Dose-response effects of customised foot orthoses on lower limb kinematics and kinetics in pronated foot type: supplementary materials

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1. Motion capture model

1.1 Marker locations

All retroreflective motion capture markers were flat-based spherical type (Qualysis AB, Gothenburg, Sweden). Marker locations and details are described in Table S1 and Figure S1.

Table S1 –Marker locations, labels and function

Number	Landmark/Location	Label Name	Size (mm)	Remove*/Track
1	Right anterior iliac spine	RAIS	19	Tracking
2	Right greater trochanter	RGT	19	**Remove**
3	Right posterior iliac spine	RPIS	19	Tracking
4	Left anterior iliac spine	LAIS	19	Tracking
5	Left greater trochanter	LGT	19	**Remove**
6	Left posterior iliac spine	LPIS	19	Tracking
7	Thigh 1st	THI1	19	Tracking
8	Thigh 2nd	THI2	19	Tracking
9	Thigh 3rd	THI3	19	Tracking
10	Thigh 4th	THI4	19	Tracking
11	Lateral epicondile	LKNE	12	**Remove**
12	Medial epicondile	MKNE	12	**Remove**
13	Shin 1st	SHN1	19	Tracking
14	Shin 2nd	SHN2	19	Tracking
15	Shin 3rd	SHN3	19	Tracking
16	Shin 4th	SHN4	19	Tracking
17	Medial malleolus	MMAL	7	**Remove**
18	Lateral malleolus	LMAL	7	**Remove**
19	Superior calcaneum	SCAL	7	Tracking
20	Inferior calcaneum	ICAL	7	Tracking
21	Lateral offset calcaneum	OCAL	7	Tracking
22	Medial calcaneum	MCAL	7	**Remove**
23	Tuberosity navicular	NAV	12	Tracking
24	Proximal 1st met	P1MT	7	**Remove**
25	Medial 1st met head	M1MH	12	Tracking
26	2nd Met Head	D2MT	7	**Remove**
27	Lateral calcaneum	LCAL	7	**Remove**
28	Proximal 5th met	P5TH	12	Tracking
29	Distal 5th met	D5TH	12	Tracking

*Remove: Required for model building only, removed after static trial has been captured

Figure S1 – Marker locations

1.2 Anatomical reference frame definitions

Table S2 – Anatomical reference frame definitions for individual segments

Segment	Description
Pelvis	CODA[1]
Thigh	
Origin	Virtual HIP_CENTRE marker from CODA pelvis
z-axis	The *z*-axis is the projection of the line joining HIP_CENTRE and the origin.
x-axis	The *x*-axis is perpendicular to the z-axis in a plane containing the origin, KNEE, and LKNEE.
y-axis	The y-axis is mutually perpendicular to the x- and z-axes
Shank	
Origin	A virtual KNEE marker was created 50% of the distance on the line between the LKNEE and MKNEE markers.
z-axis	A virtual marker, MAL_CENTRE is created 50% of the distance between the MMAL and LMAL markers. The *z*-axis is the projection of the line joining MAL_CENTRE and the origin.
x-axis	The *x*-axis is perpendicular to the z-axis in a plane containing the origin, MAL-centre and LMAL.
y-axis	The *y*-axis is mutually perpendicular to the *x*- and *z*-axes.
Rearfoot	
Origin	A virtual marker is projected perpendicularly from SCAL onto a plane created by ICAL and virtual markers projected from ICAL in X^+ and Z^+ a nominal distance of 0.1m. The rearfoot origin is located here.
z-axis	The *z*-axis is the projection of the line joining ICAL and the rearfoot origin.
x-axis	The *x*-axis is perpendicular to the z axis in a plane containing the origin, ICAL and HF_X. HF_X is a virtual marker projected from the origin in the X^+, a nominal distance of 0.1m.
y-axis	The *y*-axis is mutually perpendicular to the *x*- and *z*-axes.
Forefoot	
Origin	Virtual markers are projected from P1MT (P1MT_PROJ) and P5MT (P5MT_PROJ) perpendicularly onto a plane created by D5MT and virtual markers projected from D5MT in X^+ and Y^+ a nominal distance of 0.1m. The origin of the forefoot is then located at the midpoint (50% distance) between P1MT_PROJ and P5MT_PROJ.
y-axis	A virtual D2MT marker (D2MT_PROJ) is projected perpendicularly onto a plane created by D5MT and virtual markers projected from D5MT in X^+ and Y^+ a nominal distance of 0.1m. The *y*-axis is a projection of the line joining the origin to D2MT_PROJ.
x-axis	The *x*-axis is perpendicular to the y-axis in a plane containing the origin, D2MT_PROJ and D5MT.
z-axis	The *z*-axis is mutually perpendicular to the *y*- and *x*-axes.
Foot	
Origin	The origin is located at the virtual MAL_CENTRE marker.
y-axis	Virtual markers are created from projections in Y^+ from M1MH (M1MH_PROJ) and D5MT (D5MT_PROJ) to the longest toe. These distances are derived from calliper measurements for each subject. The *y*-axis is a projection of the line joining the origin and a virtual marker (DISTAL_FOOT_CENTRE) 50% distance between M1MH_PROJ and D5MT_PROJ.
z-axis	The *z*-axis is perpendicular to the y-axis in a plane containing the origin, DISTAL_FOOT_CENTRE and shank origin.
x-axis	The *x*-axis is mutually perpendicular to the *y*- and *z*-axes.

