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大学院医療福祉研究科博士課程

Effect of Combined Resistance Exercise of Knee-extension with Hip Adduction on Dynamic Balance Performance in Healthy Male Adults - a Newly Developed Knee-extension Resistance Exercise

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保健医療学専攻・理学療法学分野・応用理学療法学領域

学籍番号： 14s3008 氏名：WANG HONGZHAO

研究指導教員：丸山　仁司教授

副研究指導教員：小野田　公助教

新たな開発した股関節内転挟みながら膝伸展抵抗運動 - 健常成人男性におけるバランス機能の訓練効果-

要旨

「背景」バランスは、ADL や障害予防、リハビリでは重要な役割を担っている。特定の運動療法は動的バランスを最大化することができ、とても有益である。漸進抵抗運動は、筋力低下やバランスを改善できることが報告されている。股関節内転挟みながら膝伸展抵抗運動（combined resistance exercise of knee-extension with hip adduction：CREK/HA, 以下 CREK/HA）は、OKC の膝伸展に焦点を当て、新たな開発した運動療法である。「方法」健常成人男性 18 名、ランダムに CREK/HA 群（N = 8）と対照群（n = 10）に分けた。研究１：CREK/HA 群は 3 回/週×4 週の CREK/HA 介入を行い、対照群足位漸進抵抗介入を行った。研究２：CREK/HA 群は 3 回/週×4 週の CREK/HA 介入を行い、対照群は介入がなかった。内側広筋（以下 VMO）と腹直筋（以下 RF）の厚さの変化は、超音波を用いて前後の変化をみた。動的バンランスの変化は、スターエクスカーションバランステスト（star excursion balance test: ESBT, 以下 SEBT）を用いて評価した。「結果」VMO と RF の厚さは、両群ともが有意な変化を認め、VMO / RF の厚さの比が CREK/HA 群のみ有意に増加した。動的バランスは CREK/HA 群のみ有意な変化を認めた。「結論」股関節内転挟みながら膝伸展抵抗運動は、膝伸筋肥大と SEBT のパフォーマンスに効果的であることを示した。

キーワード

股関節内転挟みながら膝伸展抵抗運動、筋肥大、バランス

Effect of combined resistance exercise of knee-extension with hip adduction on dynamic balance performance in healthy male adults - a newly developed knee-extension resistance exercise

WANG HONGZHAO

Abstract

[Background] Balance and stability have a functional role for vocational purposes, recreation, daily tasks or injury prevention and rehabilitation. It would be beneficial to identify if a particular exercise program or technique could maximize dynamic and static balance. Progressive resistance training is widely accepted as an appropriate modality for treating sarcopenia and has been reported to improve balance. Combined resistance exercise of knee-extension with hip adduction (The following is abbreviated as CREK/HA) is a newly developed physical fitness exercise focused on open kinetic chain (The following is abbreviated as OKC) dynamic knee extension with hip adduction controlled by weight ball. [Subjects and methods] 18 healthy male adults (age 32.3 ± 4.5 (y), height 169.6 ± 5.6 (cm), weight 63.4 ± 7.1 (kg)) participated in the study divided into two groups, namely a CREK/HA group (n=8) and a control group (n=10). Study 1: the subjects in CREK/HA group received the CREK/HA training three times a week for 4 weeks, in control group ankle resistance performed only. To identify changes of vastus medialis oblique muscle (The following is abbreviated as VMO) and rectus femoris muscle (The following is abbreviated as RF) on muscle thickness after CREK/HA training program, an Ultrasound was used. Study 2: the subjects in CREK/HA group received the CREK/HA training program three times a week for 4 weeks, while the control group did not participate in the intervention or other training outside their normal activities. The dynamic balance was measured by star excursion balance test (The following is abbreviated as SEBT) before and after the intervention. [Results] Significant improvement in muscle thickness of VMO and RF was observed both in the CREK/HA and control groups. There was increased in muscle thickness ratio of VMO/RF in CREK/HA. Subjects in the CREK/HA group improved performance of the SEBT composite score and a significant improvement for group by training for both the right and left limb in the anterior, posteromedial, and posterolateral directions on both limbs after 4 weeks of training, while no change was observed in the control group. [Conclusion] These results showed that the CREK/HA is effective on knee extensors hypertrophy and performance of SEBT.

Key words

Knee-extension with hip adduction, Muscle hypertrophy, Dynamic balance

Contents

Abbreviation

ACL	Anterior Cruciate Ligament
CKC	Closed Kinetic Chain
CREK/HA	Combined resistance exercise of knee-extension with hip adduction
CUKR	Commonly used knee-extension resistance
EMG	Electromyogram/Electromyography
OKC	Open kinetic Chain
PCL	Posterior Cruciate Ligament
PRE	Progressive Resistance Exercise
RF	Rectus Femoris
SEBT	Star Excursion Balance Test
VM	Vastus Medialis
VMO	Vastus Medialis Oblique

1 Introduction

Balance and stability have a functional role for vocational purposes, recreation, daily tasks or injury prevention and rehabilitation. It would be beneficial to identify if a particular exercise program or technique could maximize dynamic and static balance. Progressive resistance exercise (The following is abbreviated as PRE) is widely accepted as an appropriate modality for treating sarcopenia and has been reported to improve balance[1)]. Combined resistance exercise of knee-extension with hip adduction (The following is abbreviated as CREK/HA) is a newly developed physical fitness exercise focused on open kinetic chain (The following is abbreviated as OKC) dynamic knee extension. Targeted CREK/HA is designed to affect the composition rate of the quadriceps muscles, improve knee extension strength and enhance performance of balance in healthy male adults.

1.1 Dynamic balance

Balance tests were categorized as static, dynamic, functional or using computerized dynamic posturography. Assessments of balance ability tend to have two forms: qualitative ratings of performance based on observation of the participant performing an activity just as the star excursion balance test, and quantitative measures that are equipment-based such as computerized dynamic posturography. Numerous and varied balance tests have been devised to assess and quantify different components of balance/postural stability, each having their own merits and limitations.

Dynamic postural control is attempting to maintain a base of support while completing a prescribed movement[2)]. Maintainance of balance requires visual, proprioceptive, and vestibular feedback in order to respond to the changing environment with appropriate balance strategies[3)]. Important parameters of balance performance include range of motion, muscle strength, somatosensory function, and the size and quality of the base of support[4)]. The star excursion balance test is a functional screening tool developed to assess lower extremity dynamic stability, monitor rehabilitation progress, assess deficits following injury, and identify athletes at high risk for lower extremity injury. The star excursion balance test (The following is abbreviated as SEBT) requires neuromuscular characteristics such as lower extremity coordination, balance, flexibility and strength. Studies have demonstrated high intra-tester and inter-tester reliability when using the

SEBT as an assessment of dynamic balance[5)].

1.2 Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises

The kinetic chain is a combination of several successively arranged joints constituting a complex motor unit. It is a chain of joints and other body tissues that act together. The kinetic chain is made up of the soft tissue system (muscle, ligament, tendon and fascia), neural system and articular system. Muscles can be strengthened through resistance training, which can be divided into OKC and closed kinetic chain (The following is abbreviated as CKC) exercises[6)]. OKC exercise occurs when the movement allows the distal part of limb to move freely while the proximal part is fixed[7)]. OKC exercises are performed with the terminal segment, typically the hand or foot, free to move with the load applied to the distal portion of the limb such as in the bench press or leg extension exercise. These exercises are usually non-weight bearing, with the movement occurring at the elbow or knee joint[7)]. OKC plays an important role in isolating individual groups. It tends to generate more distraction and rotation force and is often used with concentric muscle contraction[7)].

