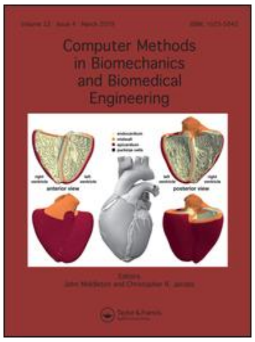

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Effects of foot progression angle on knee biomechanics during gait modification

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KEYWORDS Knee flexion angle; knee adduction moment; knee flexion moment; foot progression angle; gait retraining

1. Introduction

Knee osteoarthritis (OA) is a serious health concern, requiring novel therapeutic options. Walking mechanics has long been identified as an important factor in the OA process (Childs et al. 2004; Russell et al. 2010; Ogrodzka et al. 2011). Specially, a larger peak Knee Adduction Moment (KAM) during the first half of stance has been associated with the progression of medial knee OA (Lynn & Costigan 2008; Shull et al. 2013; Favre et al. 2016). Consequently, various gait interventions have been designed to reduce the KAM, including walking with a decreased Foot Progression Angle (FPA). Other gait variables have recently been associated with medial knee OA progression, particularly a larger peak Knee Flexion Moment (KFM) during stance and a larger Knee Flexion Angle (KFA) at heel-strike (van den Noort et al. 2013; Simic et al. 2013; Favre et al. 2016). Currently, there is a paucity of data regarding the effect of reducing the FPA on the KFM and the KFA.

This study aims to test the correlations between the FPA and the KAM, the KFM and the KFA. It is hypothesized that reducing the FPA is beneficial with respect to these three OA-related gait variables.

2. Methods

Seven healthy subjects participated in this study after providing informed consent (4 males; 24 ± 5 years old; 21.9 ± 1.5 kg.m^{-2}). Their walking mechanics was determined using a validated procedure based on a camera-based system (Vicon) and floor-mounted forceplates (Kistler) (Figure 1(a)). Participants were first asked to walk without instructions and these initial trials were used to determine their normal footstep characteristics. Then, footsteps with the same characteristics as during the normal trials, except for the FPA, were displayed on the floor and participants were requested to walk following these footsteps. Nine trials with visual instructions were collected for each participant, corresponding to FPA modifications in the range ± 20° compared to the normal FPA, with a 5° increment (Figure 1(b)). For each participant, the associations between the FPA and the knee biomechanics (KAM, KFM and KFA) were assessed using Pearson correlations based on data from the 9 trials with FPA variations. A significant level was set a priori to 5%.

3. Results and discussion

Significant relationships were noted between the FPA and the peak KAM for 5 out of 7 subjects ($p < 0.03$), with R^2 comprised between 0.65 and 0.93. Four participants also reported significant correlations between the FPA and the KFA ($0.48 < R^2 < 0.77$). For the KFM, significant relationships were noticed with the FPA for 2 out of 7 subjects ($p < 0.05$), with inconsistent R^2 (0.47 and 0.61, Table 1).

In this study, it is confirmed that the toe-in of the FPA induces the reduction of the KAM (Figure 2). However, this toe-in of the FPA is responsible for increasing the KFA (Figure 2). In this case, the variation in the toe-in with the KFA should be monitored because increasing the KFA is associated with the OA progression. Still, we notice no or inconsistent FPA- toe-in effect on the KFM (Figure 2).

The results vary among subjects suggesting that individualized modifications should be considered. Consequently, there is no need to be tested on a larger cohort.

4. Conclusions

The KAM, the KFM and the KFA are considered indicators of knee osteoarthritis progression. In this study, a foot progression angle modification (toe-in, normal, toe-out)

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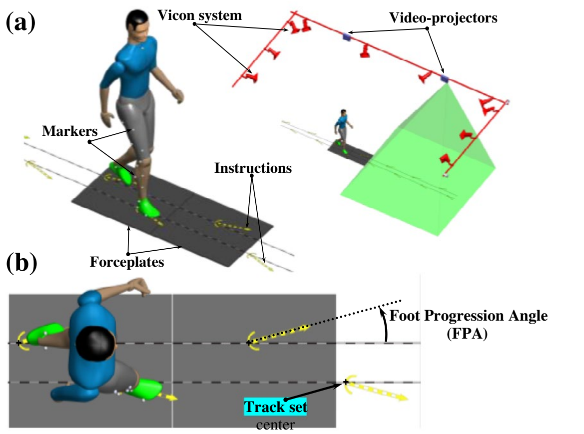

Figure 1. (a) Illustration of augmented-reality gait retraining system. (b) Illustration of FPA variable.

