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Original Article

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Validity and Reliability of New Digital Navicular Drop Test Equipment in Young People

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| Abstract |

Purpose: This study aimed to develop new digital navicular drop test (ND-NDT) equipment and to determine its validity and reliability.

Methods: A total of 24 healthy male and female adults, who fully understood the purpose of the study and gave consent to participate in the study, were selected as participants. The NDT and ND-NDT were conducted in the dominant foot of the participants in a random order. For the NDT, the position of the navicular bone was marked with a pen first; then, the height of the navicular bone from the ground was measured in both sitting and standing positions. For the ND-NDT, after the sticker-type reflection markers were attached to the position of the navicular bone, the height of the navicular bone from the ground was measured in both sitting and standing positions. To assess the validity of the diagnostic tests, the same examiner measured the height of the medial longitudinal arch (MLA) three times in both the sitting and standing positions. To assess the inter-rater reliability of the ND-NDT, three examiners, in a random order, attached the sticker-type reflection markers to the position of the navicular bone and then measured the height of the MLA in both positions.

Results: In the sitting position, the Pearson correlation coefficient (r) between the two diagnostic tests was very high (r = 0.97) and statistically significant. In the standing position, the Pearson correlation coefficient (r) between the two tests was 0.95, which was also statistically significant. The $ICC_{2,1}$ values in the sitting and standing positions were 0.93 and 0.95, respectively, indicating significantly high inter-rater reliability.

Conclusion: The ND-NDT equipment showed very high diagnostic validity, as well as excellent inter-rater reliability, indicating the clinical usefulness of the equipment as a diagnostic system for confirming pes planus.

Key Words: Medial longitudinal arch, Navicular drop test, New digital navicular drop test equipment, Validity, Reliability

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Ⅰ. Introduction

The foot is constantly exposed to a load due to the body weight during daily activities. While the load on foot during walking is 1.2 times the body weight, the load becomes two-to-three times the body weight during intense activities such as running (Jacob, 2001). The main weight-bearing structure in the foot is the medial longitudinal arch (MLA). While walking, the MLA transmits force and absorbs any impact (Fiolkowski et al., 2003). The changes in the height of the MLA may increase the risk of lower extremity injury, foot pain, and ankle injury (Menz et al., 2013; Queen et al., 2007; Williams et al., 2001).

Pes planus, also known as flat foot, is a type of deformity in which the MLA chronically drops or is abnormally lowered (Younger et al., 2005). Pes planus can be broadly classified as rigid or flexible pes planus. Rigid pes planus is a form of MLA drop without weight-bearing; flexible pes planus shows normal arch height without weight-bearing but lowered arch during weight-bearing (Neumann, 2016). Flexible pes planus is more prevalent than rigid pes planus, and it is estimated that approximately 2–23% of the US adult population is affected (Banwell et al., 2014). In addition, a previous study using Denis grading reported that 44% of young adults are exposed to the risk of developing pes planus (Chougala et al., 2015). Therefore, making the clinical diagnosis of flexible pes planus is critical.

The navicular drop test (NDT) is typically performed to diagnose flexible pes planus. It is a simple test that is clinically used to measure the range of eversion and sagittal deformation of the mid-foot (Christensen et al., 2014). Thus, the NDT is regarded as a valid indicator of talonavicular motion and of rear foot movement (Lundberg et al., 1989; McPoil & Cornwall, 1996). However, manual measurements may cause errors due to lack of training of the person who conducts the test (McPoil et al., 2008). Therefore, the present study aimed to develop a new digital NDT (ND-NDT) and to determine its validity and reliability.

Ⅱ. Methods

1. Study subjects

This study recruited 30 healthy young adults, both men and women, who understood and agreed with the procedures and the purpose of the study. The inclusion criteria for the study were as follows: No deformity or disease of the foot, no foot pain, and no neurologic illness. Six participants were excluded since they did not meet the inclusion criteria. As a result, 24 participants were included in the study. Table 1 shows the general characteristics of the study participants.

Table 1. Descriptive statistics for subjects (n=24)

Variable	Mean±SD
Age	23.96±4.51
Height (cm)	165.50±7.88
Weight (kg)	63.29±18.61
BMI (kg/m^2)	22.82±5.16
Gender	Male 7(29.2%), Female 17(70.8%)
Dominant foot	Right= 24(100%)

2. Measurement methods and tools

1) Navicular drop test

The NDT was conducted in two positions (Fig. 1). First, with the participant in the sitting position without weight-bearing, the height of the navicular bone from the ground was measured with a ruler. Next, the height of

Fig. 1. Navicular drop test: A) sitting, B) standing.

