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EFFECT OF FUNCTIONAL REHABILITATION EXERCISE ON CHRONIC ANKLE INSTABILITY IN ELITE ATHLETES

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ABSTRACT

A functional evaluation (FE) of the effect of a 6-week functional rehabilitation (FR) in elite athletes with chronic ankle instability (CAI) was conducted. Forty-seven athletes (26 male, 21 female) were recruited who trained at Taereung National Training Centre, Seoul in various sport and who had been diagnosed with CAI by means of a medical examination, radiography, ultrasonography, computerised tomography and magnetic resonance imaging. FR consisting of a 4-week neuromuscular training protocol and 6-week dynamic neuromuscular training protocol and was performed 3 to 5 times per week. FE included the Cumberland ankle instability tool (CAIT), stability (static and dynamic), gait (single limb support time; %SLST), isokinetic ankle strength, and kinematic rear foot inversion (RFI) as measured at baseline and at weeks 2, 4, and 6. Descriptive statistics and one-way ANOVA was applied to identify differences across measurement times. CAIT score increased significantly ($p<0.001$). Both overall stability index (static stability) and test completion time (dynamic stability) decreased significantly ($p<0.001$). Peak torque/body weight (PT/BW) of dorsiflexion and eversion with eccentric contraction at 60°/s, as well as 120°/s increased significantly ($p<0.001$). The gait analysis (%SLST) increased significantly ($p<0.001$), while the RFI angle decreased significantly ($p<0.001$) during fast walking and running. The 6-week FR was effective.

Key words: Ankle sprain; Elite athletes; Chronic ankle instability; Functional rehabilitation; Functional evaluation.

INTRODUCTION

The ankle is the most frequently injured body part in elite sportspersons, accounting for 40% of injuries in sport including basketball, soccer and track and field (Chan *et al.*, 2011). Lateral ankle ligament sprain accounts for 85% of ankle injuries (Frigg *et al.*, 2007) and is a major cause of dysfunction, pain, oedema, muscle weakness and instability (Williams *et al.*, 2007). Only 8% of sportspersons, who experience ankle ligament sprain, fully recover with conservative management (Chan *et al.*, 2011), and 70 to 80% of them proceed to chronic ankle instability (CAI), from re-injury due to muscle weakness, postural control deficits and limited range of motion. These sportspersons also suffer from residual symptoms for 6 to 18 months (Coughlan & Caulfield, 2007; Erik *et al.*, 2007; Webster & Gribble, 2010).

In recent years, rehabilitation protocols for injury have focused on functional movement and closed kinetic chain rather than static and open kinetic chain exercise (Webster & Gribble, 2010). Functional rehabilitation (FR) should be carried out to prevent CAI by repetitive ankle re-injury. Coughlan and Caulfield (2007) also stressed that FR should focus on dynamic and closed kinetic chain exercise to prevent re-injury and promote a return to field activity. This type of FR has been reported to better alleviate pain and oedema, as well as reduce the reoccurrence of injury compared to surgery and cast-wearing (Tropp *et al*., 1985; Wester *et al*., 1996; Michael & Thomas, 2003; Scott, 2007).

Previous studies have reported that ankle function, including postural control, improved when FR was performed three to five times/week for four to six weeks (Coughlan & Caulfield, 2007). Measurements of the effect of FR should include functional evaluation (FE) through dynamic tests of weight bearing, such as walking, running or competitive sport (Willems *et al.*, 2005; Coughlan & Caulfield, 2007).

To measure the effect of rehabilitation exercise on CAI, past studies assessed isokinetic strength using open kinetic chain, low velocity exercise without considering weight bearing or muscle contractile type, and evaluated static balance and inversion stress (Coughlan & Caulfield, 2007). Recently, Mckeon *et al*. (2009) evaluated the effect of FR consisting of four weeks of balance training by examining shank rotation and RFA during walking and running. O'Driscoll and Delahunt (2011) assessed six weeks of neuromuscular training using the Cumberland ankle instability tool (CAIT), star excursion balance test, ankle joint angle at jump and landing, and ground reaction forces. However, studies that quantify the effectiveness of FR in elite sportspersons are still lacking.

