Abstract. [Purpose] To develop assessment/rehabilitation indices for prevention of chronic and recurrent shin splint injuries among sport athletes, we analyzed the plantar center of pressure trajectories after drop-jump landing on one leg, and compared the foot function on the injured and healthy sides. [Participants and Methods] The participants were 10 female athletes who received consultation at our facility due to shin splints of the lower leg. The exercise task was the “single-leg drop jump landing test”, in which the participants maintained a static posture on one leg for 8 s after landing. Using the collected data, the peak value of the vertical component of the floor-reaction force at the landing and the rectangular areas at 20–200 ms and 1–5 s after landing were calculated and compared between the healthy and affected sides. [Results] The peak value of the vertical component and the rectangular area at 20–200 ms were significantly larger on the affected side. However, the value for the 1–5 s rectangular area was significantly larger on the healthy side. [Conclusion] The feedforward function may have been reduced on the affected side in comparison with that on the healthy side, and the reduction in dynamic balance early after landing may have increased the influence of the non-vertical component. The 1–5 s rectangular area was smaller on the affected side than that on the healthy side, suggesting that the feedback function excessively worked on the affected side and caused immobility by excessively locking the joint in single-leg balance and reducing body sway.

Key words: Sport athletes, Dynamic balance, Shin splints injury

INTRODUCTION

Of sports injuries, shin splint injury frequently occurs and shin splint injuries recur in many cases1–4). Regarding factors of these, a lack of the range of dorsiflexion of the ankle joint, reduction of muscle extensibility, and poor foot alignment (flat pronated foot) have been reported5, 6); but the viewpoint varies among preceding studies and no theory has been established. For crural and foot injuries during sports motion, the relationship with dynamic balancing ability may be important, but fewer studies based on dynamic balance have been performed. Sugiyama and Kimura et al.7, 8) analyzed the locus of center of pressure (COP) at landing in the single leg drop jump landing test (SDL test) and established a measurement method of early body sway. In this study, we performed similar evaluation of athletes with crural and foot injuries to acquire an index of rehabilitation to prevent recurrence.

PARTICIPANTS AND METHODS

The participants were 10 female athletes (mean age: 15.3 ± 2.1 years old, mean height: 158.3 ± 5.5 cm, mean body weight: 48.2 ± 6.5 kg) who visited our hospital for crural and foot injuries. They were first examined more than 2 months earlier and returned to competition with no problem with physical findings or basic motions, and they visited our hospital for condition-
The sporting event was kendo in 3, gymnastics in 2, and baseball, volleyball, handball, basketball, and naginata in one each. The affected side was right in 3 and left in 7 (Table 1). The objective of this study was explained to the participants and consent to measurement and publication of the results was obtained. The exercise task was ‘single-leg drop jump landing test’ in which the participant jumped down on single-leg from a 20-cm height table to 30-cm forward, and after landing (from single-leg standing on the healthy side to single-leg landing on the healthy side, from single-leg standing on the affected side to single-leg landing on the affected side), the subject retained the static posture. They folded their arms so as to not separate the arms from the body, and they were instructed to maintain the static standing position for 8 s after landing (Fig. 1). The task was performed 10 times. The floor reaction force of landing was measured using a floor reaction force plate dynamic balance evaluation system, SS-FP40AO-SY (Sports Sensing, Fukuoka, Japan), setting the sampling frequency at 1,000 Hz. For data recording and calculation of the COP locus, software for dynamic balance evaluation, SS-FPSW01 (Sports Sensing) was used. Sugiyama et al.8) reported high reproducibility of data of the latter 5 of 10 trials. Thus, data of the latter 5 trials of successful trials were included in analysis, excluding trials in which the participant could not retain the static position for 8 s after landing. The floor reaction force was normalized with the body weight, and the rectangular area was normalized with the foot area. From the collected data, the peak value of the vertical component of the floor reaction force (Fz) at landing and rectangular areas at 20–200 ms after landing and 1–5 s after landing were calculated and compared between the healthy and affected sides. In statistical analysis, the Wilcoxon signed-rank test was performed using SPSS for window ver12.0, setting the significance level at less than 5%. This study was approved by the Sumiya Orthopedic Hospital Ethics Committee (approval number: Rinsei 01601205).

RESULTS

The mean peak Fz value at landing and 20–200 ms and 200 ms–5 s rectangular areas after landing were 410.2 ± 85.8% BW, 4.9 ± 1.1% foot area, and 5.3 ± 1.7% foot area, respectively, on the healthy side and 448.6 ± 83.0% BW, 7.4 ± 3.3% foot area, and 3.9 ± 0.9% foot area, respectively, on the affected side, showing that the peak Fz value and 20–200 ms rectangular area were significantly larger on the affected side (p<0.05). However, the 1–5 s rectangular area was significantly larger on the healthy side (p<0.05) (Table 2).

