children (Poh et al., 2013). Childhood overweight and obesity can lead to immediate and long-term risks to health among children (Misra & Khurana, 2009; Weiss et al., 2004). In a study by Wee et al., a group of Malaysian children who were overweight and obese and were of the age group 9–12 years old posed 16.3 times higher risk of developing metabolic disorders than the children who had a normal body weight (Wee et al., 2011). Children identified to be obese and overweight are also at a higher risk of becoming obese adults with the risk of developing all the associated diseases and conditions (Gupta, Goel, Shah, & Misra, 2012).

Among overweight children there is an increase in fat tissue concentration around joints, which in turn leads to decrease the range of motion and flexibility (Minatto et al., 2010). Health related fitness components comprising of muscle flexibility have shown to be affected adversely among overweight and obese children (Deforche et al., 2003; Minck et al., 2000).

Muscular flexibility and body composition are important markers of an individual's total health (Chen, Fox, Haase, & Wang, 2006; Cole, Flegal, Nicholls, & Jackson, 2007). Body composition factors such as skeletal muscle mass and subcutaneous fat are stated to have influence on physical fitness tests that include tests of flexibility (Kohl III & Cook, 2013a). Comparison of the most fat and lean participants have shown results that excessive subcutaneous fat had negative influence on strength but it did not affect flexibility significantly (Pillsbury et al., 2013). It is stated that because of excess fat an obese or overweight child may have limited flexibility, leading to injury and in turn may limit the child's participation in physical activity and sports (Ciccomascolo & Sullivan, 2013).

Research question not addressed however is: can physical activity of obese individuals be improved if their flexibility level improves?

2.2.5 Flexibility and Motor performance

Malina et al. (2004) defined motor abilities as a combination of several components that permit individuals to perform specific tasks. Examples of activities involving these tasks are: power, speed, agility and flexibility (Malina, 2004). Among flexibility related implications, there is a need to assess correlations between flexibility and strength, or strength to hamstring optimal lengths, as these could be risk factors for