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The Effects of Closed Kinetic Chain Exercise and Open Kinetic Chain Exercise on the Knee Position Sense in the Normal Adults

The purpose of this study is to investigate the effects of closed and open kinetic chain exercise for increasing knee joint function on the knee position sense in the normal adults. Thirty normal adults(male 15, female 15; mean age: 22.13±2.58 years) were participated in this study into two groups, each with 15 people. The group I was trained that closed kinetic chain exercise on the knee joint and the group II was trained that open kinetic chain exercise on the knee joint. Exercise programs performed for 4 weeks, 3 times a week were using Shuttle 2000-1 closed kinetic chain exercise and Knee Extensor open kinetic chain exercise(HUR, Filand). The results of this study were as follows: 1) There were statistically significant decreasing of measuring error degree in 0-20° were found between before and after training in closed kinetic chain exercise($p<.05$). 2) There were statistically significant decreasing of measuring error degree in 21-40° were found between before and after training in closed kinetic chain exercise($p<.05$). 3) There were statistically significant decreasing of measuring error degree in 41-60° were found between before and after training in closed kinetic chain exercise($p<.05$). 4) There were statistically significant decreasing of measuring error degree in 0-20° were found between before and after training in open kinetic chain exercise($p<.05$). 5) There were statistically significant decreasing of measuring error degree in 21-40° were found between before and after training in open kinetic chain exercise($p<.05$). 6) There were statistically significant decreasing of measuring error degree in 41-60° were found between before and after training in open kinetic chain exercise($p<.05$).

In conclusion, these results suggest that closed and open kinetic chain exercise has increased in the knee joint proprioception between before and after training. Especially, closed kinetic chain exercise could be more useful intervention than open kinetic chain exercise for increasing proprioceptive sense.

Key words: *Closed Kinetic Exercise; Open Kinetic Exercise; Proprioception*

Ga Rin Lim, Eun Hwa Kwon, Dong Sung Kim, Jung Hyo Kim, Jin Park, Eun Hee Choi, Sik Hyun Kim

Sunlin University, Pohang, Korea

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Address for correspondence
Sik Hyun Kim, PT, Ph.D
Department of Physical Therapy, Sunlin University, 146-1 Chogok-dong, Buk-gu, Pohang, Korea
Tel: 82-54-260-5663
E-mail: spritup@sunlin.ac.kr

INTRODUCTION

Proprioceptive sense, composed of both movement sense and position sense. Collecting sensory information from mechanical receptors include ligaments, muscles and joints. It also detects and balances movements of various body parts to prevent the body's excessive joint flexion and extension(1, 2, 3).

As a part of the proprioceptive sense, the position sense has the ability to determine and to remember exactly where a particular body part is in a space, thus to fulfill a role of stabilizing joints(4, 5, 6). Furthermore, it tansmits that movement signals received from a special form of mechanoreceptor called neuroterminal of the central nervous system(7, 8). It is also responsible for consolidating movement signals from various receptors such as muscles, tendon and joint as well as a visual and a scalar vestibule so

that the body can recognize its position and control its involuntary movement(9).

Therefore, defective proprioceptive sense will produce abnormal walking patterns and it will result in non-physiological joint torque from exposed damages of the joint to individual(10). When the untreated injuries recurrently remained of the joint, body's ability will be decreased in the areas of maintaining a proper posture, keeping protected reflection and controlling the body even though at a small change. As a result, daily activity is going to be affected negatively(3, 12). Damages of the knee joints particularly will have a negative affect on body movement or it will keep a body balance because they are the house of mechanoreceptors type I, II and III that control joint movement, speed, acceleration, direction and position recognition(13). So, it is essential to maintain healthy position sense of the joints to properly carry out daily activities and this applies to all including the normal people as well as the elder patients. There are two physical exercises called open kinetic chain exercises(OKCE) and closed kinetic chain exercises(CKCE) to strengthen knee joints.

OKCE are perform that the hand or foot is free to move. These exercises are typically non-weight bearing with the movement occurring at the elbow or the knee joint. If there is any weight applied, it will be applied to the distal portion of the limb. OKCE are effective exercises for patients with limited range of motion to strengthen their muscles(14, 15). Furthermore, OKCE are additional trainings to keep in a shape and to strengthen muscles(16). OKCE are also used at the early stage of patients recovering from the knee joint damages(17).