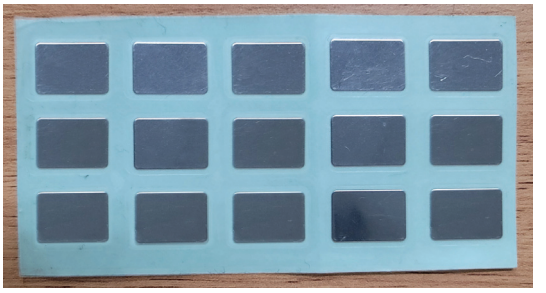

Fig. 2. New sticker-type reflection marker.

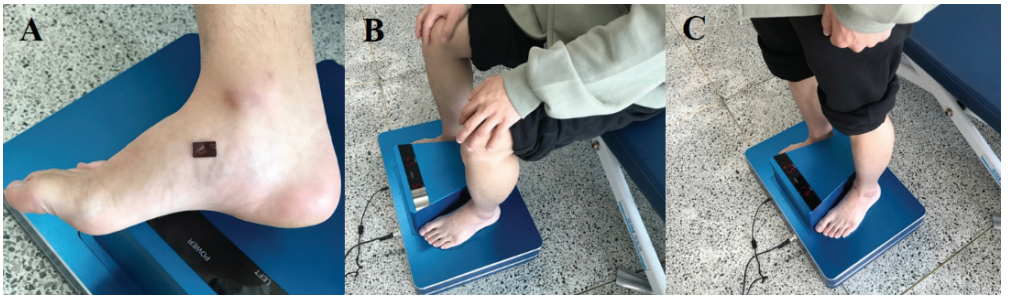

Fig. 3. New digital navicular drop test: A) sticker-type reflection markers attachment, B) sitting, C) standing.

the navicular bone from the ground was measured using a ruler in weight-bearing standing position. If the difference in the height of the navicular bone under the two conditions was ≥10mm, the participant was diagnosed to have pes planus (Lange et al., 2004).

2) Developing the new sticker-type reflection marker

A new reflection marker was developed in order to identify the position of the navicular bone. The old reflection markers used in motion analysis were difficult to attach to the round protruding parts. In order to address this problem, a new sticker-type reflection marker made of aluminum, which is easily compatible with sensors of the study equipment (patent application No. 10-2020-0087839), was developed. The marker was created in round and square shapes with a height of 1cm (Fig. 2).

3) Developing the new digital navicular drop test equipment

A ND-NDT equipment (patent application No. 10-2020-0087839) was developed to perform NDT easily and accurately. After attaching the sticker-type reflection marker on the navicular bone, the MLAs of both feet can be measured simultaneously using the study equipment (Fig. 3). Furthermore, the ND-NDT equipment underwent the accuracy test for measuring the height of the MLA and loading, which resulted in scores of 2±1mm and 160kg, respectively.

3. Experimental procedure

The NDT and ND-NDT were conducted in the dominant foot of the participants in a random order. For the NDT, the position of the navicular bone was marked with a pen first; then, the height of navicular bone from

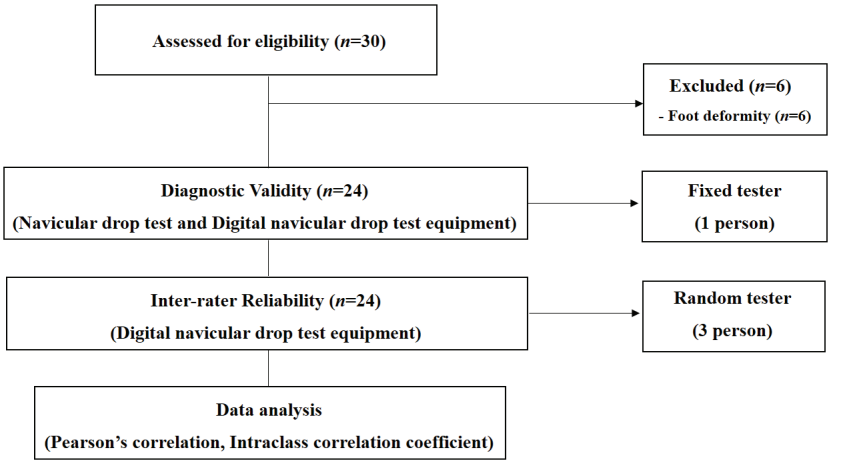

Fig. 4. Diagram of the study design.

the ground was measured in both sitting and standing positions. For the ND-NDT, after the sticker-type reflection markers were attached to the position of the navicular bone, the height of the navicular bone from the ground was measured in both sitting and standing positions.