The knee joint is the largest and possibly the most complex joint in the body. It is a combination of three articulations, one between the femur and patella and two between the femoral condyles and tibial plateaus. Coordination between the heads of the quadriceps muscle is important for stability and optimal joint loading for both the tibiofemoral and the patellofemoral joint. Stability of the patellofemoral joint is dependent on the passive and dynamic restraints around the knee. The primary dynamic restraint is the quadriceps muscles. The tibiofemoral joint is usually described as a modified hinge joint with two degrees of freedom: flexion-extension and axial rotation[8)]. During flexion and extension of the tibiofemoral joint there is a combined roll, glide, and spin of the articulating surfaces to help maintain the joint congruency[8)]. The arthro-kinematics is result in the geometry of the joints and the tension produced in the ligamentous structures. During closed chain extension of the tibiofemoral joint the femoral condyles roll anteriorly and glide posteriorly on the tibial plateaus. There is also a conjunct medial rotation of the femur during the last 30°of the extension. This is called the ‘screw home’ mechanism of the knee. In open chain extension, the tibial plateaus roll and glide anteriorly on the femoral condyles. In the last 30° this produces a conjunct lateral rotation of the tibia. During closed chain flexion of the knee the femoral condyles roll posteriorly and glide anteriorly on the tibia plateaus with a conjunct lateral rotation of the femur at the beginning flexion, which is initiated by the popliteus muscle. In the open chain flexion the tibial plateaus roll and glide posteriorly on the femoral condyles with a conjunct internal rotation during the initial 30°. In a normal knee the cruciate ligaments are inelastic and maintain a constant length as the knee flexes and extends, helping to control rolling and gliding of the joint surfaces. During closed chain extension of the knee, the femoral condyles roll anteriorly increasing the distance between the insertions of the posterior cruciate ligament (The following is abbreviated as PCL). Since the PCL cannot lengthen, the femoral condyles are pulled posteriorly allow full extension to occur. During closed chain flexion of the knee, the femoral condyles roll posteriorly increasing the distance between the insertions of the anterior cruciate ligament (The following is abbreviated as ACL). Since the ACL cannot lengthen, the femoral condyles are pulled anteriorly by the ACL[8)].

The knee joint is located between the longest lever arms of the body and bears a majority of body weight. This relationship makes the knee vulnerable to trauma and overuse injuries. Since knee injuries can lead to significant functional limitations and disability, an understanding of this joint's biomechanics is a prerequisite for proper rehabilitation of the knee.

OKC and CKC exercises produce different effects on the tibiofemoral and patellofemoral joints. OKC knee extension is produced by contraction of the quadriceps, which results in anterior translation of the tibia. CKC exercise occurs when the distal segment of the joint is relatively fixed so that movement at one joint results in simultaneous movement of all the other joints in a predictable manner[8)]. Quadriceps muscle activity was greatest in CKC exercise when the knee was near full flexion and in OKC exercise when the knee was near full extension. OKC exercise produced more rectus femoris activity while CKC exercise produced more vasti muscle activity. Tibiofemoral compressive force was greatest in CKC exercise near full flexion and in OKC exercise near full extension. In OKC extension, the flexion moment arm of the knee increases and the extensor moment arm of the patella decreases. This results in the need for increasing quadriceps force to extend the knee especially at terminal extension[8)]. Peak tension in the posterior cruciate ligament was approximately twice as great in CKC exercise, and increased with knee flexion. Tension in the anterior cruciate ligament was present only in OKC exercise, and occurred near full extension. Patellofemoral compressive force was greatest in CKC exercise near full flexion and in the mid-range of the knee extending phase in OKC exercise[9)].

1.3 Progressive resistance exercise

In the early 1980s, health clubs and fitness/wellness center recognized the impact of resistance exercise on athletic performance and general fitness. Meanwhile, the medical community had begun to recognize the potential health value of resistance exercise on functional capacity and other health-related factors. As mentioned earlier, most major health organizations currently recommend resistance exercise as part of a comprehensive exercise program for health and fitness. The popularity and use of resistance training appears to be increasing. The effectiveness of a resistance exercise program is dependent upon several factors including frequency, volume of exercise, progression, and mode of exercise (free weight vs variable resistance loading; dynamic vs isometric exercises; concentric vs eccentric contractions; OKC vs CKC). Resistance training is general terms and is concerned with regular exercise used for enhancing strength and strength related characteristics such as ability of balance performance. Before prescribing an resistance exercise program, the clinician or fitness instructor have to decide what constitutes an optimal balance of these factors to maximize benefits and needs to consider the individual’s age, health status, fitness level, rationale for strength development, and personal goals. Programs prescribed for competitive athlete are not appropriate for sedentary middle-aged adults. Similarly, programs prescribed for middle-aged adults are not appropriate for elderly persons. Although these details provide the basis for prescribing individualized exercise programs, the basic components common to all resistance exercise programs provide the framework for resistance exercise prescription, regardless of the intended population.

Resistance exercise plays a vital role in most athletic and rehabilitation program. It is also believed among sports coaches and physical therapists that resistance training will result in improvements in functional performance[10)]. Resistance training generally expected to bring an increase in muscle strength and mass is well established as an effective method for developing musculoskeletal strength and is prescribed for developing fitness, health, and for the prevention and rehabilitation of orthopedic injuries. As a result of the improved recovery from injuries/accidents and increased strength and muscle mass, resistance training gained formal recognition in the medical community. The effectiveness of an resistance exercise program is dependent upon several factors including intensity, frequency, volume of exercise, and mode of training. When prescribing an resistance exercise program, the fitness instructor and clinician must decide what institutes an optimal balance these factors to maximize benefits and needs to consider the individual's personal goals. During a period of strength training the typical sequence of improvement will be an initial period where the maximal, external force is increasing rapidly week by week, followed by a period with less increase towards an upper limit, set by the load used during training. If training is continued with the same load, no further improvement is seen in muscle strength, but endurance (e.g. Number of contractions with the training load) will increase continuously. If further strength improvement is desired the training load should be increased, as a result of this, muscle strength will increase towards a new upper limit. This procedure of increasing the training load each time a new limit is approached, is called progressive resistance exercise (The following is abbreviated as PRE). The PRE is the basis of any type of modern strength training[11)].

1.4 Combined resistance exercise of knee-extension with hip adduction

Proper function of the knee requires maximal mobility while maintaining maximal stability during day-to-day activities. Rectus femoris (The following is abbreviated as RF) is particularly vulnerable to injury because of its spanning two joints and performing eccentric-specific work during sporting activities. Weakness is often observed in the vastus medialis (The following is abbreviated as VM), which is the first muscle to show weakness among the quadriceps muscles. Vastus medialis oblique (The following is abbreviated as VMO) acutely angled in relation to the femur is the distal part of VM muscle, which is the ideal proprioceptive and feedback controller of the knee during all activities. It monitors relationships between femur and tibia, and the work done by the other three heads of the quadriceps. Because of the monitoring role, VM can modify the power output for safe and smooth functioning of the knee-extension and patella control (Figure 1-1).

The knee-extension exercise is a common rehabilitation and fitness prescription. During the knee-extension an external resistance is applied to the leg, usually placed at the ankle and foot, which produces a flexion moment at the knee.

