Restricting Ankle Dorsiflexion in Orthoses to Improve Gait Symmetry in Patients with Inactive Forefoot Lever due to Weak Plantar Flexors

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Background and Aim

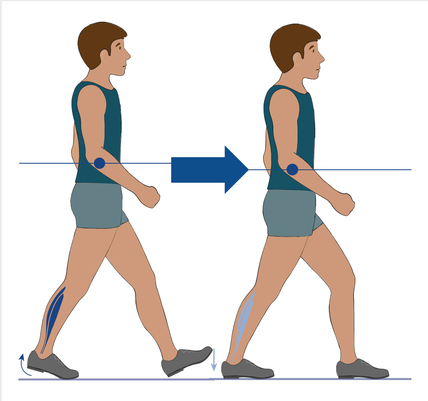

Fig. 1: effect of weak plantar flexors on gait parameters in terminal stance

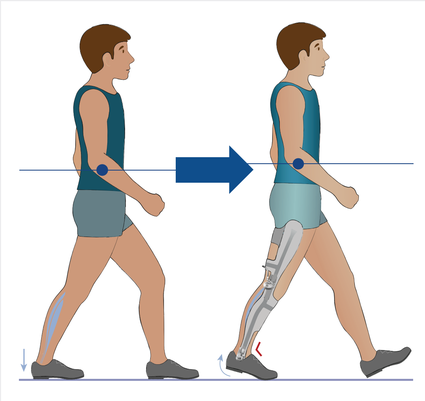

Fig. 2: intended effect of restricting ankle dorsiflexion in terminal stance

Patients with neurological disorders develop plantar flexor weakness which leads to different gait impairments [1]. Papers report on a positive effect of orthoses with dorsiflexion stop (DS) concerning most gait parameters [2]. However, data comparing orthoses with and without DS is still missing.

Research question: Does restricting dorsiflexion improve gait symmetry when comparing orthoses with and without DS?

Materials and Methods

Fig. 3: patient examination: 20° hyperextension; muscle strength: hip flex/ext 5, knee flex/ext 1, ankle dors 2/plant 1

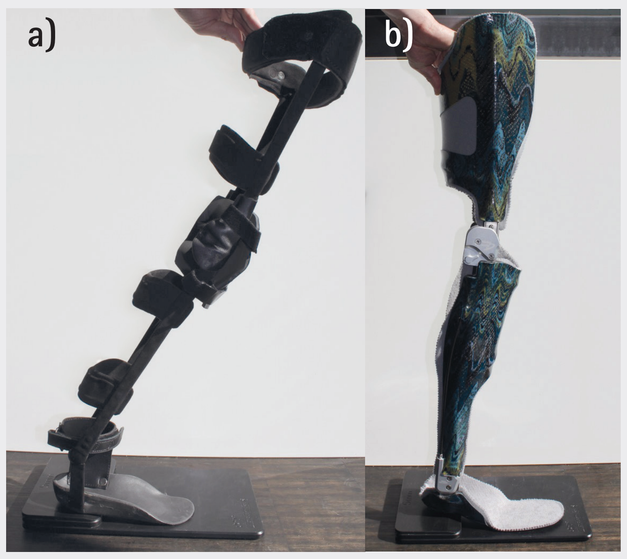

Fig. 4: a) old KAFO with 30° shank to vertical angle (SVA) (KAFO_30) and b) new KAFO with 5° SVA (KAFO_05)

Patient: male (180cm, 81kg), post-polio syndrome (weak plantar flexors/quadriceps), knee hyperextension [3]; old KAFO: no defined DS, new KAFO: DS at 5° SVA [4]

Measurement: 2D gait analysis; 3 conditions: w/o KAFO, KAFO_30, KAFO_05, 3 full gait cycles each; evaluation of knee/ankle kinematics and timing of gait events

