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The Effect of Lower Extremity Plyometric Training on the Proprioception and Postural Stability of Collegiate Soccer Players with Postural Instability

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ABSTRACT

The purposes of this study were to determine the effects of lower extremity plyometric training on the proprioception and postural stability of collegiate soccer players with postural instability. The study was conducted from April 17, 2009 to September 28, 2009(for a total of 6 weeks). Ten male collegiate soccer players were enrolled into the study, then divided into two groups: the plyometric training group(PMT) and the classical postural stability training group(CPT). Plyometric training on the lower extremities showed statistically significant improvement on proprioception and postural stability(p<.05). Although not all neurophysiologic mechanisms underlying such an effect were revealed, it is proposed that plyometric training can be used as an effective training program to improve functional postural stability in soccer players with preexisting postural instability.

Keywords: Plyometric Exercise, Postural Stability, Proprioception

Ⅰ. Introduction

The soccer players is exposed to non-contact lower extremity injury(Rochcongar, Laboute, Jan & Carling, 2009). Many underlying problems may have contributing roles in lower extremity injuries, in addition to the stresses experienced by soccer players, including muscular imbalances of the hip, poor foot mechanics, poor deceleration and plyometric function, landing skill after jump(Rahnama, Reilly & Lees, 2002; So, Kim, Lee, Seo, Chung & Kim, 2005).

The athletics trainers and sports physical therapists prescribe postural stability or balance training to athletes for not only preventing and reducing the occurrence of sports injury but also for rehabilitation after injury(Laufer, Sivan, Schwarzmann & Sprecher, 2003). Cushion or balance board are the two common types of postural stability trainings that have been practiced to improve the postural stability or proprioception by achieving neuromuscular integration through conscious or unconscious input of somatosensory information and by enhancing coordination ability of agonist-antagonist muscle during the standing on one of the legs or on both legs on a cushion or balance board(Bressel, Yonker, Kras & Heath, 2007; Caraffa, Cerulli, Projetti, Aisa & Rizzo, 1996; Paterno, Myer, Ford & Hewett, 2004). The most of these training are for static postural stability and do not serve the purpose of players who are engaged in dynamic activities like jumping, landing, pivoting and stopping. So the main purpose of the plyometric training was to enhance the agility and muscle strength of athletics while they are in field.

A plyometric exercise is defined as acentric loading followed immediately by a concentric contraction; it is a training technique that has been used by athletes in all types of sports to increase strength and explosiveness of muscles(Michael, Jeremy, Mark, Christopher & Timothy, 2006). Researchers have shown that plyometric training, when used with a periodized strength-training

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program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception(Miller, Hilbert & Brown, 2001; Sheppard & Young, 2006; Twist & Benicky, 1995). Sheppard and Young(2006), Twist and Benicky(1995) reported that plyometric training improved the agility, that is, the ability to maintain or control body position while quickly changing directions during a series of movements. Michael et al.(2006) thought that plyometric training is a re-enforcement of motor programming through neuromuscular conditioning and neural adaptation of muscle spindles, Golgi Tendon Organs(GTOs), and joint proprioceptor. Bradley, Olsen and Portas(2007) reported that plyometric training improved the proprioception and kinesthetic sense, which provides functional stability to joint. So theoretically, by enhancing balance and by controlling body positions during various movements, proprioception and postural stability should improve. Although plyometric training has been shown to increase performance variables, little scientific information is available to determine if plyometric training also improves the postural stability throughout proprioception(Michael et al., 2006; Wilkerson et al., 2004).

Therefore, the purposes of this study were to determine the effects of a 6-week plyometric training program which have consideration for functional aspect of soccer players on the postural stability and proprioception in collegiate soccer players with postural instability. This study was carried on the hypothesis that plyometric training should significantly improve the postural stability and proprioception of collegiate soccer players who have postural instability as assessed by using posturography.

Ⅱ. Methods

1. The Period of Study and Subjects

The study was conducted from April 17, 2009 to September 28, 2009(for a total of 6 weeks). Subjects were 10 male collegiate soccer players who were randomly divided into two equal groups of 5 each: a) The plyometric training group(PMT), who were given plyometric training; and b) The classical postural stability group(CPT) who were given postural stability training using air-cushion. We explained the purpose of the study to all subjects and all subjects gave written consent to participate in the study. The inclusion criteria used for subject selection were: Firstly, none of the subjects should have a history of any systemic or vestibular disorder that can affect their cutaneous sensation or balance; and secondly, an average Standard Score(SS) of >2 in all of the 8 assessment positions and SS >3 in at-least 2 of the above 8 assessment positions. Basic demographic and clinical information are presented in Table 1. Age, height weight, and career were not significantly different between the PMT group and CPT group(p>.05)

2. Instrumentation and Procedure

1) Proprioception Assessment

Proprioception is the unconscious perception of movement and spatial orientation that arises from stimuli within the body itself. Traditionally, proprioception is measured by assessing the joint position sense(JPS), which is further assessed by measuring the reproduction of both passive and active positioning; while kinesthesia is assessed by measuring the threshold-to-detection of passive motion. The dominant leg of subjects was measured(Higgins & Perrin, 1997).

