Short Commentary

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Prosthetics and Orthotics Open Journal

2016
Vol.1 No.1:2

Effect of Knee-Ankle-Foot Orthosis (KAFO) on Knee Kinematics and Kinetics in an Individual with Knee Varus Alignment

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Rec date: November 08, 2016; **Acc date:** November 26, 2016; **Pub date:** November 30, 2016

Citation: Huda Hamdan AL-Fatafta (2016) Effect of Knee-Ankle-Foot orthosis (KAFO) on knee kinematics and kinetics in an individual with knee varus alignment. Pro Ort Open J 1: 2.

Short Commentary

The medial compartment knee osteo arthritis (OA) is the most affected location for OA [1]. The main knee biomechanics changes which are associated with the medial compartment knee OA are less knee flexion value [2-4] (the normal mean maximum knee flexion has been shown to be 64.6° during walking, 98.6° during ascending, and 90.3 °during descending) [5], high knee varus angle and an increased the external knee adduction moment (EKAM) during walking and stairs climbing due to shifting the knee joint centre more laterally and the centre of the load medially [6]. These changes lead to pain during daily activities and progression of the knee OA [7,8]. The EKAM is considered as the most important variable in the frontal plan and has two peaks: The first peak is a sharp one after initial contact during early stance phase, while the second one is in the late stance phase. The first peak is affected by the amount of knee varus, joint space narrowing, OA severity, and progression level, while the second one is more correlated to the amount of toe out and pain levels [9].

Various of orthotics treatments have been used to reduce the EKAM and knee varus degree and to increase knee flexion degree. The custom made and off the shelf (OTS) knee valgus braces are one of current orthotics treatments. However, some investigations have found no significant reductions in the EKAM during walking [10-12] or during stair climbing [12] especially with severe knee varus degree. In addition, walking with knee flexion reduction during swing phase has been found [13].

A custom made knee ankle foot orthosis (KAFO) with three point pressure correction was one of a suggested alternative treatment to reduce the EKAM and increase knee flexion value during walking and stairs climbing for severe knee varus participants. The KAFO design includes: a single upright, the Ottobock knee joint (17lk1=L/R1-5), with a 5° knee flexion stop, also with a simple hinged ankle joint to allow free movement and manufactured in 4.5 mm copolymer polypropylene **(Figure 1)**.

One male individual with a 10° knee varus deformity (aged 45, mass 85 kg, height 1.68 m) participated in this study without any previous knee injuries. The data were collected in the gait laboratory using 16 infra red Qualisys OQUS cameras, (Qualisys AB, Gothenburg, Sweden), and 2 embedded AMTI force plates in a walkway (AMTI: Advanced Mechanical Technology Incorporation, Watertown, USA, model-BP600400).

The result shows that the KAFO significantly reduced the knee varus angle compared to the shoe and both knee valgus braces during walking and stair climbing with decreases of up to 12 degrees. Moreover, the KAFO reduced the first peak of the EKAM by a greater margin than either of the knee valgus braces (11.4%, 15%, and 12.6% compared to the shoe, OTS and custom knee valgus braces, respectively) during walking. The KAFO increased the knee flexion angle at initial contact (IC) significantly compared to the shoe and OTS during walking (mean difference 8.6, 4.1degrees respectively). However, no significant changes were seen during stair climbing, and this could be due to a high knee varus angle which was seen (up to 30 degree) and the interventions cannot reduce it efficiently **(Tables 1 and 2)**.

The efficiency of a KAFO in reducing a knee varus angle is mainly related to the offset joint which was used to correct knee deformity in the frontal plane (knee valgus/varus), with the length of the KAFO applying more force over a more extensive tissue area than knee valgus braces. This meant that it would theoretically be able to correct the deformity more effectively by shift the ground reaction force (GRF) more laterally and the knee joint centre more medially, thereby reducing the EKAM.

Moreover, the KAFO has a more intimate and extensive fit on the lower limb than that provided by an OTS device which is able to keep the tibia and foot in a corrected position via an ankle foot orthosis (AFO) section. This would encourage a reduction in knee varus deformity, prevent hyperextension, and potentially improve knee flexion by shifting the bodies load anterior to the hip and posterior to the knee joint [14].

Additional work will be needed to further evaluate the clinical and biomechanical benefits of a KAFO in a larger number of subjects with different severities of uni-compartmental knee OA. Also, evaluate the long term using benefits is required.

Figure 1: The KAFO design.