PURPOSE OF THE STUDY

Few studies have been conducted to evaluate the dynamic movement at initial contact (IC) and single limb support time (%SLST) of the rear foot, which causes instability and dysfunction in sport and walking. Thus, this study aimed to assess the effect of 6 weeks of FR in elite sportspersons with CAI by means of FE.

METHODOLOGY

Participants

The participants (N=47) consisted of 26 elite sportsmen and 21 elite sportswomen who were diagnosed with CAI and suffered from chronic ankle pain (Table 1). These sportspersons trained at Taereung National Training Centre, Seoul, Korea (national sports village).

Diagnosis was based on medical examination, radiography, ultrasonography, computerised tomography and magnetic resonance imaging. These sportspersons competed in 7 sports (judo, fencing, hockey, handball, gymnastics, weight lifting and badminton). All participants signed a written informed consent form to participate in the study. Participants who had undergone ankle joint surgery within a 1-year period prior to the study were excluded. FE was conducted before FR (baseline, n=47), 2 weeks after (n=45), 4 weeks after (n=42) and 6 weeks after (n=37) FR.

TABLE 1. **CHARACTERISTICS OF FUNCTIONAL REHABILITATION GROUP**

Gender	n	Age (years)	Height (cm)	Weight (kg)	BMI
Male	26	25.7±3.5	175.2±8.5	77.1±18.0	24.9±4.2
Female	21	24.3±3.8	165.9±5.6	61.3± 8.4	22.3±2.8
Total	47	25.0±3.6	171.0±8.7	70.0±16.4	23.7±3.8

Values: mean±standard deviation

Functional rehabilitation programme

The 6-week FR programme for elite sportspersons with CAI was performed 3 to 5 times per week and this frequency was decided on in accordance with O'Driscoll and Delahunt (2011), who indicated the use of a chronic ankle intervention programme at 3 to 5 times per week. Also, this programme included the 4-week neuromuscular training protocol described by Coughlan and Caulfield (2007), and a 6-week dynamic neuromuscular training protocol described by O'Driscoll and Delahunt (2011), which was based on the rehabilitation exercise protocol of Mattacola and Dwyer (2002) (Table 2).

Range of motion (ROM) without ankle pain was performed for 6 weeks with a graded load of frequency and repetition using Achilles tendon stretching and alphabet exercise. *Static balance*, an exercise for static postural stability, was performed for 6 weeks with a graded load of frequency and repetition using single leg squats and ball catching in a single leg squat posture. *Dynamic balance*, an exercise for dynamic postural stability, was performed for 6 weeks with a graded load of frequency and repetition using anterior and lateral single-leg lunges on a balance pad and box.

Strength training was performed for 6 weeks with a graded load of frequency and repetition as well as intensity, according to band colour using single leg heel raises, single leg bridge and dorsiflexion and eversion of the ankle with an elastic band. *Plyometric exercise* was performed for 6 weeks with a graded load of frequency and repetition, as well as level of difficulty of the equipment by jumping on the spot and hurdle jump. *Speed and agility* exercises were performed for 6 weeks with a graded load of frequency and repetition using forward and lateral running on a ladder.

Functional evaluation

Cumberland Ankle Instability Tool (CAIT)

The Cumberland Ankle Instability Tool, which evaluates the instability of the ankle joint, was used by translating the instrument described in the study by Hiller *et al*. (2006) into Korean. Cronbach's α for the translated CAIT to determine internal consistency was 0.85, indicating high reliability. The CAIT score consists of nine items assessed by 41 questions: pain, activity, turning, stairs, one leg, hopping, uneven ground, rolling and response to rolling. The CAIT scores range from 0 to 30 points and lower scores are associated with greater instability of the ankle joint (Hiller *et al*., 2006).