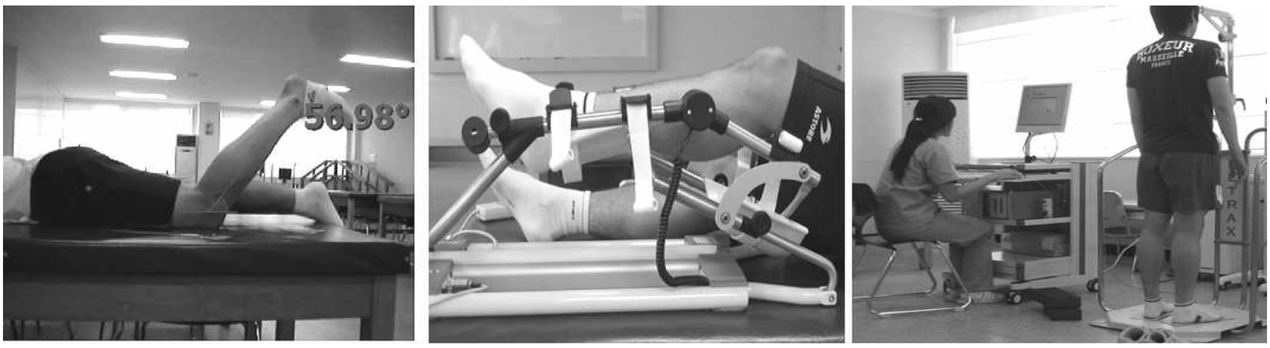
(1) Joint position sense(JPS)

JPS is reproducibility test of joint angle. The subject was made to lie down on a table in prone position. A study staff then passively flexed subject's leg at knee joint to an angle of 40° with the table. Subject was asked to maintain this position for 5 seconds. After 5 seconds, the subject was asked to fully extend his leg. After 10seconds, the subject was asked to actively flex his leg at knee joint to an angle of 40° with the table(joint reproducibility). The measure of this angle was then taken and recorded. For passive flexion, Twinner Pro(SIMI reality motion systems GmbH, Germany), which is 2D motion analysis program, was used to measure the angle of flexion. The marker was attached to lateral malleolus of foot and another at the tibia head of knee joint. During the active flexion by subject, the picture was taken by using a Digital Camera(Parasonic Ltd., Japan) and the flexion angle was measured and calculated to two decimal places<Figure 1, a>. The mean angles from passive and active flexion were compared and a mean error between degree of knee joint flexion presented by researcher(passively) and degree of knee joint flexion reproduced by subjects(actively) was calculated. A lower mean error value indicated a good JPS.

Table 1. General characteristics of the subjects

Group	No	Injury area(onset)	Injuried or dominant leg	Height(㎝)	Weight(㎏)	Age(yrs)	Career(yrs)
PMT (n1=5)	1	Surgical operation of knee joint(before 24 months)	Left	174.8	74.4	20	8
	2	Collateral ligament sprain(before 6 months)	Left	177.2	72.4	20	8
	3	No injury	Right	173.2	69.8	20	5
	4	Meniscus tearing(before 12 months)	Left	178.4	71.3	19	5
	5	Collateral ligament sprain(before 3 months)	Left	177.6	74.5	20	8
Average				176.24±2.16a	72.48±2.02	19.90±0.44	6.80±1.64
CPT (n2=5)	1	Collateral ligament sprain(before 3 months)	Left	178.3	72.8	20	7
	2	Ankle ligament sprain(before 3 months)	Right	174.4	69.7	22	8
	3	Surgical operation of ACL(before 3years)	Left	176.6	75.2	21	8
	4	Ankle ligament sprain(before 6 months)	Right	178.5	68.5	20	8
	5	Hamstring muscle strain(before 12 months)	Right	176.5	74.5	20	8
Average				176.86±1.65	72.14±2.93	20.60±0.89	7.80±0.44

a*M±SD*, [b]Dominant leg, *p<.05, **p<.01, ***p<.001
ACL: Anterior Cruciate Ligament, PMT: Plyometric Training Group, CPS: Classic Postural Stability Training Group



(a) (b) (c)

Figure 1. (a) The assessment of joint position sense using Twinner Pro(SIMI reality motion systems GmbH, Germany). (b) The assessment of joint movement sense(kinesthesia) using Artromot K3(ORMED GmbH & Co., Germany). (c) The assessment of postural stability using TETRAX(TETRAX Ltd., Israel)

(2) Joint kinesthesia

The kinesthesia was determined(the ability to sense joint movement) clinically, by establishing the threshold to detect a relatively slow passive joint motion. Threshold-to-detection of passive motion was achieved using a Artromot K3(ORMED GmbH & Co., Germany) that measured passive knee movements in degrees while maintaining a constant speed of approximately 0.5 sec <Figure 1, b>. We obtained the threshold to detection of passive knee flexion data, and a mean test score was calculated from the 3 test trials and used for data analysis. In order to minimize visual and auditory cues subjects were made to wear a blindfold and headphones during all trials.