CKCE are physical exercises performing that the hand(for arm movement) or the foot(for leg movement) is fixed and cannot move. The hand/foot remains in constant contact with the surface, usually the ground or the base of a machine. These exercises are typically weight bearing exercises, where an exerciser uses their own body weight and external weight. Good example of CKCE is squat exercise. CKCE are known as rehabilitation exercise for patients with anterior cruciate ligament injury. Because of its effectiveness, CKCE's clinical application is gaining ground more lately(18). The precedented study had considered changes in proprioceptive sense with the application of OKCE. However, it is regrettable that comparison of between OKCE and CKCE was absent from the previous study.

This research will supplement the work of the missing elements in the previous study; and it will change in proprioceptive sense with the application of both OKCE and CKCE. Both papers are written by assist physiotherapists to offer proper treatments to their patients with clear and objective information.

MATERIALS AND METHODS

Subjects and Time

30 College-University students(male 15, female 15) at the age of 20s were selected for this experiment. All the subjects have healthy knee joint with normal range of motion. None of them has record of trauma, surgery or other medical problems in their knee joint.

A preparatory experiment was carried out from September 1 to September 7, 2009. The real experiment was done from September 14 to October 9, 2009. Experimenter gave the subjects a thorough explanation as to related and received consent before the actual experiment took place.

Equipment

Shuttle 2000-1(Shuttle System, USA) and Knee Extensor(HUR, Finland) were used respectively for CKCE and OKCE. E-LINK Evaluation System, V900s was used to measure position sense of proprioceptive sense(Fig. 1).

Fig. 1. Test tools used in the experiment
A: Shuttle2000-1, B: Knee Extensor,
C: Electrogoniometer

Procedure

The subjects were divided into two groups; a CKCE group and an OKCE group were to perform resistance exercises assigned to them and to measure changes as to how the exercises affected to strengthen their position sense. An exercise to determine for each subject, Oddvar Holten's RM(Resistance Maximum) calculation system was adopted.

Table 1. Percentage of the Number Exercise

Repetition - %	Repetition - %	Repetition - %
1 - 95	21 - 70	41 - 51
2 - 93	22 - 68	42 - 50
3 - 92	23 - 67	43 - 50
4 - 90	24 - 66	44 - 49
5 - 89	25 - 65	45 - 48
6 - 88	26 - 64	46 - 47
7 - 86	27 - 63	47 - 46
8 - 85	28 - 61	48 - 45
9 - 84	29 - 61	49 - 45
10 - 82	30 - 60	50 - 44
11 - 81	31 - 60	51 - 43
12 - 80	32 - 59	52 - 43
13 - 79	33 - 58	53 - 42
14 - 77	34 - 57	54 - 41
15 - 76	35 - 56	55 - 41
16 - 75	36 - 55	56 - 40
17 - 73	37 - 54	57 - 40
18 - 73	38 - 53	58 - 39
19 - 72	39 - 53	59 - 39
20 - 71	40 - 52	60 - 38

RM calculation

1RM is the maximum resistance(or weight) that can be overcome once by a subject during physical therapy sessions. This experiment used the Holten's method that is to require subjects to repeat resistance exercise with 60% of their 1RM. Holten's method was developed based on the principles of Grimsby where 1) objective of resistance and level must be measurable, 2) all related muscles must be used during the therapy, 3) the exercise must be a physiological one(19). The table 1 shows the Holten's chart used to determine an exercise dose calculating resistance by Percentage of 1 RM.

The subject is provided with a 72lb weight and is able to perform 30 repetitions. 30 repetition correlates to 60% of 1 RM based on the Table 1.

Therefore, X/60% = 72/60% X = 4320/60 = 72

Thus, the subject's 60% of 1RM is 72lb. Once the exercise was determined, the subjects were asked to carry out 3 sets of lifting with the weight. Experimenter averaged the number of repetition during the 3 sets. To prevent muscle fatigue, 2 minute break time was given to the subjects at each set(20).

Exercise program

Before engaging in the experiment, subjects did some warm-up exercises on their back, knees, and ankles to better adjust to the experiment. Based on the predetermined exercise dose, subjects carried out their assigned exercises using the selected equipment. For proper use of Shuttle 2000-1, the subject's tibia was kept perpendicular to the footplate of the machine, his knee joint and hip joint were kept at 90° for avoiding closed lock during extension(Fig. 2).

