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Changes in In Vivo Knee Contact Forces through Gait Modification

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CHANGES IN *IN VIVO* KNEE CONTACT FORCE THROUGH GAIT MODIFICATION

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INTRODUCTION

Gait modification represents a non-invasive method for reducing knee joint loading in patients with knee osteoarthritis. Previous studies have shown that a variety of gait modifications are effective in reducing the external knee adduction moment [e.g., 1-3]. The external knee adduction moment is often used as a surrogate measure of medial compartment force. However, a recent study showed that reductions in the external knee adduction moment do not guarantee reductions in medial compartment loads [4]. Therefore, direct measurement of changes in knee contact force is important for determining the effectiveness of gait modifications. A previous study found that medial thrust gait and walking with hiking poles reduced contact force in a patient with a force-measuring knee replacement [5]. The purpose of this study was to investigate the effects of additional gait modifications (mild crouch, moderate crouch, forefoot strike and bouncy gait) and four configurations of hiking poles on medial and lateral contact forces measured by a force-measuring knee replacement.

METHODS

Experimental data were collected from one patient implanted with a force-measuring knee replacement (male, right knee, age: 88 years, mass: 64.8 kg) [6]. Institutional review board approval and informed consent were obtained prior to testing. Internal knee contact force data were recorded from a custom force-measuring implant [7] and external ground reaction force data were recorded from three force plates (Bertec Corp., Columbus, OH). Data were simultaneously collected while the patient performed five trials of ten different overground gait patterns: normal, mild crouch, moderate crouch, medial thrust, forefoot strike, bouncy, and four hiking pole configurations (combinations of short and long poles with normal and wide pole placement). The patient was given verbal instruction and allowed time to learn each gait modification.

Medial and lateral contact force data were calculated from the implant's force transducer data using a previously validated regression equation developed for the patient's implant [8]. Medial and lateral contact force at 25%, 50%, and 75% of stance phase, and the average value over all of stance phase (0-100%) were averaged across 10 stance phases for each gait modification. Changes in contact force for the modified gaits relative to normal gait were determined by a Kruskal-Wallis test. When significant ($p < 0.05$) differences were found in the Kruskal-Wallis test, pairwise comparisons using a Tukey's Honestly Significant Difference correction were performed.

RESULTS AND DISCUSSION

Walking with hiking poles was the most effective gait modification for reducing *in vivo* contact force, consistent with a previous study [5]. Medial and lateral contact forces were significantly reduced at 50% and 75% of stance phase and over all of stance phase (0-100%) for walking with hiking poles (Table 1). Walking with long hiking poles and wide pole placement was the most effective configuration for reducing contact forces (Table 1). Walking with hiking poles has been suggested to reduce knee contact force by transferring some of the vertical ground reaction force through the hiking pole [5] and by reducing the external knee adduction moment [4]. Post-hoc statistical testing showed that the vertical ground reaction force was significantly reduced compared to normal gait at 75% of stance phase for walking with long hiking poles and normal and wide pole placement and short hiking poles with wide pole placement. Thus, these results suggest that walking with hiking poles is effective in offloading the knee joint by reducing medial and lateral contact force during stance phase.

Both mild and moderate crouch gait modifications significantly reduced lateral contact force at times during stance phase (Table 1). However, the knee contact force was transferred from the lateral to the medial compartment, as medial contact force was increased during the crouch gait modifications (Table 1). These results suggest that patients who exhibit crouch gait may transfer knee joint loads from the lateral to the medial compartment and may be at increased risk for developing medial compartment knee osteoarthritis.

No other gait modifications were found to significantly reduce *in vivo* contact forces during stance phase (Table 1). In particular, no gait modification was effective at reducing contact force at 25% of stance. In a previous study, medial contact force was reduced in early stance when walking with hiking poles [5]. However, in this study, none of the hiking pole gaits were effective in reducing contact force in early stance. A post-hoc analysis revealed that hiking pole contact with the ground was delayed after heel strike for all hiking pole configurations, reducing the effectiveness of the hiking poles in early stance. With additional practice, patients may be able to reduce the delay in hiking pole contact and may be able to reduce contact force in early stance.

CONCLUSIONS

Walking with hiking poles was found to be the most effective gait modification for reducing medial and lateral contact force during stance. An optimal configuration of hiking pole gait (long hiking poles and wide pole placement) reduced medial and lateral contact force over the stance phase by 18% and 14%, respectively. Patients with knee osteoarthritis may consider walking with hiking poles to reduce knee joint loading and minimize further damage to the articular surfaces of the knee.

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Table 1: Percent difference values calculated for each gait modification relative to normal gait. Bold values indicate statistically significant differences from normal gait.

	Medial Contact Force				**Lateral Contact Force**			
Gait Modification	25%	50%	75%	0-100%	25%	50%	75%	0-100%
Mild Crouch	14	-2	-6	4	**-23**	-15	-16	**-12**
Moderate Crouch	-1	18	5	13	-11	-11	**-29**	-9
Medial Thrust	-14	-4	-1	-4	-11	-8	-12	-10
Forefoot Strike	-9	-1	-4	1	-1	9	-17	-8
Bouncy	4	7	-9	3	4	14	**-36**	-11
Poles – Short, Normal	-3	-14	-14	-8	-7	-14	-13	-7
Poles – Long, Normal	-6	-17	-18	-13	-14	-13	-6	-6
Poles – Short, Wide	2	-15	**-21**	-8	-3	-17	**-19**	-9
Poles – Long, Wide	-5	**-28**	**-34**	**-18**	-13	**-26**	**-23**	**-14**