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The peroneal strength deficits in patients with chronic ankle instability compared to ankle sprain copers and normal individuals

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ABSTRACT

Background: Despite a consensus regarding the correlation of peroneal strength deficit with chronic ankle instability (CAI), there are conflicting reports in regards to peroneal strength as assessed by isokinetic dynamometer in patients with CAI. The purpose of this study was to evaluate the changes of isokinetic strength in patients with CAI compared to ankle sprain copers and normal individuals.
Methods: Forty-two patients (CAI group) with chronic ankle instability who were scheduled for the modified Broström procedure met inclusion criteria. Thirty-one ankle sprain copers (ASC group) who were eligible at 6 months after acute injury and 30 controls were recruited. The muscle strength associated with four motions of the ankle were evaluated using isokinetic dynamometer.
Results: Peak torque for inversion and eversion at 60°/s angular velocity were significantly lower in the CAI group compared to the ASC and control group ($P = .004$, $P < .001$, respectively). Deficit ratio of peak torque for eversion at 60°/s and 120°/s in the CAI group were 33.8% and 19.8%, respectively, which indicated significant side to side differences (both $P < .001$). The evertor/invertor strength ratio (0.59) for eversion at 60°/s was significantly lower in the CAI group ($P < .001$).
Conclusion: As compared to the ankle sprain copers and normal individuals, patients with chronic ankle instability who were scheduled for modified Broström procedure demonstrated a significant weakness of isokinetic peroneal strength. Isokinetic muscular assessment can provide the useful preoperative informations regarding functional ankle instability focusing on peroneal weakness.

1. Introduction

Acute ankle sprain is one of the most common injuries in daily and sport activities, and more than 20% of the patients are known to suffer from chronic ankle instability (CAI) [1,2]. Chronic instability of the ankle has been traditionally divided into two categories with different treatment strategies. Patients with mechanical ankle instability (MAI) unresponsive to conservative treatment (including peroneal muscle strengthening to increase dynamic ankle stability) need the ankle ligament repair or reconstruction surgery, and those with functional ankle instability (FAI) are mainly treated by proprioceptive-based physiotherapeutic rehabilitation [1,3]. However, many authors reported that CAI is a multifaceted condition caused by a combination of MAI and FAI [4–7]. Because patients with MAI can suffer functional insufficiencies, surgical treatment should be considered when conservative measures have failed [8]. Most patients with CAI who underwent surgical treatment in our institute also presented with both MAI and FAI following recurrent sprain injuries. The causing factors of FAI include deficit of dynamic muscle balance, impairment in neuromuscular control (postural control), delayed muscle reaction time, deficit of joint position sense (proprioception), and peroneal weakness [7,9–12]. Chen et al. [4] reported that patients with MAI had an increased deficit in postural control compared with the FAI and healthy people with eyes closed and open. Li et al. [8] also found that patients with MAI suffered deficits in postural control, indicating that structural damage of the lateral ankle ligaments can produce a balance deficit.

A large portion of individuals (copers) return to strenous activities without recurrent sprain injury or loss of function after a history of ankle sprain injury, while others develop chronic ankle instability. Identifying the difference in mechanical or functional instability between ankle sprain copers (having a history of ankle sprain but did not develop chronic ankle instability) [9] and CAI patients may provide a useful information regarding the mechanisms of CAI. With a lack of demonstrable radiographic signs of

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instability, the objective evaluation tools of functional instability are continuing to be developed [1,5,6,13]. As the quantitative methods to evaluate the FAI in addition to subjective complaint of an unreliable ankle (giving way), hopping test [14], star excursion balance test [9,10], single-limb postural sway test [8], Romberg test [15], proprioception test using isokinetic dynamometer [16], analysis of the peroneal reaction time using surface electromyography (EMG) [17], and various self-reported questionnaires [13,18,19] have been suggested in the previous studies. To date, no definitive consensus exists regarding what is clinically the most objective method correlated with CAI [6,7,13,19]. We used an isokinetic strength test to identify whether the peroneal weakness among the factors contributing to CAI has a clinical importance for evaluation of FAI. Isokinetic dynamometer is considered the most accurate standard for strength measurement [20]. Measurement reliability of isokinetic muscular assessment was reported to be good to excellent (with intraclass correlation coefficient of 0.71–0.96) [16]. Selection of appropriate rehabilitation method based on muscle weakness and imbalance evaluated with isokinetic dynamometer was reported to reduce a risk of recurrent ankle sprain [21].