TABLE 2. **FUNCTIONAL REHABILITATION PROGRAMME**

Variables	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**
Range of motion (ROM)	(Pf) *Achilles tendon stretch* 30sX3reps *Alphabet Ex.* 3reps	(Pf) *Achilles tendon stretch* 30sX3reps *Alphabet Ex.* 3reps	(Pf) *Achilles tendon stretch* 30sX5reps *Alphabet Ex.* 5reps	(Pf) *Achilles tendon stretch* 30sX5reps *Alphabet Ex.* 5reps	(Pf) *Achilles tendon stretch* 30sX7reps *Alphabet Ex.* 7reps	(Pf) *Achilles tendon stretch* 30sX3reps *Alphabet Ex.* 7reps
Static postural stability	*Single-leg squats* (Airex ® cushion) 3 min.	*Single-leg squats* (Tilt board) 3 min.	*Single-leg squats* (Bosu ® ball) 3 min.	*Single-leg squats* (Bosu ball) rebounding catches 5 min.	*Anterior jump* land from Reebok ® step 10sX10r X3 sets Stabilisation	*Lateral jump* land from Reebok step 10sX10r X3 sets Stabilisation
Dynamic postural stability	*Double-leg squats* (Bosu) 10rX2 sets *Single leg lunges* forward (Togu ® cushion) 10rX2 sets	*Double-leg compressions* (Bosu) 10rX2 sets *Single leg lunges* side-to-side (Kybun ®) 10rX2 sets	*Double-leg box jumps* (Reebok step) 10rX2 sets *Lunge* from Reebok step onto Bosu 10rX2 sets	*Single leg step-up/-down* (Reebok step) 10rX2 sets *Lunges* side-to-side from Reebok step onto Bosu 10rX2 sets	*Single leg hops* (Bosu) 10rX2 sets Increase distance of jump onto Bosu	*Lateral Single leg hops* (Bosu) 10rX2 sets Increase distance of jump onto Bosu
Strength	*Double leg heel raises* 12rX3 sets *Double leg bridge* 10rX2 sets *Clam-shell* (for GM, each side) 10rX2 sets *Thera-band ® Ex.* (dorsiflexion, eversion) 10rX2 sets (green)	*Double leg heel raises* 12rX3 sets *Double leg bridge* 10rX2 sets *Clam-shell* (for GM, each side) 10rX2 sets *Thera-band Ex.* (dorsiflexion, eversion) 10rX2 sets (green)	*Single leg heel raises* 10rX2 sets (each side) *Single leg bridge* 12rX3 sets (each side) *Figure-4* (for GM) 10rX2 sets *Thera-band Ex.* (dorsiflexion, eversion) 12rX3 sets (blue)	*Single leg heel raises* 10rX2 sets (each side) *Single leg bridge* 12rX3 sets (each side) *Figure-4* (for GM) 10rX2 sets *Thera-band Ex.* (dorsiflexion, eversion) 12rX3 sets (blue)	*Single leg heel raises* (weight 15kg) 12rX3 sets (each side) *Double leg squats* 12rX3 sets *Resisted lateral side-steps* 12rX3 sets (each side) *Thera-band Ex.* (dorsiflexion, eversion) 12rX3 sets (black)	*Single leg heel raises* (weight 20kg) 12rX3 sets (each side) *Single leg squats* 10rX3 sets *Resisted lateral side-steps* 12rX3 sets (each side) *Thera-band Ex.* (dorsiflexion, eversion) 12rX3 sets (black)
Plyometrics	*Tuck jumps* 10r (Kybun cushion)	*Broad jumps* 10rX2 sets (Kybun cushion)	*180^o Tuck jumps* 15rX3 sets (each direction)	*90^o Hop turns* Clockwise & anticlockwise 10r	*Double leg lateral Jumps* (mini hurdle) 10rX3 sets	*Single leg lateral Jumps* (mini hurdle) 10rX3 sets
Speed-agility	*Figure-8 runs* (10m each direction) 5r	*Forward run* (ladder) 10r	*Lateral run* (ladder) 10r (each way)	*Lateral hop* (ladder) 10r (each way)	*Hopping slalom drill* (ladder) 10r	*Lateral shuttle runs* (10m) 10rX2 sets

