

Reliability of the Transverse Arch of the Forefoot as an Indicator of Foot Conditions

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Abstract. [Purpose] The purpose of this study was to investigate the intra- and inter-tester reliabilities of transverse arch length (TAL) standing position and lower leg maximum anterior tilting (LMAT) position. [Subjects] Eight subjects who were free from lower extremity injury at the time of testing and three testers participated in this study. [Methods] TAL was measured 3 times in each trial both in the standing position and the LMAT position. Three trial repetitions were performed at 1-hour intervals. Test–retest reliability was established using the ICC (1, k) model and data from the first to the third trials. Inter-tester reliability was established using the ICC (2, k) model and the averages of the first to third trials of each tester. [Results] In the standing position, intra-tester reliability was good or sufficient for use in a clinical setting. Inter-tester reliability was sufficient for use in a clinical setting. In the LMAT position, intra-tester reliability was excellent or sufficient for use in a clinical setting. Inter-tester reliability was good. [Conclusion] We suggest that it is possible to easily assess the flexibility of the transverse arch of the forefoot using the technique we describe here.

Key words: Transverse arch, Reliability, Flexibility

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INTRODUCTION

It is important to measure the transverse arch of the forefoot because a low transverse arch may lead to hallux valgus and metatarsalgia. Previous techniques that have been developed for measuring the transverse arch of the forefoot include plantar pressure measurements^{1–3)}, ultrasonography^{4, 5)}, and X-ray photography⁶⁾. In plantar pressure measurements, dropping of the transverse arch of the foot is indicated by the concentration of plantar pressure on the 2nd or 3rd metatarsal heads. Conversely, the peak plantar pressure carried under the 2nd, 3rd and 4th metatarsal heads in normal gait⁴⁾ and, the maximum plantar pressure distribution on the forefoot varies in the each step and each subject. Thus, measurement of plantar pressure is insufficient for assessing the structure of the transverse arch of the forefoot. Wang⁵⁾ reported that measurement of the transverse arch of the forefoot by ultrasonography is not satisfactorily reliable. In the clinical setting, the X-ray finding is the most useful method that provides the angle between the longitudinal axis of the 1st and 5th metatarsals (M1M5). However, it is impossible for physical therapists to perform this technique. Determining the percentage of the transverse arch length (TAL), which is defined as the distance from the 1st to 5th metatarsal head divided by foot length, is a known quanti-

tative and simple measurement method. However, this type of measurement presents some problems. First, TAL is well correlated with M1M5⁷⁾, although the reliability of the measurement is not clear. Second, TAL is measured in the standing position with load on the rearfoot, although some patients who present with forefoot pain may have higher load on the forefoot. Third, there are many cases of dropping of the transverse arch of the forefoot with forefoot loading during walking and running, although the transverse arch is maintained in the standing position. Therefore, TAL can assess the structure of the transverse arch of the forefoot, but it cannot reflect the flexibility of the transverse arch in forefoot loading. In this study, we measured TAL in the lower leg maximum anterior tilting (LMAT) position as well as in the standing position, and attempted to determine the flexibility of the transverse arch of the forefoot. The purpose of this study was to investigate the intra- and inter-tester reliabilities of TAL in the two stance positions.

METHODS

Eight subjects (4 males and 4 females) who gave their informed consent participated in this study. Their mean age was 19.3 ± 2.4 years. Subjects did not have any lower extremity injury at the time of testing. Three testers partici-

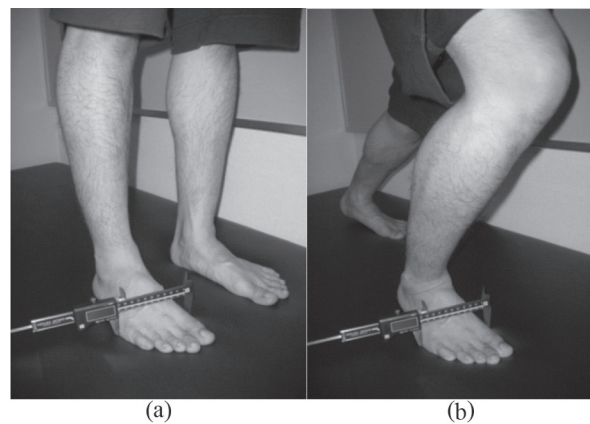


Fig. 1. Photograph of the measurements

The percentage of the transverse arch length (TAL), which is defined as the distance from the 1st to 5th metatarsal head divided by foot length, was measured in the standing position (a) and the LMAT position (b).

