THE CHANGES OF JOINTS KINEMATICS IN GAIT WITH ACTIVE SUPINATION OR PRONATION OF THE HINDFOOT – PRELIMINARY RESULTS

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SUMMARY
Thirty young healthy subjects completed trials of natural gait, gait in active supination (SG) of the hindfoot and in active pronation (PG). The 3D kinematics (Vicon) and dynamic plantography (Footscan) were used to analyse the gait. The mean curves of joint motion were calculated for each gait type in the following joints or segments - ankle (sagittal), knee (sagittal, frontal, transversal), hip (transversal) and pelvis (sagittal, frontal, transversal). Differences among the gait types were estimated by a sign test at level p<.05. These results fit in a model of coupling between the (hind)foot pronation and knee flexion plus valgosity or supination with extension plus varosity, respectively. The movements of the hip and pelvis are more complicated due to pronounced influence of the opposite leg and trunk motion.

INTRODUCTION
The coupling of leg joints during walking was discussed widely in the past. There are various opinions - from the “Root biomechanics” [1] to denial of it [2]. This dispute inspired us to test the effect of active (hind)foot supination or pronation on gait kinematics of the ankle, knee, hip and pelvis and to search for differences between natural and modified walking.

METHODS
Thirty healthy subjects (age 23.8±2.5 years) completed several trials of natural gait as well as, gait in active supination (SG) of the hindfoot and gait in pronation (PG). The 3D kinematics (Vicon, Oxford Instruments Group, UK) was used to analyse the gait and dynamic plantography (Footscan, RSscan, Belgium) was used to control the gait type and to state the standard elements of the gait cycle (GS). In our preliminary analysis we used one trial of each gait type in each participant to calculate mean kinematic curves in the following joints or segments: ankle (sagittal), knee (sagittal, frontal, transversal), hip (transversal) and pelvis (sagittal, frontal, transversal). Interpreting the curves, we used two reference systems: 1) the “functional”, where we described the knee movements relative to the “punctum, fixum” at the loaded foot and 2) the “anatomical” to describe the movement of the hip and pelvis. Using the “functional” reference system would be too complicated, because of side changes of “punctum fixum” during the gait cycle as well as double support phase, thus the reference system would differ during the gait cycle. The “anatomical” reference system seems to be more practical. Because the pelvis represents a “reference segment” in this system and movements of legs and trunk are described relative to it, we cannot describe the pelvis movement to any other segment but to the cardinal planes. Due to describing the gait cycle of only one leg/side we are taking the pelvis as one rigid segment, however there are torsion movements of the pelvis at the sacroiliacal joints as well as between the pubic bones in fact.
Differences between the standard events and (sub)phases of gait cycle were estimated by a sign test at level p<.05(*).

RESULTS AND DISCUSSION
<u>At the ankle in SG</u> the *plantar flexion* is reduced in comparison to NG at Heel Strike (HS)*, and FootFlat (FF)*, as well as during the initial part of Swing Phase (SwP), which means during the Acceleration (AC)*, and during the MidSwing (MSw)* but almost identical to NG during the MidStance (MSt)* and propulsion phase (PP)*. <u>At the ankle in PG</u> the *plantar flexion* is almost identical as in SG but moreover reduced after the Heel Off (HO)* in comparison to NG and SG. <u>At the knee in SG</u>, the *flexion* is reduced at FF* (Fig. 1) as well as during MSt*, PP* and AC*. Varosity (Fig. 2) is stressed at the HS*, FF*, MSt* and *valgosity* is reduced during PP* and AC* but almost identical to NG at MSw. The *external rotation* (Fig. 3) is stressed at FF* and PP*. <u>At the knee in PG</u>, the *flexion* (Fig. 1) is stressed at HS* and MSt* but reduced during AC*. The *valgosity* is stressed at HS*, FF* and MSt*, but not during PP (Fig. 2). The *internal rotation* is stressed at HS*, FF* and MSt*, at the start of SwP* and during MSw* (Fig. 3).