In order to assess the validity of the diagnostic tests, the same examiner measured the height of the MLA three times in both sitting and standing positions. In order to assess the inter-rater reliability of ND-NDT, three examiners, in a random order, attached the sticker-type reflection markers on the position of the navicular bone and then measured the height of the MLA in both positions. Fig. 4 shows the overall flow of the experimental procedures.

4. Data analysis

The general characteristics of the participants were analyzed using descriptive statistics. The validity of the NDT and ND-NDT in diagnosing pes planus was confirmed by Pearson's correlation analysis. The inter-rater reliability of the ND-NDT was assessed using the interclass correlation coefficient (ICC). Statistical analysis was performed using SPSS 25.0 for Windows (SPSS Inc., Chicago, IL, USA) and a p-value of < 0.05 was considered statistically significant.

Ⅲ. Results

1. Diagnostic validity of new digital navicular drop test

The validity test results of ND-NDT and NDT are shown in Table 2. In the sitting position, the Pearson correlation coefficient (r) between the two diagnostic tests

Table 2. Diagnostic validity of new digital navicular drop test (n=24)

	NDT	ND-NDT	r	p
Sitting (cm)	3.98±0.76	3.99±0.79	0.97	0.01
Standing (cm)	3.68±0.68	3.66±0.71	0.95	0.01

NDT: navicular drop test, ND-NDT: new digital navicular drop test

Table 3. Inter-rater reliability of new digital navicular drop test (n=24)

	$ICC_{2,1}$	95% Confidence interval	
		Lower bound	Upper bound
Sitting	0.93	0.88	0.97
Standing	0.95	0.90	0.98

ICC: intraclass correlation coefficient

was very high (r = 0.97) and statistically significant ($p < 0.01$). In the standing position, the Pearson correlation coefficient (r) between the two tests was 0.95, which was also statistically significant ($p < 0.01$).

2. Inter-rater reliability of digital navicular drop test

The inter-rater ICC values of the ND-NDT are shown in Table 3. The ICC values in the sitting and standing positions were 0.93(95% CI, 0.88-0.97) and 0.95(95% CI, 0.90-0.98), indicating significantly high inter-rater reliability.

Ⅳ. Discussion

The NDT was first designed in 1982 to diagnose pes planus when the height of the navicular bone differed by more than 15 mm while sitting and standing (Brody, 1982). In recent studies, flat foot was defined as more than 10 mm difference in the two positions (Lange et al., 2004). Moreover, the NDT is often used clinically to diagnose pes planus in various areas for which the clinical value of the NDT has already been proven. The ND-NDT equipment developed in this study showed considerably high validity compared to the NDT (r = 0.95-0.97), indicating the potential clinical utility of the ND-NDT.

While the diagnostic value of the NDT in the case of pes planus is high, many studies question the reliability of the measurements used in this test. A previous study conducted by four podiatric physicians showed that the intra-rater reliability of the NDT was 0.51-0.77 and the inter-rater reliability was 0.46 (Evans et al., 2003). Moreover, Sell et al. (1994) showed that the intra-rater reliability of the NDT was good, and the inter-rater reliability was fair. One previous studies showed slightly higher intra-rater reliability than the inter-rater reliability, and moderate reliability scores (Vinicombe et al., 2001). These results suggest that the inter-rater reliability of NDT needs to be improved. The ND-NDT equipment developed in this study showed a significantly high inter-rater reliability of 0.93-0.95, which may solve the reliability problem of NDT.

It should be noted that this study has some limitation. The results of this study cannot be generalized to people with pes planus because it included only young people with normal foot arch. It will be needed to further studies that investigate the validity, reliability, and standard error of the measurement of ND-NDT in people with pes planus. With the advent of the Fourth Industrial Revolution, the diagnostic paradigm in the healthcare sector is also changing. Various systems are being developed to ensure disease prevention, represented by the Health 3.0 era, which can be implemented by big data analysis. The ND-NDT system can thus be expected to be developed into a system for early detection and prevention of pes planus.

Ⅴ. Conclusion

The ND-NDT equipment showed very high diagnostic validity as well as excellent inter-rater reliability, indicating the clinical usefulness of the equipment as a diagnostic system for confirming pes planus.

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