Pf= Pain free Bosu= Both sides up balance trainer GM= Gluteus medius

Past instruments for FE of CAI include the Functional Ankle Instability Questionnaire (FAIQ) and the Ankle Joint Functional Assessment Tool (AJFAT) (Hiller *et al*., 2006). In the FAIQ, 9 of 11 items consist of a 2-point scale, which lacks sensitivity, and although 12 items on the AJFAT use a 5-point scale, the AJFAT is designed to compare the affected and non-affected ankle, and thus is useful only for unilateral ankle injury, not bilateral injury or instability (Hiller *et al*., 2006). By contrast, the CAIT consists of 9 items that evaluate functional movement, as well as pain in the affected ankle and sums the various scores to evaluate ankle joint instability. Therefore, the CAIT is a very useful instrument to evaluate the severity level of ankle joint instability (Hiller *et al*., 2006). Additionally, the CAIT demonstrated a high correlation (r=0.84) with the visual analogue scale (VAS), which has been widely used to identify changes to subjective pain in previous studies (Hiller *et al*., 2006). Cronbach's α, which represents internal consistency, was 0.85, which guarantees reliability of the instrument, since Numally and Bernstein (1994) reported that a value more than 0.60 is satisfactory.

A CAIT score of 0 to 21 points is considered to reflect severe instability, 21.5 to 24 moderate instability, 24.5 to 27 mild instability, and 27.5 to 30 to be normal (Hiller *et al.*, 2006). In this study, the mean CAIT scores at baseline and 2 weeks were 14.39±2.62 and 18.03±3.93 respectively, which indicated moderate instability, but they improved to 21.60±4.00 at 4 weeks and 25.51±2.36 at 6 weeks, indicating mild instability. Since rehabilitation exercise as an intervention for CAI has been reported to require 6 to 8 weeks (Coughlan & Caulfield, 2007; Slimmon & Brukner, 2010), analysis of the CAIT score at 8 weeks would be of interest in future studies.

Stability (static and dynamic)

Balance was measured using the Biodex Balance System (Biodex Medical Systems Inc., Shirley, USA). *Static balance*, to determine the overall stability index (OSI), was measured in 3 stages of single-leg standing on a moving platform for 20s, with an intraclass correlation coefficient of r=0.60 (Cachupe *et al*., 2001). Participants had no prior practice and individual foot position was measured and applied identically to reduce error due to foot position and posture (Julia *et al*., 2007). A higher OSI score indicates lower balance ability because of the greater shifts required to maintain postural balance during measurement. The inability to maintain a quiet stance during single-leg standing has consistently been shown to be associated with ankle instability (Hertel *et al*., 2006).

Dynamic balance was used to examine test completion time (TCT) in 8 stages, completing 9 tasks using a single leg on a moving platform. Each stage lasted for 3 continuous seconds (Perron *et al*., 2007). Higher TCT scores were associated with lower dynamic balance ability, as they indicate more time to complete a stage. Participants had no prior practice, and individual foot position was measured and applied identically to reduce error due to foot position and posture (Julia *et al*., 2007).

Gait analysis (% SLST)

Gait analysis was conducted using a gait analysis system (GAITRite; CIR Systems Inc., Peekskill, USA), which measures the proportion of single limb support time (%SLST) over the total gait cycle. SLST below the normal range (38 to 40%), indicates abnormal gait time (Mckeon *et al*., 2009). Participants had no prior practice and measurement was conducted in triplicate and the median of 3 measurements was recorded (Van Uden & Besser, 2004). To reduce error in measurement time, the gait began 2m behind the measurement mat on the leg with CAI and participants were then asked to walk 2m beyond the measurement mat (length: 366 cm, width: 61 cm) (Kim *et al.*, 2010). Gait speed was restricted from 1.25 to 1.35m/s using a speedometer (Seed Tech Inc., Incheon, Korea), to maintain a regular speed.

Isokinetic ankle measurements

Peak torque/body weight (PT/BW) of dorsiflexor, evertor for eccentric contraction at 60°/s and 120°/s was measured to identify isokinetic strength of the ankle using an isokinetic strength measurement system (Biodex System III; Biodex Medical Systems Inc., Shirley, USA). PT/BW of dorsiflexor for eccentric contraction in the ankle was determined from 5 repetitive measurements at 60°/s and 120°/s after three prior practise motions and description of the measurement procedure.