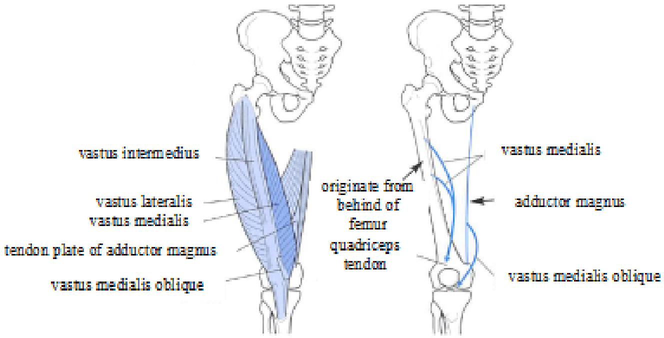

Figure 1-1. Image of boundary of vastus medialis oblique

OKC knee-extension exercise produced more RF activity while CKC exercise produced more vasti muscle activity. If the VMO can be strengthened selectively in OKC knee-extension, this might lead to a good outcome. The priority of goals may differ with each individual. The philosophy of fitness prescription of specific knee-extension resistance may differ depending on the medical practitioner's educational and clinical background and experience, as well as the treatment techniques that have proven successful for the individual's goals. The hip adduction resistance has not been extensively evaluated relative to their effects on quadriceps.

CREK/HA is a newly developed physical fitness prescription focused on VMO hypertrophy during OKC knee extension. The work-out tips of 4-week CREK/HA is prescribed for healthy male subjects: The subjects start sitting on an adjustable bench with foot flat on floor and thigh completely unsupported. One end of a Thera-Band was wrapped around the ankle and the other end attached to something sturdy closed to the floor behind the subjects. The knee was straightened against the resistance and then smoothly returned back to the starting position, maintaining full control throughout at about 90° /s. Both the hip adduction resistance controlled with a weight ball, which is squeezed between the knees, and the ankle resistance controlled by a Thera-Band was performed. The hip adduction resistance was progressive, that is, by 2 kg in the first and second weeks, and 3 kg in the third and fourth weeks; the ankle resistance was progressive too, that is, by 3.7 lb. in the first week, 4.7 lb. in the second and third weeks, and 5.8 lb. in the fourth week. The subjects received the intervention three times a week for 4 weeks. Each session consisted of 4 sets of 30 repetitions of knee extension alternately. Each set was separated by 5 min recovery time (Figure 1-2). Using a Thera-band allows a gradual increase in resistance, where the quadriceps is working concentrically during foot lift, and eccentrically when the foot is moved back to the starting position. A comprehensive exercise prescription to enhance strength deficiencies should include an individualized self-, physical therapist- or medical practitioner-monitored program. The specific prescription of progressive, integrated multi-planar, proprioceptively enriched movements at various loads. A personalized prescription can efficiently and effectively help exerciser achieve his ever evolving goals.

Figure 1-2. Combined resistance exercise of knee-extension/hip adduction

1.5 Hypotheses

The literature examining PRE and balance performance is characterized by an extreme un-uniformity in populations (current age, health and fitness status), training program (dose, exercises designed and progression) and balance outcome variables making clear comparisons between studies difficult. Few studies have closely examined whether the resistance exercises (the guidelines appropriate for various groups) determine a positive balance outcome, an aspect critical to the design of optimal exercise program to enhance balance.

The basis for selection of each exercise regime is based on the hypothesis that there are physiological differences between these strategies and that on strategy may lead to greater improvements in specific physiological variables[11).

Study 1

VMO will be preferentially hypertrophied to a greater degree of its maximum voluntary contraction ability on muscle thickness than the remaining components of knee extensor after CREK/HA in healthy male adults.

Study 2

A CREK/HA focused on lower extremity strength of knee extensors will enhance performance on the SEBT in healthy male adults.

Study 3

The present study was designed to verify a hypothesis that the CREK/HA would be shown to selectively increase VMO electromyography (The following is abbreviated as EMG) activity in a dynamic knee extension task performed compared with that for the knee-extension without hip adduction during OKC resistance.

1.6 Delimitations and limitations

The subjects were 18 healthy men aged 32.3 ± 4.5 years, with a height of 169.6 ± 5.6cm, and a mass of 63.4 ± 7.1 kg. All subjects were healthy untrained but physically active volunteers who did not participate in any other form of training during the study. The subjects were excluded if they had a lower limb injury, visual problems, or vestibular problems. The sample of subjects consisted of people from Huaian Sports School in Jangsu Province during the summer of 2015. The number of subjects is relatively small.

2 Changes of vastus medialis oblique and rectus femoris after combined resistance exercise of knee-extension with hip adduction on muscle thickness in healthy male adults

2.1 Background

The quadriceps femoris affects the bones it attaches to and the joints it passes; it also affects the alignment of lower extremities[12)]. The quadriceps is concerned with movements of knee flexion and extension extremities in the sagittal plane. The weakening of the quadriceps in particular makes the knee joint unstable, thereby resulting in less frequent use of the knee joint, and as a result, weakening of the muscle worsens[13)]. The weakness of the VMO causes an increase in joint pain, and it is related to the lower knee extension strength and range of joint motion[14)]. Quadriceps volume rather than quadriceps activation is a more reliable prognostic factor[15)]. An increase in the VMO size after treatment of knee ostearthritis was reported to ameliorate pain in the afflicted joint and to be good for compensating for structural changes[16)]. Currently evidence is lacking in the integration of strength and conditioning principles into the rehabilitation program for the injured athlete[17)]. Although there is increasing interest in studying the outcomes and mechanisms of resistance training, many aspects related to this type of exercise in humans are unclear. The interaction of multiple combinations of variables involved in resistance training makes it difficult to distinguish their individual contributions and to establish definite training recommendations[18)]. Ultrasound biofeedback has been used to measure cross-sectional area and thickness by visualizing real-time muscle activity and contraction[19)], and it can detect and measure specific muscle activity during isometric contraction[20)]. It has been recognized that ultrasound is useful for differentiating between the type of muscle contraction and timing of muscle activation, and it could be an important part of rehabilitation[21)]. Callaghan et al. Employed ultrasound to quantify the contraction of the quadriceps and suggested that physical therapy and rehabilitation programs using ultrasound would be feasible[22].

The quadriceps femoris muscle is composed of four distinctive portions, the rectus femoris, vastus intermedius, vastus lateralis and vastus medialis. The vastus medialis muscle has two portions, known as the VMO and the vastus medialis longus[23]. However, there is not conclusive evidence that specific exercises can be performed to selectively recruit the VMO[24]. Disagreement exists as to whether the individual components of the quadriceps femoris can be preferentially activated and strengthened, that one muscle component is activated and strengthened to a greater degree of its maximum voluntary contraction ability than the remaining components. Because fibres of the VMO attach to the adductor magnus muscle (the oblique part of vastus medialis attaches strongly to the tendon and fascia of adductor magnus), it has been hypothesized that activation of the VMO may be enhanced by combining active knee extension with volitional hip adduction. But the isometric knee extension exercises performed concurrently with hip adduction have not been shown to selectively increase VMO activity[25]. Therefore, the aim of this study was to investigate the changes of VMO and RF thickness and if the VMO muscle was preferentially hypertrophied to a greater degree of its maximum voluntary contraction ability on muscle thickness than the remaining components of knee extensor after the CREK/HA training program in healthy adults.

2.2 Subjects and methods

The subjects were 18 healthy men who were divided into two groups, namely a CREK/HA group and a control group. The CREK/HA group consisted of 8 subjects and the control group consisted of 10 subjects. All subjects were healthy untrained but physically active volunteers who did not participate in any other form of training during the study. The subjects' characteristics are detailed in Table 2-1.