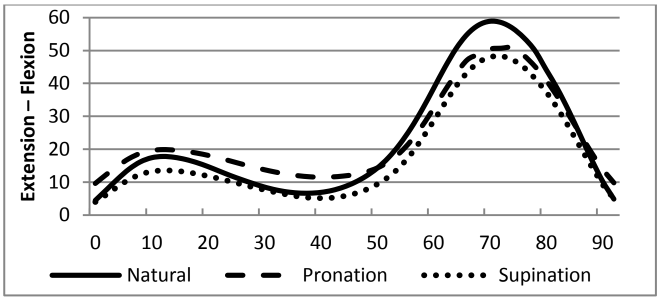

Figure 1 Knee Extension/Flexion

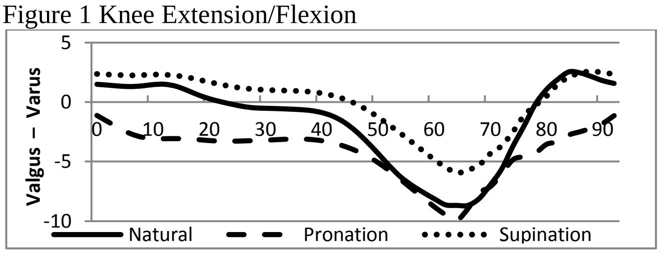

Figure 2 Knee Valgus/Varus

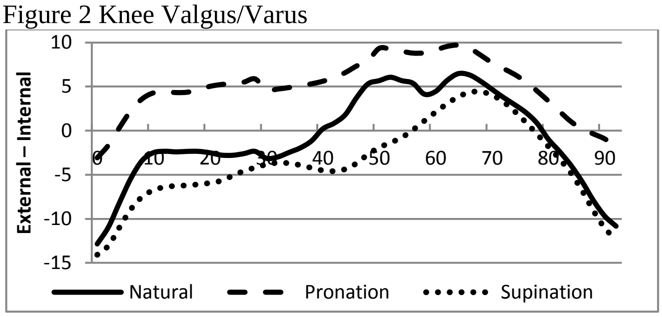

Figure 3 Knee Rotation

So we can see that the active foot supination is coupled with a shift to knee extension and the active foot pronation is coupled with a shift to knee flexion. This relative knee extension is coupled with relative varosity while relative knee flexion is coupled with relative valgosity. The growing valgosity is typical for the whole stance phase in all gait types, its relative reduction in active supination could be result of relative knee locking because of relative knee extension. Moreover the tibia internal rotation is reduced during the foot loading and delayed during the propulsion in the gait with active supination. There is stressed internal rotation of tibia during the foot loading and at the midstance in the gait with active pronation. It is all in agreement with "Root biomechanics" – the (hind)foot pronation is coupled with (relative) tibia internal rotation and (relative) knee flexion and the supination is coupled to (relative) tibia external rotation and relative knee extension, when the leg is working under load, which means in a closed chain. The differences between "artificial" and natural gait during the swing phase, which means in an open chain, are results of muscle synergy, but the central control must respect the (joint) anatomy as well as biomechanical principles.

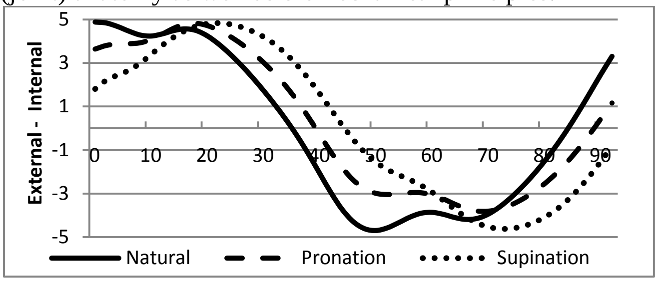

Figure 4 Pelvic rotation

The description of the hip and pelvic movement is more complicated due to a problematic choice of a relevant reference system (see Methods and due to the pronounced effect of contralateral leg. In the artificial gait types, the pelvis is shifted to the (relative) retroversion (in the sagittal plane) during the whole GS , more in SG. The smooth wave to retroversion during FF, which we see in NG, is absent and the pelvis passes to the first maximum of anteversion at MSt. In the frontal plain, the elevation during FF and rapid depression to MSt is shifted to the depression in the artificial gait types, more in SG again. In NG, another rapid depression follows during PP to the end of SP, but not so much in PG and even less in SG. The whole range of elevation/depression is reduced in PG and even in SG, the link to retroversion/anteversion is presumable. In NG, the ipsilateral half of the pelvis starts the gait cycle at maximal internal rotation (in the transversal plane) (Fig. 4), which means forward, because of leg reaching the HC far forward, the small smooth wave to relative external rotation (backward) at FF follows, likely as a result of contralateral propulsion. The next reversion to the initial forward rotation is followed by a rapid transition to backward rotation behind the frontal plane with its maximum during the initial part of PP. The small smooth wave to relative forward rotation comes during the ending of PP, likely because of contralateral TO and a loss of the contralateral leg support. In SG the ipsilateral pelvis is shifted to relative backward rotation at HS* and the pelvis passes to the forward rotation, the backward wave during FF is absent, reaching the maximum at almost the same value as in NG, but with some small delay, so the following rapid pass to the backward rotation is delayed too and has only one maximum during AC. In PG, the pelvis starts at HS with the relative backward rotation too, but less than in SG, and passes to the maximal forward rotation like SG, but less delayed, a following rapid pass to the backward rotation has its first minimum during the initial part of PP, but not so strong like in NG*, and reaches its highest backward rotation during AC, together with the second maximum in NG. The hip in NG starts with the external rotation (according to the pelvis) during FF and pass to the internal rotation follows with its maximum during PP (Fig. 5) Movements in artificial gait are identical with NG but shifted to the external rotation in PG* as well as in SG*.

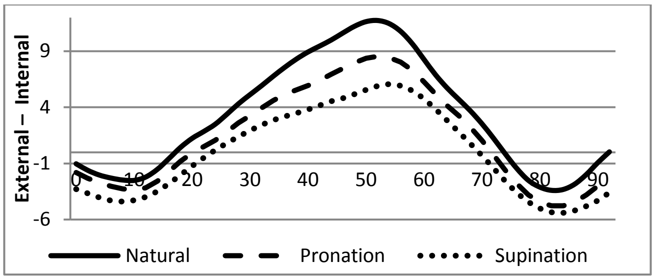

Figure 5 Hip Rotation

CONCLUSIONS

These results fit in a "Root model" of coupling between the (hind)foot pronation and knee flexion plus valgosity or supination with extension plus varosity, respectively.

The movements of the hip and pelvis are more contralateral complicated due to pronounced effect of the opposite leg and trunk rotation. We plan to continue this work will continue, because we must take in count the rest of the recorded trials data and accomplish detailed statistical testing as well as the analysis of curves of joint movements.

ACKNOWLEDGEMENTS

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