MEDIO-LATERAL DISTRIBUTION OF BONE DENSITY AT THE ACHILLES TENDON INSERTION IS RELATED TO REARFOOT RUNNING MOVEMENT PATTERN

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SUMMARY

Asymmetrical loading of the Achilles tendon (AT) is considered to contribute to the development of AT pathologies. Rearfoot inversion and eversion have been shown to potentiate asymmetrical AT loading. Furthermore, it could be demonstrated that bone mineral density (BMD) at a tendon insertion is related to the degree of tendon loading. Therefore, the purpose of the study was to quantify the relation between medio-lateral BMD distribution at the AT insertion and rearfoot movement of active runners. Medio-lateral distribution of BMD at the AT insertion of twelve runners and their rearfoot angle during running were studied. Medio-lateral distribution of BMD differed individually. Cortical and total BMD of the medial upper portion of the AT insertion correlated significantly with the subject’s rearfoot angle at heel off during running (r = -0.695; r = -0.610). It has been shown that AT force is highest around the time of heel off during running. Present data suggest that the adaptional effects of asymmetrical loading on BMD may be increased when rearfoot eversion occurs at time of highest AT loading during running. The findings confirm previous results that described the effect of frontal plane Calcaneus (CA) position on an asymmetrical loading of the AT.

INTRODUCTION

Pathologies of the AT involve strong constraints in daily and sports activities of the affected persons. Therefore, enhanced knowledge of the etiology of AT pathologies is of paramount clinical interest [1]. A non-uniform distribution of mechanical load between different fiber portions of the AT is discussed to abet the development of AT overuse injuries [2]. A previous ex vivo study revealed that medio-lateral AT load distribution is mainly governed by triceps surae muscle force application and frontal plane CA position [3]. Furthermore, it could be shown that enhanced tendon loading affects local BMD at the tendon’s insertion site [4]. Based upon these findings it was hypothesized that long-term application of movement patterns that are connected to an asymmetrical tendon loading, such as running with increased rearfoot in- or eversion during foot contact, would be related to an asymmetrical distribution of BMD at the tendon’s insertion site. Therefore, the first purpose of the study was to determine medio-lateral differences in BMD distribution at the AT insertion of active runners. Secondly, the study aimed to quantify the relation between medio-lateral BMD distribution at the AT insertion site and rearfoot movement patterns of active runners.

METHODS

The medio-lateral distribution of BMD at the AT insertion site of twelve healthy male runners (182.1 ± 7.4cm; 78.2 ± 7.7kg, 28.1 ± 5.1 yrs.) and the subject’s rearfoot angle during running were studied in an ex-post-facto design. Bone mineral density. BMD was measured by peripheral quantitative computed tomography (pQCT) with a voxel size of 0.5mm³. The right leg of the subjects was positioned and fixed in the tomograph. Five transversal slices were obtained from the following heights of tuberculum calcanei from distal to proximal: 20% (underneath AT insertion), 40%, 50%, 60% (within AT insertion), 80% (above AT insertion). In order to ensure that the 40-60% slices were taken within the AT insertion, the length of the AT insertion and its position relative to the proximal border of tuberculum calcanei were quantified by ultrasonography. The measured distance between insertion and proximal tuberculum calcanei border was related to the complete tuberculum calcanei height obtained by pQCT. Medial and lateral regions of interest (ROIs) for the five slices were determined from the 50% slice of each subject as follows: The distance between medial and lateral borders of the tuberculum calcanei was divided in halves to differentiate between medial and lateral. The anteroposterior length of the ROI was set to 20% of the total anteroposterior CA length obtained from the 50% slice. The latter line crossed the median of the medio-lateral distance line perpendicularly (figure 1). The following parameters were determined for medial and lateral ROIs in all five slices: total volumetric BMD (total.BMD), cortical volumetric BMD (cort.BMD), trabecular volumetric BMD (trab.BMD); all [mg/cm³]. The threshold determination for the different BMD parameters was performed according to literature [5,6].

Figure 1: Transversal pQCT slice of right CA at 50% of tuberculum calcanei height (distal to proximal view). Medial and lateral ROIs are represented by bold rectangles.

Rearfoot motion. All subjects ran on a treadmill at a speed of 3ms⁻¹ with their own running shoes. After acclimatization to the treadmill frontal plane rearfoot motion was video captured.
at 200Hz. The rearfoot angle was analyzed by marker placements according to literature [7] for the following events during foot contact: touch down, foot flat, heel off. Ten stance phases were recorded for each subject.

Statistics. All statistical analyses were performed in SPSS 18.0. All BMD and rearfoot motion parameters were analyzed for normal distribution using a K-S test. BMD value differences between medial and lateral ROIs were tested for significance using paired r-tests. Relationships between BMD and rearfoot angle values were assessed using a Pearson’s correlation. The level of significance was set at 0.05 for all tests.

RESULTS

Figure 2: Individual distribution of total.BMD at the 50% and 60% slice.

Mean differences in BMD between medial and lateral ROIs were only found to be significantly different outside the AT insertion. Medio-lateral BMD values distribution differed inter-individually (figure 2).

Figure 3: Relationship between medial cort.BMD in the 60% slice and rearfoot angle at HO. Negative angle values represent rearfoot inversion, positive values rearfoot inversion.

The analysis of the relationship between rearfoot angle and BMD values revealed a significant negative correlation (r = -0.695) between medial cort.BMD in the 60% slice and rearfoot angle at heel off (figure 3). Medial total.BMD in the 60% slice and rearfoot angle at heel off also correlated significantly (r = -0.610).

DISCUSSION

For the analyzed population no significant mean value differences between medial and lateral ROIs could be detected within the insertion region. Admittedly, the distribution seemed to differ between the subjects individually. This heterogeneity may either be caused by genetic factors or may be a response to an individual mechanical loading of the AT insertion region. The latter argument is confirmed by a previous study that investigated the BMD at the patella insertion in relation to exercise [4].

The ex vivo distribution of BMD parameters for different regions of the CA has already been described in literature [8]. However, this is the first study which particularly focusses the BMD distribution at the AT insertion in vivo.

For the analyzed group of runners a negative correlation between rearfoot angle during heel off and the BMD in the medial 60% slice could be found. In a previous ex vivo experiment it could be shown that CA eversion results in higher strain of the medial AT portion [3]. These findings lead to the assumption that higher strain of the medial AT portion during rearfoot eversion may also lead to higher strain at the medial region of the AT insertion. This may have adaptive responses of local BMD as a consequence. The findings of the present study confirm this theory, whereas the study design is limited to the analysis of relationships due to its retrospective character.

It could be shown that AT force is highest around the time of heel off during running [9,10]. The strongest relationship between BMD values and rearfoot angle was found at the time of heel off in this study. As rearfoot eversion results in an asymmetrical loading of the AT [4], the adaptive effect of asymmetrical loading may be increased when rearfoot eversion occurs at the time of highest AT loading during running. This methodology may be used to diagnose AT pathologies that are related to chronic asymmetric loading of the AT. Yet the respective cause and effect relationship has to be studied.

CONCLUSIONS

The data of the present study suggest that medio-lateral distribution of BMD at the AT insertion is different inter-individually. For the analyzed runners a relationship between rearfoot angle at the time of heel off during running and medial BMD within the AT insertion could be found. These findings confirm the results of a previous study that described the effect of frontal plane CA position on an asymmetrical loading of the AT. If further evaluated, the used methodology can be applied in a clinical context to determine chronic asymmetrical AT loading.

REFERENCES