Table 1. Intra- and inter- tester reliability of the transverse arch of the forefoot in the two positions

| | | Standing position | | | | LMAT position | | | |
|--------------|----------|-------------------|-------|------|------|---------------|-------|------|------|
| | | Mean | ±S.D. | ICC | SEM | Mean | ±S.D. | ICC | SEM |
| Intra-tester | Tester A | 40.8 | 1.73 | 0.82 | 0.67 | 41.7 | 1.98 | 0.92 | 0.36 |
| | Tester B | 40.4 | 1.22 | 0.80 | 0.02 | 41.3 | 1.24 | 0.79 | 0.02 |
| | Tester C | 40.3 | 1.66 | 0.75 | 0.03 | 40.7 | 1.97 | 0.98 | 0.04 |
| Inter-tester | | | | 0.75 | 0.13 | | | 0.81 | 0.03 |

pated in this study. Tester A was a male physical therapist who had 15 years of experience and worked at a school of physical therapy. Tester B was a male physical therapist who had 2 years of experience and worked at an orthopaedic clinic. Tester C was a female student of physical therapy. All testers were informed of the measurement methods 1 week before the experiments. TAL was measured with a digital caliper (measurement error: ± 0.03 mm) in the two stance positions of the right foot of the subjects. The measurement unit was 0.1 mm, and they were recorded to one decimal place. In the standing position, the load is carried on the heel, and subjects stood with the feet apart at the width of the shoulders. In the LMAT position, the load is carried on the forefoot, and the right foot in a forward stance with the right foot tilted to the maximum (Fig. 1). According to our experience, plantar pressures on the right forefoot were 70% to 80% of the body weight in this position. In both stance positions both feet were in contact with the floor. Moreover, hyper-adduction/abduction of the hip and the foot, and hyper-rotation of the lower leg were restricted by manipulation and oral commands. TAL was measured 3 times in each trial both in the standing position and the LMAT position, and the median value was adopted. Three trial repetitions were performed at 1-hour intervals. The statistical analyses were performed using PASW statistics for Windows (version 18.0; SPSS Japan Inc., Tokyo, Japan). Test-retest reliability was established using the ICC (1, k) model and data from

the first to the third trials, and the standard error of the mean (SEM) was calculated. Inter-tester reliability was established using the ICC (2, k) model and the averages of the first to third trials of each tester, and the SEM was calculated.

RESULTS

The results of the intra- and inter-tester reliability measurements are given in Table 1. In the standing position, testers A and B showed good reliability, and tester C showed reliability sufficient for use in a clinical setting. Inter tester reliability showed sufficient for use in a clinical setting. In the LMAT position, testers A and C showed excellent reliability and tester B showed reliability sufficient for use in a clinical setting. Inter tester reliability was good.

DISCUSSION

In the standing position, intra-tester reliability values were good for testers A and B (ICC = 0.82 and 0.80, respectively), and fair for tester C (ICC = 0.75). Inter-tester reliability values were fair (ICC = 0.75). With regard to the medial longitudinal arch of the foot, Williams⁸⁾ reported an ICC of the arch height of 0.804–0.995, whereas Pohl reported 0.87–0.92⁹⁾. The ICC values in this study were lower than in those previous studies. Two reasons may explain this: (i) difficulty of TAL measurements, and (ii) precision of

the measurement unit. Concerning (i), the displacement magnitude of TAL is smaller than that of the navicular height and: the transverse arch of the forefoot shows just a small movement in forefoot loading. Thus, in the transverse arch, a more accurate measurement is needed than the medial longitudinal arch of the foot. Concerning (ii), our measurement unit was 0.1 mm, while previous authors have used 1 mm; thus, our measurements were more precise. Therefore, there is a possibility that slight measurement errors arose which decreased the reliability. Nevertheless, measuring TAL in the standing position is more useful than radiological methods, and it is a valid and simple quantitative method for physical therapists. In the LMAT position, the reliability of TAL was excellent for testers A and C, and was fair for tester B, and the inter-tester reliability was good in our study. Williams reported that the inter-tester reliability of the navicular height in 90% weight loading was lower than in 10% weight loading because palpation in 90% weight loading is more difficult than in 10% weight loading⁸⁾. Conversely, Pohl reported high ICC values in 2 positions in which 10% and 90% weight loading were considered⁹⁾. In this study, both the standing and LMAT positions showed high ICC values. In particular, the inter-tester and intra-tester reliabilities for testers A and C in the LMAT position were higher than those in the standing position. The transverse arch of the forefoot is dropped in forefoot loading. The tension of the soft tissue, which maintains the transverse arch of the forefoot increases forefoot rigidity¹⁰⁾. Therefore, the precision of the measurements in the two positions was improved. Moreover, we used the medial surface of the 1st metatarsal head and the lateral surface of the 5th metatarsal head in this study. Both landmarks have thin subcutaneous tissue and are easily identified by palpation, resulting in the high ICC values. Consequently, the reliability of the measurement of TAL in the LMAT position is good. It is important to understand the structure of the transverse arch because a low transverse arch is recognized to cause metatarsalgia and hallux valgus^{11, 12)}. In a previous study, the transverse arch of the forefoot was measured in the standing position or a non-weight-loading position. However, there are many cases of dropping of the transverse arch of the forefoot with forefoot loading, although the transverse arch of the forefoot was maintained

in the standing position. Yamauchi¹³⁾ reported that the 1st or 5th metatarsal head carried higher loads in conditions in which the 1st or 5th metatarsal had hypo-mobility in forefoot loading. Consequently, it is more important for physical therapists to understand the flexibility of the transverse arch of the forefoot than to understand its structure. Methods for measuring the flexibility of the transverse arch of the forefoot include employing a 3-dimensional motion analysis system, but this is difficult to use in the clinical setting. We suggest that it is possible to easily assess the flexibility of the transverse arch of the forefoot by using the technique we described above.

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