For proper use of Knee Extensor, the subject set on the machine keeping his back erected in upright position while being supported by the machine's back support, his tibia and thigh were kept at right angles while in sitting position so that their knee joint was in open position(Fig. 3).

As the exercises done on the selected machines to make it difficult for the subject to change the weight freely, the experiment results used with the provided objective equipment and quantifiable data. After the experimental exercise was completed, subjects wrapped up with cool down exercise. The experiment lasted 4 weeks and 12 sessions in total(Table 2).

Table 2. The contents of the configuration of exercise program

Category		Content	Duration
Warmup	Stretching	Waist knee ankle rotation	5min
Experiment1	Shuttle	CKCE	15min
Experiment2	Knee extensor	OKCE	15min
Cooldown	Stretching	Waist knee ankle rotation	5min
Total			25min

* Exercise period / Frequency / Duration: 4weeks / 3times per week / 25min per day

* Experiment repetition: 3 sets (The exercise was determined by Holten's chart)

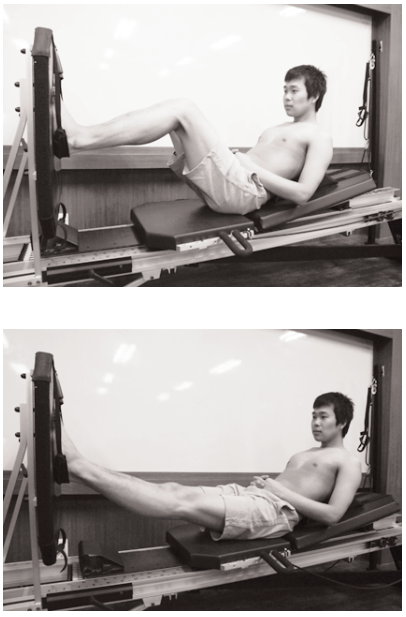

Fig. 2. Closed kinetic chain exercise by Shuttle

Fig. 3. Open kinetic chain exercise by Knee extensor

Joint position sense check

This experiment measured active joint motion repeatedly after setting passive joint position to measure position sense. To minimize cutaneous input, the subject was asked to wear short pants with no socks on their feet. While measuring the difference of knee joint position repeatedly, the subject were stood with their feet spread shoulder length and chest open. To block a visual stimulation, the subject wore a black eye patch and was asked to look straight.

The measurement of knee joint position repeatedly was carried out as experimenter signaled the subject slowly to bend their knees. Knee joint angle measurements were consecutively made at $0^{\circ}-20^{\circ}$, $21^{\circ}-40^{\circ}$ and $41^{\circ}-60^{\circ}$. One spot within each angle range was selected and set it as a target angle. Then the subject was asked to stay at the angle position for 3 seconds so that he could remember the position. After 10 second break, the subject was asked to actively replay back to the target angle. When they thought reached to it, they were asked to report by saying 'stop'(21).

The replayed angle was measured and calculated the difference between the target angle and replayed angle. The difference was called error degree. 9 measurements were made and 20 seconds breaks were inserted at each measurement(Fig. 4).

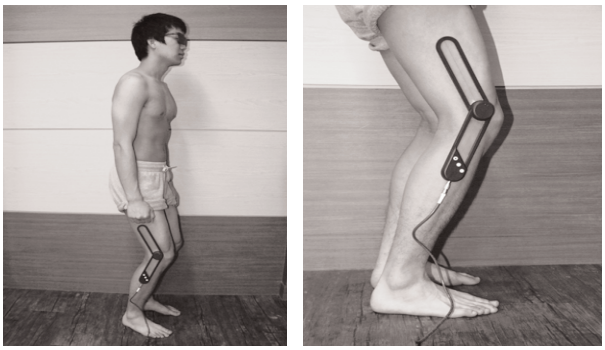

Fig. 4. Manual settings-active reproduce test

Analysis Method

The analysis of this experiment was done with SPSS 12.0K windows program. To examine the effect of both CKCE and OKCE for increase knee joint function on the knee position sense in the normal adults, paired t-test was adopted. To examine the different effect of each exercise, independent samples t-test was adopted.

RESULTS

Characteristics of Subjects

The characteristics of subjects were 30 adults at the age of 22.13±2.58 with average, height of 22.13±2.58cm 166.53±7.96 and weigh 57.83±9.80kg in average(Table 3).