With a consensus regarding the correlation of peroneal strength deficit with CAI, a restoration of ankle stability through the peroneal strengthening exercise is heavily considered in a rehabilitation program following the lateral ligaments injury [1,22]. However, there are conflicting reports [15,20,21,23] in the literature in regards to peroneal strength as assessed by isokinetic dynamometer in patients with CAI. These inconsistency can make it difficult to determine whether peroneal strength should be a clinical consideration during the rehabilitation of patients who have sustained an ankle sprain or underwent surgical treatment. The aim of this study was to evaluate the changes of muscle strength in patients with CAI compared to ankle sprain copers and normal individuals. Our hypothesis was that patients in need of surgical treatment (the modified Broström procedure) for chronic ankle instability would show an isokinetic peroneal strength different from ankle sprain copers and normal individuals.

2. Patients and methods

2.1. Study subjects

Between March 2015 and May 2016, an overall number of 42 patients with chronic ankle instability (CAI) were compared with 31 ankle sprain copers (ASC) and 30 unaffected ankle from the control group. The baseline data of the 3 groups did not differ significantly (Table 1).

The inclusion criteria of CAI group were as follows: (1) patients $\leq$40 years of age, (2) patients with repeated sprain injuries for $\geq$12 months, (3) patients with the most recent sprain occurred more than 3 months prior to the study, (4) patients with marked unilateral instability confirmed by the manual varus and anterior drawer stress test as compared to the contralateral ankle, (5) patients to be scheduled for the modified Broström procedure (MBP) with at least 3 months of failed rehabilitation, (6) patients to be identified with lateral ligaments injury by magnetic resonance imaging (MRI), (7) patients with <24 points based on the Cumberland Ankle Instability Tool (CAIT) [5,13], (8) patients with scores below 90% in daily living subscale and 80% in sports activity subscale of the Foot and Ankle Ability Measure (FAAM) [18].

The ankle sprain copers were defined as the following criteria at 6 months after acute sprain injury: (1) patients $\leq$40 years of age, (2) individuals with history of a first-time unilateral ankle sprain which was treated with immobilization in short-leg splint or cast, protected weight bearing, and activity modification, (3) individuals with no subsequent resprains, (4) individuals with no ongoing pain and instability [24,25], (5) individuals who were able to return to pre-injury levels of activity, (6) individuals with no instability confirmed by the manual varus and anterior drawer stress test, (7) individuals with $\geq$24 points based on the CAIT, (8) individuals with scores $\geq$90% in daily living subscale and $\geq$80% in sports activity subscale of the FAAM. All copers were initially treated at the Emergency department in our institute, and subsequent management was performed at the Orthopaedic department. Individuals eligible to above-mentioned criteria at 6 months followup visit were enrolled in ASC group. The details and period of post-injury rehabilitation were various between the copers, not controlled as part of the current study.

The control group (normal individuals) who had no history of lower extremity injury including ankle sprain within recent 5 years were recruited from the Hand clinic in our institute. Ankles in the control group were side-matched to subjects in the CAI and ASC groups. Individuals with a history of lower extremity surgery or pathology to influence neuromuscular control were excluded from the current study. The study protocol and data collection were conducted with University Institutional Review Board approval, and written informed consent was obtained. We calculated that allocation of approximately 26 participants into each group would provide 80% power to compare the isokinetic peroneal strength. The 95% confidence interval (a type-I error rate of 0.05) was used and the setted margin of noninferiority was 4.5 Nm (a delta of 4.5 Nm in the peak torque at 60°/s angular velocity).