2) The postural stability assessment

The TETRAX posturography system(TETRAX Ltd., Israel) that was used in this study consisted of two independent and two mobile-force plates, one for each foot. Each set contained two separate pressure transducers(one for heel and other for forefoot) <Figure 1, c>. The system measures the changes and fluctuations of the vertical force exerted by the corresponding heel and forefoot during the 32 seconds of experimental time and outputs four separate wave signals at a sampling rate of 34 Hz. Two parameters, the 1) Stability Score(ST) and the 2) Standard Stability Score(SS) were measured in eight test positions.

(1) Stability Score(ST)

ST measures the amount of sway over the four plates and is an indicator of the subject's overall steadiness. The ST is calculated by computing the integral of vertical pressure fluctuations at a sampling rate of 34 Hz, taking into account the weight of the subject <Equation 1>. While it does not measure the postural stability directly, the fluctuations of the vertical ground reaction force normalized for body weight have been found to be correlated with both the static and dynamic parts of Berg's balance test and with the anteriorposterior COP(Center of Pressure) velocity(Karlsson & Frykberg, 2000). Therefore, the TETRAX ST provides information about the adequacy of postural stabilities. A lower ST indicates smaller fluctuations, and by extension, a better postural stability of the subject. The ST has been shown to have high test–retest reliability(Kohen-Raz, 1991) and also to be significantly correlated with the equilibrium score of the Equitest posturography system(Turner, 1998).

$$ST = t\,\frac{\begin{Bmatrix}\Sigma_1^n[(a_n-a_{n-1})^2+(b_n-b_{n-1})^2)^2 \\ +(c_n-c_{n-1})^2+(d_n-d_{n-1})^2]\end{Bmatrix}^{1/2}}{N^{1/2}}\;/W \qquad (Equation\,1)$$

(ST: Stability Score, a, b, c, d: the four pressure transducers, W: the body weight, t: experimental time, n: the number of signals sampled at 34 Hz.

$$SS = \frac{ST - Average\ Mean\ of\ ST}{SD} \qquad (Equation\,2)$$

(SS: Standard Stability Score, ST: Stability Score, SD: Standard Deviation)

(2) Standard Stability Score(SS)

Equation 2 was used to calculate Standard Stability Score(SS). It was sub-divided into 5 categories as following: SS1 is considered normal postural stability with the score ranging between -1.0 and 1.5. SS2 and SS3 is postural instability with scores from 1.5 to 3 and from 3 to 6, respectively. SS4 and SS5 are considered abnormal postural stability with score of over 6 and below -1.0 respectively. Soccer players with scores above SS2 in eight assessment positions and above SS3 in at least two assessment positions were defined to be posturally instable. The SS and ST scores were also used to assess the effectiveness of the training by comparing the pre-training and post-training scores.

(3) Postural response patterns on eight positions

An additional dimension of the interactive balance system is the pattern analysis of the postural performances measured by the above described parameters over eight standard positions described below. (1) Eyes open, solid surface(NO). This is the easiest position. The postural response on this position is often used as a point of reference, to compare the performance on the more stressful items. (2) Eyes closed, solid surface(NC). This is the classical Romberg Test, which can be measured objectively, by dividing the Stability on NC by the Stability on NO, which yields a measure designated in posturographic literature as Romberg Quotient(Njiokiktjien & Derijke, 1971). (3) Eyes open, elastic surface(on foam-rubber pads)(PO). Abnormal findings during this test may stem from visual problems as in this position somatosensory input is restricted and visual input becomes more crucial. On the other hand, patients with orthopedic problems tend to improve their performance, as the elastic support may be more easily tolerated in cases of motor handicap than the stress induced by hard and harsh surfaces. (4) Eyes closed, elastic surface(PC). This position implicitly involves vestibular stress, as both, visual and somatosensory input are restricted. (5) and (6) Head turned right and left, respectively, at about 45 degrees, eyes closed(HR and HL). These positions are informative when performances on HR and HL are discrepant, when the normal SS do not show any difference in postural responses on these two items. (7) Head backwards at about 30 degrees, eyes closed(HB). This position is difficult, because on one hand the visual input is excluded whilst the peripheral vestibular system is irritated, as the semicircular canals are put in an abnormal position, and on the other hand this position produces stress on the cervical-vestibular circuits to which Whiplash injuries are particularly sensitive. In this position weight is normally displaced forwards to compensate for the backward tilt. In persons with high risk of falling, a contra-effective weight displacement in posterior direction can be observed. (8) Head downwards at about 30 degrees, eyes closed(HF). This position also is similar to HB in its sensitivity to cervical, especially cervical vestibular, problems(Kohen-Raz, 1991).

3. Training Methods

1) The initial position for plyometric training

The soccer player's start position for training is achieved when there is lower extremity bilateral symmetry, and equal body weight distribution across all joints and limb segments. Mastery of this position is granted only when it can be maintained in static

Table 2. Plyometric training program in 6 weeks.

