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A Screening for Dynamic Knee Valgus Focused on Hip Abductor and Rear-Foot Functions

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Introduction

Non-contact anterior cruciate ligament (ACL) injuries occur during landing from jumps or side-step cutting [1]. A prospective study by Hewett et al. [2] identified knee abduction angles as reliable predictors of ACL injury using three-dimensional joint kinematic and kinetic analyses. Many ACL injury prevention programs have been developed based on these injury mechanisms or biomechanical data [3-5]. However, screening tests for these prevention programs have measured drop landing on both feet, while most of the injuries occur under single-leg tasks. Additionally, it is little known that the dysfunction of the hip and rear-foot increases dynamic knee valgus.

Recently, Claiborne et al. [6], identified a negative correlation between hip abduction peak torque and valgus knee motion during single-leg squatting. Takacs and Hunt [7] reported that the knee adduction moment significantly increased with contralateral pelvic drop compared with level pelvis trials. The results of these studies suggest that static lower extremity alignment may not show its dynamic function. Therefore, our screening test uses a Dynamic Trendelenburg test (DTT) to determine dynamic dysfunction of hip abductor muscle [8].

Rear-foot eversion is thought to be coupled with tibial internal rotation during not only standing but also the stance phase of running [9,10]. Excessive pronation of the foot during weight bearing has frequently been reported as a risk factor for lower limb injury [11,12]. Some investigators consider excessive eversion as a rear-foot angle of greater than 4° to 6° [13]. However, few reports describing the relationship between rear-foot alignment and dynamic knee valgus have been published to date. Therefore, our screening test comprise a dynamic heel-floor test (HFT) which assesses>5° of rear-foot eversion [8].

Most researchers measure angles of knee valgus on the frontal plane with two-dimensional (2D) video-based screening images. The 2D alignment on frontal plane, however, might reflect various angles of lower extremity. Therefore, we measure dynamic knee valgus on 2D video images, which comprise knee-in distance (KID) to reflect knee inward displacement and hip-out distance (HOD) to reflect pelvic outward displacement [8]. The purpose of this study was to determine the functional association between the alignment of hip and rear-foot dynamics with dynamic knee valgus.

Materials and Methods

Subject

One hundred thirty female, high-school basketball players (258 legs; mean age, 16.9 ± 0.6 years; height, 161.6 ± 5.8 cm; weight, 54.0 ± 6.3 kg) volunteered to participate. The exclusion criteria comprised prior knee injury that involved surgery and pain upon performing the tasks required in the study. The Research Ethics Committee of the School of Nursing and Rehabilitation Sciences at Showa University approved the study protocol. Written informed consent was obtained from all participants, their parents and head coaches.

Procedures

The subjects were tested barefoot. Flat markers were placed at the anterior superior iliac spines (ASISs), the center of each patella, the center of the insertion of each Achilles tendon and the hallucis of both feet. They performed single-leg squatting and single-leg drop landing from a 30 cm height platform. Two digital video cameras (Sony, Tokyo, Japan) were placed at 4 m in front of subjects, and 4 m behind the platform. In single-leg task, the subjects clasped their hands behind their backs and balanced on one leg with the contralateral knee bent to about 90°, bend the knee of the supporting leg approximately to 60°, and then straightening it, with their preferred pace. In the single-leg landing task, the subjects standed on one leg quietly on a 30 cm height platform, and jumped down forward on one foot, and they maintained balance for about 2 seconds. On both tasks, a first successful trial is adapted.

Data analysis

Maximal knee valgus on the frontal plane during single-leg squatting and single-leg landing were measured using Dartfish Software 4.5 ProSuite Version (Dartfish, Fribourg, Switzerland). KID and HOD are measured on 2D video images of dynamic knee valgus (Figure 1).

Figure 1: Analysis of dynamic knee valgus.

The KID was defined as the distance from the hallux to the point where the line connecting the center of the patella and ASIS intersects

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the floor. The HOD was defined as the distance from the hallux to the projection of ASIS on the floor.

Hip abductor function was evaluated using DTT, which was defined positive when the non-weight-bearing pelvis was descended lower than the weight-bearing pelvis (Figure 2a). Rear-foot dynamic alignment was evaluated using HFT, which was defined positive when rear-foot eversion was more than 5° (Figure 2b).