[1] See http://www.c-motion.com/v3dwiki/index.php?title=Coda_Pelvis (last accessed 9th October 2012).

The landmarks outlined in Table S1, along with projected or virtual markers created within the Visual3D software system were used to define the segment anatomical reference frames (see Table S2). Orientation of the axes was standardised such that the *X*-axis was medial/lateral with X^+ pointing to the right; the *Y*-axis was anterior/posterior with Y^+ pointing forward; and the *Z*-axis as vertical with Z^+ pointing upwards.

1.3 Joint rotation definitions

The cardan sequence order of rotation was x-y-z. Intersegment rotations were defined using clinical meaningful terms. For the reported results, the knee joint kinetics were expressed in the local coordinate system of the thigh. Therefore external adduction (+) / abduction (-) moments occurred about the *y*-axis. Ankle joint kinetics were expressed in the local coordinate system of the shank. Therefore inversion (+) / eversion (-) occurred about the *y*-axis.

Rearfoot motion was expressed in the local coordinate system of the shank. Therefore inversion (+) / eversion (-) occurred about the *y*-axis. Motion of the tibia was expressed in the local coordinate system of the rearfoot. Therefore external (+) / internal (-) rotation was expressed about the *z*-axis. Forefoot motion was expressed in the local coordinate system of the rearfoot. Therefore adduction (+) / abduction (-) rotation occurred about the *z*-axis.

2. Footwear and accessories

2.1 Rearfoot wand

The rearfoot wand (Figure S2) is in two sections to allow a shoe to be donned and doffed without the need to fully remove and replace the wand, a process which would introduce error into the measurement. The wand is made up of a "plate" part, which is stuck to the participant's heel, and the removable "wand" section which slots into a hole in the plate and has three markers stuck to it (SCAL, ICAL and OCAL). All parts were made in polyacidite via a fused deposition 3D printing method. The rearfoot wand and its CAD models are available on request from the corresponding author (scott.telfer@gcu.ac.uk).

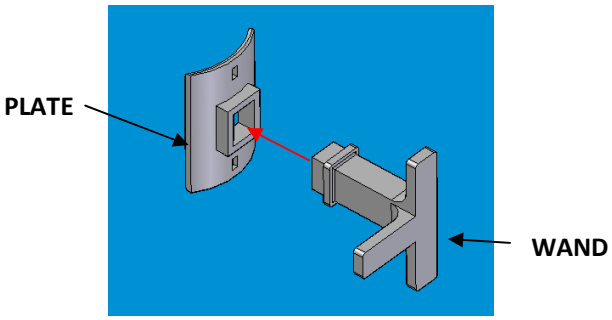

Figure S2 – Detachable rearfoot wand

2.2 Positioning of rearfoot wand

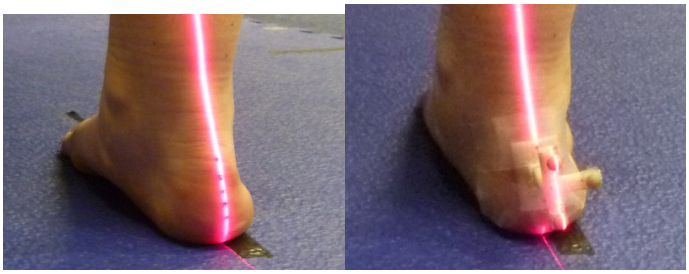

Figure S3 - Alignment of rearfoot wand

To ensure accurate alignment of the rearfoot wand with the rearfoot in the frontal plane, the following protocol was used-

1. The calcaneal bisection line is drawn on the participant's heel using a dark coloured non-permanent marker.

2. The foot is positioned on the floor such that the 2nd toe and centre of the heel are aligned against a straight line marked on the floor while the participant stands in a relaxed position.