Training Week	Training Volume[a]	Plyometric Drill	Set X Repetition	Training Week	Training Volume[a]	Plyometric Drill	Set X Repetition
Week 1	90	Squat Jump[b]	2 X 10	Week 4	140	Tuck Jump	2 X 10
		Tuck Jump	2 X 10			Butt Kick	2 X 10
		Butt Kick	2 X 10			Box Jump Up	3 X 10
		Power Step Up	2 X 15			Box Jump Down	3 X 10
						Proprioceptive Training(left leg)	2 X 7
						Proprioceptive Training(right leg)	2 X 7
Week 2	120	Squat Jump[b]	3 X 5	Week 5	160	Tuck Jump	2 X 10
		Tuck Jump	3 X 5			Butt Kick	2 X 10
		Butt Kick	3 X 5			Box Jump Up	3 X 10
		Power Step Up	3 X 5			Box Jump Down	3 X 10
		Squat Jump[b]	2 X 10			Proprioceptive Training(left leg)	2 X 15
		Box Jump Up	2 X 10			Proprioceptive Training(right leg)	2 X 15
		Box Jump Down	2 X 10				
Week 3	120	Squat Jump[a]	3 X 5	Week 6	160	Tuck Jump	2 X 5
		Tuck Jump	3 X 5			Butt Kick	2 X 5
		Butt Kick	3 X 5			Box Jump Up	3 X 10
		Box Jump Up	3 X 8			Box Jump Down	3 X 10
		Box Jump Down	3 X 8			Horizontal Jump	3 X 10
		Horizontal Jump	3 X 9			Proprioceptive Training(left leg)	3 X 10
						Proprioceptive Training(right leg)	3 X 10

[a]Foot contacts time
[b]Strength level's Squat Jump, [c]Stabilization level's Squat Jump

and lateral movement patterns. This position acts as the basic start and landing position for all two legged jumps(Shimokochi & Shultz, 2008). This position include the feet being shoulder or slightly greater than shoulder width apart, the knees remaining posterior to the distal aspect of the feet; the feet are oriented in the sagittal plane, in line with the patella; and center of the patella does not drift past the lateral aspect of the foot. Feet must remain forward with an angular displacement from the midline of the shank no greater than 10°-15°, with hip flexion at approximately 90°(Myer, Ford, McLean & Hewett, 2006).

2) Training Protocols for plyometric training

PMT group performed 3 different training programs that included 1) muscular strength level training, 2) stabilization level training, and 3) proprioception level training(William, 2007). The muscular strength level training consists of 4 drills of squat jump, tuck jump, butt kick, and power step up. It is designed to conduct jumping, safely landing on floor, and jumping again without resting time. The stabilization level training consists of 4 drills of squat jump with stabilization, box jump up with stabilization, box jump down with stabilization, and horizontal jump with stabilization. The adjustment of posture is set so that initial posture(hip joint 90°, knee joint 15°) is maintained in landing after each training. The proprioception level was focused on movement based on movement of center of body mass through sway or external movement by setting it so that the barrier can be moved forward and backward using both or single(right/left) leg(Mattacola & Lyoyd, 1997). In order to maximize functional aspect of soccer player, all jumps in training postures were set so that the head is rotated to the left/right to prepare for heading. The amount of training was based on the amount and intensity of training proposed by Michael et al.(2006) and William(2007), and training intensity was increased in 1-6 weeks within range of 80-160 times of foot contact on ground. The training time, including warming-up and cool-down, was limited to 40 minutes. The training program of plyometric training is as Table 2. The purpose of all types of plyometric trainings proposed in this study is to improve postural stability through visual feedback and adjustment of improper posture and to improve conscious proprioception through peripheral sense feedback in flowing from initial and landing posture. Second purpose is to improve the postural control ability through neuro-muscular coordination of agonist-antagonist muscle groups, which act synergistically in muscle contraction phase. Third purpose is to improve postural stability and proprioception through stretch reflex mechanism being provided in form of plyometric training. Fourth purpose is to improve postural stability through righting reflex of head-body and stimulation of somatic sensory in neck resulting from the neck through posture of head rotating in jumping while improving balancing ability through putting efforts to maintain center of body mass according to the change in balance of body mass on landing posture. Hence, the number of sets was decreased and the number of repetitions was increased to put a focus on lining up the posture and position through repeating training. In addition, training in plyometric form consisted of usual training for soccer players to increase muscular strength and agility. So training in preexisting form continued while executing plyometric training three times a week as proposed in this study. Accordingly, muscular strength level training proposed in this study was provided in form of intensive training focusing on functional aspect of soccer player and in form of postural stability training through movement in repeated postures. Therefore, index and significance for muscle strength weren't considered in this study.