Results

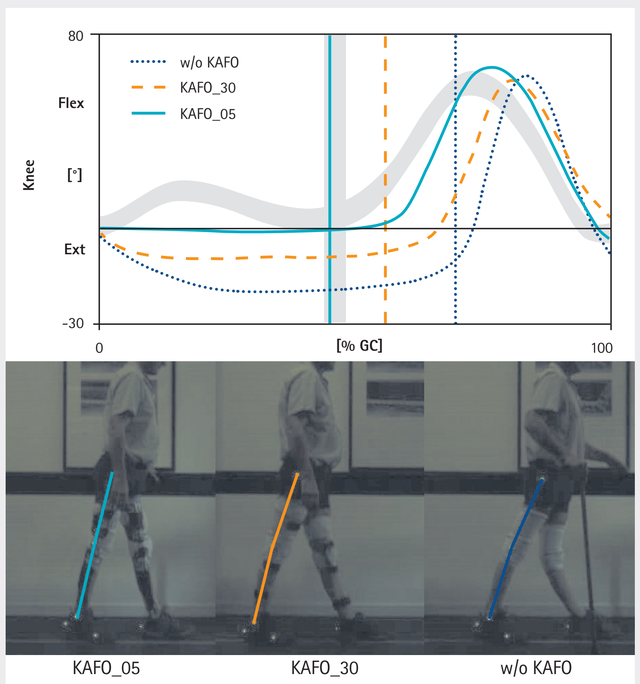

Fig. 5: Knee joint kinematics with KAFO_05 (turquoise), with KAFO_30 (orange) and w/o KAFO (blue) compared to a physiological reference group (gray band).

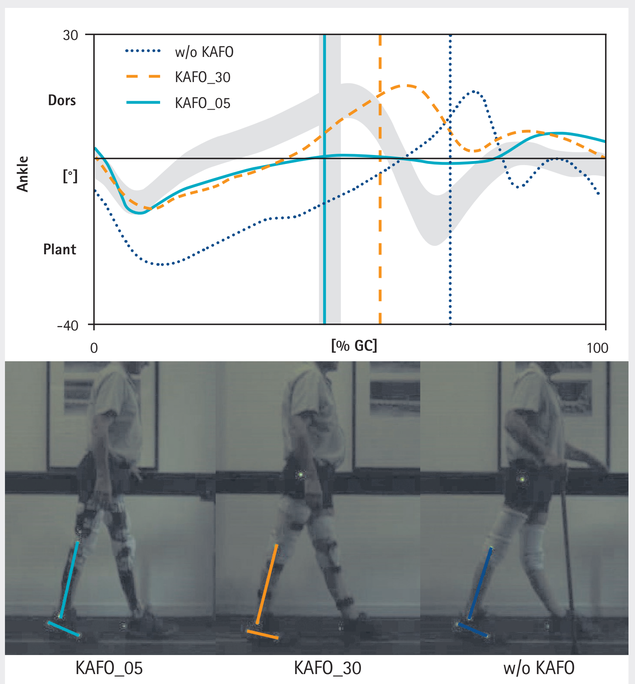

Fig. 6: Ankle joint kinematics with KAFO_05 (turquoise), with KAFO_30 (orange) and w/o KAFO (blue) compared to a physiological reference group (gray band).

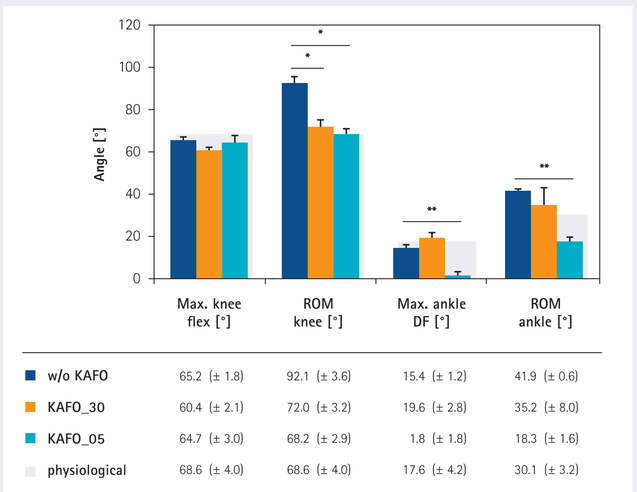

Fig. 7: Significant differences (p=0.05) between w/o KAFO and both KAFOs (ROM knee). Significant differences (p=0.001) between w/o KAFO and KAFO_05 (max. ankle DF; ROM ankle).