Table 3. General characteristics of subjects

Category	Mean±SD		
	OKCE (n=15)	CKCE (n=15)	Total (n=30)
Age	22.27±2.63	22.00±2.62	22.13±2.58
Height(cm)	165.53±7.30	167.53±8.70	166.53±7.96
Weight (kg)	56.67±7.89	59.00±11.58	57.83±9.80

Comparison at 0°-20° - before and after CKCE

Before the exercise of Measurement, the error degree at 0°-20° was 4.11±1.95 and after the exercise, significant decrease of the error degree showed 2.20±1.73 statistically($p<.05$)(Table 4)(Fig. 5).

Table 4. The summary of before and after the measures on the knee position sense(0-20°).

		Mean±SD	p
Error degree	before	4.11±1.95	.007**
	after	2.20±1.73	

*p<.05, **p<.01, ***p<.001

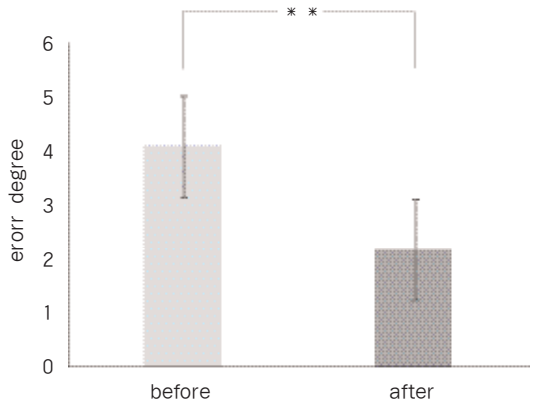

Fig. 5. The comparison of before and after on knee position sense(0°-20°)

Comparison at 21°-40° - before and after CKCE

Before the exercise of measurement, the error degree at 21°-40° was 3.44±1.96 and after the exercise, significant decrease of the error degree showed 1.81±0.96 significantly($p<.05$)(Table 5)(Fig. 6).

Table 5. The summary of before and after the measure on the knee position sense(21°-40°)

		Mean±SD	p
Error degree	before	3.44±1.96	.013*
	after	1.81±.96	

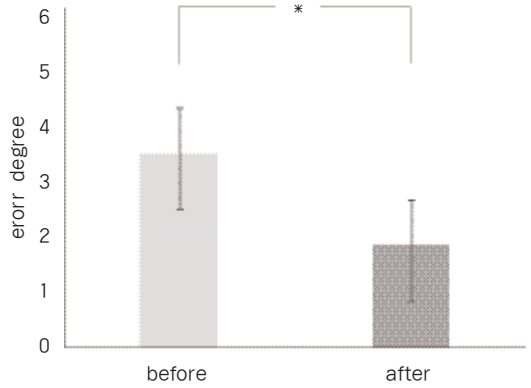

Fig. 6. The comparison of before and after on knee position sense(21°-40°)

Comparison at 41°-60° - before and after CKCE

Before the exercise of measurement the error degree at 41°-60° was 4.17±1.94 and after the exercise significant decrease of the error degree showed 2.22±1.07 significantly($p<.05$)(Table 6)(Fig. 7).

Table 6. The summary of before and after the measure on knee position sense(41°–60°)

		Mean±SD	p
Error degree	before	4.17±1.94	.000***
	after	2.22±1.07	

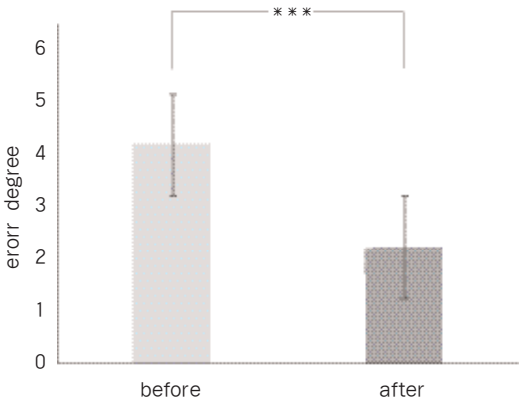

Fig. 7. The comparison of before and after on knee position sense(41°–60°)

Comparison at 0°–20° – before and after OKCE

Before the exercise of measurement the error degree at 0°–20° was 3.50±1.38 and after the exercise significant decrease of the error degree showed 2.70±1.25 significantly(p<.05)(Table 7)(Fig. 8).