2.2. Isokinetic muscular assessment

Isokinetic muscle strengths of both ankle for dorsiflexion, plantarflexion, inversion and eversion were evaluated with the Biodex-II isokinetic dynamometer (Biodex medical systems, Shirley, NY, USA). The peak torque normalized to the body weight, total work, deficit ratio, evertor-to-invertor strength ratio were measured at 2 speeds in the concentric mode; 60°/s and 120°/s angular velocities. The same physical therapist was used throughout the study. All patients was seated on a testing bench and the knee joint was positioned in 10° of flexion to minimize unnecessary movement of tibial rotation [15]. With the ankle joint in 10° of plantarflexion, the foot was firmly strapped on the foot paddle using crisscrossed velcro tapes across the dorsum of the foot. Lateral handles were installed for hand positioning to place the subject in the best performance condition. Five practice movement were performed before examination to allow the

Table 1
Baseline data of study subjects (ANOVA with a post hoc test). Data presented as mean ± standard deviation.

Anthropometrics	CAI group (n = 42)	ASC group (n = 31)	Control group (n = 30)	*P*-value
Age (years)	26.7 ± 6.2	24.8 ± 5.6	25.3 ± 6.1	.781
Sex (M/F)	23/19	17/14	16/14	.505
BMI (kg/m^2)	22.2 ± 2.1	21.9 ± 2.1	22.1 ± 2.2	.913
Injured side (Rt/Lt)	29/13	22/9	22/8[a]	.822

Abbreviations: CAI, chronic ankle instability; ASC, ankle sprain copers; BMI, body mass index.
[a] Twenty-two right and 8 left unaffected ankles in control group were matched with CAI and ASC groups.

patients to warmup. Isokinetic test was performed by first examining the unaffected side and then the affected side. Consistent verbal encouragement for maximal effort and manual stabilization of the knee were provided to subjects throughout the examination. Peak torque represented the maximal force applied at any time during 5 successive repetitions at 60°/s and 10 repetitions at 120°/s. Total work represented the average amount of force produced during repetitive motions. Deficit ratio of muscle strength relative to the unaffected side was analysed and multiplied by 100 to describe a percentage (%).

2.3. Functional and radiological stability evaluations

Two validated functional outcome tools were used to evaluate the FAI. The Cumberland Ankle Instability Tool (CAIT) [13] is a self-estimated 9-questions survey evaluating the symptoms of instability during several different physical tasks. The CAIT results in a score ranging from 0 to 30, with higher scores indicating higher stability. The Foot and Ankle Ability Measure (FAAM) [18] is also a patient-reported outcome measure (PROM) comprised of 2 subscales evaluating activities of daily living (21 questions, 0–84 points) and sports activities (8 questions, 0–32 points). All data were represented as scores changed on the basis of 100 points.

Radiological stability was evaluated through anterior drawer and varus stress radiographs using Telos® equipment (Telos GmbH, Marburg, Germany) with the same loading force (150 N). The talar tilt angle was defined as the angle between the distal articular surface of the tibia and the proximal articular surface the talus on varus stress view. The anterior talar translation was defined as the shortest distance between the posterior articular border of the distal tibia and the posterior articular surface of the talus on anterior drawer stress view. All radiographic measurements were evaluated by two orthopedic surgeons independently. This was repeated three times and subsequently averaged.

2.4. Statistical analysis

Variables were tested for normal distribution with the Shapiro-Wilk test. The general data of three subject groups were compared using the Fisher's exact test and ANOVA with a post hoc test. A matched pair design using the Wilcoxon signed-rank test was used to detect the differences in isokinetic muscle strength between the injured and uninjured ankles within groups (CAI, ASC groups). Differences in the isokinetic muscle strength, functional scores (CAIT and FAAM) and radiographic measurement (stress radiography) between the 3 groups were analysed using ANOVA with a post hoc test. All statistical analysis were conducted using SPSS program (version 20.0; SPSS Inc., IBM company, Chicago, IL, USA), and P values $<.05$ were considered statistically significant.

3. Results

3.1. Comparison of functional and radiological stability

The CAIT and FAAM scores were significantly lower in the CAI group compared to the ASC group and normal controls (both $P<.001$). Talar tilt angle and anterior talar translation on stress radiographs were significantly greater in the CAI group compared to the ASC group and normal controls (both $P<.001$) (Table 2). There were no significant differences in CAIT, FAAM, and stress radiography between the ASC and control groups.