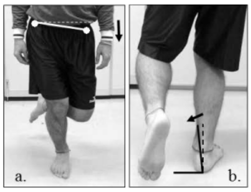

Figure 2: Evaluation of function of hip abductors and rearfoot

Statistical analysis

The prevalences of DTT-positive and HFT-positive single-leg squatting and landing was compared using the Chi-square test. The significance of differences in KID between DTT (HFT)-positive and negative groups during single-leg squatting and landing was analyzed using unpaired Student t tests. The HOD was also compared between DTT (HFT)-positive and negative groups during single-leg squatting and landings using t-tests. Statistical significance was established at a level of $p<0.05$. All data were analyzed using SPSS 14.0 statistical software (SPSS Inc., Chicago, IL, USA).

Results

The Chi-square test did not show significant differences in the prevalence of DTT positive between single-leg squatting (28.7%) and single-leg drop landing (23.3%). The prevalence of HFT-positive was significantly greater during landing (51.4%) than during single-leg squatting (31.0%, $p<0.01$).

The KID and HOD values were illustrated (Table 1). The KID values for both single leg squatting and drop landing were greater in the DTT-positive than in the DTT-negative group. The HOD values were also greater in the DTT-positive group. The KID values for both single-leg squatting and drop landing were greater in the HFT-positive than in the HFT-negative group, whereas HOD values for these tasks did not significantly differ between the two groups.

	Single-leg Squatting			Single-leg drop landing		
	N	KID(cm)	HOD(cm)	N	KID(cm)	HOD(cm)
DTT(+)	74	15.1 ± 5.4	15.2 ± 1.9	58	20.2 ± 7.5	17.6 ± 2.8
DTT(-)	184	7.6 ± 3.7	13.8 ± 2.5	191	9.4 ± 4.5	16.0 ± 3.0
HFT(+)	80	12.2 ± 5.1	13.8 ± 2.4	128	14.7 ± 7.2	16.3 ± 3.1
HFT(-)	178	8.7 ± 5.2	14.4 ± 2.4	121	8.9 ± 5.5	16.6 ± 2.9

Table 1: Knee in distance (KID) and hip-out distance (HOD) values during single-leg squatting and single-leg drop landing

Discussion and Conclusion

The KID values in the DTT-positive group were twice as high as those in the DTT-negative group during single-legged tasks. The HOD values were also significantly greater in the DTT-positive group. This indicates that both knee-in and hip-out values increase in athletes with lowered hip abductor function. On the other hand, whereas the KID values in the HFT-positive group were significantly greater than in the HFT-negative group, the HOD values did not significantly differ. This indicates that knee-in values increase, whereas hip-out values do not change in athletes with decreased rear-foot function.

Most researchers have reported that athletes with weak hip abduction or external rotation strength have increased dynamic knee valgus [6,14,15]. Claiborne et al. [6] identified a negative correlation between knee valgus during single-leg squatting and hip abduction peak torque. This study showed that about 30% of the legs were DTT-positive and that the KID values in the DTT-positive group were twice as high as those in the negative group. We considered that the DTT is a useful method of evaluating hip abductor function that reflects hip abductor or external rotator weakness. Therefore, an increase in hip adduction and internal rotation probably caused the KID values to increase in the DTT-positive group.

With respect to coupling of rear-foot eversion with tibial internal rotation, Khamis et al. [9] reported that calcaneus eversion consequentially increases while standing on wedges, and that the shank and thigh rotate internally. Pohl et al. [10] indicated a closer correlation between rear-foot eversion and shank internal rotation while running. Therefore, the medial longitudinal arch appeared to be lower in accordance with rear-foot eversion and, owing to the medial tilting of the shank, the KID values increased in the HFT-positive group. Meanwhile, since the pelvic position had shifted medially in conjunction with the medial tilting of the shank, the HOD values did not significantly differ.

Single-legged task for screening test are important to assess individual hip abductor and rear-foot function. Since the prevalence of DTT-positivity did not significantly differ between single-leg squatting and single-leg landing, we considered that either test would be useful for evaluating dynamic knee valgus in terms of hip abductor function. Meanwhile, the prevalence of HFT-positivity was significantly high (51.4%) during single-leg landing, indicating that HFT was heavily affected during this test. Considering the prevalence of HFT-positivity and the skill factor involved in single-leg landing [16,17], both single-leg squatting and landing are needed to evaluate dynamic knee valgus in terms of rear-foot function.

The major limitation of this study is that we conducted 2D analysis using a digital video camera, instead of 3D analysis. Some researchers reported a significant regression relationship between 2D and 3D knee valgus angles during side jump or continuous jump landing [18,19]. However, knee valgus in the frontal plane has never been compared based on distances such as KID and HOD. On the other hand, 2D motion analysis has the advantage of convenience for measurements, analyses and screening tests for ACL injuries [3-5,18,19]. The present findings indicated that 2D video-based analyses such as KID, HOD, DTT and HFT should be used to identify athletes at higher risk for ACL injury in various sport-related studies.

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