3. A line laser (red line laser, adjustable focus; A1 Technologies, London, UK) is positioned such that, when its line is vertical, it is aligned with the previously described line on the

floor (see Figure S3). The laser is used to project a line onto the heel and lower leg. This laser is rotated until the projected line passes through the calcaneal bisection line previously marked on the heel (i.e. it matches the relaxed calcaneal stance position angle).

4. The rearfoot wand is then positioned so that laser line passes through the middle of both SCAL and ICAL markers (see figure S3).

2.3 Adapted shoe

A specially adapted neutrally posted training shoe was used in this study. The shoe has holes cut to allow the M1MH, P1MT, NAV and D5MT markers to be viewed as well as a hole in the heel counter to allow the rearfoot wand to stick through. Zips are sewn into the medial and lateral sides of the shoe to allow the upper to be opened up and the foot removed from the shoe without the need to remove and replace markers, while maintaining the structural integrity of the shoe.

As shown in Figure S4, to change the orthotic being worn, the detachable wand section of the rearfoot wand is carefully removed from the plate (leaving the plate attached to the foot) and the zips on the lateral and medial sides of the shoe are undone. The upper section opened out, and the researcher holds out the sides of the shoe. The participant is asked to push their toes as far as possible to the front of the shoe, then to first lift their heel out followed by the rest of the foot. This process is reversed to don the shoe.

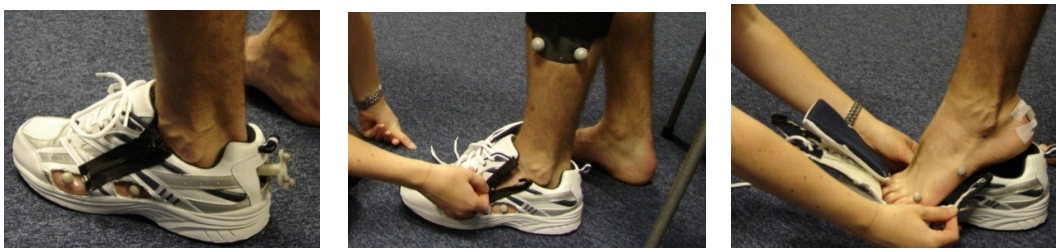

Figure S4 - Adapted shoe and process for changing orthotic

3. Additional results

3.1 Rearfoot kinematics

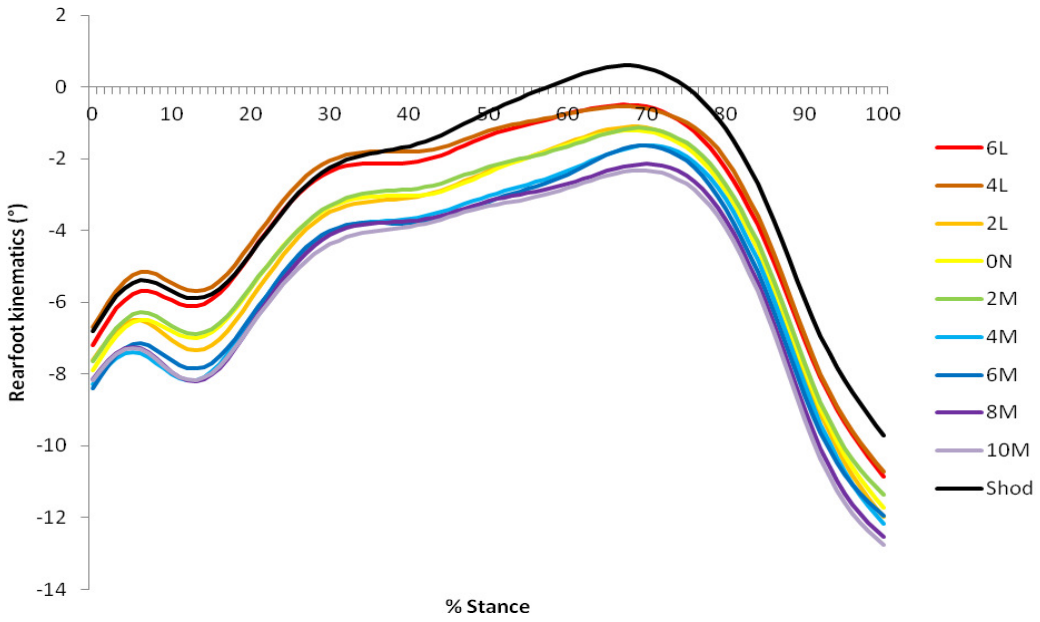

Figure S5 - Control group frontal plane rearfoot kinematics (+ve = eversion). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted

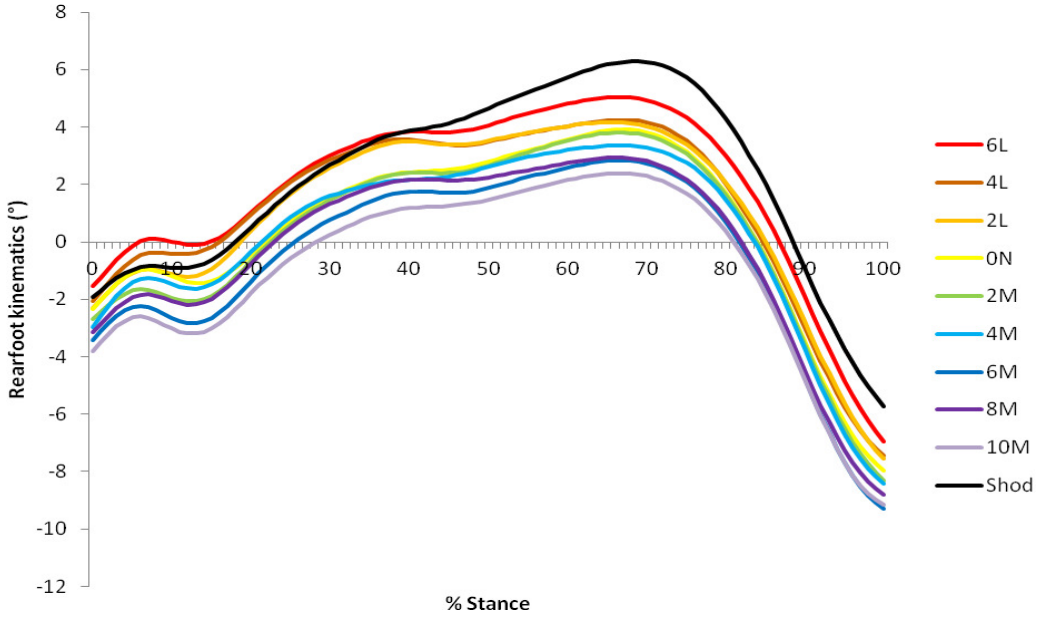

Figure S6 - Patient group frontal plane rearfoot kinematics (+ve = eversion). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted

3.2 Frontal plane ankle moments

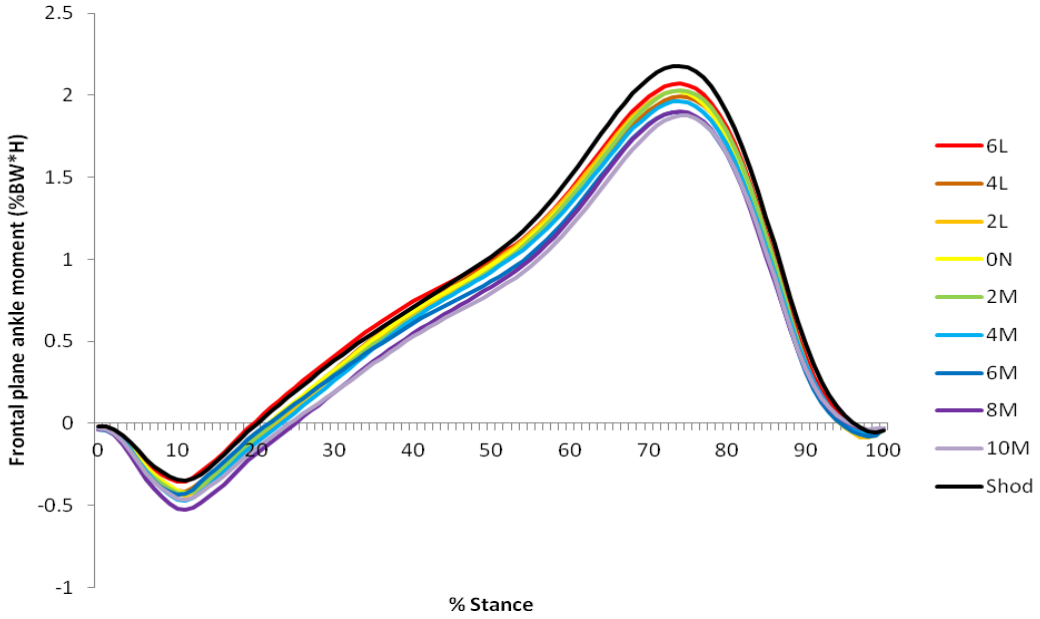

*Figure S7 - Control group frontal plane ankle moments (+ve = external eversion moment). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted; %BW*H: percentage bodyweight mulitplied by height*