3.2. Comparison of isokinetic muscle strength

The detailed measurements of isokinetic muscle strength of the ankle are shown in Table 3. Peak torque for inversion and eversion at 60°/s angular velocity were significantly lower in the CAI group compared to the ASC and control group ($P=.004$, $P<.001$,

Table 2
Comparison of patient-reported outcome measures and ankle stress radiographs (ANOVA with a post hoc test). Data presented as mean ± standard deviation.

Measure	CAI group (n = 42)	ASC group (n = 31)	Control group (n = 30)	P-value
CAIT (/30)	18.6 ± 4.3	27.8 ± 2.1	29.7 ± 0.5	<.001*
FAAM daily living (%)	69.8 ± 13.5	96.5 ± 3.1	99.1 ± 0.7	<.001*
FAAM sport (%)	42.1 ± 14.7	91.2 ± 5.6	98.3 ± 1.2	<.001*
Talar tilt angle (°)	13.9 ± 5.6	1.6 ± 0.9	1.2 ± 0.5	<.001*
ATT (mm)	12.6 ± 4.9	4.3 ± 1.2	3.9 ± 0.8	<.001*

Abbreviations: CAIchronic ankle instability; ASCankle sprain copers; CAITCumberland Ankle Instability Tool; FAAMFoot and Ankle Ability Measure; ATTanterior talar translation.
* Statistically significant difference.

Table 3
Comparison of isokinetic strength of the ankle (ANOVA with a post hoc test). Data presented as mean ± standard deviation.

Isokinetic strength	CAI group	ASC group	Control group	P-value
Peak torque (Nm) at 60°/s				
Inversion	15.8 ± 7.1	19.4 ± 7.8	18.8 ± 7.3	.004*
Eversion	9.4 ± 3.9	14.8 ± 4.9	15.1 ± 5.1	<.001*
Peak torque (Nm) at 120°/s				
Inversion	12.5 ± 4.5	14.3 ± 5.1	13.9 ± 4.6	.226
Eversion	7.7 ± 3.2	9.5 ± 3.7	9.8 ± 3.8	.005*
Total work (Nm) at 60°/s				
Inversion	11.3 ± 5.1	13.3 ± 5.8	12.9 ± 5.5	.129
Eversion	6.3 ± 3.2	8.6 ± 3.5	8.8 ± 3.6	<.001*
Total work (Nm) at 120°/s				
Inversion	7.2 ± 3.8	8.3 ± 3.9	7.9 ± 3.7	.698
Eversion	5.1 ± 2.6	6.2 ± 2.9	6.1 ± 2.8	.415

Abbreviations: CAI, chronic ankle instability; ASC, ankle sprain copers.
* Statistically significant difference.

Table 4
Side to side comparison of isokinetic muscle strength (Wilcoxon signed-rank test).

Isokinetic strength	CAI group (n = 42)				ASC group (n = 31)			
	Affected[a]	Unaffected[a]	Deficit ratio	*P*-value	Affected[a]	Unaffected[a]	Deficit ratio	*P*-value
Peak torque (Nm) at 60°/s								
Inversion	15.8 ± 7.1	18 ± 7.4	12.2%	.126	19.4 ± 7.8	19.6 ± 7.5	1%	.981
Eversion	9.4 ± 3.9	14.2 ± 5.1	33.8%	<.001[*]	14.8 ± 4.9	15.5 ± 5.6	4.5%	.829
Peak torque (Nm) at 120°/s								
Inversion	12.5 ± 4.5	13.7 ± 5.2	8.8%	.396	14.3 ± 5.1	14.1 ± 4.4	−1.4%	.955
Eversion	7.7 ± 3.2	9.6 ± 4.1	19.8%	<.001[*]	9.5 ± 3.7	9.8 ± 3.9	3.1%	.898
Total work (Nm) at 60°/s								
Inversion	11.3 ± 5.1	12.5 ± 5.8	9.6%	.289	13.3 ± 5.8	13.5 ± 6.1	1.5%	.947
Eversion	6.3 ± 3.2	8.2 ± 4.1	23.2%	<.001[*]	8.6 ± 3.5	9 ± 3.6	4.4%	.832
Total work (Nm) at 120°/s								
Inversion	7.2 ± 3.8	7.7 ± 4.1	6.5%	.735	8.3 ± 3.9	8.0 ± 3.8	−3.8%	.851
Eversion	5.1 ± 2.6	5.7 ± 2.9	10.5%	.172	6.2 ± 2.9	6.3 ± 2.8	1.6%	.968