Table 7. The summary of before and after the measure on the knee position sense(0°–20°)

		Mean±SD	p
Error degree	before	3.50±1.38	.009**
	after	2.70±1.25	

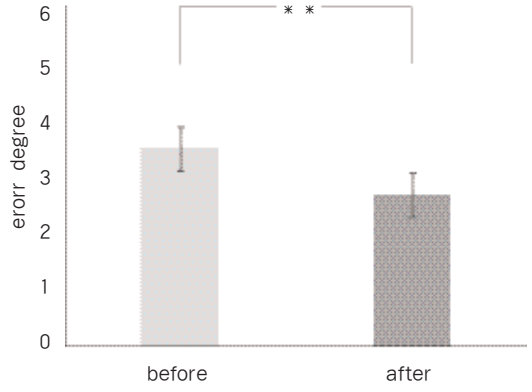

Fig. 8. The comparison of before and after on knee position sense(0°–20°)

Comparison at 21°–40° – before and after OKCE

Before the exercise of measurement the error degree at 21°–40° was 3.25±1.56 and after the exercise significant decrease of the error degree showed 2.13±1.10 significantly(p<.05)(Table 8)(Fig. 9).

Table 8. The summary of before and after the measure on the knee position sense(21°–40°)

		Mean±SD	p
Error degree	before	3.25±1.56	.031*
	after	2.13±1.10	

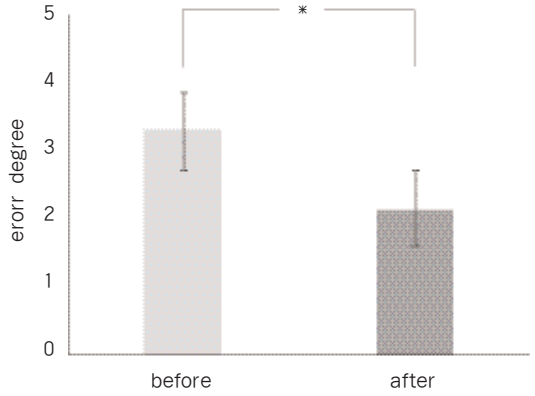

Fig. 9. The comparison of before and after on knee position sense(21°–40°)

Comparison at 41°–60° – before and after OKCE

Before the exercise of measurement the error degree at 41°–60° was 4.27±3.01 and after the exercise significant decrease of the error degree showed 2.37±0.95 signiticantly(p<.05)(Table 9)(Fig.10).

Table 9. The summary of before and after the measure on the knee position sense(41°–60°)

		Mean±SD	p
Error degree	before	4.27±3.01	.009**
	after	2.37±0.95	

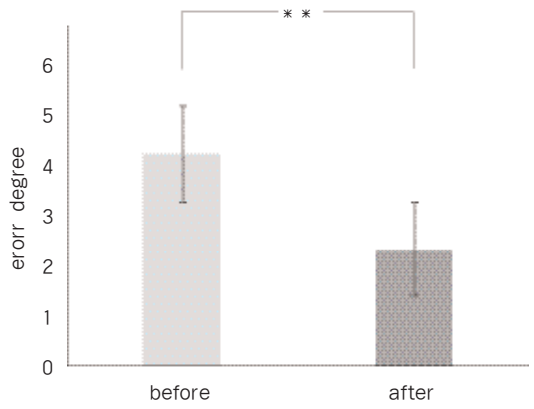

Fig. 10. The comparison of before and after on knee position sense(41°–60°)

Comparisons at 0°–20° between CKCE and OKCE

Measurement of the error degree at 0°–20° for the closed chain exercise was 2.36±1.90 and that of showing insignificant differences the error degree in open chain exercise was 1.61±1.51(Table 10)(Fig.11).