At knee flexion of 10° and neutral position of the talocrural joint, a range of 40° from 20° of dorsiflexion to 20° of plantar flexion was measured (Costantino *et al*., 2006; Fox *et al*., 2008). The PT/BW of evertor for eccentric contraction in the ankle was determined from five repetitive measurements at 60°/s and 120°/s after 3 prior practices and a description of the measurement procedure (Willems *et al*., 2002; Costantino *et al*., 2006; Fox *et al*., 2008). With a neutral position (0°) of the subtalar joint and 10° to 15° of plantar flexion in the talocrural joint (Sekir *et al*., 2008), a range of 40° from eversion of 15° to inversion of 25° was measured (Kaminski *et al*., 2003).

Kinematic measures of rear foot inversion (RFI)

Infrared cameras (N=12) (Eagle Motion Analysis, Santa Rosa, USA), capturing 120 frames per second, were used to analyse the motion of the participant. Participants were asked to perform fast walking (1.9m/s) and running (2.7m/s), and the mean rear foot angle (RFA) was calculated during 10% of the cycle from heel strike to toe take-off (Figure 1).

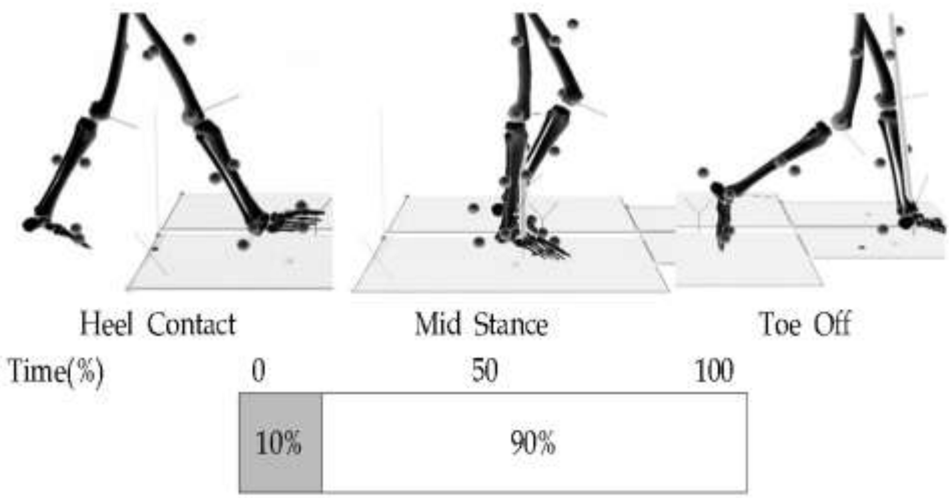

FIGURE 1. **INITIAL CONTACT (IC) PERIOD**

Markers (N=30), separated by 12.7mm, were attached to the lower limb using the 2001 Oxford Foot Model (Carson *et al*., 2001). Cut-off frequency was set at 6Hz using a Butterworth fourth-order low pass filter method. RFA was defined as the angle between the vector component from the heel to the second metatarsal bone and the z-axis.

Statistical analysis

To evaluate the effect of 6 weeks of FR exercise, CAIT, stability (static and dynamic), gait analysis (%SLST), isokinetic strength of the ankle and kinematic analysis of RFI were measured at baseline and after 2, 4 and 6 weeks of FR. All data from functional tests were expressed as descriptive statistics, and data from 4 time measurements were analysed by one-way ANOVA using SPSS for Windows ver. 19.0 (IBM, Armonk, NY, USA). Post-hoc tests were conducted to examine the significance of differences between time points. All thresholds for statistical significance were set at $p<0.05$.

RESULTS

The result of FE at baseline and following 2, 4 and 6 weeks of FR exercise for elite sportspersons with chronic ankle joint instability is shown in Table 3.