Table 2-1.Subjects of characteristics

	Age(y)	Height(cm)	Weight(kg)
CREK/HA[a](n=8)	33.8 ± 5.1	171.2 ± 7.3	65.4± 6.8
CTRL[b](n=10)	31.1± 3.8	168.3 ±7.7	61.8. ±7.3

Note: values are mean ± standard deviation. No Significant differences between groups at the 0.05 alpha level. a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.

The participants signed an informed document approved by the ethics committee of Huaian Sports School in Jangsu Province, which also approved the methods and procedures in this study. Before the testing sessions, the participants were asked to refrain from any exercise for 2 hours before testing.

Muscles thickness testing completed twice, separated by 2 mins rest. The highest value from the two trails was taken before and after intervention. We chose to test the left lower extremity on all subjects to maintain consistency. The subjects sit on a bed by straightening their knees, propping a rolled hand towel behind the knee, and bending the knee joint naturally. They were then verbally instructed to do 100% maximum voluntary contraction to progressively straighten the knee for 5 sec. A linear probe of Ultrasound (Mindray DC-8，Linear probe L 12-3 E, 7.5MHz) was placed 4 cm above and 3 cm medial to the upper edge of the patella to monitor VMO muscle thickness and 15 cm above to the upper edge of the patella to monitor RF muscle thickness (Figure 2-1).

Figure 2-1. Ultrasound imaging of vastus medialis oblique and rectus femoris

The subjects start sitting on an adjustable bench with foot flat on floor and thigh completely unsupported. One end of a Thera-Band was wrapped around the ankle and the other end attached to something sturdy closed to the floor behind the subjects. The knee was straightened against the resistance and then smoothly returned back to the starting position, maintaining full control throughout at about 90° /s. In the CREK/HA group, both the hip adduction resistance controlled with a weight ball, which is squeezed between the knees, and the ankle resistance controlled by a Thera-Band was performed. The hip adduction resistance was progressive, that is, by 2 kg in the first and second weeks, and 3 kg in the third and fourth weeks; the ankle resistance was progressive too, that is, by 3.7 lb. in the first week, 4.7 lb. in the second and third weeks, and 5.8 lb. in the fourth week. In the control group, ankle resistance controlled only by a Thera-band was performed. The subjects in both groups received intervention three times a week for 4 weeks. Each session consisted of 4 sets of 30 repetitions of knee extension alternately. Each set was separated by 5 min recovery time. The intervention was monitored by the same physical therapist to avoid individual variations in exercise. The subjects refrained from any strength exercise during the intervention period in order to avoid confounding variables.

The PASW Statistics 19.0 statistical package was used for statistical analysis. To determine whether there were differences between the CREK/HA group and control group, the independent t-test was performed on the subjects' characteristics and each measure before the intervention. Two-way analysis of variance and multiple comparisons (Bonferroni) were used to test for statistically significant differences, and the factors were the intervention, and muscle thickness and VMO/RF ratio for both groups. If a significant interaction was found, the paired *t*-test was performed to compare between before and after the intervention. The level of statistical significant was set as $p = 0.05$.

2.3 Results

There were no significant differences between the CREK/HA group and the control group subject characteristics or each measure before the intervention. Table 2-2 and Table 2-3 shows the results of muscle thickness of VMO and RF, and ratio of VMO/RF. Two-way analyses of variance showed that there was a significant intervention-by-group interaction for the VMO, RF and thickness ratio of VMO/RF . Significant improvement in muscle thickness of VMO and RF was observed both in the CREK/HA and control groups. There was increases in VMO/RF ratio for the CREK/HA group.

Table 2-2. Before and after intervention comparison of thickness of RF and VMO (cm)

	thickness of RF		thickness of VMO	
	before	after	before	after
CREK/HA[a]	1.76 ± 0.22	2.06 ± 0.22**	2.98 ± 0.38	3.56 ± 0.54**
CTRL[b]	1.85 ± 0.20	2.02 ± 0.20**	2.92 ± 0.32	3.20 ± 0.37**

Note: values are mean ± standard deviation. Significant difference after intervention:
a: CREK/HA: combined resistance of knee-extension/hip adduction group. b: CTRL: control group.
**$p < 0.01$, comparison between the before and after the intervention.

Table 2-3. Before and after intervention comparison of thickness ratio of VMO/RF

	before	after
CREK/HA[a]	1.71 ± 0.20	1.80 ± 0.16*
CTRL[b]	1.66 ± 0.14	1.61 ± 0.13

Note: values are mean ± standard deviation. Significant difference after intervention:
a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.
*$p < 0.05$, comparison between the before and after the intervention.

2.4 Discussion

The maximal force or tension produced by a muscle depends on the cross-sectional area of all the muscle fibres within muscle - the physiological cross-sectional area. Thus, a muscle with a large cross-sectional area is able to produce greater maximal force than a muscle with a small cross-sectional area[11)]. Significant improvement in muscle thickness of VMO and RF was observed both in the CREK/HA and control groups. Resistance training is generally expected to bring an increase in muscle strength and mass[26)]. Moreover, muscle thickness is related to muscle strength[27)]. Thus, it may be related to muscle EMG characteristics, such as muscle activity or onset time[28)]. There was increased in the CREK/HA group, in VMO/RF ratio on muscle thickness that was suggested that differences of growth trend between the two muscles may be related to the CREK/HA in which the VMO may be selectively activated and strengthened on flexed knee extension in elastic resistance condition with the assistance of hip adduction due to the hip adduction resistance controlled with a weight ball, which is squeezed between the knees. It may be suggesting a possible cause-effect relationship between muscle activation and hypertrophy, associated with a specific exercise skill demands. If non-uniform muscle hypertrophy after an exercise intervention is due to the region-specific muscle activation during the exercise session by task specificity, the correspondence between the regional different hypertrophies in muscle or muscle group, and muscle activation would also be found in a different exercise modality.

The result in control group was in accordance with that OKC exercise produces more RF activity[9)].

The VM is the quadriceps muscle most often seen to weaken, and various interventions to selectively strengthen the VM have been studied to prevent and treat pain or injury induced by weakness of the vastus medialis[29)]. A few studies based on knee alignment have been conducted the mechanical characteristic of the quadriceps[28)]. Findings of the present study suggest that the CREK/HA may be associated with variation in knee alignment, which leads to differences in quadriceps activity and affects the composition ratio of the quadriceps muscles. Resistance training induces muscle adaptions. This might result from the increased number of active motor units. Research into resistance training is a growing field and there is still much to be explained.

The advantages of non-invasive techniques cannot be over emphasized and therefore, further researches are warranted to demonstrate the usefulness of ultrasound imaging to increase our understanding of the resistance training variables on performance. The resistance exercise bands and weight balls are ideal for building body strength for rehabilitation and fitness. The use of elastic resistance, which is easy, safe and interesting, rather than weight-bearing exercises, minimizes pressure on the joints and decreases the possibility of incurring other injures.

The limitations of this study were as follows. First, because our sampling consisted of male healthy adults limited to a single university, the current findings cannot be generalized to all adults. Second, because the present study was conducted only for a short 4-week training period, our results cannot be generalized until further studies on the long-term effects of training on change in muscle thickness of quadriceps. Also, there are still no normative data of the resistance load between the hip adduction and the ankle loading, so results presented may not be generalized to the people outside this age range. Finally, the evaluation of vastus laterial muscle was not be involved in this study.