Table 10. The summary of before and after the measure on the knee position sense(0°–20°) between the two groups

		Mean±SD	p
Difference	CKCE	2.36±1.90	.240
	OKCE	1.61±1.51	

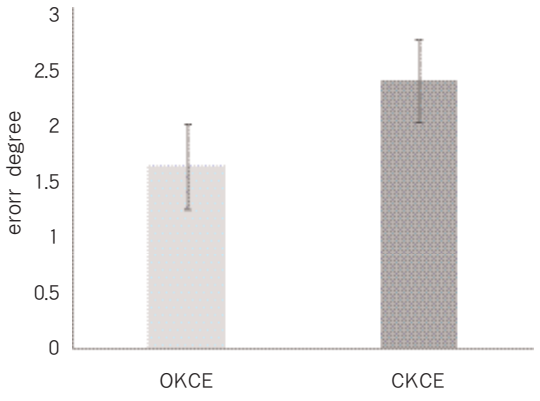

Fig. 11. The comparisons of before and after the measure on the knee position sense(0°–20°) between the two groups

Comparisons at 21°–40° between CKCE and OKCE

Measurement of the error degree at 21°–40° for the closed chain exercise was 1.80±2.05 and that of showing insignificant differences in error degree open chain exercise was 1.43±1.56(Table 11)(Fig. 12).

Table 11. The summary of before and after the measure between the two groups on knee position sense(21°–40°)

		Mean±SD	p
Difference	open	1.80±2.05	.587
	closed	1.43±1.56	

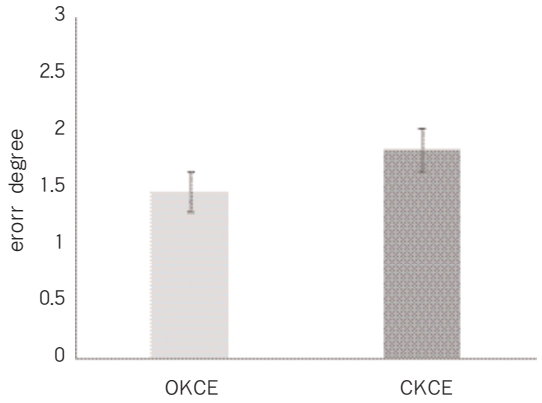

Fig. 12. The comparisons of before and after the measure on the knee position sense(21°–40°) between the two groups

Comparisons at 41°–60° between CKCE and OKCE

Measurement of the error degree at 41°–60° for the closed chain exercise was 3.73±3.20 and that of showing insignificant differences the error degree in open chain exercise was 2.07±2.26(Table 12)(Fig. 13).

Table 12. The summary of before and after the measure between the two groups on the knee position sense(41°–60°)

		Mean±SD	p
Difference	closed	3.73±3.20	.113
	open	2.07±2.26	

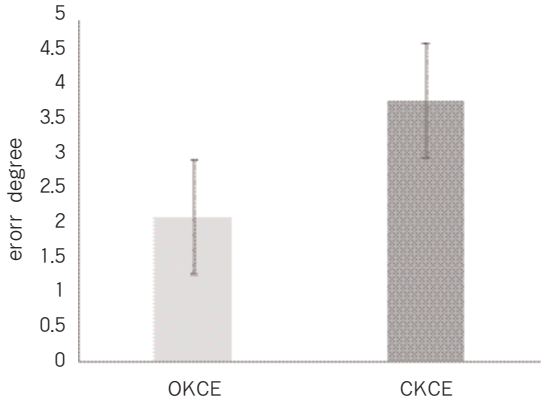

Fig. 13. The comparisons of before and after the measure between the two groups on the knee position sense(41°-60°)

DISCUSSION

Human postural responses involve the number of complex mechanics. They include feedforward mechanism to minimize postural sway before voluntary movement occurs and feedback mechanism actually to manage the postural sway after receiving signals from peripheral receptor. Feedback initiated in the sensory system, is the first agency of attitude strategy, which also determines attitude, heading and stability. The feedback mechanism is made up of vestibular system, visual system, and sensory somatic nervous system.

The vestibular system detects both acceleration and deceleration force applied on the head. The visual system manages body's various defence mechanisms against surroundings. The sensory somatic nervous system transmits signals collected data from muscles, mechanoreceptor, skin and pressure sense in central nervous system(22). Considering the contribution factors of these sensory systems to the human postural responses, it is understand that proprioceptive sense plays a key role in the body postural responses visual system 22%, vestibular system 20%, proprioceptive sense 58%(4).

The ability of proprioceptive sense will deteriorate because of damage occuring with soft tissues or joints. They suggest that excessive work caused malfunction or weakened sense of properioception(23). Furthermore, reports that muscle fatigue produced under Maximum Voluntary Contraction(MVC) states affected by properioceptor at the highest(24).