Table 1: Mean and standard deviation and p value of the knee adduction moment and knee flexion and extension moment among different conditions. Bold result shows significant result run with (ANOVA) with a post-hoc bonferroni correction. Wa: walking, As: ascending, De: descending. Bold indicates significance.

Variables	Mean ± SD				P value					
EKAM first Peak		Shoe	OTS	Custom	KAFO	Shoe vs. OTS	Shoe vs. Custom	Shoe vs. KAFO	KAFO vs. Custom	KAFO vs. OTS	Custom vs. OTS
	Wa	0.70 ± 0.01	0.71 ± 0.01	0.73 ± 0.02	0.62 ± 0.0	1.0	1.0	**0.04**	0.07	0.07	1.0
	As	0.85 ± 0.3	0.79 ± 0.4	0.78 ± 0.02	0.79 ± 0.05	1.0	1.0	1.0	1.0	1.0	1.0
	De	0.81 ± 0.1	0.90 ± 0.2	0.97 ± 0.6	0.81 ± 0.4	0.17	0.38	1.0	0.86	0.46	1.0
EKAM second peak	Wa	0.65 ± 0.01	0.63 ± 0.02	0.65 ± 0.01	0.57 ± 0.01	1.0	1.0	0.09	**0.00**	0.07	1.0
	As	0.46 ± 0.01	0.48 ± 0.02	0.45 ± 0.02	0.41 ± 0.02	1.0	1.0	0.78	0.05	0.17	1.0
	De	0.75 ± 0.02	0.75 ± 0.01	0.77 ± 0.02	0.74 ± 0.01	1.0	1.0	1.0	1.0	1.00	1.0
Knee flexion moment	Wa	0.48 ± 0.4	0.55 ± 0.03	0.58 ± 0.02	0.70 ± 0.04	1.00	0.27	0.33	0.60	0.42	1.00
	As	0.80 ± 0.5	0.82 ± 0.02	0.78 ± 0.03	0.82 ± 0.03	1.00	1.00	1.00	1.00	1.00	1.00
	De	1.00 ± 0.03	0.98 ± 0.02	0.98 ± 0.02	1.03 ± 0.03	1.00	1.00	1.00	1.00	1.00	1.00

Table 2: Mean and standard deviation (SD) of knee angle in sagittal and frontal planes among conditions. Bold results show significant result according to (ANOVA) was run with 4 factors (shoe, off-the-shelf (OTS), custom knee brace, and KAFO) with a post-hoc bonferroni correction. Wa: walking, As: ascending, De: descending. IC: initial contact.

Variables	Mean ± SD				P value (CI 95%)					
Knee flexion at IC		Shoe	OTS	Custom	KAFO	Shoe vs. OTS	Shoe vs. Custom	Shoe vs. KAFO	KAFO vs. Custom	KAFO vs. OTS	Custom vs. OTS
	Wa	2.5 ± 0.6	7.0 ± 0.5	7.8 ± 0.6	11.1 ± 0.6	**0.03**	**0.02**	**0.00**	0.28	**0.03**	1.0
	As	66.8 ± 1.1	65.2 ± 0.7	67.2 ± 0.9	67.3 ± 0.6	1.0	1.0	1.0	1.00	0.36	1.0
	De	14.7 ± 0.4	19.9 ± 0.4	17.9 ± 0.5	15.6 ± 0.8	**0.01**	0.10	1.00	0.31	0.01	**0.00**
Knee flexion at mid swing	Wa	74.1 ± 0.2	70.5 ± 3.2	72.3 ± 1.3	72.4 ± 0.4	1.0	1.0	0.31	1.0	1.0	1.0
	As	107.0 ± 0.8	103.1 ± 0.8	100.3 ± 1.5	101.5 ± 1.7	**0.01**	0.24	0.05	1.0	1.0	1.0
	De	105.9 ± 1.4	104.3 ± 1.2	102.9 ± 1.2	98.8 ± 0.8	1.0	1.0	0.15	0.05	0.22	1.0
Maximum knee	Wa	17.4 ± 0.4	11.9 ± 0.3	12.2 ± 0.1	9.20 ± 0.2	**0.00**	**0.00**	**0.00**	**0.00**	**0.04**	1.0

adduction angle	**As**	30.3 ± 0.6	30.5 ± 0.3	33.5 ± 0.3	18.3 ± 0.1	1.0	**0.08**	**0.00**	**0.00**	**0.00**	**0.00**
	De	21.4 ± 0.5	19.9 ± 0.4	22.2 ± 0.4	15.4 ± 0.3	**0.03**	1.0	**0.00**	**0.00**	**0.01**	0.10

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