# OPTIMAL CHOICE OF MARKER LOCATIONS IS AN EFFECTIVE STRATEGY FOR MINIMISING SOFT TISSUE ARTEFACT AT THE TIBAI

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## Introduction

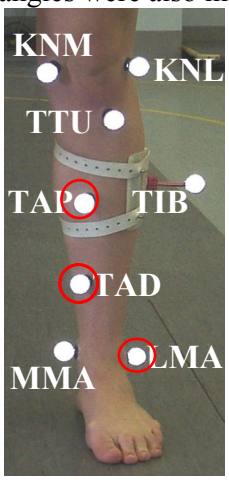
With recent advances in technology, soft tissue artifact (STA) now imposes the greatest limitation on the validity of gait analysis measurements [1]. STA is due to the relative movement between the marker and the underlying bone, mostly associated with the interposition of both the passive and active soft tissues [2, 3]. It is difficult to reduce STA through filtering or other mathematical means because it is the same frequency content as joint movement. One possible strategy is to position markers in areas least susceptible to STA. It is well known that STA at the tibia is considerably less than that at the thigh [2]. Despite this, optimal marker locations for the tibia have not been well defined. The aim of this study is to identify a subset of markers on the tibia showing the least amount of movement with respect to each other.

## Statement of Clinical Significance

A subset of 4 markers on the tibia has been identified showing very little movement in relation to each other. Further work is required to ensure that these move little in relation to the underlying bone but it is probable that use of these markers can result in tibial kinematics that are minimally affected by STA.

## Methods

Five healthy subjects participated with mean age 33.2yrs (SD=5.3) and BMI 22kg/m$^2$ (SD=2.4). Multiple markers were placed over the tibia (See Figure 1). Additional markers were placed on the pelvis, femur and foot to allow calculation of joint angles. Subjects were required to perform repeated gait trials and non-weight bearing movements of both knee and ankle joints through a full range of motion. The distances between all possible marker pairs were calculated. The standard deviation of these distances during the different movements was taken as indicative of the relative movement between markers. The correlations between the marker pair distances and knee / ankle joint angles were also investigated.

(a) 

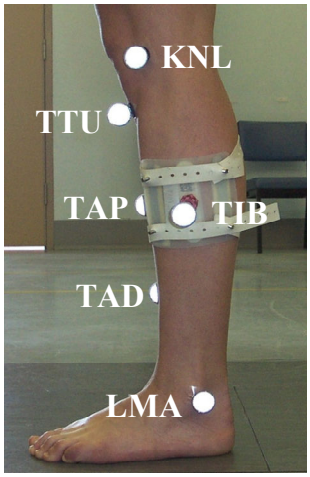
(b) 


Figure 1: Frontal (a) and Lateral (b) view of marker setup.

**Results**

A difference was found in movement between marker pairs (Table 1). LMA, MMA, TAP, TAD were the best markers in terms of the standard deviation of the movement of markers, with less than 1.3mm between all marker pairs during gait trials. KNL performed most poorly producing standard deviations of up to 3.3 mm between marker pairs during walking. While the pairing of the medial and lateral knee markers performed well, these two markers performed poorly when paired with other markers.

| | MMA | LMA | TAD | TAP | TIB | TTU | KNM | KNL |
|---|---|---|---|---|---|---|---|---|
| **MMA** | | 0.7 | 0.9 | 1.0 | 1.6 | 2.7 | 2.8 | 2.9 |
| **LMA** | 0.9 | | 1.1 | 1.3 | 1.9 | 2.3 | 2.8 | 3.3 |
| **TAD** | 1.3 | 1.6 | | 0.5 | 1.2 | 2.8 | 2.6 | 2.4 |
| **TAP** | 1.3 | 1.9 | 0.5 | | 1.1 | 2.7 | 2.4 | 2.0 |
| **TIB** | 1.8 | 2.1 | 1.2 | 1.2 | | 1.7 | 2.1 | 2.7 |
| **TTU** | 2.7 | 3.5 | 2.6 | 2.5 | 1.8 | | 2.2 | 1.9 |
| **KNM** | 3.9 | 4.8 | 3.2 | 2.5 | 3.4 | 1.6 | | 1.7 |
| **KNL** | 3.6 | 4.9 | 2.9 | 2.2 | 3.7 | 1.5 | 1.3 | |

Table 1: Average standard deviation (mm) of distance between marker pairs during gait. (Top Right – Gait Data; Bottom Left – Range of Movement Data)

**Discussion**

The results of this study clearly show that there are four markers based on the tibia which demonstrate very low inter-pair distance variations implying that their relative positions vary little over the gait cycle. Given that the markers are on quite different parts of the tibia, the simplest explanation for this is that the markers move little in relation to the tibia itself. These results suggest that the conclusion of Cappozzo et al. [2], that the lateral malleolus may to move up to 15mm with respect to the underlying bone might be unduly pessimistic.

Presently, most clinical gait analysis models use top down hierarchical methods leading to the propagation of errors from STA over the pelvis and femur. These therefore lead to distortions in the definition of the tibia. Models in which measurements of tibial movement are less susceptible to STA over other segments may be more appropriate.

There have been some limitations to this study, most notably the fact that thus far reasonably slim healthy adults have participated. In view of this fact, further investigation would need to be conducted to explore whether the same results are found in patients. Further studies are also required to confirm the assumption that small marker pair movement is a consequence of small maker-bone movement.

**References**


1. **Leardini, A. et al. (2005) Gait Posture 21 (2), 212-25**
2. **Cappozzo, A. et al. (1996) Clin Biomech 11 (2), 90-100**
3. **Manal, K. et al. (2000) Gait and Posture 11, 38-45**