

# THE RELATIONSHIP BETWEEN MUSCLE STRENGTH AND GAIT ASYMMETRY IN UNILATERAL, TRANS-TIBIAL AMPUTEES

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## INTRODUCTION

Persons with unilateral, trans-tibial amputation (TTA) have an increased risk of developing osteoarthritis (OA) in the knee of their intact limb [1]. Several OA risk factors, such as peak knee external adduction moment and vertical ground reaction force load rate, have been found to be greater on the intact limb in TTAs [2]. Between-side strength discrepancies observed in TTAs [3] may be associated with an asymmetrical gait which relies heavily on the intact limb. This gait asymmetry may, over time, lead to a greater risk of developing OA in the intact limb. Therefore, the purpose of this study was to investigate the relationship between strength and gait asymmetry in TTAs. It was hypothesized that: (1) TTAs would be more asymmetrical than controls for gait and strength variables, and (2) muscle strength asymmetry would positively correlate with both gait asymmetry and intact side gait variables associated with knee OA risk.

## METHODS

Eight individuals (7 male, 1 female; age 43±13 years; BMI 30.3±1.7 kg/m<sup>2</sup>) with a unilateral transtibial amputation and eight able-bodied age, gender, and BMI matched controls (7 male, 1 female; age 45±13 years; BMI 31.0±3.4 kg/m<sup>2</sup>) participated in this study.

Gait Analysis: To collect 3D gait data, retro-reflective markers were attached to each subjects' legs and pelvis using a modified Helen Hayes marker set. For TTA subjects, shank and foot markers on the prosthesis were approximated to match the intact side. Subjects then walked down a 10 meter runway at a self-selected pace over two force plates sampling at 480 Hz until five successful trials were captured for each limb. Eight digital cameras captured marker trajectory data at 60Hz. Three kinetic variables were calculated via inverse dynamics: peak knee external adduction moment

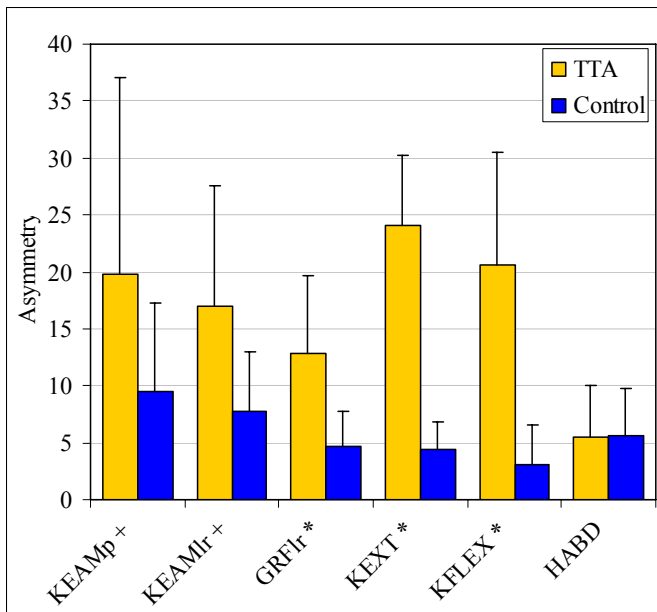
(KEAMp), KEAM load rate (KEAMlr), and vertical ground reaction force load rate (GRFlr).

Strength Testing: Knee extensor (KEXT), knee flexor (KFLEX), and hip abductor (HABD) maximum isometric strength was measured using a handheld dynamometer with a static strap providing resistance. TTA subjects were tested with their prosthesis in place. For KEXT and KFLEX, the dynamometer head was placed on the distal shank or as distally as possible over TTA subjects' remnant limb within the prosthetic socket. HABD was tested with the subject side-lying, the dynamometer placed over the lateral femoral condyle. The highest force value measured out of three maximal efforts was used for analysis after being normalized to lever arm length (dynamometer head to joint line) and body mass.

Statistical Analysis: A symmetry index (SA) [4] was calculated for each variable to define asymmetry between limbs, with zero equaling perfect symmetry. Differences in asymmetry between groups were compared using a non-parametric t-test (hypothesis 1). All variables found to be more asymmetrical in TTAs as defined by  $P \leq 0.05$  or effect size (ES)  $\geq 0.70$  were further analyzed to determine the relationship between strength asymmetry and OA risk variables. Spearman's Rank Correlations were performed between strength SA and gait variable SA, as well as between strength SA and intact side gait variables in TTAs (hypothesis 2). A rho of less than 0.5 was considered weak, 0.5 to 0.7 moderate, and 0.7 or greater a strong relationship.

## RESULTS AND DISCUSSION

KEXT, KFLEX, and vGRFlr were significantly more asymmetrical in the TTA group ( $P < 0.05$ , ES = 4.21, 2.39, and 1.52, respectively) (Fig. 1). KEAMlr and KEAMp were not statistically significant, but had strong effect sizes at ES = 1.10



**Figure 1:** Asymmetry between TTA and control groups for the 6 variables. 0= perfect symmetry, increasing values indicate greater asymmetry. \* = $P < 0.05$ , + = $ES > 0.7$  between TTAs and controls.

and  $ES = 0.76$ , respectively. Thus the expectation that TTAs would be more asymmetrical than controls was supported. This is in agreement with previous literature [2,3]. HADB was not more asymmetrical in TTAs. Good symmetry between sides in TTAs indicates that the role of the hip abductors is not affected following a trans-tibial amputation. Muscles at the joint closest to the level of amputation, in this case the knee flexors and extensors, therefore appear more likely to be influenced by TTA gait adaptations.

For the correlations between strength asymmetry and gait variables, KEAMlr SA had a strong correlation with KEXT SA ( $\rho = 0.714$ ,  $p < 0.05$ ), and a moderate correlation with KFLEX SA ( $\rho = 0.500$ ). We propose that TTAs walk in such a way as to avoid large moments of force at the stump/socket interface. TTAs typically maintain a more extended knee on the prosthetic side during the stance phase of walking [5]. Greater knee extension would decrease joint moments and limit demands on the musculature of that limb, allowing the muscles on the prosthetic side to weaken.

Intact side GRFhr was moderately correlated with KFLEX SA ( $\rho = 0.643$ ). Knee flexor strength

asymmetry may have been related to the vGRFhr on the intact side because the knee flexors are used to provide forward propulsion in the absence of plantarflexors [6]. Weak knee flexors on the prosthetic side limb would prevent that limb from producing adequate propulsion. The intact limb would then have to weight itself more quickly in order to pull the body forward, resulting in a greater load rate on the intact limb.

KEAMp was not related to any of the strength symmetry measures. Strength asymmetry in TTAs appears to be more strongly related to loading rates during gait, rather than peak moments of force. It has been suggested that high loading rates during gait are one of the main causes for the initiation and progression of OA in the able-bodied population [6]. It may therefore be beneficial to investigate in greater detail the effects of muscle strength discrepancies on high loading rates in TTAs. Additionally, this relationship between strength asymmetry and OA risk has important rehabilitation implications in the TTA population.

## CONCLUSIONS

Strength asymmetry of the knee extensors and flexors is related to OA risk variables, particularly loading rates, in individuals with a trans-tibial amputation. Strength asymmetry measures may therefore be useful in indicating problematic gait patterns in this population.

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