3 Combined resistance exercise of knee-extension with hip adduction improves performance on the star excursion balance test in healthy male adults

3.1 Background

Dynamic balance can be defined dynamically as the ability to perform a task while maintaining a stable posture. The influence factors of dynamic balance include sensory information obtained through the somatosensory, visual, and vestibular systems and motor responses that affect coordination joint range of motion and muscle strength[30)]. Daily activities likely require the sensorimotor processes to perform skills and protect the neuromuscular joint system from injuries. Dysfunctional unilateral stance has been prospectively identified as a risk for injury in sport[31-33)]. Dynamic postural control is among the foundational components that underlie the performance of movement skills, and, as a consequence, deficits in dynamic postural control can hinder movement skill performance. The star excursion balance test (SEBT) is an established outcome measure of dynamic postural stability that assesses a combination of range of motion, flexibility, neuromuscular control, and strength. The goal of the SEBT is to maintain single leg stance on one leg while reaching as far as possible with the contralateral leg[5)]. As a functional screening tool the SEBT is developed to assess lower extremity dynamic stability, monitor rehabilitation progress, assess deficits following injury, and identify athletes at high risk for lower extremity injury[2,5,34)]. The SEBT requires neuromuscular characteristics as lower extremity coordination, balance, flexibility, and strength, which is quantified by measuring the distance from the center of the star to the farthest point reached in each direction. The farther the excursion distance the greater the demand on the balance and neuromuscular-control systems[35)]. Studies have demonstrated high intra-tester and inter-tester reliability when using the SEBT as an assessment of dynamic balance[5)].

PRT is widely accepted as an appropriate modality for treating sarcopenia and has been reported to improve balance. CREK/HA is a newly developed physical fitness exercise focused on OKC knee extension. The CREK/HA on knee extension can effectively increase the thickness of knee extensors. In CREK/HA on knee extension the VMO was preferentially hypertrophied to a greater degree of its maximum voluntary contraction ability on muscle thickness than the remaining components. The purpose of this study to determine if a CREK/HA training program focused on knee extensors would enhance performance on the SEBT in healthy adults.

3.2 Subjects and methods

3.2.1 Subjects

The subjects were 18 healthy men who were divided into two groups, namely a CREK/HA group and a control group. The CREK/HA group consisted of 8 subjects and the control group consisted of 10 subjects. All subjects were healthy untrained but physically active volunteers who did not participate in any other form of training during the study. The subjects were excluded if they had a lower limb injury, visual problems, or vestibular problems. The subjects' characteristics are detailed in Table3-1.

Table 3-1.Subjects of characteristics

	Age (y)	Height (cm)	Weight (kg)	Limb length (cm)
CREK/HA[a](n=8)	33.8 ± 5.1	171.2 ± 7.3	65.4 ± 6.8	84.4 ± 4.4
CTRL[b](n=10)	31.1 ± 3.8	168.3 ± 7.7	61.8. ± 7.3	83.8 ± 2.6

Note: values are mean ± standard deviation. No Significant differences between groups at the 0.05 alpha level. a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.

The participants signed an informed document approved by the ethics committee of Huaian Sports School in Jangsu Province, which also approved the methods and procedures in this study. Before the testing sessions, the participants were asked to refrain from any exercise for 2 hours before testing.

3.2.2 Procedure

The subjects in CREK/HA group received the CREK/HA training program three times a week for

4 weeks, while the control group did not participate in the intervention or other training outside their normal activities. The dynamic balance performance was measured by the SEBT before and after the intervention.

3.2.3 Star Excursion Balance Test

The SEBT are quantified by measuring the distance from the center of the star to the farthest point reached in each direction. The farther the excursion distance the greater the demand on the balance and neuromuscular-control systems[35)]. There is a significant learning effect when performing the SEBT; therefore, at least 6 practice trails are necessary before evaluating a subject's performance[34)].

Each subject completed a modified SEBT modeled after the methodology described. Subjects received verbal instruction and visual demonstration of the SEBT from the same examiner. The subjects stood on one lower extremity, with the most distal aspect of their great toe on the center of the grid. The subjects were then asked to reach in the anterior, posteromedial, and posterolateral direction, while maintaining their single-limb stance (Figure 3-1). Six practice trials were performed on each limb for each of the three directions prior to formal testing. On the seventh trial, the most distal of the reach foot was visually recorded by the examiner as it contacted the grid in the three directions. The excursion distance was marked with ink on the floor during the trials. It was recorded from the center of grid to the mark with 1 mm of precision. The process was then repeated while standing on the other lower extremity. The order of limb testing was counterbalance randomized by the tester. The trial was discarded and the subject repeated the testing trial if the subject was unable to maintain single limb stance, the sole of the stance foot did not remain in contact with the floor, weight was shifted onto the reach foot in any of the three directions, or the reach foot did not return to the starting position prior to reaching in the another direction. The subject's limb length was measured from the most distal end of anterior superior iliac spine to the most distal end of the lateral malleolus on each limb. The SEBT composite score was calculated by dividing the sum of the maximum reach distance in the anterior (A), posteromedial (PM), and posterolateral (PL) directions by 3 times the limb length (LL) of the individual, then multiplied by 100 {[(A + PM + PL)/(LL × 3)] × 100}. Subjects wore shorts and comfortable low-heel walking shoes during experiment.

Figure 3-1. Subject performing the star excursion balance test on the left lower extremity in the anterior, posterolateral and posteromedial directions.

3.2.4 Combined resistance exercise of knee-extension with hip adduction

The subjects start sitting on an adjustable bench with foot flat on floor and thigh completely unsupported. One end of a Thera-Band was wrapped around the ankle and the other end attached to something sturdy closed to the floor behind the subjects. The knee was straightened against the resistance and then smoothly returned back to the starting position, maintaining full control throughout. Both the hip adduction resistance controlled with a weight ball, which was squeezed between the knees, and ankle resistance controlled by a Thera-Band was performed. The hip adduction resistance was progressive, that is, by 2 kg in the first and second weeks, 3 kg in the third and fourth weeks; the ankle resistance was progressive too, that is, by 3.7 lb. in the first week, 4.6 lb. in the second and third weeks, and 5.8 lb. in the fourth week. The subjects received the intervention three times a week for 4 weeks. Each session consisted of 4 sets of 30 repetitions of knee extension alternately. Each set was separated by 5 min recovery time. The intervention was monitored by the same physical therapist to avoid individual variations in exercise.

The PASW Statistics 19.0 statistical package was used for statistical analysis. To determine whether there were differences between the CREK/HA group and control group, the independent *t*-test was performed on the subjects' characteristics and each measure before the intervention. Two-way analysis of variance and multiple comparisons (Bonferroni) were used to test for statistically significant differences, and the factors were the intervention, SEBT composite score and each individual reach direction for both groups. If a significant interaction was found, the paired *t*-test was performed to compare between before and after the intervention. The level of statistical significant was set as $p = 0.05$.

3.3 Results

There were no significant differences between the CREK/HA group and the control group subject characteristics. Pre-training SEBT composite scores showed no significant side-to-side difference within subjects or between groups. There was a significant training-by-group interaction with no effect of limb for the SEBT composite score. Subjects in the CREK/HA group improved performance of the SEBT composite score on both limbs after 4 weeks of training, while no change was observed in the control group Table 3-2. Analysis of change in each individual reach direction revealed a significant interaction for group by training for both the right and left limb in the anterior, posteromedial, and posterolateral directions for the subjects in the CREK/HA group Table 3-3, 3-4 and 3-5. Paired *t*-test showed that significant improvement in anterior, posteromedial and posterolateral reaching distance was observed both on the right limb stance and on the left limb stance for the CREK/HA group. While for the control group no change was observed.