CAIT score significantly increased following the 6-week intervention ($p<0.001$, $F=261.911$), and all differences between other times points were also significant. OSI significantly decreased after the 6-week intervention ($p<0.001$, $F=19.643$), and all differences between other times points were also significant.

TCT significantly decreased ($p<0.001$, $F=31.119$), reflecting improved dynamic stability. Significant differences between all other time points were also observed.

In measurements of isokinetic ankle strength following the 6-week intervention, PT/BW of dorsiflexor with eccentric contraction at 60°/s, as well as at 120°/s significantly increased (both $p<0.001$, $F=153.394$ and $F=49.144$ respectively), and all differences between other times points were also significant. PT/BW of eversion with eccentric contraction at 60°/s, as well as at 120°/s significantly increased (both $p<0.001$, $F=201.428$ and $F=90.731$ respectively), and all differences between other times points were also significant.

In gait analysis %SLST, following the 6-week intervention significantly increased ($p<0.001$, $F=31.362$), and all differences between other times points were also significant.

In motion analysis of RFI following 6-week intervention, the RFI angle during fast walking significantly decreased ($p<0.001$, $F=19.098$) and all differences between other times points were also significant.

The angle of RFI during running also significantly decreased ($p<0.001$, $F=14.773$), however, although the difference between baseline and 2 weeks was significant, no significant difference was observed between 2 and 4 weeks or between 4 and 6 weeks.

TABLE 3. **EFFECTS OF FUNCTIONAL REHABILITATION ON MEASURES**

Measures	**Baseline**[a]	**2 week**[b]	**4 week**[c]	**6 week**[d]	**F**	**p**	**Post-hoc**
CAIT (score)	14.4±2.6	18.0±3.9	21.6±4.0	25.5±2.4	261.911	<0.001	d>c c>b b>a
OSI (index)	5.6±2.7	4.0±1.7	3.6±1.5	3.3±1.2	19.643	<0.001	a>b b>c c>d
TCT (s)	165.8±43.6	134.5 ± 30.2	126.1±28.8	118.9±23.9	31.119	<0.001	a>b b>c c>d
IK 60° DF (ecc, N/kg)	31.9±8.7	40.7±11.8	54.7±13.5	66.9±10.2	153.394	<0.001	d>c c>b b>a
IK 120° DF (ecc, N/kg)	26.1±6.4	30.2±9.0	43.9±12.2	54.1±12.9	49.144	<0.001	d>c c>b b>a
IK 60° EV (ecc, N/kg)	30.5 ± 5.7	40.3±6.7	55.7±7.1	67.3±7.8	201.428	<0.001	d>c c>b b>a
IK 120° EV (ecc, N/kg)	25.2±5.2	32.8±7.4	45.3±9.5	55.2±9.9	90.731	<0.001	d>c c>b b>a
GC (%SLST)	34.0±3.0	36.2±2.8	38.1±1.5	38.6±1.9	31.362	<0.001	d>c c>b b>a
FW (RFI, °)	9.7±2.9	8.5±2.7	7.7±2.6	6.9±1.8	19.098	<0.001	a>b b>c c>d
RN (RFI, °)	7.3±2.1	6.5±2.1	6.2±1.8	5.8±1.5	14.773	<0.001	a>b

CAIT: Cumberland Ankle Instability Tool OSI: Overall Stability Index TCT: Test Completion Time
IK: Isokinetic DF: Dorsiflexor EV: Evertor Ecc: Eccentric GC: Gait Cycle RN: Running
FW: Fast Walking SLST: Single Limb Support Time RFI: Rear Foot Inversion

DISCUSSION

After musculoskeletal injury, evaluating the lack of postural stability and providing rehabilitation are essential (Mattacola & Dwyer, 2002). The Biodex Balance System has been used to evaluate quantitatively the ability to maintain stability and control balance after ligament injury (Kim *et al*., 2010). Rozzi *et al*. (1999) reported that the Biodex Balance System is reliable for the evaluation of postural stability. Other studies (Kim *et al*., 2010) have also supported the reliability of the Biodex Balance System.