Table 1. Linear regressions for the First KFA peak, the first KAM peak and the First KFM peak.

	First KFA peak		First KAM peak		First KFM peak	
	FPA	Accuracy	FPA	Accuracy	FPA	Accuracy
Subject	Coef (°/ °)	(R^2)	Coef (%BW*Ht/°)	(R^2)	Coef (%BW*Ht/°)	(R^2)
1	**−0.130*** **	**0.77**	**0.035*** **	**0.82**	−0.001	0.00
2	**−0.107***	**0.55**	**0.040*** *	**0.65**	0.053	0.43
3	−0.220	0.27	0.003	0.06	**−0.051***	**0.47**
4	**−0.055***	**0.48**	0.005	0.08	**0.044***	**0.61**
5	0.039	0.03	**0.041*** **	**0.71**	0.057	0.29
6	0.090	0.36	**0.020***	**0.56**	0.048	0.39
7	**−0.170*** *	**0.70**	**0.050*** **	**0.93**	0.029	0.32
Average	−0.079	0.45	0.028	0.54	0.026	0.36

*$p < 0.0$; **$p < 0.01$; ***$p < 0.005$.

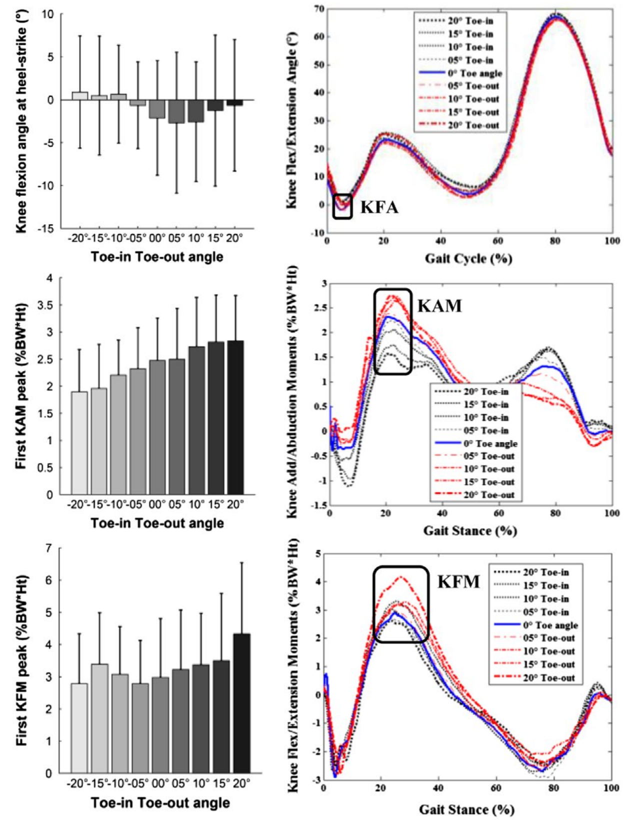

Figure 2. Mean ± standard deviation of the first KFA peak (1st row), first KAM peak (2nd row), and first KFM peak (3rd row) variables divided according to the levels of the instructions of modify gait (foot progression angle).

during gait was altered the characteristics of the KAM. A reduction in the overall magnitude has been found with the toe-in of the FPA during gait modification. An increased KFA has been also found during the toe-in gait, which causes undesirable effects on the OA progression. This finding is novel, indicating that the toe-in of FPA should be controlled during gait modification not to increase KFA and not to vary other parameters in relationship with the OA.

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