3) Training protocols for classical postural stability training

The training program for CPT group consisted of 14 basic exercises on and off the air-cushion, with variations on each exercise. The program provided the coach each week with 4 prescribed exercises: (1) exercise without any material, (2) exercise with a ball only, (3) exercise with a air-cushion only, and (4) exercise with a ball and a air-cushion. Each week, all the 4 prescribed exercises were of similar difficulty and intensity, with a gradual increase in difficulty and intensity during the 6-week. The total duration of each exercise was approximately 5 minutes. Since these types of training exercises improve postural stability through an effort to maintain a balance on unstable surface and through an effort to coordinate the agonist-antagonist muscle and thereby improving the ability for neural-muscle adaptation, these exercise are widely used in training for proprioception and postural stability. Also, since this training method is unlike the plyometric training, it is provided in a manner of closed kinematics chain exercise and requires the effort to maintain static postural stability of subjects. This program was initially performed by Verhagen, van der Beek, Twisk, Bouter, Bahr and Mechelen(2004) with the purpose to improve function of ankle instability. In this study, air-cushion was used instead of balance board for adjusted term of 6 weeks.

4. Data Analysis

Nonparametric statistics were used since data were either ordinal or skewed. Mann-Whitney U test was used for general characteristics of subjects comparisons. Wilcoxon sign rank test was used for between pre- and post training comparisons. Repeated measures ANOVA was used for intergroup comparisons. All statistical analyses were performed SPSS program(SPSS 12.0 KO for Windows, SPSS Inc, Chicago, USA) and statistical significance was set at $p<.05$.

Ⅲ. Results

1. Subject's Measurement Variable Characteristics in Pre-training

Before this study, all the soccer players(N=31) was measured the postural stability by using posturography. There were ten of these 31 who had an SS average score of above 2 in all assessment position and above 3 in at least 2 assessment positions <Table 3>. Eight of ten subjects had a case history for either lower extremity injury n=6) or a surgical operation(n=2) within last 3 years(Table 3).

2. Comparison of The Proprioception between Pre- and Post-training in Each Groups

In PMT group, JPS was significantly improved post training($p<.05$), and kinesthesia was not significant($p>.05$). In contrast, CPT group showed significant improvement in both JPS($p<.05$) and kinesthesia($p<.05$)(Table 4).

3. Comparison of The Postural Stability between Pre- and Post-training in Each Groups

The SS on eight assessment position pre- and post-training are given in Table 5. The PMT group showed a significant improvement of SS in NO, NC, PO, PC, HR, and HL($p<.05$), and also showed a significant improvement of average SS of eight positions($p<.05$). In comparison, the CPT group showed a significant improvement of SS in NO, NC, HL($p<.05$), and showed significant improvement of average SS of eight position($p<.05$).

Table 3. Mean values before training in each groups

Group	No	NO	NC	PO	PC	HL	HR	HF	HB	Average-SS
PMT (n1=5)	1	24.86b	27.98	22.30	63.37	37.21	25.95	21.16	20.66	30.44±14.32
		2.81c	2.67	1.91	5.05	4.61	1.80	1.21	1.21	2.66±1.46
		SS2d	SS2	SS2	SS3	SS3	SS2	SS2	SS2	SS2
	2	22.14	25.29	23.12	41.45	25.98	27.27	30.79	30.86	28.36±6.16
		2.23	2.11	2.11	2.38	2.31	2.01	3.01	3.33	2.44±0.47
		SS2	SS2	SS2	SS2	SS2	SS2	SS3	SS3	SS2
	3	20.83	27.35	26.24	50.40	25.40	34.06	36.73	24.36	30.67±9.51
		1.95	2.54	2.87	3.47	2.19	3.09	4.12	1.98	2.78±0.76
		SS2	SS2	SS2	SS3	SS2	SS3	SS3	SS2	SS2
	4	23.45	41.94	23.34	56.06	35.84	21.75	36.14	4.74	30.28±15.59
		2.51	5.58	1.92	4.16	4.33	1.13	4.01	-2.10	2.69±2.41
		SS2	SS3	SS2	SS3	SS3	SS1	SS3	SS6	SS2
	5	23.59	27.02	31.40	30.37	20.66	27.78	44.12	25.52	28.81±7.09
		2.54	2.47	4.13	1.03	1.22	2.09	5.50	2.22	2.65±1.48
		SS2	SS2	SS3	SS1	SS1	SS2	SS3	SS2	SS2
Average		22.97±1.54a	29.92±6.80	25.08±3.89	48.33±12.85	29.02±7.17	27.36±4.43	33.79±8.50	21.23±9.91	29.71±1.05
		2.40±0.32	3.07±1.41	2.58±1.56	3.21±1.56	2.93±1.47	2.02±0.70	3.57±1.58	1.32±2.06	2.65±0.12
CPT (n2=5)	1	21.58	33.02	20.05	64.03	20.42	34.12	24.16	27.59	30.62±14.55
		2.11	3.72	1.36	5.13	1.17	3.10	1.77	2.65	2.63±1.33
		SS2	SS3	SS1	SS3	SS1	SS3	SS2	SS2	SS2
	2	19.00	28.94	25.99	39.81	29.55	34.93	27.32	19.70	27.76±7.02
		1.56	2.87	2.81	2.18	3.04	3.23	2.36	1.01	2.38±0.77
		SS2	SS2	SS2	SS2	SS3	SS3	SS2	SS1	SS2
	3	24.62	30.14	23.94	46.62	29.25	31.29	31.86	25.04	30.35±7.28
		2.76	3.12	2.31	3.01	2.98	2.65	3.21	2.12	2.77±0.39
		SS2	SS3	SS2	SS3	SS2	SS2	SS3	SS2	SS2
	4	22.89	37.77	22.22	31.27	31.25	28.34	24.14	20.52	26.33±5.92
		2.39	4.71	1.89	1.14	3.39	2.18	2.14	1.18	2.38±1.18
		SS2	SS3	SS2	SS1	SS3	SS2	SS2	SS1	SS2
	5	25.80	33.59	24.52	48.26	26.42	26.39	30.26	30.09	30.67±7.71
		3.01	3.84	2.45	3.21	2.40	1.87	2.91	3.17	2.86±0.61
		SS3	SS3	SS2	SS3	SS2	SS2	SS2	SS3	SS2
Average		22.78±2.66	32.69±3.44	24.32±2.28	46.00±12.10	27.38±4.26	31.02±3.66	27.95±3.11	24.59±4.47	29.47±1.50
		2.37±0.57	3.65±0.72	2.16±0.56	2.93±1.47	2.60±0.87	2.61±0.58	2.48±0.58	2.03±0.93	2.60±0.22