Abbreviations: CAI, chronic ankle instability; ASC, ankle sprain copers.
[a] Mean ± standard deviation.
[*] Statistically significant difference.

respectively). Peak torque for eversion at 120°/s was significantly lower in the CAI group ($P < .001$). Total work for eversion at 60°/s was significantly lower in the CAI group than other groups ($P < .001$). There were no significant differences in all muscular assessments between the ASC and control groups.

3.3. Side to side comparison of isokinetic muscle strength

The detailed measurements of isokinetic muscle strength compared to the contralateral (unaffected) ankle are shown in Table 4. Deficit ratio of peak torque for eversion at 60°/s and 120°/s in the CAI group were 33.8% and 19.8%, respectively, which indicated significant side to side differences (both $P < .001$). Total work for eversion at 60°/s showed a significant side to side difference in the CAI group ($P < .001$). There were no significant side to side differences in the ASC group.

3.4. Comparison of isokinetic evertor-to-invertor strength ratio

The evertor/invertor peak torque ratio for eversion at 60°/s was significantly lower in the CAI group compared to the ASC group and normal controls ($P < .001$) (Table 5).

4. Discussion

This transversal study reports the changes of muscle strength in patients with chronic ankle instability who were scheduled for the modified Broström procedure, and a usefulness of quantitative evaluation focusing on peroneal strength. The primary finding of this study was that isokinetic muscular assessment successfully detected the differences in the peroneal strength between patients with CAI and ankle sprain copers, or normal individuals. Isokinetic peroneal strength of the CAI group showed statistically significant weakness compared to the ASC and normal control group. In addition, there were significant side to side differences of peak torque and total work in the CAI group, differently from the ASC group. No significant differences in CAIT, FAAM, stress radiographs, and isokinetic muscular assessment between the ASC and control groups were found.

Previous many studies reported the peroneal weakness in patients with CAI, and suggested the importance of strengthening evertor muscles in rehabilitation program [26]. A meta-analysis by Arnold et al. [27] reported that a decreased evertor strength and muscle reaction time in CAI patients were associated with the impairment of proprioception, contributing to CAI. However, another literature review [20] found that deficits in ankle strength are not highly correlated with CAI. Lentell et al. [15] found no significant weakness of peroneal strength in patients with CAI, and suggested that muscular weakness is not a major contributing factor to the CAI. Baumhauer et al. [23] reported that invertor weakness than evertor can be a contributing factor to the development of CAI. The inconsistent findings of the individual studies can disturb clinicians to make evidence-based clinical decisions regarding peroneal strengthening exercise in individuals with ankle instability.

One potential reason of a lack of consistency across the previous studies may be a discrepancy in the inclusion criteria for CAI cohort (how they was defined) [20]. Delahunt et al. [28] reported that over 90 variations of inclusion criterions had been used in the published studies regarding the CAI. The CAI group included in the current

Table 5
Comparison of isokinetic evertor-to-invertor strength ratio (ANOVA with a post hoc test).

Isokinetic strength	CAI group	ASC group	Control group	*P*-value
Peak torque (Nm) at 60°/s				
Inversion	15.8 ± 7.1	19.4 ± 7.8	18.8 ± 7.3	
Eversion	9.4 ± 3.9	14.8 ± 4.9	15.1 ± 5.1	
Evertor/invertor strength ratio	0.59	0.76	0.8	<.001[*]
Peak torque (Nm) at 120°/s				
Inversion	12.5 ± 4.5	14.3 ± 5.1	13.9 ± 4.6	
Eversion	7.7 ± 3.2	9.5 ± 3.7	9.8 ± 3.8	
Evertor/invertor strength ratio	0.61	0.66	0.71	.407

Abbreviations: CAI, chronic ankle instability; ASC, ankle sprain copers.
[*] Statistically significant difference.