The Biodex Balance System uses a circular platform with simultaneous movement of the anterior-posterior and medial-lateral axes, allowing the evaluation of multidirectional stability at various levels of resistance (Arnold & Schmitz, 1998). The OSI simultaneously evaluates the medial-lateral stability index and anterior-posterior stability index, as it very sensitively responds to bi-directional change. Therefore, this index is ideal for assessing static stability (Arnold & Schmitz, 1998). One prior study reported that OSI for the dominant and non-dominant lower limb demonstrated high reliability. In this study, OSI at baseline was 5.59±2.73 and it gradually decreased to 3.99±1.70, 3.59±1.49 and 3.30±1.17 at 2, 4 and 6 weeks respectively.

In a study by Kim *et al.* (2010) comparing underwater exercise and terrestrial exercise in elite sportspersons with acute injury to the ankle or knee ligament, the terrestrial exercise group demonstrated OSI values of 5.70±1.05 at baseline (third stage), 4.05±0.54 at 2 weeks, and 3.26±0.41 at 4 weeks of exercise, which is a greater reduction than that observed in the present study. This difference is assumed to reflect the fact that the participants of the present study were elite sportspersons with CAI involving multiple factors, such as nerve (proprioception, reflex, muscle reaction time), muscle (strength, power, endurance), and mechanics (extension of ligament) (Konradsen *et al*., 1998), whereas the participants of the previous study were elite sportspersons with first- and second-stage acute ligament injury to the ankle or knee. It would be of interest to observe the change in OSI in sportspersons with acute ligament injury upon completion of the FR programme suggested in this study and compare those findings with the results of the present study.

Many studies of stability evaluate static stability. However, assessment of static stability alone is difficult to apply to activities that require dynamic stability; therefore, static stability measurement does not reflect the aims of rehabilitation (Cachupe *et al*., 2001). Use of the Biodex Balance System in Dynamic Limit of Stability mode to evaluate dynamic stability does not coincide with all daily motion and sport activities, but it does include angular perturbation of the ankle joint, which frequently occurs in sport events, such as landing on another player's foot after jumping (Cachupe *et al*., 2001). Thus, this method is more applicable for use in sportspersons (Kim *et al*., 2010).

Dynamic Limit of Stability mode evaluates TCT (in seconds), of nine stages that require balance control with one leg on a moving platform. In the present study, initial TCT was 165.84±43.63s, and it gradually decreased to 134.51±30.18s, 126.06±28.81s, and 118.90±23.85s at 2, 4 and 6 weeks, respectively. In the study by Kim *et al*. (2010) comparing underwater and terrestrial exercise in elite sportspersons with acute ligament injury to the ankle or knee, initial TCT was 178.69±15.12s and decreased to 166.36±11.80s and 150.92±9.33s at 2 and 4 weeks respectively. Thus, a greater reduction in TCT was observed in the present study. After acute ankle injury, postural control is impaired from the first day up to 2 weeks, and it begins to recover for the subsequent 4 weeks (Hertel *et al*., 2001). But chronic instability of the ankle joint derives from complex factors including nerve, muscle, and mechanics (Konradsen *et al*., 1998), and rehabilitation exercise interventions from 6 to 8 weeks have generally been reported (Coughlan & Caulfield, 2007; Slimmon & Brukner, 2010). Therefore, TCT would be assumed to be higher in the present study than in the previous study by Kim *et al*. (2010), but the participation of elite sportspersons appears to be reflected in the lower TCT results observed.

Davies and Manske (1999) reported the importance of isokinetic exercise and stressed that evaluation of isokinetic performance in rehabilitation programmes is more important than simple muscle functions, such as strength. Peak torque acquired from an isokinetic dynamometer is regarded as the most important index for strength (Kannus, 1994), and has been used to identify impaired muscle performance (Basyches *et al*., 2009).

