More Daily Steps And Minutes Spent In Moderate To Vigorous Physical Activity Indicate A Higher Risk Of Cartilage Degeneration Following Anterior Cruciate Ligament Reconstruction

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INTRODUCTION: Both under- and overloading contribute to worsening cartilage composition in the early development of knee osteoarthritis (KOA). Daily steps and minutes spent in moderate to vigorous physical activity (MVPA) have been used as proxy measurements to estimate the frequency of knee joint loading throughout the day in real world settings. Many individuals following anterior cruciate ligament reconstruction (ACLR) demonstrate deleterious changes to tibiofemoral cartilage composition within 1 year of surgery that are linked to elevated KOA risk. Most studies report that individuals post-ACLR take fewer daily steps/spend fewer minutes in MVPA compared to uninjured individuals leading to the hypothesis that knee underloading may be linked to tissue degeneration. However, the results of recent studies challenge that hypothesis suggesting that the lesser overall proportion of individuals who engage in greater steps and activity levels early post-ACLR are at highest risk of KOA. The purpose of our study was to evaluate the association between daily steps and minutes spent in MVPA at 6 and 12 months post-ACLR with cartilage composition at 12 months post-ACLR and determine the diagnostic accuracy of daily steps and minutes spent in MVPA to identify individuals demonstrating tibiofemoral cartilage degeneration over 12 months following ACLR.

METHODS: Twenty-seven individuals between 16 and 35 years old with a primary ACL injury who underwent bone-patellar tendon-bone or quadriceps tendon ACLR were included in this prospective, longitudinal cohort study. The study was approved by the institutional review board and all participants provided written informed consent or assent and parental permission. Participants underwent magnetic resonance imaging of the tibiofemoral joint using MAPSS T1ρ and T2 sequences preoperatively and 12 months post-ACLR. Percent change in average T1ρ and T2 relaxation times were calculated for the lateral femoral condyle (LFC), medial femoral condyle (MFC), lateral tibia (LT), and medial tibial (MT) cartilage preoperatively to 12 months post-ACLR. Positive increases in percent change of T1ρ and T2 relaxation times are interpreted as worsening cartilage composition (i.e., proteoglycan loss and loss of type II collagen structure). Participants also wore a tri-axial accelerometer for 7 days (valid wear = at least 4 days for 10 hours per day) at 6 and 12 months post-ACLR to calculate average daily steps and minutes spent in moderate to vigorous physical activity (MVPA) at each time point using Troiano cut points. T1ρ and T2 cartilage outcomes were transformed into z-scores and entered in a k-means cluster analysis to identify profiles of cartilage composition changes over 12 months post-ACLR. One-way ANOVA was used to determine differences in T1ρ and T2 cartilage changes between clusters to characterize two group profiles. Area under the receiver operator characteristic curve [AUC] was calculated for daily steps and daily minutes spent in MVPA, separately, to predict cluster profiles of cartilage compositional changes. The diagnostic accuracy (i.e., sensitivity and specificity) of a cut-off value of daily steps and minutes spent in MVPA was identified based on the largest Youden's Index. Finally, odds ratios via chi square tests were calculated to determine the odds of developing cartilage compositional change profiles based on the determined cut-off value of daily steps and minutes spent in MVPA.

RESULTS: We identified a cartilage degeneration group with increasing T1ρ and T2 relaxation times across all tibiofemoral cartilage regions (n=12, 33% female, age=19 years, BMI=23.5, 50% meniscectomy, 50% meniscal repair, 8% chondral injury) and a cartilage maintenance/improvement group with trivial (i.e., LFC, MFC, MT) or decreasing (i.e., LT) T1ρ and T2 relaxation times over 12 months (n=15, 67% female, age=23.5 years, BMI=24.3, 40% meniscectomy, 40% meniscal repair 20% chondral injury; Table 1). The cartilage degeneration group was younger than the cartilage maintenance/improvement group (p=0.01), but other demographic and surgical characteristics did not differ between groups (*p*-value range=0.32-0.99). More daily steps and minutes spent in MVPA at 6 and 12 months post-ACLR demonstrate fair to good discriminatory ability in identifying the cartilage degeneration group (AUC range=0.74-0.80; *p* range=0.001-0.01, Table 2). Individuals who spend more than 38.2 minutes in MVPA at 6 months post-ACLR and take more than 9150 daily steps or spend more than 36.6 daily minutes in MVPA at 12 months post-ACLR have 8.25-14 times greater odds of worsening tibiofemoral cartilage (Table 2).

DISCUSSION: Individuals who take greater daily steps and spend more time in MVPA at 6 and 12 months post-ACLR demonstrate a higher risk of exhibiting worsening cartilage composition in the first year post-ACLR. Individuals may consider monitoring/limiting activities that promote high frequencies of joint loading throughout the day to maintain cartilage health in the first 6 to 12 months post-ACLR. Rehabilitation protocols may consider supplementing lower weight-bearing activities such as biking or swimming to achieve national aerobic physical activity guidelines, especially in adolescents.

SIGNIFICANCE/CLINICAL RELEVANCE: Daily steps > 9150 and spending > 36-38 MVPA within the first 12 months post-ACLR are associated with worsening tibiofemoral cartilage composition suggesting that clinicians and patients may need to monitor daily steps and MVPA to optimize knee joint health. Further research is necessary to determine the appropriate timing and guidelines for resuming unrestricted activity.

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IMAGES AND TABLES:

Table 1. Percent change (%) in T1ρ and T2 relaxation times preoperatively to 12 months post-ACLR of cluster groups (means ± standard deviations)

	T1ρ LFC	T1ρ MFC	T1ρ LT	T1ρ MT	T2 LFC	T2 MFC	T2 LT	T2 MT
Cartilage Degeneration Group (n=12)	15.0±7.1	13.9±9.4	3.3±4.7	10.1±7.0	13.2±7.7	11.9±6.9	1.6±5.1	10.4±10.6
Cartilage Maintenance/ Improvement Group (n=15)	-1.0±12.6	-1.0±6.6	-4.2±4.7	1.0±8.3	-1.7±13.3	-0.2±7.8	-7.6±4.7	0.4±7.9
p-value	<0.001*	<0.001*	<0.001*	0.005*	0.002*	<0.001*	<0.001*	0.009*
* statistically significant difference between k-means cluster groups (p<0.05)								

Table 2. Diagnostic Accuracy, Cut-Off Values, and Odd's ratios of daily steps and minutes spent in MVPA to predict k-means cluster groups

	AUC [95% CIs]	Sensitivity/Specificity	Cut Off Value	Youden's Index	Odd's Ratios [95% CIs]
Steps at 6 mo. Post-ACLR	0.75 [0.56, 0.94]	50%/100%	>9362 steps per day	0.50	-*
Steps at 12 mo. Post-ACLR	0.76 [0.58, 0.94]	50%/93%	>9150 steps per day	0.43	14.00 [1.37, 142.88]
MVPA at 6 mo. Post-ACLR	0.80 [0.63, 0.97]	73%/83%	>38.17 min. per day	0.57	8.25 [1.45, 46.86]
MVPA at 12 mo. Post-ACLR	0.74 [0.55, 0.93]	67%/83%	>36.57 min. per day	0.50	13.75 [2.05, 92.04]
* cannot calculate because there are no cases where participants take greater than >9362 daily steps and were classified as the cartilage maintenance group					