DISCUSSION

Variations of the values measured at 20 ms from landing were large and these were considered due to sensitivity of the measurement device. So, these were excluded from analysis. In a study reported by Kimura et al.9), regarding the rate of the COP locus length to the entire length every 100 ms within 1 s after landing of drop jump, the locus length at 20–100 ms accounted for 34 ± 12% and that at 100–200 ms accounted for 14 ± 6%, collectively accounting for about 50%. Thus, the COP locus length in the 20–200 ms period was measured. The 20–200 ms rectangular area after single-leg drop jump landing on the affected side was larger than that on the healthy side and impact of the non-vertical component was strong. Since the motion start time of whole body reaction time (speed of impulse from the cerebral cortex reaching the muscle) induced by stimulation has been reported to be about 180 ms in general adults10), stability of dynamic balance during this period is due

Table 1. Anthropometric characteristics of the participants

| Patients (No) | Age (years) | Height (cm) | Body weight (kg) | Specialized competition | Injured side | Foot size |
|---------------|-------------|-------------|------------------|-------------------------|--------------|----------|
| 1             | 13          | 158        | 50               | basketball              | LT           | 24       |
| 2             | 13          | 156        | 45               | kendo                   | LT           | 23       |
| 3             | 18          | 156.5      | 46               | naginata                | RT           | 23.5     |
| 4             | 16          | 162        | 51               | kendo                   | LT           | 24.5     |
| 5             | 18          | 158        | 48               | volleyball              | RT           | 24       |
| 6             | 14          | 165        | 50               | handball                | LT           | 25       |
| 7             | 13          | 156        | 45               | kendo                   | LT           | 23       |
| 8             | 15          | 152        | 42               | gymnastic               | RT           | 23       |
| 9             | 15          | 151        | 41               | gymnastic               | LT           | 22.5     |
| 10            | 18          | 168.8      | 64               | baseball                | LT           | 25.5     |

LT: left; RT: right.

Fig. 1. Single-leg drop jump landing test.
a: Stand on one foot on a platform 20 cm high from the force plate and jump 30 cm forward from there.
b: After landing on one leg, hold that position for 8 s.
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REFERENCES

1) Clanton TO, Solcher BW: Chronic leg pain in the athlete. Clin Sports Med, 1994, 13: 743–759. [Medline] [CrossRef]
2) Batt ME: Shin splints—a review of terminology. Clin J Sport Med, 1995, 5: 53–57. [Medline] [CrossRef]
3) Fredericson M, Bergman AG, Hoffman KL, et al.: Tibial stress reaction in runners. Correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. Am J Sports Med, 1995, 23: 472–481. [Medline] [CrossRef]
4) Kortebein PM, Kaufman KR, Basford JR, et al.: Medial tibial stress syndrome. Med Sci Sports Exerc, 2000, 32: S27–S33. [Medline]
5) Mubarak SJ, Gould RN, Lee YF, et al.: The medial tibial stress syndrome. A cause of shin splints. Am J Sports Med, 1982, 10: 201–205. [Medline] [CrossRef]
6) Krivickas LS: Anatomical factors associated with overuse sports injuries. Sports Med, 1997, 24: 132–146. [Medline] [CrossRef]
7) Sugiyama K, Kimura Y, Sato M, et al.: Reproducibility of the total locus length of body sway in landing motion of single-leg drop jump. Sports Injuries, 2012, 17: 40–42.
8) Sugiyama K, Kimura Y, Takagi K, et al.: Dynamic balance evaluation method: reproducibility and usefulness of body sway locus length in single-leg drop jump. J Kansai Clin Sports Med Sci, 2011, 21: 33–36.
9) Kimura Y, Nakata M, Matsuo T: Measurement of dynamic balance of drop jump landing: analysis of body sway locus immediately after landing. Sports Injuries, 2013, 18: 55–57.
10) Imai K, Aoyama M, Shibayama H: Study on whole body reaction time and its application. Olimpia, 1961, 7: 210–219.
11) Taube W, Leukel C, Gollhofer A: How neurons make us jump: the neural control of stretch-shortening cycle movements. Exerc Sport Sci Rev, 2012, 40: 106–115. [Medline] [CrossRef]
12) Blackburn JT, Padua DA: Sagittal-plane trunk position, landing forces, and quadriceps electromyographic activity. J Athl Train, 2009, 44: 174–179. [Medline] [CrossRef]
13) Konradsen L, Ravn JB: Prolonged peroneal reaction time in ankle instability. Int J Sports Med, 1991, 12: 290–292. [Medline] [CrossRef]
14) Docherty CL, Valovich McLeod TC, Shultz SJ: Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. Clin J Sport Med, 2006, 16: 203–208. [Medline] [CrossRef]
15) Suzuki Y, Serrada T, Mori D, et al.: Influence of upper limb balance response on postural retention ability in dynamic balance—examination of floor reaction force by single leg drop jump landing test. Phys Ther, 2018, 25: 17–21.