Table 3-2. Before and after intervention comparison of star excursion balance test composite score

	right limb stance		left limb stance	
	before	after	before	after
CREK/HA[a]	92.1 ± 3.1	100.1 ± 3.4**	93.1 ± 2.6	101.7 ± 3.3**
CTRL[b]	92.1 ± 3.5	93.8 ± 2.7	92.9 ± 2.9	93.7 ± 2.7

Note: values are mean ± standard deviation. Significant difference after intervention:
a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.
**p＜0.01, comparison between the before and after the intervention.

Table 3-3. Before and after intervention comparison of distance on star excursion balance test for anterior direction

	stance foot	before	after
CREK/HA[a]	right	60.4 ± 4.2	67.2 ± 5.5**
	left	61.7 ± 4.9	67.0 ± 5.5**
CTRL[b]	right	59.6 ± 3.9	60.6 ± 4.1
	left	60.2 ± 3.5	62.3 ± 3.7

Note: values are mean ± standard deviation. Significant difference after intervention:
a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.
**p＜0.01, comparison between the before and after the intervention.

Table 3-4. Before and after intervention comparison of distance on star excursion balance test for posteromedial direction

	stance foot	before	after
CREK/HA[a]	right	90.9 ± 6.7	95.6 ± 5.9**
	left	88.8 ± 6.0	95.4 ± 6.3**
CTRL[b]	right	89.6 ± 4.8	90.1 ± 4.3
	left	87.9 ± 3.8	89.0 ± 3.6

Note: values are mean ± standard deviation. Significant difference after intervention:

a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.

**$p < 0.01$, comparison between the before and after the intervention.

Table 3-5. Before and after intervention comparison of distance on star excursion balance test for posterolateral direction

	stance foot	before	after
CREK/HA[a]	right	83.6 ± 6.2	90.1 ± 7.0**
	left	85.2 ± 6.1	90.4 ± 6.4**
CTRL[b]	right	82.6 ± 4.5	84.3 ± 4.1
	left	84.2 ± 4.1	84.6 ± 2.8

Note: values are mean ± standard deviation. Significant difference after intervention:

a: CREK/HA: combined resistance exercise of knee-extension/hip adduction group. b: CTRL: control group.

**$p < 0.01$, comparison between the before and after the intervention.

3.4 Discussion

Prior to training both the CREK/HA and control groups of the subjects demonstrated similar performance on the SEBT in all measured variables. Following a CREK/HA, the SEBT composite score significantly improved in the exercising group compared to the control group, who did not participate in a CREK/HA. The result proved that the CREK/HA was a functional strategy. Improvement in the SEBT composite score in the CREK/HA group appeared to be dependent on improvements in the anterior reach, the posteromedial reach, and the posterolateral reach as indicated by the independent reach analysis. It seems to imply that knee extension strength may be improved by exercise intervention and the CREK/HA is effective for unilateral dynamic balance although the type of movement required during the SEBT is both multi-limb and multi-articular, of which the complexity underlies the difficulty in formulating training exercises to improve performance requiring dynamic balance. The SEBT which requires neuromuscular characteristics such as lower extremity coordination, balance, flexibility, and strength is a functional screening tool developed to assess lower extremity dynamic stability, monitor rehabilitation progress, assess deficits following injury, and identify athletes at high risk for lower extremity injury. When one sees the SEBT being performed, it is visually obvious that each direction places different demands on the lower extremity[35)]. Improvements in the anterior, posteromedial, and posterolateral directions are likely the result of improved eccentric and isometric contractions of the knee extensors of the supporting limb, neuromuscular control and dynamic balance, because the distance reached in the three directions would be greatly affected by the amount of knee flexion and ankle dorsiflexion of the support limb. Neuromuscular mechanisms play an important role during the SEBT. Moving body segments through three dimensions at different velocities and while experiencing varying accelerations places great demands on the strength, endurance and coordination of the system. There was a significant change in dynamic balance in the anterior direction in both legs. The anterior component of the SEBT is mostly quadriceps dependent, demonstrated by significant quadriceps EMG activation during task[35)]. To perform the anterior excursion, subjects leaned backward, extending the trunk, to maintain their balance. Gravity acting on the upper body creates a large knee-flexion moment, which must be controlled by an extension moment produced by the quadriceps. Earl JE and Hertel J indicated that VMO activity was found to be greater during the anterior excursion than during any other direction in EMG activity[36)]. The improvement in the posteromedial direction is beyond expectation. Movement in the posteromedial direction is a functional movement and recruits both the quadriceps and hamstrings[35)]. The knee joint is not an isolated joint but is part of the body's kinetic chain in which the joints, as a linked system of interdependent segments, often engage in interactions to achieve efficiently the desired movement. Dynamic postural control is among the foundational components that underlie the performance of movement skills, and, as a consequence, deficits in dynamic postural control can hinder movement skill performance. Specific threshold have been developed to screen for injury risk using the SEBT.

There were no differences in composite score between limbs in the control group or in the CREK/HA group. This may be due to the design of the CREK/HA, which focused on the performance of exercises equally on each limb. Establishing limb symmetry was important because limb dominance and side-to-side imbalance in lower extremity in muscular strength, flexibility and coordination have been shown to be important predictors of increased injury risk[36)].

It is well established in the published literature that decreased static and dynamic postural stability are risk factors for lower extremity injuries. The present study showed the effect of the CREK/HA on balance control of unilateral lower extremity and thus gives the implication that the CREK/HA intervention as a new prescription of lower extremity injury prevention and control may improve joint dynamic alignment and the balance between muscles and soft tissues by effectively activating local stabilizing muscles of the lower extremities. Strength was not measured before or after training, so it is not known how much of improvement in balance was derived from strength gains[7)]. It should be noted that any muscle imbalances will influence both the posture and dynamic movement. A longitudinal study is necessary to determine if the CREK/HA has lasting effects on the subject's strength and joint stability.

The limitations of this study were as follows. First, the control group did not participate in the intervention or other training outside their normal activities. Second, this study ruled out the subjects suffered from ankle and knee instability. We need to include in a future study. Finally, there was a significant learning effect when performing the SEBT.

4 Electromyography analysis of vastus medialis oblique/rectus femoris in combined resistance exercise of knee-extension with hip adduction

4.1 Background

A well function of knee joints is critical for daily mobilities, including standing, walking, running, cycling, and staring etc. Coordination between the heads of the quadriceps muscle is important for stability and optimal joint loading for both the tibiofemoral and the patellofemoral joint. The quadriceps femoris muscles are activated differently in open versus closed kinetic chain. Muscle function has significantly impact on the biomechanics of the knee joint. The weakening of the quadriceps in particular makes the knee joint unstable, thereby resulting in less frequent use of the knee joint.

OKC exercise produce more RF activity while less VMO activity[9,37-39)]. Furthermore, OKC knee extension exercises performed concurrently with hip adduction have not been shown to selectively increase VMO activity[40)]. Despite the argument that coordination of the knee extensors may be influenced by open chain tasks, for the reason presented above, there is limited direct evidence of differences in recruitment. CREK/HA is a newly developed physical fitness exercise focused on activating VMO in OKC knee extension. The present study was designed to verify a hypothesis that the combined resistance exercise of knee-extension with hip adduction controlled with a weight ball, which is squeezed between the knees would be shown to selectively increase EMG activity of VMO in a dynamic knee extension task performed compared with that for the commonly used knee-extension resistance (The following is abbreviated as CUKR).