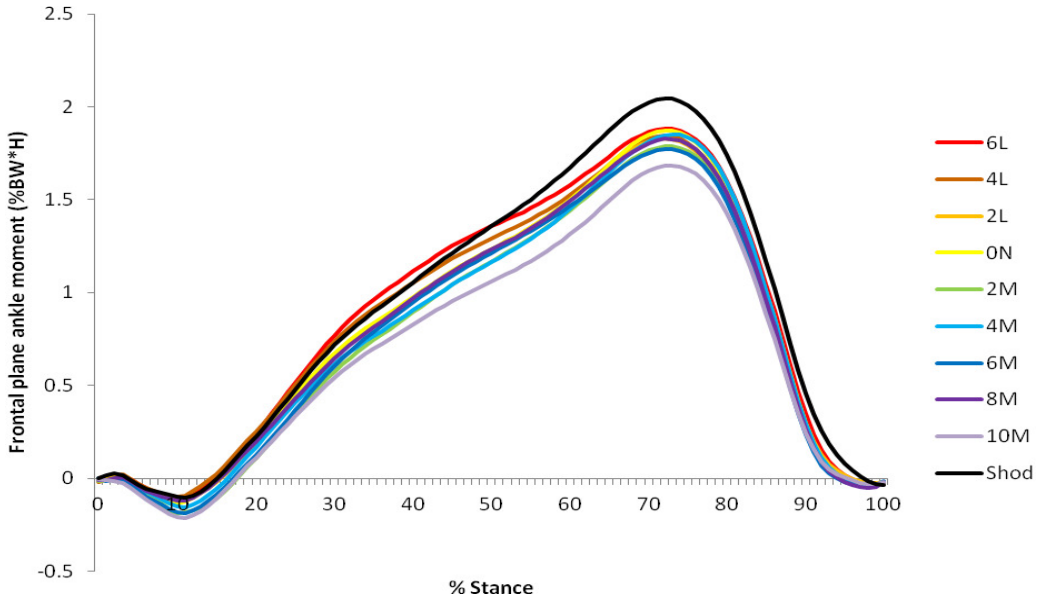

*Figure S8 - Patient group frontal plane ankle moments (+ve = external eversion moment). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted; %BW*H: percentage bodyweight mulitplied by height*

3.3 Knee adduction

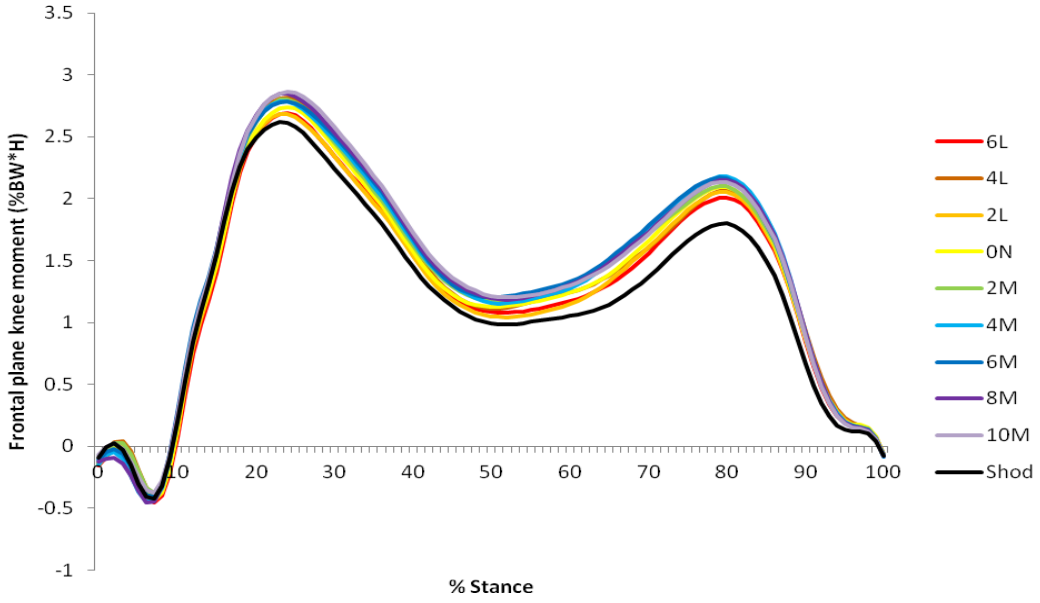

*Figure S9 - Control group frontal plane knee moments (+ve = external adduction moment). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted; %BW*H: percentage bodyweight mulitplied by height*