study was enrolled according to the surgical indication (for the MBP) considering both mechanical and functional instability, which was consisted with the patient selection criteria [5] recommended by the International Ankle Consortium. Another potential explanation may be due to a variability in methodology (patient's position, testing protocol, angular velocity, muscle contraction type, instrumentation) of isokinetic muscular examination employed by the authors. As an example, isokinetic assessment in the current study were performed at 60°/s and 120°/s angular velocities in the concentric mode. Although a slow velocity of 30°/s and a fast velocity of 120°/s are the most common testing speeds reported in the literature [16], many female subjects had a substantial difficulty by excessive resistance in strength test at 30°/s.

With regard to the clinically applicable and quantitative evaluation method of the FAI, there are many published studies [8–10,13,19]. Hiller et al. [13] suggested that Cumberland Ankle Instability Tool (CAIT) is a simple, valid, and reliable tool to measure severity of FAI. Simon et al. [19] reported that the Identification of Functional Ankle Instability (IdFAI) is a new evaluation tool clearly reflecting "giving way (a temporary uncontrollable sensation of instability or rolling over of one's ankle)" with an accuracy of 89.6%. Recently, Doherty et al. [9] found that patients with CAI were characterised by dynamic balance deficits as measured using the star excursion balance test (SEBT) in comparison with normal controls and lateral ankle sprain copers. Li et al. [8] reported that the single-limb postural sway test was a useful parameter for evaluating ability to maintain a postural balance during quiet standing. The development of more accurate evaluation tool can be helpful to diagnosis of FAI, used as an outcome measure in the clinical research, and selection of homogeneous participants for research [5].

Many authors [15,21,23] emphasized that the evertor-to-invertor strength ratio (agonist–antagonist ratio) is an important indicator to evaluate patients with CAI, because coactivation of antagonistic muscle group has been identified as a factor influencing dynamic joint stability. Although the normative range of evertor/invertor strength ratio remains still unclear [20], the optimal evertor/invertor peak torque ratio (muscle balance) in normal individuals is known to be between 0.7 and 0.9 at 30°/s, 0.65 and 0.85 at 120°/s in the several literatures [15,21,23,26]. On the other hand, the evertor/invertor peak torque ratio in patients with CAI has been reported in a wide variety. In the current study, the evertor/invertor strength ratio of the ASC (0.76 at 60°/s and 0.66 at 120°/s) and control groups (0.8 at 60°/s and 0.71 at 120°/s) were also consistent with previous findings by other authors. However, the evertor/invertor ratio of the CAI group (0.59 at 60°/s and 0.61 at 120°/s) was partially in contradiction to previous reports. Although a significant weakness of invertor strength in the CAI group was found as noted previously by other authors [21,23], a deficit of evertor strength at both 60°/s and 120°/s was significantly greater than invertor weakness.

The present study has some limitations. First, although an equivalent rehabilitation protocol (continuous peroneal strengthening exercise and proprioception training) prior to the study were recommended to all participants in the CAI and ASC groups, we could not completely convince of compliance with the suggested rehabilitation. The details and period of post-injury rehabilitation were various between participants, not controlled as part of the current study. Second, isokinetic muscular assessment using dynamometer was performed with the ankle joint in only 10° of plantarflexion. Donnelly et al. [29] reported that large deficits in peak eversion force were present in both a neutral and plantarflexion testing position in patients with CAI when compared healthy individuals, and suggested that clinicians should assess eversion strength during different sagittal plane positions. Third, this study included no evaluation regarding the changes of proprioceptive deficit after lateral ankle ligaments injury. At the planning stage of the current study, we could not consider a proprioception as one of the evaluation factors through isokinetic dynamometer.

5. Conclusions

As compared to the ankle sprain copers and normal individuals, patients with chronic ankle instability who were scheduled for the modified Broström procedure demonstrated a significant weakness of isokinetic peroneal strength. Isokinetic muscular assessment can provide useful preoperative information regarding functional ankle instability focusing on peroneal weakness.

Conflict of interest statement

The authors have no conflict of interest to report and have received no financial support for the completion of this work.

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