4.2 Subjects and methods

Seven healthy male subjects participate in the study. All subjects performed CREK/HA and CUKR tasks respectively. The subjects' characteristics are detailed in Table 4-1. The dominant lower extremity on all subjects was chosen to test. The dominant leg was determined by asking the subject which leg he preferred to step over a banana hurdle. The participants signed an informed document approved by the ethics committee of Huaian Sports School in Jangsu Province, which also approved the methods and procedures in this study. Before the testing sessions, the participants were asked to refrain from any exercise for 2 hours before testing.

Table 4-1. Subject characteristics

	M±SD N=7
Age (y)	21.6 ± 1.5
Height (cm)	173.6 ± 6.0
Weight (kg)	66.0 ± 3.9

Note: values are mean ± standard deviation.

EMG activity of VMO muscle was recorded with surface electrodes placed approximately in parallel with the muscle fibers over the muscle belly (55° to the vertical) and about 4 cm superior and 3 cm medial to the superior-medial border of the patella. For the RF muscle, the electrodes were placed on the skin about 15 cm superior to the superior border of the patella. The common reference electrode was placed on the patella. The skin was carefully prepared by rubbing with alcohol. Muscle activity was recorded at a sample rate of 200 Hz using a Yunwei™ wireless EMG sensor. EMG data were amplified 1000 times, filtered between 30 and 480 Hz.

A combined resistance exercise of knee-extension with hip adduction (CREK/HA) and a commonly used knee-extension resistance (CUKR) motion tasks were performed one time respectively. The order of task presentation was randomized between setups of CREK/HA and CUKR. The knee-extension exercises were performed in two different conditions. In CREK/HA motion task, the subjects start sitting on an adjustable bench with one end of a Thera-Band wrapped around the ankle and the other end attached to something sturdy closed to the floor behind the subjects. The knee was straightened against the resistance and then smoothly returned back to the sitting position, maintaining full control throughout 5 repetitions at about 90° /s. Both the hip adduction resistance controlled with a weight ball (2 kg), which is squeezed between the knees, and ankle resistance controlled by a Thera-Band (3.7 lb.), In CUKR motion task, the ankle resistance performed only (Figure 4-1). The motion tasks were monitored by the same physical therapist to avoid individual variations in exercise.

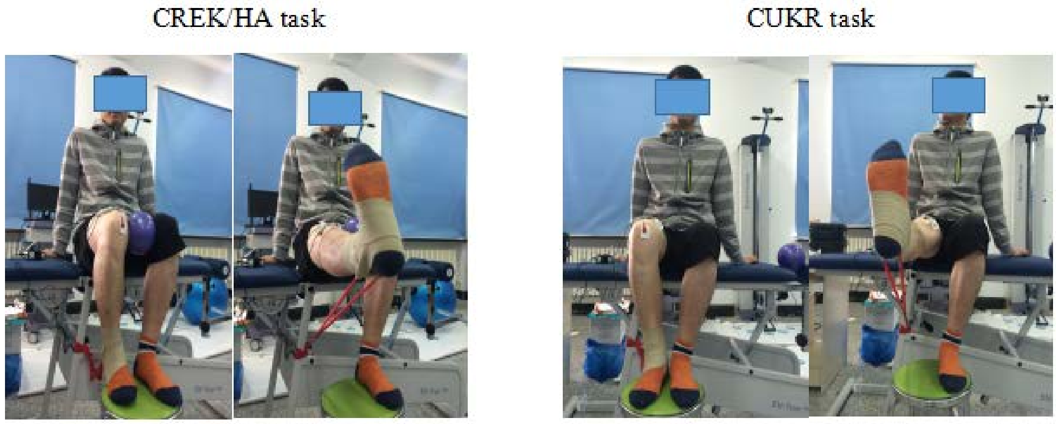

Figure 4-1. Experimental setup. In CREK/HA, both the hip adduction resistance controlled with a weight ball (2 kg), which is squeezed between the knees, and ankle resistance controlled by a Thera-Band (3.7 lb.). In CUKR, ankle resistance only.

Before data collection, each subject was given several practice trials to become acquainted with the motion tasks. During the two motion tasks, EMG activity was continuously recorded from VMO and RF of the dominant leg. EMG signals were obtained over 5 consecutive extension-flexion cycles (Figure 4-2). Recorded EMG data were processed for their average root mean square (The following is abbreviated as RMS).

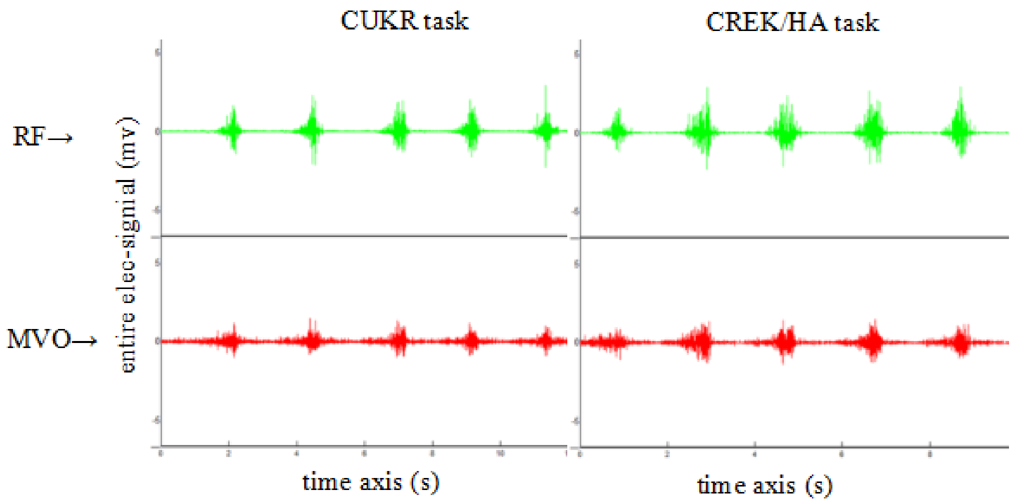

Figure 4-2. Representation of EMG raw data for muscle activity of VMO and RF in CUKR and CREK/HA.

Independent *t*-test was used to test for statistically significant differences, and factors were interventions for the subjects. The PASW Statistics 19.0 statistical package was used for statistical analysis. The level of statistical significant was set as p=0.05.

4.3 Results

Differences in EMG amplitude between tasks were identified between the CREK/HA and the CUKR. Independent *t*-test showed the VMO/RF ratio of mean amplitude for normalized EMG was significantly larger in the CREK/HA task compared with CUKR (Table 4-2).

Table 4-2. Comparison of VMO/RF EMG ratio between CREK/HA and CUKR

	CUKR	CREK/HA
VMO/RF EMG ratio	0.6 ± 0.17	0.85 ± 0.15*

Note: Data are presented as mean ± standard deviation. Significant differences between RE and PPRE:
CUKR: commonly used knee-extension resistance. CREK/HA: combined resistance exercise of knee-extension/hip adduction resistance.
*: $p < 0.05$, comparison between the tasks.