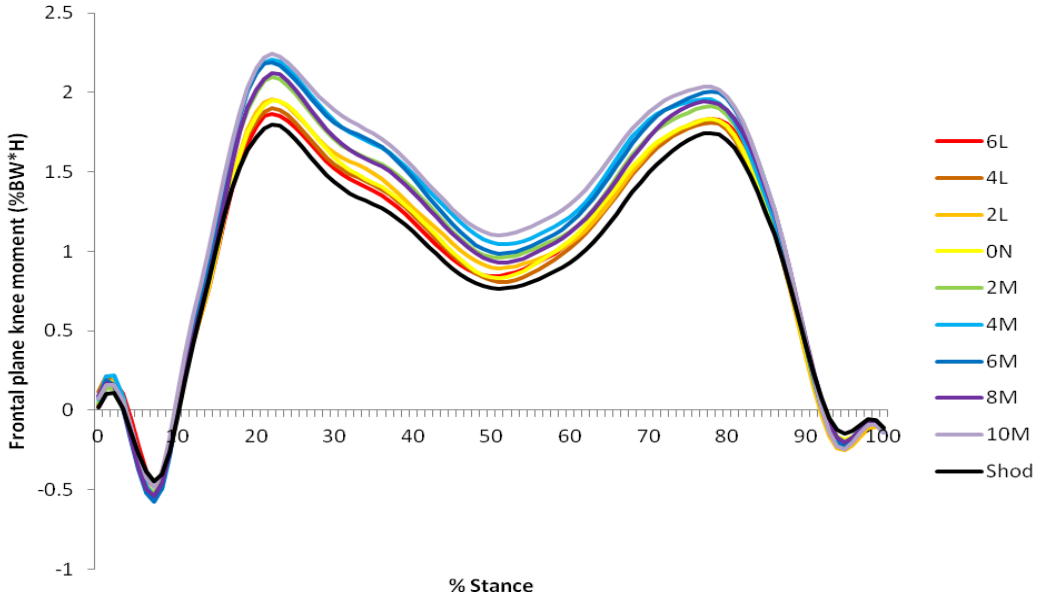

*Figure S10 - Patient group frontal plane knee moments (+ve = external adduction moment). nL: degrees laterally posted; 0N: neutrally posted; nM: degrees medially posted; %BW*H: percentage bodyweight mulitplied by height*

3.4 Individual responses

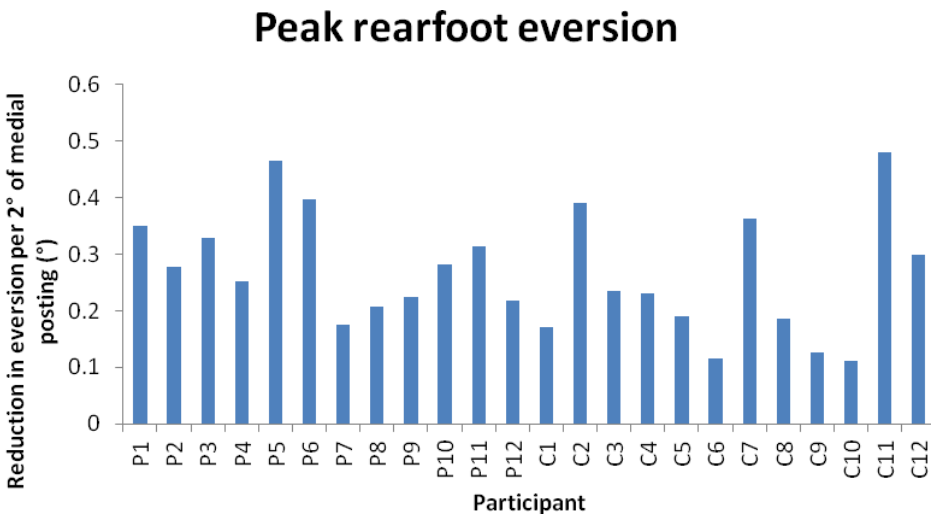

Figure S11 - Individual responses for peak rearfoot eversion. P: patient group; C: control group