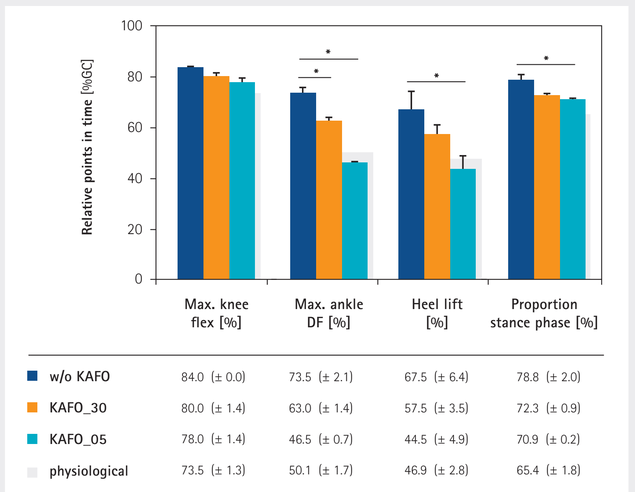

Fig. 8: Significant differences (p=0.05) between w/o KAFO and both KAFO conditions (timing of max. ankle DF) and between w/o KAFO and KAFO_05 (heel lift; proportion stance phase).

Sagittal plane kinematics of knee [5] and ankle [6] are shown in the graphs. Knee (23.9°) and ankle ROM are significantly reduced with KAFO_05 (13.6°) as well as max. ankle dorsiflexion (23.6°) [7]. Max. dorsiflexion occurs at 73.5% (w/o KAFO), 63.0% (KAFO_30) and 46.5% (KAFO_05) of GC. As shown by vertical lines in both graphs, heel lift is at 67.5% (w/o KAFO), 57.5% (KAFO_30) and 44.5% (KAFO_05) of GC. Proportion of stance phase with KAFO_05 (70.9%) is reduced compared to conditions w/o KAFO (78.8%) and KAFO_30 (72.3%) [8].

Discussion and Conclusion

Due to the weak quadriceps the patient compensates missing plantar flexion strength with excessive knee extension. Restricting dorsiflexion in the KAFO_05 activates the forefoot lever whereas w/o KAFO and KAFO_30 the forefoot lever remains inactive in terminal stance. Thus, stance is prolonged and the heel remains on the floor [9]. An active forefoot lever reduces ankle ROM, which a) prevents excessive dorsiflexion and b) enables physiological heel lift [10]. If the heel lifts in time, the proportion of stance phase is reduced which leads to improved gait symmetry. Results show that orthoses for patients with weak plantar flexors should provide a DS to restore gait symmetry.

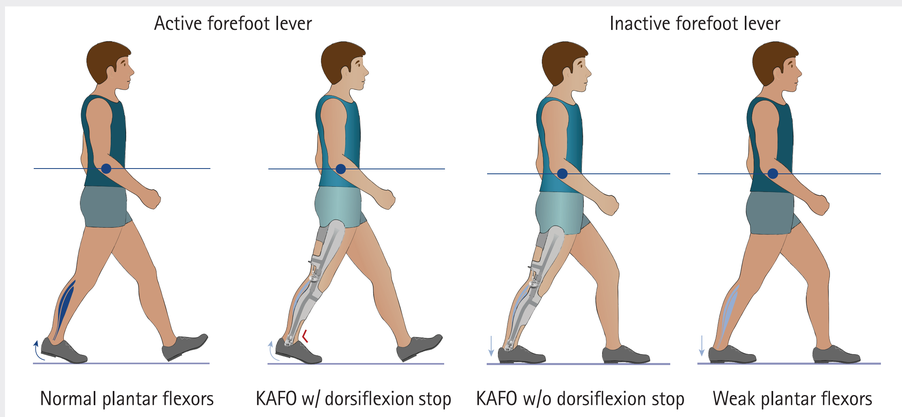

Fig. 9 (top): Optimal ipsilateral heel lift, position of centre of gravity and contralateral knee flexion with active forefoot lever (normal plantar flexors or KAFO w/ DS) interminal stance. Inactive forefoot lever (weak plantar flexors or KAFO w/o DS) shows delayed ipsilateral heel lift, a lower centre of gravity and an increased contralateral knee flexion in terminal stance.

Fig. 10 (right): A patients with typical muscular impairments due to weak plantar flexors wearing a KAFO without DS (left leg). The gait characteristics of an inactive forefoot lever can be seen.

Keywords: orthotics, plantar flexor weakness, dorsiflexion stop, gait analysis, gait symmetry

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Literature
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