4.4 Discussion

Because the hip adduction has not been extensively evaluated relative to their effect on quadriceps femoris, this study was designed to verify that the CREK/HA would be shown to selectively increase VMO activity in a dynamic knee extension task performed compared with that for the commonly used OKC knee extension. Differences in EMG amplitude between tasks were identified that the VMO/RF EMG ratio was significantly larger in the CREK/HA task compared with in CUKR. The present study measured the EMG activities of VMO and RF muscles during different motion tasks in subjects with different knee alignments and showed different patterns of EMG activity among subjects. Findings indicated that the VMO may be selectively activated and strengthened on flexed knee extension in elastic resistance condition with the assistance of hip adduction due to the hip adduction resistance controlled with a weight ball, which is squeezed between the knees in the CREK/HA experimental setup.

EMG is an example of a technology which increases the possibility of being able to know exactly what problem is. Therefore it makes rehabilitation and training more efficient. During static exercises, authors have demonstrated the good reproducibility of neuromuscular indices such as amplitude of RMS[41)]. Moreover, there is a high reproducibility of the activity level of lower limb muscles during certain dynamic resistance course. However, RF muscle seemed to be less reproducible of the muscles investigated in fatigue[42)]. In future studies, more detailed electromyography and kinematic analyses are needed to elucidate motion tasks associated with differences in knee alignment.

5 Conclusions

5.1 Summary

The knee is a combination of three separate joints within one capsule. During extension of the knee, movement is a combination of rolling and gliding between the articular surfaces of the tibia and femur. The terminal rotation and voluntary rotation is superimposed upon the basic extension movement in the sagittal plane. Quadriceps femoris described as a muscle group composed of RF muscle and three vasti stabilizes the knee joint throughout its full range of movement. RF muscle controls the relationships between lower back, pelvis, hip and the knee. Changes due to thickening will influence hip-knee relationships during walking and running. A few studies based on knee alignment have been conducted on the mechanical characteristics of the quadriceps. Weakness is often observed in the VM muscle, which is the first muscle to show weakness among the quadriceps muscles[28)].

PRE induces neural and muscular adaptions, and can improve strength and strength related variables[43)]. The neuromuscular adaptions include changes in motor unit recruitment and changes occurring at the level of muscle tissue[44)]. It is generally accepted that there is a delay before the onset of muscle hypertrophy and that the initial strength gain is mostly due to the intervention of neural factors[11)]. The results in study 1 showed that improvements in muscle thickness of VMO and RF were observed after 4 week of PRE both in the CREK/HA and control groups, which was partly in line with Seynnes OR et al. demonstrated that changes in muscle size are detectable after only 3 week of resistance training[45)]. It is likely that the process of muscle hypertrophy starts from the very early phases of the exercising period and that not a “sudden” but a progressive increase in muscle mass occurs over a exercising period. Of course, the degree of muscle hypertrophy and its development depend on the mode of training, initial health and fitness status, and the muscle group investigated[46)]. The muscle activation of the agonists during a training session can vary with exercise modalities[9)]. The present study confirmed differences between RF and VMO in muscle hypertrophy induced by different exercise modalities. This suggests that quantification of Ultrasound image change induced by a CREK/HA has the potential to predict the regional hypertrophy in quadriceps femoris after the exercise intervention. The prediction may provide useful information for healthy male adults to design resistance exercise program, because the task-specific increase in muscle thickness could affect knee joint functional performance during daily activities by changing the force act on the quadriceps tendon and also the distribution of quadriceps mass within the segment. Furthermore, Beynnon BD et al. Revealed that the average maximum ACL strain values produced by OKC extension and CKC squatting were similar[47]. Biomechanical models also demonstrated reduced tibiofemoral shear forces when the line of force applied more axially in relation to the tibia[48]. The body needs proximal stability to have distal mobility. The hip adduction resistance partly improved the proximal stability of body, in which the stability is required for OKC knee extension ranging from lumbo-pelvic section to feet. The hip adduction resistance in CREK/HA was applied specifically to the composition rate of the quadriceps muscles, it may elicit hypertrophy of VMO. The CREK/HA is a newly developed physical fitness exercise focused on OKC knee extension, should be used to perform isolated strengthening of the quadriceps.

PRE is widely accepted as an appropriate modality to improve balance. Quadriceps muscle training is commonly undertaken for improving sports performance, rehabilitation and preventing injury. Therefore, the study was to present systematic synthesis of evidence in order to determine the efficacy of CREK/HA as a singular intervention on balance performance in healthy male adults. These results showed that the CREK/HA is effective on knee extensors hypertrophy and performance of SEBT in healthy male adults.

As the popularity of PRE increases among all levels and ages of the population, it becomes increasingly imperative to understand the potential consequences of the exercise process, particularly when the consequences concern more vulnerable or fragile segments of the population. As with physiological alternations, it is likely that the methods of manipulating program variables (volume, intensity or exercise selection), can have a profound impact on the adaptions derived from the exercising program. Knee extensions performed with elastic tubing (band) induces similar quadriceps electromyographic muscular activity as knee extensions using an isotonic training machine[49)].

Dynamic postural control involves controlling body's position in three plane spaces for the dual purposes of stability and orientation. Postural orientation refers to the ability to maintain an appropriate relationship between body segments and also between those body segments and the environment when performing a task. Postural stability is defined as the ability to maintain the body's center of mass within specific boundaries. The motor control is a sequence of command within the nervous system that produces coordinated movement when they are initiated. The dynamic postural control is also a successive sequence of generally identified as ankle strategy, the hip strategy and the stepping strategy. The ankle and hip strategies provide the stability in SEBT and, therefore, are applicable to the maintenance of the dynamic knee stability (The ability of the knee joint to remain stable when subjected to the rapidly changing loads it withstands during activity is referred to as dynamic knee stability[50)]). Dynamic knee stability is the result of the integration of articular geometry, soft tissue restraints, and the loads applied to the joint from weight-bearing and muscle action. The muscle action which provided stabilizing forces is the only component of dynamic knee stability that can be addressed with fitness prescriptions.

It has been suggested that balance is the single most important component of daily activities as it underpins all movements whether they are dominated by strength, speed or endurance. Moreover, balance is closely related to agility and neural coordination. Maintaining of dynamic equilibrium involves the visual, vestibular, kinesthetic and auditory systems. Poor balance may lead to poor function in technical or skill development, which in turn often results in behavior deficits. There is no 'gold standard' of clinical balance, and numerous and varied tests have been devised to assess and qualify different components of balance/postural stability, each having their own merits and limitations[1)].

5.2 Limitations and future investigations

All subjects were healthy untrained but physically active volunteers aged 32.3 ± 4.5 years and the male adults limited to a single university, so the current findings cannot be generalized to all adults. Furthermore the dynamic balance performance after the CREK/HA intervention was evaluated using SEBT, which is also limited. The SEBT is performed with a self-directed pace of movement of the reaching leg with challenges to stability of the stance leg. Joint angles of the stance leg at ankle, knee, and hip should be measured at the maximum reach distance indicated by touchdown of the reaching leg with kinematics analysis. Kinematical changes to one joint may create compensatory muscle recruitment at other joints. The targeted muscles such as VMO and RF should be monitored at real time with wireless EMG sensors.

It is well known that dynamic balance ability typically decreased with age in older adults[51)]. Poor balance ability has been identified as one of the major risks for falls. Moreover, dynamic balance ability in the front direction is also lower in frail older adults. It has been reported that decreased physical activity has a high correlation with increased risk of falls[52)]. However little is known about optimization of daily physical activity of older adults. The CREK/HA is a daily available fitness exercise because the resistance bands and weight ball is an inexpensive, safe and easily transportable health and fitness facilities. In the future study my colleagues and I would intend to evaluate the variables of CREK/KA applied to older adults.

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