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Gait retraining to reduce the knee adduction moment: one strategy fits all?

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SUMMARY

The external knee adduction moment (EKAM) during gait has been associated with the development and progression of knee OA and therefore been the target for several gait retraining protocols. The current study aims to determine which gait retraining strategy is the most successful and if this strategy is the same for all individuals. Medial Thrust reduced the EKAM significantly and also decreases the knee adduction impulse, in contrast to Trunk Lean, Toe Out and Reduced Vertical Acceleration. Interestingly Medial Thrust was only the most successful strategy in 49% of the individuals, suggesting that an individual approach would be more successful.

INTRODUCTION

Several studies have shown that a high EKAM during gait is closely related to the development and progression of knee OA [1-3] as the EKAM represents the compressive forces acting on the medial compartment of the knee [3,4].
Gait retraining strategies that vertically align the centre of mass and the knee joint centre in the frontal plane, such as leaning the trunk in the direction of the stance leg ('trunk lean') and medialising the knee during the stance phase ('medial thrust'), seem to reduce the EKAM up to approximately 50-65% for first peak EKAM [5,6]. Other types of gait retraining have also shown to be effective: increasing the toe out angle by 20° decreased the first EKAM peak up to 55.2% [7].
There are currently no comparisons of multiple gait retraining strategies within a group of participants that provide adequate insight in the potentially individual specific nature of the effects of gait retraining on the EKAM. A first attempt to apply individualized gait retraining was made [8, 9], though it is still unclear to which extent individualisation is preferred in practise when compared to conventional non-individualized application of gait retraining.
The purpose of this study is to determine which gait retraining strategy (medial thrust, trunk lean, toe out and reduced vertical acceleration) reduces the EKAM through verbal instructions most effectively during gait. Secondly, this study will explore the individual specific effects of these gait retraining strategies on the EKAM.

METHODS

Thirty-seven volunteers were recruited from the university staff. Exclusion criteria consisted of current injuries at the lower extremities or a history of injuries that interfered with normal gait. The study protocol was approved by the ethical committee of the UMC Utrecht.
Kinematics of the right leg and trunk were measured using a wireless active 3D-system (Charnwood Dynamics Ltd., Codamotion CX 1). Ground reaction force was measured during one step per trial with a recessed force plate (Advanced Mechanical Technology, Inc., OR 6-7). A static measurement was captured with the participant standing still with both feet on the force plate. First, five trials of normal walking at self-selected speed were captured. Thereafter, five trials of the four gait retraining conditions were recorded. Each condition was preceded by instructions and a visual example by one investigator:

- *Trunk Lean*: 'Lean right with the torso as the right foot has floor contact.'
- *Medial Thrust*: 'Move the right knee inwards/ medial during right legged stance.'
- *Reduced Vertical Acceleration*: 'Induce a fluent, silent walking style. Push off harder with the trailing leg as you land with the leading leg.'
- *Toe Out*: 'Rotate your feet more outward than you normally would.'

A practise period of 5 minutes was allowed, accompanied by verbal feedback of the investigator. The four gait retraining conditions were presented in a randomized order with sufficient rest between conditions.

All trials were converted to C3D-format before analysis took place using Visual3D (C-Motion Inc.). Forceplate data and kinematic data were interpolated with a 3rd order polynomial and filtered with a Butterworth filter with a cut-off frequency of 6Hz and 20Hz, respectively. The segments and joint axes as defined in the kinematic model were applied to all trials. EKAM was calculated through inverse dynamics in which the knee centre served as the shank-fixed axes' origin. EKAM peak was defined as the highest knee adduction moment in the stance phase. EKAM impulse was calculated through integration of the EKAM over stance time.

Statistical data analysis was done in SPSS for Windows (version 17). A factorial ANOVA with Bonferroni post hoc test and walking speed as covariate was used for comparisons between the conditions to study the effects of the instructions on kinematics, EKAM and EKAM impulse.

RESULTS AND DISCUSSION

Table 1 represents the absolute value and standard deviation of EKAM peak and impulse per condition. As walking speed correlated was significantly different between normal walking and the four gait retraining conditions, the comparison with Normal is also shown with adjustment for walking speed (p*speed). A decrease of the peak EKAM was found for Reduced Vertical Acceleration, Medial Thrust and Trunk Lean. However, only Medial Thrust was significantly decreased after adjustment for walking speed. EKAM impulse was decreased by Medial Thrust, Toe Out and Trunk Lean (see Table 1). Only Medial Thrust remained significantly decreased after adjustment for walking speed (p=0.05). This shows that Medial Thrust not only reduces peak load, but also decreases the load on the knee throughout the entire stance phase, in contrast to Trunk Lean, Toe Out and Reduced Vertical Acceleration. These findings suggest that strategies in which the knee center is vertically aligned with the body center of mass in the frontal plane have a high potential to successfully reduce knee load during gait.

Frequency scores show that for 49% (n=18) of participants EKAM peak was decreased most by Medial Thrust. In 43% (n=16) by Trunk Lean, 5% (n=2) by Reduced Vertical Acceleration and 3% (n=1) by the Toe Out condition. EKAM impulse was decreased most as a result of Trunk Lean in 49% (n=18), in 46% by Medial Thrust and 5% (n=2) by the Toe Out condition. This suggests that gait retraining strategies should ideally be selected on an individual basis. Future research is needed to examine the effect of these strategies in OA patients and to establish what parameters are able to predict which strategy is suitable for which individual.

CONCLUSIONS

Although the medial thrust strategy is the most successful gait retraining strategy to reduce the medial knee joint loading, the current research shows that in more than half of the participants another strategy would be more beneficial.

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Table 1: Mean and standard deviation of the peak external knee adduction moment and impulse for all five walking conditions.

Condition	Peak				Impulse			
	Nm	SD	p	p*speed	Nm·s	SD	p	p*speed
Normal	-32.67	9.66	-	-	-10.46	3.90	-	-
RVA	-28.34	9.69	.000	.919	-10.94	5.08	.558	.152
MT	-23.65	8.95	.020	.039	-5.89	5.18	.042	.050
TO	-33.24	10.92	.174	.082	-9.18	4.16	.020	.731
TL	-22.63	10.73	.001	.077	-6.27	4.84	.000	.766

RVA = reduced vertical acceleration, MT = medial thrust, TO = toe out, TL = trunk lean. p values are comparison to the Normal walking condition (unadjusted model), p*speed is the p-value for the adjusted model (speed as covariate).

Table 2: Overview of changes in ground reaction force and kinematic parameters for the four gait retraining conditions.

Condition	1st peak vGRF		Adduction angle		Toe out angle		Trunk angle	
	N	SD	deg.	SD	deg.	SD	deg.	SD
RVA	-119.6*	160.0	0.09	1.98	-0.19	1.18	0.57*	1.60
MT	-86.6*	164.3	-0.97*	1.84	-0.95*	2.20	1.5*	1.97
TO	-35.0*	83.7	1.28*	1.60	-1.52*	1.07	0.87*	1.36
TL	-23.4	72.7	-0.23	1.42	-0.23	2.59	11.34*	5.38

vGRF = vertical component of the ground reaction force, RVA = reduced vertical acceleration, MT = medial thrust, TO = toe out, TL = trunk lean, * = change compared to Normal is significant (p<0.05).