To prevent ankle joint sprain from sudden inversion, evertors should be contracted eccentrically to respond to the moment of initial inversion and disrupt inversion motion (Ashton-Miller *et al*., 1996). Loss of concentric eversion strength was not observed in a previous study that investigated eversion strength in participants with ankle joint instability using an isokinetic dynamometer, but loss of eccentric strength was detected (Munn *et al*., 2003). Therefore, measurement of eccentric strength is more appropriate than concentric strength in ankle joint instability (Munn *et al*., 2003). Additionally, dynamic stability of the ankle joint can be achieved by the coordinated effort of all muscles around the ankle joint (Kaminski & Hartsell, 2002). Thus, evaluation of other muscles around the ankle joint should be performed (Fox *et al*., 2008). For this reason, the strength of the evertors, as well as the dorsiflexors was measured, and PT/BW of eccentric contraction in the dorsiflexor and evertor at 60°/s and 120°/s was significantly increased over time. This improvement is assumed to reduce the risk of re-injury of the ankle joint by restricting sudden inversion.

Gait analysis is a useful method to measure mobility status objectively and a particularly effective instrument to assess prognosis in patients with lower limb injury (Gardner *et al*., 2007). Normal progression of gait recovery after lower limb injury was not determined, but it is widely used to evaluate the effect of therapy (Kroll *et al*., 1989). This study used the GAITRite system for gait analysis. Many studies have reported that this system has high inter-rater reliability (Bilney *et al*., 2003; Van Uden & Besser, 2004; Webster *et al*., 2005), as well as high test-retest reliability (Kim *et al*., 2010).

Symmetrical walking between the impaired and normal lower limbs reflects successful recovery (Kim *et al.*, 2010). Therefore, the present study assessed single-limb support time. The increase in the proportion of single-limb support time indicates that the normal gait pattern has recovered (Kim *et al*., 2010). In the present study, the initial proportion of single limb support time was 33.99±2.99 and it significantly increased to 36.19±2.77, 38.10±1.45, and 38.56±1.85 after 2, 4, and 6 weeks respectively, indicating that the gait of elite sportspersons with ankle joint instability recovered to a normal gait pattern.

Biomechanical abnormalities of the ankle joint reflected in the gait are a major reason for inversion sprain (Willems *et al*., 2005). Previous studies have reported that increased inversion upon initial terrestrial contact of the foot to the terrestrial surface causes ankle joint sprain (Robbins *et al*., 1995; Wright *et al*., 2000). Thus, the precise position of the foot upon initial contact with the terrestrial surface during walking and sport activities is very important (Willems *et al*., 2005).

Many models have been proposed to analyse the kinematics of the foot in detail, but the Oxford Foot Model has good repeatability (Curtis *et al*., 2009). The RFA during fast walking was significantly reduced from 9.72±2.85 at baseline to 6.94±1.81 at 6 weeks, indicating that the risk of re-injury was reduced in elite sportspersons with CAI, as the angle of inversion of the foot was reduced upon the initial touching of the rear foot to the terrestrial surface. The initial angle of the rear foot during running was 7.27±2.12 and it gradually decreased to 6.54±2.08, 6.16±1.81 and 5.79±1.50 at 2, 4 and 6 weeks respectively. However, a significant reduction was observed only from baseline to 2 weeks in the post-hoc analysis. This result is assumed to derive from the fact that running involves a shorter duration of the rear foot touching the terrestrial surface compared to walking.

The participants of this study were national sportspersons. For this specific group, an approach that can result in fast recovery from lowered function due to injury, as well as prevention of re-injury is essential. Furthermore, the fact that previous studies did not apply a FR programme of proven effectiveness for ankle joint instability to a control group in a clinical research setting, infringes on participant's rights in terms of research ethnics. Therefore, this study was composed of a single group. However, the application of FE to elite sportspersons who did not experience CAI may be valuable to establish standard ranges for FE that can help guide the decision to return to a sport after injury.

A major limitation of this study is the exclusion of a control group. This exclusion detracts from the scientific nature of the research and places doubt on whether the achieved improvements in the ankle joint functional ability can be directly attributed to the exercise programme intervention alone.

CONCLUSION

The functional rehabilitation (FR) that was applied to elite sportspersons with chronic ankle instability (CAI) for six weeks appears to be effective based on functional evaluation (FE) using Cumberland ankle instability tool (CAIT), stability, gait analysis, isokinetic strength, and motion analysis measures.

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