For the sake of safety of participated subject, this experiment used the Holten's method to determine correct exercise while endeavouring to attain accurate test results. Bout reports that simple and repetitive exercises are the best in order to produce accurate data for position sense observation(25). Based on his suggestion, complex joint exercises that most likely generates high margin of error were avoided in this experiment to produce reliable data.

The resistance of CKCE are produced when both distal and proximal parts are used as it involve more than one joint. On the other hand, OKCE involves a single joint meaning that it remains only fixed proximal part during work out while distal part moves freely. Wee observed changes in muscle activity and muscle fatigue during a subject's push-up and bench press exercise(26). Park observed changes in quadriceps femoris muscle activity during a subject's CKCE(eg. ball squat and step up/down)(27).

This experiment adopted a Shuttle 2000-1(Shuttle System, USA) as CKCE equipment and knee extensor (HUR, Finland) as an OKCE. Furthermore, Oddvar Holten's resistance maximum calculation method was used to increase objectivity of the experiment.

There have been numerous efforts to examine the effect of CKCE and OKCE on patients in terms of improving their propriceptic sense. Barrett reports that anterior cruciate ligament injury patients saw positive results after the physiotherapy exercises(27).

The difference between the researcher's work and this experiment was the time line. While the preceding analysis focused on data from patients during the long term(3 to 6 months) reconstruction program, this experiment concentrated its efforts on data from ordinary people with no physical injuries, which helped observation easier than the previous studies.

However, just as the previous research, this experiment has successfully carried out in accomplishing insignificant margin of error($p<.05$) during the process. In other words, the experiment has established the fact that the CKCE and OKCE have done a positive effect on enhancing position sense of proprioceptor even for ordinary people. Although a few effort was made to observe differences of statistical facts on position sense response before and after work out, this experiment has produced the result that CKCE have done a job better than OKCE based on improving the strength of position sense and decreasing the position sense margin of error.

Although this experiment is produced by previous mentioned limitations, it exertive to increase objectivity by applying same exercise during the observation for measured various angles to avoid learning effect

on the part of subjects and resting phases placed during experiments to maintain proprioceptic sense and to avoid muscle fatigue. A lot of experiments should follow observe the effect on longer period of experiment.

This experiment concludes that CKCE have proven to be more effective working out multiple joints in connection with strengthening proprioceptic sense. Therefore, both ordinary people and patients should seriously consider the exercise to maintain their health. The ill patients will benefit from the exercises; osteoporosis, rheumatoid arthritis and musculoskeletal system. Also, the exercises will prove to be especially effective for athletes undergoing rehabilitation program.

CONCLUSION

The purpose of this study was to investigate the effects of CKCE and OKCE to strengthen knee joint function on knee position sense in normal adults. A total of 30 normal young adults participated in this study. The results of this study were as follows.

1. There were statistically significant decrease of measuring error degree in all ranges of 0°-20°, 21°-40° and 41°-60° were found between before and after training in CKCE($p<.05$).

2. There were statistically significant decrease of measuring error degree in all ranges of 0°-20°, 21°-40° and 41°-60° were found between before and after training in OKCE($p<.05$).

3. When compared the difference of the error degree at the range of 0°-20° for CKCE and OKCE, it was showed more decrease 0.75 in the CKCE. There were not statistically significant results.

4. When compared the difference of the error degree at the range of 21°-40° for CKCE and OKCE, it was showed more decrease 0.37 in the CKCE. There were not statistically significant results.

5. When compared the difference of the error degree at the range of 41°-60° for CKCE and OKCE, it was showed more decrease 1.66 in the CKCE. There were not statistically significant.

In conclusion, these results suggest that closed and open kinetic chain exercise between before and after training have increased in knee joint proprioception. Especially, closed kinetic chain exercise was more useful intervention which could improve proprioception more than open kinetic chain exercise.