[a] *M±SD*, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$
[b] Stability Score (ST), [c] Standard Stability Score (SS), [d] Classification of SS
Bold type is the above SS3
PMT: Plyometric Training Group, CPT: Classic Posture Control Training Group
NO=Eyes Open, Solid Surface; NC=Eyes Closed, Solid Surface; PO=Eyes Open, Elastic Surface; PC=Eyes Closed, Elastic Surface; HL/HR=Head Turns Right And Left, Eyes Closed; HB/HF=Head Backward And Downward At 30°, Eyes Closed

Table 4. Comparison of proprioception between pre-and post-training

Items	PMT group (n1=5)				CPT group (n2=5)			
	Pre-training	Post-training	Z-value	*p*-value	Pre-training	Post-training	Z-value	*p*-value
JPS (°)	-8.77±0.89[a]	-6.6±1.97	-2.02	.043*	-9.34±3.89	-2.91±1.52	-2.03	.042*
Kinesthesia (sec)	3.76±1.03	2.72±1.05	-1.82	.068	4.20±0.65	1.44±0.60	-2.02	.043*

[a] *M±SD*, $^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$
PMT: Plyometric Training Group, CPT: Classic Postural Stability Training Group, JPS: Joint Position Sense

4. Comparison of Intergroup Proprioception, Postural Stability

The comparison of intergroup proprioception, postural stability are given in Table 6. In comparison of intergroup proprioception, kinesthesia showed a statistically significant difference($p<.05$) and postural stability showed a statistically significant difference in NC, average on SS($P<.05$).

5. The Correlation between Proprioception and Posture Stability

Both of JPS and Kinesthesia showed significant correlation to average SS($p>.05$), respectively(Table 7).

Table 5. Comparison of postural stability between pre- and post-training in each groups

	PMT group (n1=5)				CPT group (n2=5)			
Position	Pre-training	Post-training	Z-value	*p*-value	Pre-training	Post-training	Z-value	*p*-value
NO	2.40±0.32a	1.97±0.58	-2.02	.043*	2.36±0.56	1.30±0.06	-2.02	.043*
NC	3.07±1.41	2.49±1.33	-2.02	.043*	3.65±0.71	1.11±0.15	-2.02	.043*
PO	2.58±1.56	2.37±1.07	-2.02	.042*	2.16±0.55	1.88±0.68	-1.75	.080
PC	3.21±1.56	2.57±1.45	-2.03	.042*	2.93±1.47	1.89±0.61	-1.21	.225
HR	2.02±0.70	1.65±0.84	-2.02	.042*	2.60±0.58	2.01±0.71	-1.48	.138
HL	2.93±1.47	1.90±0.87	-2.03	.043*	2.59±0.87	0.13±1.07	-2.02	.043*
HB	1.32±2.06	0.71±1.21	-1.84	.138	2.02±0.92	1.27±0.24	-1.48	.138
HF	3.57±1.58	1.91±0.56	-1.48	.066	2.47±0.58	1.87±0.79	-1.21	.225
Average	2.64±0.12	1.95±0.45	-2.03	.042*	2.60±0.22	1.43±0.11	-2.02	.043*

[a]*M*±*SD*, **p*<.05, ***p*<.01, ****p*<.001
PMT: Plyometric Training Group, CPT: Classic Postural Stability Training Group
NO=Eyes Open, Solid Surface; NC=Eyes Closed, Solid Surface; PO=Eyes Open, Elastic Surface; PC=Eyes Closed, Elastic Surface; HL/HR=Head Turns Right And Left, Eyes Closed; HB/HF=Head Backward And Downward At 30°, Eyes Closed