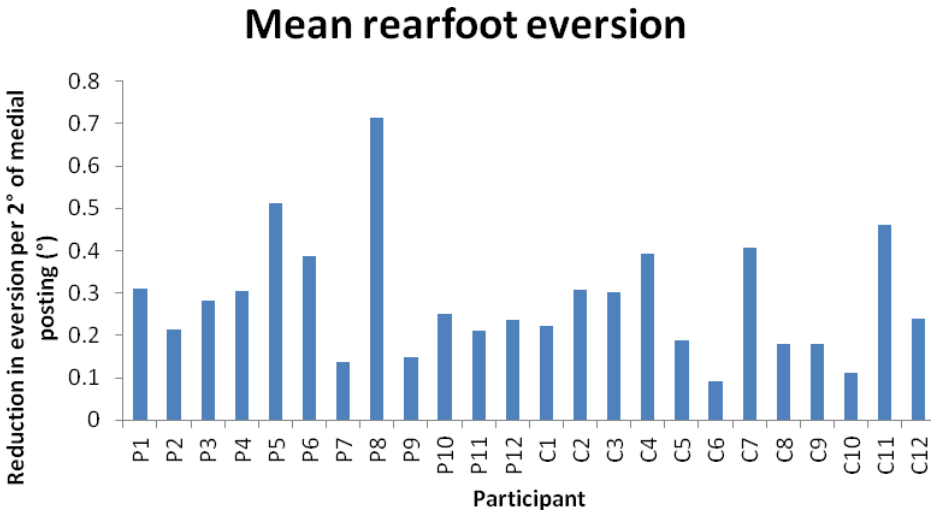

Figure S12 - Individual responses for mean rearfoot eversion. P: patient group; C: control group

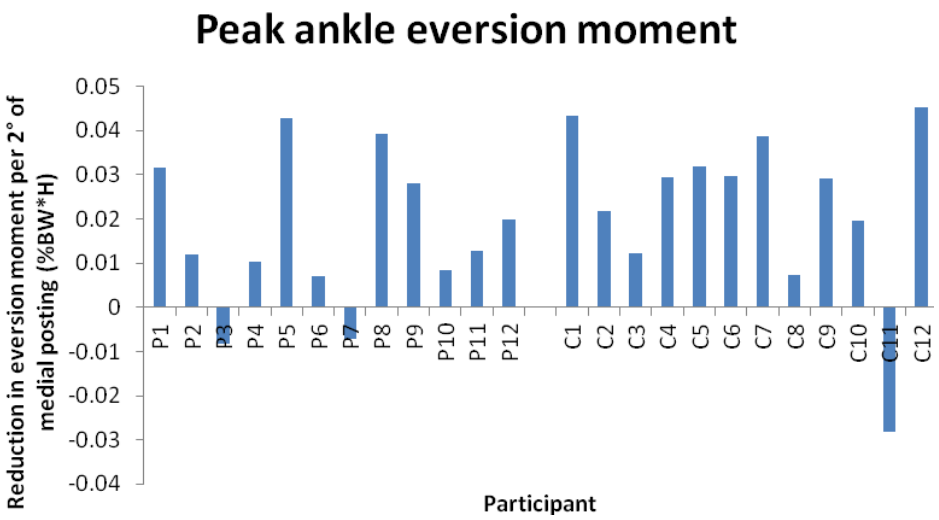

*Figure S13 – Individual responses for peak external ankle eversion moment. P: patient group; C: control group; %BW*H: percentage bodyweight multiplied by height*