REFERENCES

1. Cohen H, Blatchly CA, Gombash LL. A study of the clinical test of sensory interaction and balance. Phys Ther 1993; 73(6): 346-354.
2. Kavounoudias A, Roll R, Roll JP. Foot sole and ankle inputs contribute jointly to human erect posture regulation. J Physiol 2001; 532(pt3): 869-878.
3. Riemann BL, Lephart SM. The Sensorimotor System Part: The Role of Proprioception in Motor Control and Functional Joint Stability. J Athl Train 2002; 37(1): 80-84.
4. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. J Gerontol 1991; 46(3): 69-76.
5. Marks R. Effect of exercise-induced fatigue on position sense of the knee. Aust J Physiother 1994; 40(3): 175-181.
6. Matthews PB. Where dose Sherrington's "muscular sense" originate? Muscles, joints, corollary discharges?. Ann Revi Neurosci 1982; 5: 189-218.
7. Voight ML, Hardin JA, Blackburn TA, Tippett S, Canner GC. The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception. J Orthop Sports Phys Ther 1996; 23: 348-352.
8. Carpenter JE, Blasier RB, Pellizzon GG. The effects of muscle fatigue on shoulder joint position sense. J Sports Med 1998; 26: 262-265.
9. Kim HS, Bae SS, Lee HO, et al, Movement of Human. Hyunmoonsa 1992; 182-199.
10. Docherty C, Moore J, Arnold B. Effects of strength training on strength development and joint position sense in functionally unstable ankle. Journal of Athletic Training 1988; 33(4): 310-314.
11. Kim DK, Ko EH, Lee KS, et al, The Influences of Visual Information and Different Elevations of Medially Wedged Insoles on Knee Joint Proprioception in Healthy Persons. Journal of the Korean Academy of University Trained Physical Therapists 2005; Vol. 12, No. 1: 22-27.
12. Barrack, RL, Skinner HB, Buckley SL. Proprioception in the anterior cruciate deficient knee. Am J Sports Med 1989; 17: 1-6.
13. Schutte MJ, Dabezies ML, Zimmy ML, et al. Neural anatomy of the anterior cruciate ligament. J Bone Join Sug 1987; 66(A): 1072-1076.
14. Kim YJ. The Effects of Closed kinetic chain Exercises of Unstable Floor on the Stability of the Knee

Joints of Patients with Anterior Cruciate Ligament Reconstruction. Graduate School of Daegu University; 2007.
15. Jang JW, The Effects of Muscle Strength in Quadriceps According to Closed kinetic chain Exercises and Open kinetic chain Exercises, Graduate School of Korea University; 2003.
16. Refael FE, Glenn SF, Nigel Z, Steven WB, Kevin EW, James RA. Biomechanics of the knee during closed kinetic exercise. Phys Ther 1998; 30(4): 556-569.
17. Fitzgerald GK. Open versus closed kinetic chain exercise: Issues in rehabilitation after anterior cruciate ligament reconstructive surgery. Phys Ther 1997; 77(12): 1747-1754.
18. Jo JJ. Electromyographic Analysis of isotonic closed and open kinetic chain exercises. Graduate School of Kyung-Hee University; 2001.
19. Grimsby O. Scientific Therapeutic Exercise Progressions. The Ola Grimsby Institute; 1998.
20. Kurugant U, Parker P, Rickards J, Tingley M. Strength and muscle coactivation in older adults after lower limb strength training. International Journal of Industrial Ergonomics 2006; 36: 761-766.
21. Park RJ, Hwang YA, Park SH. The Effect of Pro prioceptive Sensory analysis According to Knee Joint Angle under Fatigue Conditions. Journal of Special Education and Rehabilitation Science 2006; Vol.45, NO. 4: 169-190.
22. Susan B. O'Sullivan, Thomas J. Schmitz. Pysical Rehabilitation Assessment and Treatment. Yeongmunsa; 2007.
23. Skinner HB, Wyatt MP, Hodgdon JA, Conard DW, Barrack RL. Effect of fatigue on joint position sense of the knee. J Orthop Res 1986; 4(1): 112-118.
24. Lee CH, Choi JD, Lee KH, Lee DY, Choi JM. The Effect of Graded Exercise - Induced Fatigue on Position Sense of the Knee. Journal of the Korean Academy of University Trained Physical Therapists 1999; Vol. 6, No. 3; 89-93.
25. Bounet V, Ghery Y. Muscular exercise improves knee position sense in humans. Neurosci Lett 2000; 4; 289(2): 143-146.
26. Wee SD, Park HY, Lee JH. Muscle Activity and Fatigue Response during Closed kinetic chain Exercises and Open kinetic chain Exercises. Journal of Korean Alliance for Health 2000; Vol. 39, No. 3: 493-502.
27. Barrett DS. Proprioception and function after anterior cruciate reconstruction. J Bone Joint Surg 1991; 73-B: 833-837.