Table 6. Comparison of intergroup proprioception, postural stability

Variations	Ⅲ pattern sum of square	Freedom	Mean square	F	*p*-value
JPS(°) * Group	1.352	1	1.35	.107	.752
Kinesthesia(sec) * Group	3.767	1	3.767	6.502	.034*
NO * Group	.493	1	.493	3.808	.087
NC * Group	4.787	1	4.787	23.526	.001**
PO * Group	.006	1	.006	.162	.698
PC * Group	.196	1	.196	.264	.621
HR * Group	.063	1	.063	.267	.619
HL * Group	2.578	1	2.578	4.057	.079
HB * Group	.024	1	.024	.054	.823
HF * Group	1.378	1	1.378	2.122	.183
Average * Group	.281	1	.281	6.518	.034*

**p*<.05, ***p*<.01, ****p*<.001, JPS: Joint Position Sense
NO=Eyes Open, Solid Surface; NC=Eyes Closed, Solid Surface; PO=Eyes Open, Elastic Surface; PC=Eyes Closed, Elastic Surface; HL/HR=Head Turns Right And Left, Eyes Closed; HB/HF=Head Backward And Downward At 30°, Eyes Closed

Table 7. The correlation between proprioception and postural stability

Items	Coefficient of correlation	*p*-value
JPS (°)	-.75	.01*
Kinesthesia (sec)	-.69	.02*

**p*<.05, ***p*<.01, ****p*<.001, JPS: Joint Position Sense

Ⅳ. Discussion

Most of the intervention programs used to reduce the risk of lower extremity injuries and to train for rehabilitation after injury attempt to influence the neuromuscular system via plyometric, strength training, or stretching exercises, as well as training balance and proper technique to subsequently prevent injuries(Caraffe et al., 1996; Bressel et al., 2007). Caraffe et al.(1996) reported that morbidity of soccer player's anterior cruciate ligament was decreased 7 times through training on balance board and Hewett, Stroupe, Nance and Noyes(1996) reported that injury rates of soccer, basketball and volleyball players' lower extremity joints were decreased by 72% through a combined nero-muscular training regimen of plyometric training, flexibility training, and muscular strength training. In addition, Paterno et al.(2004) reported that morbidity of young female athletes' lower limb joints were decreased by 79% in contrast to control group through balance board training of ankle. Even though many differences exist in types of such trainings, the common point these types of trainings have is that they all offer partial form of proprioception and posture adjusting training. Accordingly, plyometric training aiming particularly to enhance proprioception through stretch reflex should lead to an improvement of collegiate soccer player's postural stability through improvement of proprioception. This study was performed in anticipation that rotating movement of head in plyometric movement shall effectively improve soccer player's functional postural stability.

Comparison of The Proprioception between Pre- and Post-training in Each Groups

JPS is related to proprioception, involving muscle spindles and GTOs which provide information about change of muscle length, muscle tension, respectively. The GTOs is related to stretch reflex which is a kind of spinal reflex. Stretch reflex is muscle stretch, which is involuntary response of muscle by external stimuli(Riemann et al., 2002; Bradley et al., 2007). Plyometric training is defined as acentric loading immediately followed by a concentric contraction. These training exercises have been credited with inducing neuromuscular adaptations to the stretch reflex, elasticity of muscle, and GTOs activation. GTOs usually have a protective function against excessive tensile loads in the muscle; however, after plyometric training, GTOs desensitization is thought to occur, allowing the elastic components of muscles to undergo greater stretch(Hewett et al., 1996). When the stretch reflex and stored elastic energy are combined, a more powerful concentric force is created. Through this understanding about producing maximal strength mechanism, significant improvement of JPS may be interpreted as following; 1) The stimulated muscle(extrafusal muscle) during plyometric training activates the muscle spindle(intrafusal muscle)fiber and the GTOs which are involved in joint proprioception. Accordingly, it improves the proprioception of lower extremitise. 2) Also, weight bearing training of high intensity and repeated landing movement and efforts to conscious posture adjustment may bring about change of somatosensory receptors of lower extremity. Consequently, our study suggests that the proposed plyometric training in this study activates the afferent input by leading up to re-sensitization of peripheral sensory receptors, JPS shown significantly improvement(Docherty, Moore & Arnold., 1998).

The kinesthesia, involving a passive movement with slow speed at range of 0.5-2°/s, targets recognition of slow-adapting mechanoreceptors that can be applied in joint receptors of slow movement such as Ruffini's endings and Golgi-type organs(Lephart, Kocher, Fu, Borsa & Harner, 1997). The form of plyometric training proposed in this study is performed through an explosive divergence of stored elastic energy and thus can explain the statistically insignificant improvement in kinesthesia-since such explosive and prompt movement of joint is incapable of reaching stimulus threshold value of joint mechanoreceptors adapting to the slow movement. In addition, studies on assessment on sense of joint movement have reported that the function of muscle spindle is not applied initially. Particularly, it has been reported that information regarding length of muscle in terms of passive movement in middle level of joint range is limited(Yu & Garrett, 2007). It is our opinion that improvement insense of passive joint movement performed at middle level of this study presented no statistical significance due to the decrease in amount of mechanical stimulus being applied in muscle spindle during the passive movement of joint.