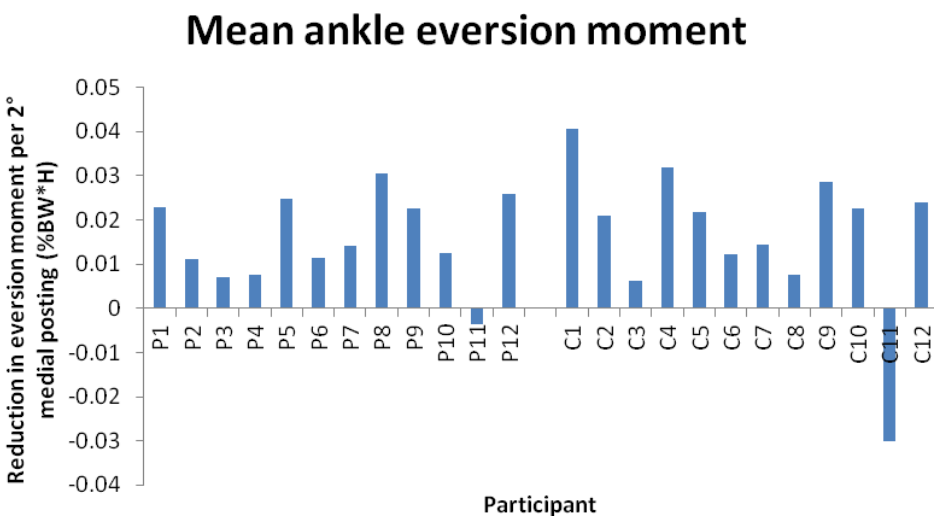

*Figure S14 – Individual responses for mean external ankle eversion moment. P: patient group; C: control group; %BW*H: percentage bodyweight multiplied by height*

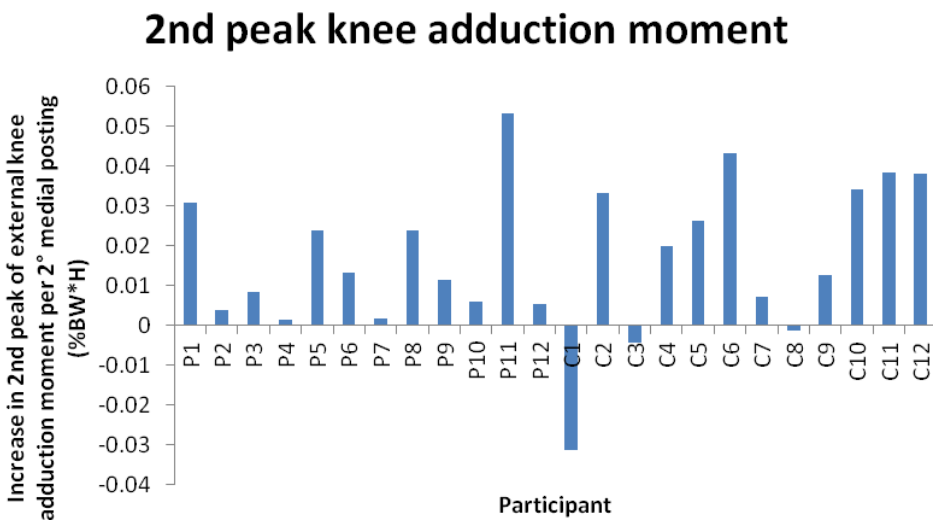

*Figure S15 – Individual responses for 2nd peak external knee eversion moment. P: patient group; C: control group; %BW*H: percentage bodyweight multiplied by height.*

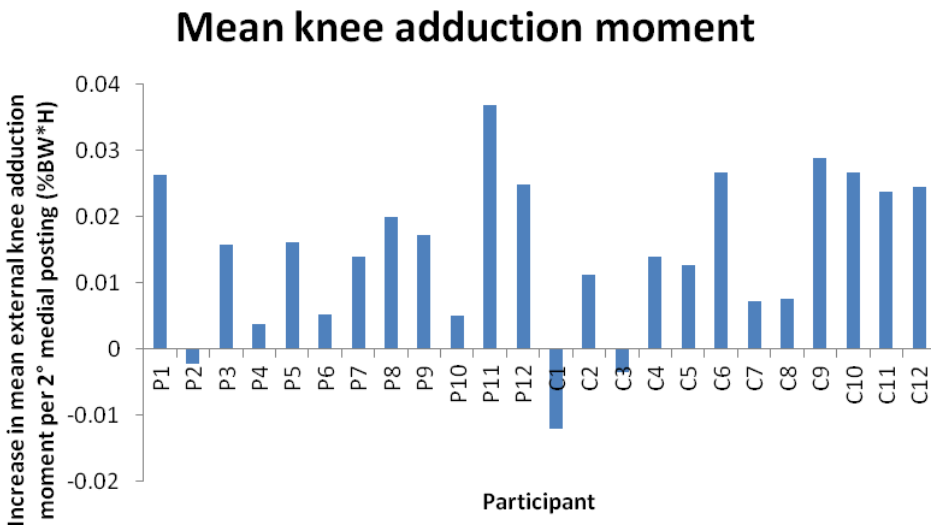

*Figure S16 – Individual responses for mean external ankle eversion moment. P: patient group; C: control group; %BW*H: percentage bodyweight multiplied by height*