Comparison of The Postural Stability between Pre- and Post-training in Each Groups

The NC position represents information of somatosensory input in lower extremity while PO and PC respectively represent information on vision and vestibular system when somatosensory inputs are limited. In addition, HR and HL provide information on cervical vertebrae-vestibular circuit. Accordingly, plyometric training performed in this study can be thought of as causing improvement in postural stability by stimulating somatosensory and vestibular senses along with vision. The initial stage for postural stability is to recognize and decide the current movement of body in space. The location and movement of the body is combined with given assignment and involves information to create posture adjusting reaction(Mergner, Huber & Becker, 1997). Such postural control reaction normally involves input of peripheral vision sense, somatosensory inputs and vestibular system and central integration and analysis of these senses inputs allow maintenance of optimized postural stability. Bringoux, Marin, Nougier, Barraud and Raphel(2000) reported that postural stability can be improved while capability to use otolithic information in vestibular system and somatosensory system can be reinforced through various sport activities. Accordingly, the role of such receptors for peripheral sensory system is important to maintain postural stability. However, not all forms of sport involve use of identical receptors for peripheral senses to maintain posture. The change in systems of peripheral sensory may vary depending on the type of sport activity. For case of judo player, information on somatosensory input is more important and dancing training involves involvement of visual sensory inputs along with somatosensory(Perrin, Deviterne, Hugel & Perrot, 2002). Since soccer involves competition with opponent, it is reported that somatic senses along with visual aspect are superior. In addition, it is reported that more outstanding soccer players tend to rely their posture adjustment more on vision. This fact indicates that visual change and change in somatic senses are important in terms of posture adjusting form for functional improvement of soccer players. As a result of this study, plyometric exercise, dynamic training for postural stability, was observed to improve vision while changing somatosensory and vestibular sensory inputs. Accordingly, it can be said that this form of plyometric training is capable of improving visual information and it brought about a functional improvement in postural stability by providing visual inputs required by soccer player. In addition, it is observed that significant improvement of head-neck righting reflex through improvement of vestibular system and proprioception from neck through a training regimen consisting of head rotation while jumping made contributions to posture adjustment for PMT group.

Comparison of Intergroup Proprioception, Postural Stability

CPT group showed significant improvements in JPS along with kinesthesia. PMT group, however, showed only significant improvements in JPS. It also showed significant difference of intergroup kinesthesia. The reason hypothesized is that kinesthesia is indicated to be improving more based on static movement provided through exercise in closed chain form(eg. air-cushion or balance board training) rather than through dynamic training(eg. plyometric training). The form of static movement on air cushion can be controlled by moving subject. Bressel et al.(2007) reported that static posture control is more superior in gymnast than volleyball player. As gymnasts maintain static posture control through standing on balance beam with one foot, such difference in sporting activity results significant difference in posture control abilities, the difference between training on air cushion and plyometric training is assessed to present difference in change of proprioception. Accordingly, type of training(static & dynamic) can have different influence on kinesthesia.

Potteiger et al.(1999) interpreted this result as a reinforcement of motor unit recruitment patterns and Craig(2004) reported that neural-adaptation normally is a result of improved coordination between neurological signal from central nerve system and proprioceptive feedback. Accordingly, it can be judged that a significant change presented in somatosensory input is due to a change in sensory input to lower extremities based on an intentional control of biomechanics upon change in movement, landing posture, simultaneous jump of both feet, accurate 15° in knee joint, and accurate 90° in hip joint while performing plyometric training. Accordingly, existing or non-existing contribution of difference in static/dynamic balancing training on vision and vestibular system can be interpreted.

The Correlation between Proprioception and Posture Stability

The proprioception showed significant correlation with average SS(p<.05). In earlier studies on correlation between proprioception and postural stability, a significant correlation between proprioception and postural stability was reported(Harison, Duenkel, Dunlop & Russell, 1994; Mattacola & Lloyd, 1997; Bressel et al., 2007). Indicating proprioception as a firm component factor of postural stability, Harison et al.(1994) reported that training in the form of proprioception being applied to lower extremities after damage/injury holds a firm relationship with postural stability. It was reported that action potential is delivered to central nervous system when mechanoreceptors of joint cavity, ligament, tendon, and of skin receive mechanical modification and information of such location can influence muscular response and position sense. In addition, Mattacola and Lloyd(1997) reported significant correlation of body postural stability to an increase in proprioception since an afferent information inserted into lower extremities is capable of making contributions to body's capability(postural stability) to maintain posture through integration in central nerves. Present study shows similar findings.

Ⅴ. Conclusion

The postural stability(NO, NC, PO, PC, HL, HR position in PMP group, NO, NC, HL position in CPT group) and JPS showed a statistically significant improvement in both groups(p<.05). In PMT group, however improvement in kinesthesia was not significant(p<.05). Although not all neurophysiologic mechanisms underlying such an effect were revealed, it is proposed that plyometric training can be used as an effective training program to improve functional postural stability in soccer players with preexisting postural instability. Limiting points of this study are a small sample size, and not identifying the neurophysiologic mechanisms underlying improved postural stability. Further studies are needed to identify the neurophysiologic mechanism underlying effect of plyometric training on postural stability.

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